Emotional Avatars
- Evaluation of Sequence Effects in Facial Expressions

Bachelorarbeit

IM STUDIENGANG ANGEWANDTE INFORMATIK DER FAKULTÄT WIRTSCHAFTSINFORMATIK UND ANGEWANDTE INFORMATIK
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Abstract

According to Scherer [05] emotions are the interface of a human being and its environment. This environment does not only consist of the social environment around us. Nowadays, computers are a part of everyday life. The way emotions can be transferred via computer is by using human avatars. To improve recognisability of emotions represented by avatars, one has to know the factors it is influenced by. To determine whether the sequence of structure of an emotion is one of these influence factors, an online experiment was conducted. Therefore video stimuli were created using avatars which perform two different sentiments, disgust and pain. The sequence of Action Units of these facial expressions were altered, resulting in the natural sequence, one with averaged values and a reversed sequence. Under these conditions, no significant influence on the recognition rate could be observed. Despite these results, under different conditions, future studies could reveal sequence effects on the recognisability of emotions and facial expressions.

Zusammenfassung

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List of Abbreviations

SECs  Stimulus Evaluation Checks
FACS  Facial Action Coding System
AU    Action Unit
1. Introduction

Emotions are an important way of non-verbal communication. Emotions and therefore facial expressions are the interface between a human being and its environment (cf. [06]). On the one hand, research on emotion and facial expressions is a big issue in human science. To be able to describe facial expressions precisely, Ekman and Friesen developed a system called Facial Action Coding System [01]. This system contains all minimal Action Units of facial expressions.

On the other hand, also computer science has a great interest in research on emotion. Human-like avatar faces are the way facial expressions and emotions can be transferred by computers. Having a better understanding about which factors influence the recognisability of emotion helps to design avatars even more realistic. More realistic avatars have advantages for various applications. One example is that psychological studies using avatar faces gain reliability when the avatars are more realistic. Another application example is the use for transmitting emotions in collaborative virtual environments (cf. [02]). Also knowledge about better recognisability of emotions can influence the creation of animated characters as in video games, animation movies or advertising.

The research issue of the present paper is whether the order in which the Action Units of emotional facial expressions emerge has an influence on the recognisability of emotions. Therefore two emotional facial expressions disgust and pain were chosen. The Action Units for these facial expressions were worked out. Three different orders were chosen as experimental conditions. From these, video stimuli were created and evaluated using an online survey.

The next section provides an overview of related work on the psychological background, avatar studies, previous work about sequence effects of AUs and techniques for creating avatars. Thereafter the experimental design is described, which consists of the study design and the creation of the video stimuli and online survey. In Section 4 the experimental procedure and results are presented with a description of the experimental sample. Finally, Section 5 provides the conclusion.
2. State of Research

The following section provides a rough overview of the current state of research and fundamental scientific work. First, the physiological background is illustrated. The development of emotion is displayed with Scherer’s theory of the development of emotion and the fundamental technique of describing facial expression, FACS by Ekman and Friesen, is explained. Thereafter, scientific avatar studies are presented to illustrate the effectiveness of avatar faces in research of facial expression and emotion. Following, a previous study about sequence effects of AUs in facial expressions is presented. At the end of this section, two different tools for creating avatar faces are presented, the FaceGen Modeller and FACSGen.

2.1. Development of emotion

According to Scherer [05], there is no common definition of emotion. This is due to the fact that an emotional process has many different components. There are cognitive, motivational and action components. The most relevant function of emotion is to interfere between a subject and its environment.

Emotion is also an adjustment mechanism. It evaluates the relevance of an environmental stimuli and adapts to changes. By decoupling the reaction to an environmental change, emotion creates a delay where the situation can be reevaluated. This reassessment and the reaction of other individuals to own emotion can lead to a different action. The evaluation of environmental and intern stimuli develop an emotion.

Scherer worked out a dynamic model of this stimulus evaluation with five levels of evaluation which are called Stimulus Evaluation Checks [07], abbreviated SECs. 1) The novelty check, observes inner and outer stimuli and checks whether a new adaption to the environment is necessary. This includes not only new occurrences but also new consequences which emerged. 2) The intrinsic pleasantness check determines the possible reaction to the new stimuli. It checks whether the response is liked and will be encouraged or it is disliked and therefore should be avoided. 3) The goal/need significance check estimates the relevance the stimulus has for the individual. This check is divided into five sub-checks: 3a) The relevance for major goals is estimated. 3b) The probability of the consequences are assessed. 3c) It is checked whether the outcome matches the expectation. 3d) The stimuli is checked whether it is beneficial for personal goals. 3e) It is examined how urgent the action must be. 4) The coping ability check
considers whether negative consequences can be overcome and it can be gained from the positive ones. This check has also four sub levels: 4a) The cause of the event is tried to find out. 4b) It is considered whether the outcome can be controlled. 4c) The power sub check evaluates the needed resources to change the outcomes. 4d) The adjustment evaluation checks the potential to adapt to the event and its outcomes. 5) The norm/self compatibility check is only relevant in social organised species. It evaluates the social consequences of a possible action. The two sub checks are 5a) the check against norms of social groups and 5b) the check against the effect on internal values like morals or self ideal.

The most obvious way of communicating emotions are facial expressions. The ability to do emotional facial expressions is congenital, but depends on cultural and ethnical influences. The ability to communicate emotion is a vast advantage for social organised species. To summarise, the function of emotion is to adapt the human organism to environment, which plays a central role in human development.

2.2. Facial Action Coding System

The Facial Action Coding System is a technique to describe facial expressions. The first version of FACS was published in the year 1976 by Paul Ekman and Wallace Friesen [01]. Their goal was to invent a new system and derive a new terminology, which allows a specific description of facial action for any kind of study.

To develop such a system they had to agree on properties and constraints beforehand. They decided to study what is clearly visible, because subtle changes may be too small for differentiation. Also other facial changes like skin colour (blushing), sweat or tears were not included into FACS. Additionally Ekman and Friesen had to decide between the following two approaches. Either they describe minimal action units or every possible combination which results in a different facial expression. The choice was the first approach, because including every distinctive gestalt would result in too many items. The method to derive every minimal facial action should be anatomical on the base of every single muscle whose action results in a visible movement. This helps to describe and differentiate the individual Action Units, hereafter referred to as AUs.

The first step for Ekman and Friesen to develop FACS was to study anatomical texts on the facial muscular system. They had to learn how muscle actions change appearance. For the second developing step the scientists reviewed photographs of themselves performing every single muscular action. Thus they decided whether one can distinguish between the various actions. For facial expressions which can
be made by more than one muscle only one Action Unit was taken into FACS. Also one muscle can produce more than one possible distinguishable facial expressions. This, among other reasons, is why these minimal units were called "Action Units" instead of "muscle actions" or the like. All in all, the following Action Units for facial movement (see table 1) were included in Ekman and Friesen’s Facial Action Coding System.

After developing single AUs, Ekman and Friesen investigated combinations of two Action Units. The majority of these combinations were additional. A further amount of combinations produced new appearances. These combinations were added to FACS. There were also combinations of two AUs, which were too alike or cannot be done at the same time. These combinations were listed as alternatives, which can only be scored one at a time. After investigating all two AU combinations, Ekman and Friesen repeated this process for combinations of three AUs. This resulted in thousands of photographs and only distinct combinations were included into FACS. Of the combinations of 4, 5, 6, 7 or 8 Action Units, the scientists only studied a small number.

The Facial Action Coding System focuses on movement. To score facial action precisely, it is advised to use video records with the ability to slow motion, stop motion, and go back to neutral face to compare. Still photographs can be scored as well, but only when there is a photograph of the neutral expression. It takes around 100 hours to learn FACS and practice scoring.

After developing FACS, Ekman and Friesen analysed the reliability of FACS by means of an experiment. 34 videos of facial movement were scored by six coders, who learned FACS by Manual, and the experts, Ekman and Friesen. They compared the scoring and measured reliability with an own formula called Agreement Index. The mean Agreement Index comparing the scores of the six coders with the ones of the experts was 0.822. This value indicates a high reliability for individuals who learned FACS by themselves. According to Ekman and Friesen, the reliability rises with practice and improvement.
Table 1: Facial Action Units [03, p. 8]

<table>
<thead>
<tr>
<th>AU Number</th>
<th>FACS Name</th>
<th>Muscular Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Inner Brow Raiser</td>
<td>Frontalis, Pars Medialis</td>
</tr>
<tr>
<td>2.</td>
<td>Outer Brow Raiser</td>
<td>Frontalis, Pars Lateralis</td>
</tr>
<tr>
<td>4.</td>
<td>Brow Lowerer</td>
<td>Depressor Glabellae; Depressor Supercilli, Corrugator</td>
</tr>
<tr>
<td>5.</td>
<td>Upper Lid Raiser</td>
<td>Levator Palpebrae Superioris</td>
</tr>
<tr>
<td>6.</td>
<td>Cheek Raiser</td>
<td>Orbicularis Oculi, Pars Orbitalis</td>
</tr>
<tr>
<td>7.</td>
<td>Lid Tightener</td>
<td>Orbicularis Oculi, Pars Palebralis</td>
</tr>
<tr>
<td>8.</td>
<td>Lips Toward Each Other</td>
<td>Orbicularis Oris</td>
</tr>
<tr>
<td>9.</td>
<td>Nose Wrinkler</td>
<td>Levator Labii Superioris, Aleaque Nasi</td>
</tr>
<tr>
<td>10.</td>
<td>Upper Lip Raiser</td>
<td>Levator Labii Superioris, Caput Infraorbitalis</td>
</tr>
<tr>
<td>11.</td>
<td>Nasolabial Furrow Deepener</td>
<td>Zygomatic Minor</td>
</tr>
<tr>
<td>12.</td>
<td>Lip Corner Puller</td>
<td>Zygomatic Major</td>
</tr>
<tr>
<td>13.</td>
<td>Cheek Puffer</td>
<td>Canius</td>
</tr>
<tr>
<td>14.</td>
<td>Dimpler</td>
<td>Buccinnator</td>
</tr>
<tr>
<td>15.</td>
<td>Lip Corner Depressor</td>
<td>Triangularis</td>
</tr>
<tr>
<td>16.</td>
<td>Lower Lip Depressor</td>
<td>Depressor Labii</td>
</tr>
<tr>
<td>17.</td>
<td>Chin Raiser</td>
<td>Mentalis</td>
</tr>
<tr>
<td>18.</td>
<td>Lip Puckerer</td>
<td>Incisivii Labii Superioris; Incisivii Labii Inferioris</td>
</tr>
<tr>
<td>20.</td>
<td>Lip Stretcher</td>
<td>Risorius</td>
</tr>
<tr>
<td>22.</td>
<td>Lip Funneler</td>
<td>Orbicularis Oris</td>
</tr>
<tr>
<td>23.</td>
<td>Lip Tightner</td>
<td>Orbicularis Oris</td>
</tr>
<tr>
<td>24.</td>
<td>Lip Pressor</td>
<td>Orbicularis Oris</td>
</tr>
<tr>
<td>25.</td>
<td>Lips Part</td>
<td>Depressor Labii, or Relaxation of Mentalis or Orbicularis Oris</td>
</tr>
<tr>
<td>26.</td>
<td>Jaw Drop</td>
<td>Masseter; Temporal and Internal Pterygoid Relaxed</td>
</tr>
<tr>
<td>27.</td>
<td>Mouth Stretch</td>
<td>Pterygoids; Digastric</td>
</tr>
<tr>
<td>28.</td>
<td>Lip Suck</td>
<td>Orbicularis Oris</td>
</tr>
<tr>
<td>38.</td>
<td>Nostril Dilator</td>
<td>Nasalis, Pars Alaris</td>
</tr>
<tr>
<td>39.</td>
<td>Nostril Compressor</td>
<td>Nasalis, Pars Transversa and Depressor Septi Nasi</td>
</tr>
<tr>
<td>41.</td>
<td>Lid Droop</td>
<td>Relaxation of Levator Palpebrae Superioris</td>
</tr>
<tr>
<td>42.</td>
<td>Slit</td>
<td>Orbicularis Oculi</td>
</tr>
<tr>
<td>43.</td>
<td>Eyes Closed</td>
<td>Relaxation of Levator Palpebrae Superioris</td>
</tr>
<tr>
<td>44.</td>
<td>Squint</td>
<td>Orbicularis Oculi, Pars Palpebralis</td>
</tr>
<tr>
<td>45.</td>
<td>Blink</td>
<td>Relaxation of Levator Palpebrae and Contraction of Orbicularis Oculi, Pars Palpebralis</td>
</tr>
<tr>
<td>46.</td>
<td>Wink</td>
<td>Orbicularis Oculi</td>
</tr>
</tbody>
</table>
2.3. Avatar studies

This subsection provides information about two previous studies on how emotions can be expressed with avatars. In the first one, the scientists Moser et al. examined cerebral response to facial expressions of emotion on human and avatar faces. In the second study Fabri et al. developed avatars with minimum details and investigated the recognition rate of emotions.

2.3.1. Comparison of cerebral response to human faces and avatar faces

In their scientific article "Amygdala activation at 3T in response to human and avatar facial expressions of emotions"[03] the authors Moser et al. investigated, whether the cerebral response to avatar facial expressions is comparable to expressions of human faces. The amygdala is a cerebral area, which is responsible for perception and processing emotional facial expressions. An amygdala response would lead to a higher significance of the usage of avatar faces in scientific studies.

For their experiment, Moser et al. took 36 coloured photographs of human faces by a standardised stimulus set and created 36 avatar faces (see figure 1). The avatars were generated on basis of Ekman and Friesen’s FACS (see 2.1) and the support of a FACS coder. The facial expressions were the five basic emotions, anger, fear, happiness, sadness and disgust, plus a neutral facial expression. These photographs were presented to twelve test subjects. The participants decided which emotion they recognised. This value was measured in percentage of correct answers. Also the reaction time was measured and a functional MRI (functional magnetic resonance imaging) was made during the experiment.

![Figure 1: Example of image stimuli of anger][03, p. 128]
The study lead to the following results. Human face expressions had a higher recognition rate. The reaction time for recognition was longer for avatar faces than for human faces. But the fMRI showed, that both, human as well as avatar faces, lead to amygdala activation. The human faces induced a higher activation of the face sensitive area, whereas the avatar faces lead to a higher activation of the cerebral area, which is responsible for facial movement. Therefore the experiment of Moser et al. shows, that amygdala response can be detected for human facial expressions as well as for computer generated avatar faces.

2.3.2. Evaluation of recognition rate of a minimum avatar

Fabri et al. designed an avatar study [02] to find out, whether and how emotions can be transferred in collaborative virtual environments, short CVEs. The avatar face that was developed for this experiment was kept to a minimum. Previous studies have shown, that it is not necessary to make the face as realistic as possible. Therefore a model was used which evokes a maximum emotional response by humans and at the same time has minimum details. The avatar face only has a few steerable units and can only perform eleven Action Units. This reduced set of AUs turned out to be sufficient for this study.

For the human stimuli, Fabri et al. took photographs from Ekman and Friesen’s "Pictures of Facial Affect". They opted for six basic emotions (surprise, fear, disgust/contempt, anger, happiness and sadness) and a neutral face, in each four different variants. These 28 different facial expressions were then transferred to the avatar face. These 64 photographs of facial expressions were shown to each participant to compare the recognition rate between human and avatar faces. The human photographs were correctly identified to 78.6 %, whereas avatar faces scored 62.2%. The study also revealed, that some emotions (surprise, fear, happiness and neutral) were recognised better on a human face, whereas anger and sadness caused a higher recognition rate on avatar faces. Fabric et al. determined the top variations of avatar facial expressions (figure 2), which caused the highest recognition. The result of this study was, that emotions can be transmitted through avatar faces, when using FACS. Also it is shown, that it is sufficient to use only a few facial features and a small subset of AUs.
Figure 2: Minimal avatars [02, p. 75]
2.4. Sequence Effects

The following research by Engelbrecht[08] investigated whether the sequence of AUs has an influence on the recognition rate of emotions in contrast to the simultaneous onset of AUs and images. This investigation is very important for the present paper because it addresses the same research issue of sequence effects on recognition rate.

For Engelbrecht’s experiment, the stimuli were created using the emotional agent Amber of EMBR System. The emotions which were chosen for this study were pain and disgust and also a neutral facial expression. The experimental conditions were still images at full AU intensity (see figure 3), videos with simultaneous onset of AUs and videos with sequential emerge of AUs. The sequential condition was achieved by permuting the three regions of interest, the mouth, eye and brow area, resulting in six permutations. The problem with creating the video stimuli was that the used system EBMR was not based on AUs. AU 9 could not be modelled directly, so it was approximated by using phonemes instead.

This experiment was conducted as an online survey, where the participants were randomly assigned to the three conditions. The experiment revealed that emotions were recognised better on videos than on still images. Disgust had a higher recognition rate in the sequence condition, whereas the sequence had no influence in the recognition rate of pain. However, the sequential condition lowered the confusion rate.

Figure 3: Emotional agent Amber [08, p. 3]
2.5. Technologies for creating avatars

The following subsection describes two tools for creating avatar faces and their facial expressions. The FaceGen Modeller is a system to create avatar faces in general. It provides a vast amount of possibilities to customise the avatars. However the FACSGen system is more specific. It was developed to create facial expressions on the base of action units.

2.5.1. FaceGen Modeller

The FaceGen Modeller [12] is a modelling software for 3D human avatar faces, developed by Singular Inversions. Singular Inversions Inc. was founded in the year 1998. Their profession is to develop software to create 3D avatar faces easily. The FaceGen Modeller is a middleware which can be used for various applications including computer and console games, education, police investigation and also for research [13].

FaceGen offers numerous possibilities to create and modify avatar faces (see figure 4), some of which are presented now [14]. The gender of the avatar can be changed with a slider from very male and male (figure 5) over to female and very female facial shapes. Per default the slider of gender is synced with a slider for colour. This causes the face to get paler the nearer the slider is to very female. This has the effect that, by default, male avatars have darker skin. The avatars age can be adjusted with a slider as well. Ages from 20 to 60 are possible. And there is also a synced slider for the characteristic colour. Additional the attractiveness of the avatar can be changed with a slider from average, attractive and typical up to creating a caricature or a monster. Equal to the other sliders, this one is also synced to a belonging colour slider. The synchronisation of the corresponding colour sliders can be turned off if wanted. Also the race of an avatar can be adjusted, but with multiple sliders. All different combinations of ethnicities are possible.

To make the face look more natural, textures can be added to the face. By default the avatars are bald, but hair can also be added with a texture. Thus the avatar can get e.g. a beard or blemished skin. Furthermore the user can create an own texture by editing the texture map which can be downloaded from FaceGen’s website [12]. One can also create a random face or an average face for any ethical origin. By importing a photograph, the modeller can create an avatar face according to the face on the photograph.
Along with the creation of facial characteristics, facial expressions can be modelled. Freeform deformation allows to deform the avatar face via drag and drop. This can be made either on one side of the face or symmetrically. Besides freeform deformation, FaceGen Modeller offers multiple morph targets like SmileClosed (figure 5) and LookLeft (figure 5). Also some emotions are part of these morph targets, but their use was not suitable for this study because the involved AUs emerge simultaneously. The morph targets can be applied with intensities from zero to one with a slider, but one can also enter values above 1 into the text field.

After creating and modifying the face, the background can be set, for instance to just a plain colour or a photograph. For an ideal appearance, also the lighting options can be changed. When done, the created avatar face can be exported and saved.

Figure 4: Screenshot of FaceGen Modeller; Possibilities to create an avatar
2.5.2. FACSGen

FACSGen is a software to create avatar facial expressions, developed by the Swiss Center for Affective Sciences at the University of Geneva [04]. According to their website [09], FACSGen is not available for external use.

The tool (see figure 6) creates facial expressions based on the FACS. It is used in combination with Singular Inversions’ FaceGen Modeller and can import any avatar face, which was created with the modeller. On the one hand FACSGen enables manipulation on static facial expressions resulting in an image. On the other hand, AUs can be manipulated via curves of intensities over time. Thus either each frame can be used as a static image of a facial expression or in total as a video clip.

To validate the software three studies were made. To verify the implemented AUs, the first study addressed professional FACS coders. Short video clips were produced, each with either one AU or a combination of AUs. Every AU increased in intensity up to maximum intensity. The coders were instructed to identify the time of presence and absence of each AU. The study showed that the implemented AUs can be recognised properly by professional FACS coders. The second study should investigate whether non-professionals can recognise the facial identity of avatar faces created by FACSGen. Therefor female and male avatar faces were produced with a neutral facial expression. The participants were asked, which gender the avatar has, which emotion the face may express (positive, neutral or negative emotion) and whether the face is realistic and could appear in reality. The result was that lay people can reliably identify the gender, emotionality and believability of avatar faces. For the third study, images of facial expressions were
created. In total four different emotions were implemented based on the corresponding AU combination, each as coloured and black-and-white image. The participants were instructed to identify the shown emotion. The recognition rate of the emotions show that people can identify emotions to an reasonable accuracy.

Figure 6: Screenshot of FACSGen [04, p. 6]
3. Experimental Design

This section explains the experimental design of this research. First, the design of the study is presented. Next, the process of creating the video stimuli is demonstrated with regard to the used tool and the actual creation of the videos. The last part of this section illustrates the creation of the online survey.

3.1. Study Design

The object of investigation in this study is to find out whether the sequence of onsets of Action Units has an influence on the recognition rate of emotions. The emotions, which were chosen for this experiment, were disgust and pain. These sentiments were selected, because they have many AUs in common, as AU 4 "Brow Lowerer", AU 6 "Cheek Raiser" and AU 07 "Lid Tightener". Hence the differentiation between these two facial expressions is not trivial as it would be for instance between happiness and sadness. Each emotion, disgust and pain, has four different variations performed by each two females and two males. The three experimental conditions are 1) AUs in naturalistic sequence and intensity, 2) AUs emerge simultaneous with equal intensity and 3) AUs emerge in reverse sequence as original. In total, there are 24 different video stimuli. To prevent that priming effects distort the results of this experiment, the stimuli were presented in two different orders. This results in the following independent variables:

- Condition: naturalistic sequence of AUs, simultaneous onset of AUs, reverse sequence of AUs
- Emotion: disgust, pain
- Gender: female, male
- Variation
- Order

The dependent variable is the correctness of answers to the question concerning the recognisability of emotion. For this experiment a between subject design was chosen, because every participant only sees the videos of one experimental condition. The research issue of this whether the sequence of emerge of AUs has an influence on the recognition rate. The recognition rate of the naturalistic sequential order of AUs shall be assumed to be significantly higher.
than the other two recognition rates. In total the following hypotheses will be investigated in this experiment:

- The order of presenting the stimuli has no influence on the recognition rate.
- The video stimuli with the naturalistic sequence of AUs have a significantly higher recognition rate than the other two experimental conditions.
- The emotions with the naturalistic sequence of AUs are assessed as more natural and easier to recognise than the other two conditions.

3.2. Stimuli Creation

The tool which was used to generate the video sequences was developed by Seuß. It produces videos using avatars which were created with the FaceGen Modeller. In contrast to the FaceGen Modeller this tool directly addresses all AUs. The software gets the avatar face with texture and a csv-file. This file contains a table of AUs over video frames and the entered values are the intensities of the corresponding AUs. On the basis of this information the tool creates an image for each frame using the FaceGen Modeller. Finally, these images have to be assembled to a video file. Due to licence issues, a direct access to this tool was not possible. Therefore, the videos were rendered by Mr. Seuss on the basis of the csv-files I sent him.

The first approach of creating the video stimuli was to use a given set of video material of an actor playing emotions. This video material was provided by the Fraunhofer IIS. Additional to these videos, the annotations of AUs with intensity, on- and offset were provided. Out of these emotions anger and fear were chosen due to their overlap of AUs. The facial expression of anger was a combination of AU 1 "Inner Brow Raiser", AU 10 "Upper Lip Raiser", AU 25 "Lips Part" and AU 26 "Jaw Drop". Fear consisted of AU 1 "Inner Brow Raiser", AU 2 "Outer Brow Raiser", AU 5 "Upper Lid Raiser", AU 20 "Lip Stretcher", AU 25 "Lips Part" and AU 26 "Jaw Drop". Both facial expressions have AU 25 and AU 26 in common. To get an input file to create a video, the intensities of the AUs were transformed from the given FACS intensities A-E into numeric values, increasing from onset to apex and decreasing until the offset. This was made for the emotions anger and fear, but also for happiness and sadness. The two additional emotions were chosen to create videos for the online survey to familiarise the participants with the structure of the survey. All four input files were converted to avatar videos. These videos were shown to FACS expert Dr. Kunz to validate them over correctness.
and believability. The feedback was not positive, as Dr. Kunz recognised AUs which did not belong to the characteristic of the observed emotions. To determine the cause, the human emotion videos were examined with the result that the actor did not meet the emotions exactly. This fact causes that the human actor videos were not suitable for this research.

The new approach was to change the chosen emotions and refer to a set of video recordings of subjects who are really disgusted and in pain. The recordings consist of eight videos by four persons, two were female and two were male. Each of these persons show facial expressions for both emotions. This results in two different variations for each emotion by one gender. Dr. Kunz coded these recordings according to the FACS guidelines in regard to the onset and intensity of the involved AUs. The AU combinations for these eight facial expressions can be seen in table 2. This table also clearly shows the overlap of AUs, the facial expressions of disgust and pain have. These are the AUs, which occur in the previously described facial expressions:

- AU 04 "Brow Lowererer"
- AU 06 "Cheek Raiser"
- AU 07 "Lid Tightener"
- AU 09 "Nose Wrinkler"
- AU 10 "Upper Lip Raiser"
- AU 15 "Lip Corner Depressor"
- AU 25 "Lips Part"
- AU 26 "Jaw Drop"
- AU 43 "Eyes Closed"

### Table 2: AU combinations of facial expressions of disgust and pain

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Gender</th>
<th>Variation</th>
<th>Action Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disgust</td>
<td>Female</td>
<td>A</td>
<td>4 6 7 9 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>4 6 7 9 15</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>A</td>
<td>4 7 10 25 26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>4 7 9</td>
</tr>
<tr>
<td>Pain</td>
<td>Female</td>
<td>A</td>
<td>4 7 10 25 26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>4 6 7 10</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>A</td>
<td>4 6 7 9 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>4 6 7 10 43</td>
</tr>
</tbody>
</table>
These video recordings and their annotations were the base for the video stimuli used in this research. Additional, the decision was made that the videos should end at the apex of the facial expression so that the intensity reaches the maximum at the end of the video sequence (figure 7).

As before, the FACS intensities had to be transformed to numeric values and entered in the table to the corresponding AU and frame value. This was made for all of the eight facial expressions. The videos were created and thereafter evaluated by Dr. Kunz. The csv-files were revised according to this feedback. This procedure was repeated until the emotions were believable and represented correctly. At this point, the videos for the conditions simultaneous and reverse were made following the same procedure. The AU of the simultaneous condition had a medium intensity. For the reverse condition the onset of the first AU was exchanged with the onset of the last emerging AU and vice versa. This exchange was also made for the second AU with the second last one. This results in a reverse order of onsets and intensities, because every AU now has the intensity of the one it was changed with. Two avatars were created, a female and a male one. For each of the eight videos the avatar with the according gender was used.

The difficulty in creating the input files was to find a suitable numeric value for the AUs over time. The result of these values could not be reviewed right away. This was possible not until the whole video is rendered. For a better estimation, a template file was generated with increasing intensity values of 0.2 steps up to 1. This file was converted to a template video. This helped to estimate the intensities by comparing the human video recordings to the template video of intensities.
Figure 7: Apex of eight video stimuli
3.3. Survey Creation

To investigate whether the sequence of emerging AUs has an influence on the recognition rate of emotions, an online experiment was made using the SoSci Surveys platform. This type of information gathering was chosen due to the advantages compared to other types of investigation. The participants can flexibly choose when to take part in the survey, their anonymity is preserved and the information is already in digital form, which facilitates data preparation.

SoSci Survey is an online tool made to support and execute online surveys [15, 16]. It was developed for scientific research and is free of charge for scientific institutions. SoSci Survey provides the following functionalities. To create online questionnaires, one can either start from scratch or choose between different predefined questions like age, gender, etc. There are also various predefined types of answers, like selections, open answer possibilities or a Likert scale. Different properties can be assigned to the questions, for example that a question must be answered before continuing. SoSci Survey provides lots of instructional information as help, FAQs and a forum to share problems.

The structure of the questionnaires of this study was the following (table 3): On the first page the participants will see a welcoming text. Thereafter general questions about the person were asked. The questions of this part were the demographical ones about age, gender and a question about the gaming behaviour (figure 8). The gaming behaviour should be evaluated over the frequency how often the participant plays video games with human avatars. These statements allow analysis of dependence later. Therefore it could be analysed whether frequent contact to human avatars has a positive or negative influence on the recognition rate. The next page of the questionnaire shows an instructional text about the structure of the survey. The following instructional section has the purpose to familiarise the participants with the structure of the experimental questions. The subsequent page of the questionnaire shows a video of the facial expression of happiness. Thereafter the participants were asked which emotion they recognised, in this case of instruction the answer possibilities were "Happiness" and "Sadness". Then the participants were asked to subjectively estimate the correctness of two statements on a Likert scale. The statements were 1) "The emotion looked very natural." and 2) "It was easy for me to recognise the emotion.". This is followed by the eight experimental questions (figure 9) with the same structure, but with the answer possibilities "Disgust" and "Pain". At the end of the questionnaire, the participants had the possibility to leave a comment about their impressions during the survey. Finally a text was shown in order to thank the respondents for their participation.
Table 3: Questionnaire structure

<table>
<thead>
<tr>
<th>Topic</th>
<th>Questions</th>
</tr>
</thead>
</table>
| Beginning | Gender  
Selection: Female, male |
|        | Age  
Dropdown menu: 5 options |
|        | Gaming behaviour: "How often do you play video games with human avatars?"  
Selection: Never/rarely, now and then, very often |
| Introduction | Emotion recognition  
Selection: Happiness, sadness |
|        | Subjective estimation: "It was easy to identify the emotion."  
Rating: 5 points: I totally agree - I do not agree at all |
|        | Subjective estimation: "The emotion appeared natural."  
Rating: 5 points: I totally agree - I do not agree at all |
| A1 - A8 | Emotion recognition  
Selection: Disgust, pain |
|        | Subjective estimation: "It was easy to identify the emotion."  
Rating: 5 points: I totally agree - I do not agree at all |
|        | Subjective estimation: "The emotion appeared natural."  
Rating: 5 points: I totally agree - I do not agree at all |
| End    | Comments  
Open answer possibility for leaving comments |
Welches Geschlecht haben Sie?

- weiblich
- männlich
- keine Angabe

Wie alt sind Sie?

Bitte auswählen

Wie häufig spielen Sie PC- / Konsolenspiele mit menschlichen Avataren?

- Nie bis Selten
- Ab und zu
- Sehr häufig
- kann ich nicht beurteilen

Figure 8: General question

Welche der folgenden Emotionen haben Sie im vorigen Video erkannt?

- Ekel
- Schmerz

Wie bewerten Sie die folgenden Aussagen?

Die Emotion sah sehr natürlich aus.

Es fiel mir leicht die Emotion zu erkennen.

Figure 9: Experimental question
To include the videos into the survey, flash player was used. Therefor one has to convert the video file into the flash format flv. The instruction of SoSci Survey [17] proposes a freeware conversion tool by DVDVideoSoft Ltd. [10]. This tool generates a html-code, a swf-file, which is the actual player, and the flv-file of the video. The html-code has to be saved as a text module in html encoding. This text module is placed into the questionnaire where the video should be displayed. The flash player and also the video in flv format has to be uploaded to SoSci Surveys.

For this study six questionnaires were needed for three conditions and each two different orders of the videos to prevent priming effects, as mentioned before. These orders were created in Java by generating a random order with the constraint that no more than two times the same occur successively. Every questionnaire contains the following set of eight videos, where D and P stand for disgust and pain respectively and F and M for female and male respectively. The numbers represent the different variations of each facial expression.

\[ D \text{ F1, D F2, D M1, D M2, P F1, P F2, P M1, P M2} \]

The two different orders are:

1) \[ D \text{ F1, P F2, D M1, D F2, P M2, P M1, D M2, P F1} \]
2) \[ P \text{ M1, D M2, P F1, D F2, P M2, P F2, D M1, D F1} \]
4. Experiment

The following section explains the experiment which was conducted for this research. First, the procedure of the experiment is illustrated including a description of the sample. Then the results of the experiment are analysed and described in regard to the three previously stated hypotheses.

4.1. Procedure

The experiment went online on 17/07/2015. The access to the experiment was a link, which was distributed on the social media platform facebook and in the social environment. All participants were randomly assigned to one of six questionnaires. One problem of this random allocation is that the experimental groups will not have the same size. To avoid this problem, once one experimental condition has enough participants the corresponding questionnaire was taken offline. However, this solution may lead to the methodic problem (cf. [11]) that answers of participants differ depending on when they take part in a survey, as soon as it gets online or just before the survey is taken offline. This problem should receive more attention in the future.

After all conditions had enough participants and the same amount of completed questionnaires, the experiment was taken offline on 01/08/2015. The experiment was online for 15 days. In this period of time, the link was clicked 159 times, 121 persons participated and 63 persons completed the survey, resulting in 21 completed experiments for each condition.

Of the 63 participants 28 participants were female and 35 male. The answer possibility for the age of the participants was categorised into eight classes of years with open ends (≤ 17, 18 - 21, 22 - 25, 26 - 29, 30 - 33, 34 - 37, 38 - 41, ≥ 42). All categories of age were represented with the following distribution in table 4 and figure 10. The difficulty in analysing the age of participants was that the possible answers in the survey were categorised into eight classes of years with open ends. Hereby the mean value can only be calculated over the categories, which might result in a difference because of the open limits. Nevertheless, the mean age category was 26 -29 years with a value around 29 years (the mean value of the categories labeled with 1-8 was 3.968).
Table 4: Distribution of age vs. condition and questionnaire

<table>
<thead>
<tr>
<th>Condition</th>
<th>Quest.</th>
<th>≤ 17</th>
<th>18 - 21</th>
<th>22 - 25</th>
<th>26 - 29</th>
<th>30 - 33</th>
<th>34 - 37</th>
<th>38 - 41</th>
<th>≥ 42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence</td>
<td>1a</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1b</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Σ</td>
<td>0</td>
<td>6</td>
<td>9</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Simultaneous</td>
<td>2a</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2b</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Σ</td>
<td>0</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Reverse</td>
<td>3a</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3b</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Σ</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>1</td>
<td>15</td>
<td>23</td>
<td>8</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>

Figure 10: Distribution of age vs. absolute frequencies
4.2. Results and Analysis

In this subsection the results of the experiment are described and analysed. Every hypothesis of this study is evaluated in this chapter.

4.2.1. Influence of stimuli order on recognition rate

At first, it was investigated whether each two order variations of experimental condition can be assembled. Therefore, it was analysed whether the presenting order of the videos has a significant influence on the recognition rate in general. The recognition rate of emotion of each of the two orders (table 5) were analysed using a chi-squared test. The null hypothesis that the order has no influence and thus both variations evoke the same recognition behaviour can not be rejected at a significance level of 5% ($\chi^2 = 0.0297 < 3.84$).

Table 5: Recognition Rate for Order A and B

<table>
<thead>
<tr>
<th>Order</th>
<th>Correct</th>
<th>Incorrect</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>59.2%</td>
<td>40.8%</td>
<td>100%</td>
</tr>
<tr>
<td>B</td>
<td>58.1%</td>
<td>41.9%</td>
<td>100%</td>
</tr>
<tr>
<td>Overall</td>
<td>58.7%</td>
<td>41.3%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Since this general effect of order is not meaningful, it has to be tested if there is an interaction between experimental condition and the order of stimuli. This is done by using logistic regression on the base of the respective recognition rate (see table 5). The null hypothesis that there is no dependency on the recognition rate between the order of stimuli and condition can not be rejected at a significance level of 5%, because the odds ratio of giving the correct answer is 0.97 for order A and correspondingly 1.03 for order B. These values are within the confidence interval which is 0.9 - 1.1. These results show, that the order in which the videos are presented in the questionnaires have no influence on the responding behaviour and thus on the recognition rate. On the basis of this result, the two orders of the experimental conditions are ignored and their data is aggregated to the corresponding condition (table 6: Overall, figure 11).
4.2.2. Influence of experimental condition on recognition rate

The issue of this research was to find out, whether the sequence of emerge of AUs has a significant influence on the recognition of emotions. In comparing the recognition rates of the three experimental conditions (figure 11), one can see that the recognition rate of the simultaneous onsets of AUs is slightly higher than of the other experimental condition, with a value of 63.7% compared to 54.2% (sequence) and 53.0% (reverse). This may lead to the assumption that the sequence of AUs has an influence on the recognition rate of facial expressions. This is contrary to the previously mentioned presumption, that the sequential order causes the highest recognition rate. To analyse the influence of the experimental conditions the following null hypothesis has to be tested.

The null hypothesis is that the sequence of AUs does not affect the recognition rate. To test this, a chi-square goodness-of-fit test was made. The null hypothesis can not be rejected at a significance level of 5% ($\chi^2 = 4.73 < 5.99$). This result

<table>
<thead>
<tr>
<th>Order</th>
<th>Sequence correct</th>
<th>incorrect</th>
<th>Simultaneous correct</th>
<th>incorrect</th>
<th>Reverse correct</th>
<th>incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>54.2%</td>
<td>45.8%</td>
<td>63.5%</td>
<td>36.5%</td>
<td>54.2%</td>
<td>45.8%</td>
</tr>
<tr>
<td>B</td>
<td>54.2%</td>
<td>45.8%</td>
<td>64.1%</td>
<td>36.9%</td>
<td>51.4%</td>
<td>48.6%</td>
</tr>
<tr>
<td>Overall</td>
<td>54.2%</td>
<td>45.8%</td>
<td>63.7%</td>
<td>37.3%</td>
<td>53.0%</td>
<td>47.0%</td>
</tr>
</tbody>
</table>

Table 6: Recognition Rate of Order A and B over the Conditions

Figure 11: Recognition rate over condition
shows that in this particular study the sequence of AUs have no significant influence on the recognition rate of emotions.

4.2.3. Influence of experimental condition on subjective assessment

For each video stimulus the participant was asked to assess how natural the emotion appeared and how easy it was to recognise the emotion. This assessment was made by rating the statements 1) "The emotion looked very natural." and 2) "It was easy for me to recognise the emotion." on a Likert scale with the values 1: "I do not agree at all" - to 5: "I totally agree". The mean values and standard derivations of assessment for each condition are provided in the following table (table 7). The following bar chart (figure 12) provides an overview on the mean values of assessment.

Table 7: Mean values of subjective assessment

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Condition</th>
<th>Natural</th>
<th>Easy</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sequence</td>
<td>Simultaneous</td>
<td>Reverse</td>
<td></td>
</tr>
<tr>
<td>Natural</td>
<td>2.90 ± 1.1</td>
<td>2.48 ± 1.1</td>
<td>2.57 ± 1.1</td>
<td>2.65 ± 1.1</td>
</tr>
<tr>
<td>Easy</td>
<td>3.06 ± 1.2</td>
<td>2.81 ± 1.3</td>
<td>2.78 ± 1.2</td>
<td>2.88 ± 1.2</td>
</tr>
</tbody>
</table>

Figure 12: Mean values of subjective assessment
Analysing these values, one can see that the values of the sequence condition were higher than of the other conditions. This suggests that the experimental condition has an influence on the subjective assessment of the participants. To test this suggestion, the two null hypotheses are stated that the experimental condition does not influence the assessment of naturalness and the assessment of difficulty. To test this, a oneway ANOVA (analysis of variance) was made for both types of assessment. At a significance level of 5% the null hypothesis can not be rejected for influence of condition on the assessment of difficulty ($F = 2.71 < 3.0$), which implicates no significant influence. Whereas the null hypothesis can be rejected for influence of condition on the assessment of naturalness ($F = 6.60 > 3.0$), at the same significance level of 5%. This means that the condition influences the assessment of naturalness.
5. Conclusion

This study investigated whether the sequence of Action Units has an influence on the recognition rate of emotions performed by avatar faces. Therefore an online experiment was conducted using videos of the facial expressions of disgust and pain as stimuli. There were three hypotheses which had to be tested: The first hypothesis states that the order in which the video stimuli were presented in the survey has no influence on the recognition rate of emotions. This could not be rejected. This results in the fact that the presenting orders do not influence the recognition rate. The second hypothesis states that the video stimuli with the naturalistic sequence of AUs have a significantly higher recognition rate than the other two experimental conditions. This hypothesis could not be rejected. That means that the order of AUs in facial expression did not influence the recognition rate in this study, what is no proof that the sequence of AUs has no influence on recognition of emotions in general. The last hypothesis stated that the emotions with the naturalistic sequence of AUs are assessed as more natural and easier to recognise than the other two conditions. This hypothesis can only be rejected partly. The experimental condition has a significant influence on the assessment of how natural the facial expression is. The condition of sequential AUs gained the highest mean rating score, which indicates that a natural sequence of AUs lets the emotion appear more naturalistic. In contrast, the experimental condition has no significant influence on the difficulty of recognising facial expressions.

The presumption that the naturalistic sequence of AUs results in a significantly higher recognition rate than simultaneous and reverse onset of AUs could not be proven by this study. This could be the research issue of following studies.

One possibility to obtain this result could be a study with a greater number of emotions. Pain and disgust, the sentiment which were used in this study, have many AUs in common which makes it difficult to distinguish between them. This is one issue which was named frequently in the participants’ comments. Also the length of the video stimuli can be varied. It could be that two seconds were just too short for participants to recognise the shown emotion. Another possibility to obtain more significant results can be the use of further developed avatars. It is conceivable that more realistic appearing avatars can raise the recognition rate. Also improved morph targets for Action Units can help to get the emotions displayed more realistic. Most AUs were performed well, but some could be improved as AU 06, which could not produce the characteristic crow’s feet around the eyes. All these possibilities create new research issues to the topic of sequence effects in facial expressions.
Bibliography

[01] Ekman, Paul; Friesen, Wallace "Facial action coding system. Investigator's guide" (1978)


[17] https://www.soscisurvey.de/help/doku.php/de:create:media (access 05.08.2015)
Appendix

This bachelor thesis comes with a CD with the following content:

- Bachelor thesis as PDF *BA_CogSys_AR.pdf*
- Folder *Input* files containing the tables which were used to create the avatar videos
- Folder *Videos* containing avatar videos
- *Survey.pdf* containing a few pages of the online survey
- Survey project *Survey_project.xml*
- Raw data of the experiment *Survey_results.pdf*
Erklärung

Ich erkläre hiermit gemäß §17 Abs. 2 APO, dass ich die vorstehende Bachelorarbeit selbstständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

Datum

Unterschrift