INVESTIGATING THE IMPACT OF SENSORY EFFECTS ON THE QUALITY OF EXPERIENCE AND EMOTIONAL RESPONSE IN WEB VIDEOS

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ABSTRACT

Multimedia is ubiquitously available online with large amounts of video increasingly consumed through Web sites such as YouTube or Google Video. However, online multimedia typically limits users to visual/auditory stimulus, with onscreen visual media accompanied by audio. The recent introduction of MPEG-V proposed multi-sensory user experiences in multimedia environments, such as enriching video content with so-called sensory effects like wind, vibration, light, etc. In MPEG-V, these sensory effects are represented as Sensory Effect Metadata (SEM), which is additionally associated to the multimedia content. This paper presents three user studies that utilize the sensory effects framework of MPEG-V, investigating the emotional response of users and enhancement of Quality of Experience (QoE) of Web video sequences from a range of genres with and without sensory effects. In particular, the user studies were conducted in Austria and Australia to investigate whether geography and cultural differences affect users' elicited emotional responses and QoE.

Index Terms—Quality of Multimedia Experience, Sensory Effects, MPEG-V, Subjective Quality Assessment, World Wide Web, Sensory Experience

1 INTRODUCTION

Multimedia content is increasingly consumed via various distribution channels, e.g., DVDs, Blu-rays, and the Internet. Online video platforms such as YouTube and Netflix offer a vast amount of video content from short user-generated videos to broadcast quality TV shows and full-length feature films. One major shortcoming with these online video platforms is that Web browsers accessing the platform require special software, e.g., Adobe Flash. With the recently introduced HTML5 video tag [1] by W3C and its integration into these platforms, video can now be consumed via Web browsers without the need for additional software.

To address Quality of Experience (QoE) in consumer multimedia environments, as current multimedia distribution channels typically only support traditional multimedia (i.e., stimulating only audition and vision), consumer electronics companies have recently started enhancing users' (viewing) experiences by adding additional sensory effects like ambient light [2]. In previous publications, we investigated the benefits and influence of sensory effects on multimedia content for different settings (e.g., genres [3]). Both publications provided promising results and we extended our investigations to enhancing the QoE with sensory effects on World Wide Web (WWW) content beyond just videos [4]; the work showed the same tendencies as in our previous publications.

In this paper, we extend our previous work and present three subjective quality assessments (referred to as user studies) conducted at the Alpen-Adria-Universität (AAU) Klagenfurt, Austria, the RMIT University in Melbourne, Australia, and the University of Wollongong (UoW), Australia. The goal of the subjective quality assessments (SQAs) is to investigate the enhancement of the QoE and how users' emotions are elicited and influenced by Web videos annotated with and without sensory effects (i.e., light, vibration and wind).

It has been well studied that movies, videos and advertising stimulate the emotions of a viewer [5][6]. Tsoneva et al. [7] conducted a user study to investigate which emotions are conveyed by different movie scenes; a representative list of emotions and their scope was subsequently generated. The list of emotions was defined by experts in the field of multimedia and derived from models such as the Pleasure-Arousal model [8]. The scope of an emotion should help the participants to select an emotion by providing them with a broader definition, e.g., for anger: annoyance, anger, rage. Furthermore, another important aspect of emotions is that a single emotion can have an intensity which conveys the information of how strong an emotion is. This intensity may be influenced by changing the state of pleasure or arousal of a subject [8]. However, video sequences accompanied by sensory effects may also influence these states and are thus investigated through the user studies presented in this paper.

Regarding light effects [2][9] and olfaction [10] in combination with multimedia, there are numerous publications that include user studies on these topics. However, in comparison to the work in this paper, the user studies focus on light effects or scent with content that is provided through broadcasting services or CDs/DVDs/Blu-ray Discs. Our approach thus provides the possibility to enhance multimedia content of well-known Web platforms such as YouTube and MyVideo.

In the remainder of the paper, the three test environments, software setup, and the test method employed are presented in Section 2. The results of the three user studies are outlined in Section 3, with a discussion presented in Section 4. Section 5 concludes the paper and includes a discussion on future work.

2 TEST ENVIRONMENT

This section describes the test environment for the three user studies and test methods employed. The user studies are based on [11] with minor modifications.

2.1 Web Browser Plug-in and Ambient Library

To implement sensory effects into the WWW, we developed software that consists of a Web browser plug-in and a library called *Ambient Library (AmbientLib)* [12]. The Web browser plug-in extracts video frames from a HTML5 video element or from the Adobe Flash Player. Furthermore, timing information for synchronizing sensory effects with the video content is provided through the Web browser plug-in to the AmbientLib. The Web browser plug-in itself uses the AmbientLib to render sensory effects on available devices (e.g., fans, vibration chair).

The AmbientLib utilizes the MPEG-V standard [13] which defines, in Part 3 entitled Sensory Information, the *Sensory Effect Description Language (SEDL)* and the *Sensory Effect Vocabulary (SEV)*. SEV describes different types of sensory effects (e.g., scent, wind, light, vibration). Sensory effects described through SEDL and SEV are referred to as Sensory Effect Metadata (SEM). The AmbientLib is capable of parsing SEM descriptions and rendering sensory effects synchronized to the video as specified within the descriptions.

Moreover, AmbientLib supports automatic color extraction for light effects. Thus, the color extractor of AmbientLib splits the video frame into nine parts. From each part the color is extracted using an average color algorithm. After the color extraction, AmbientLib renders the color of each part on available light devices with respect to their location. For example, the color calculated for the location north is rendered on the light which corresponds to this location. In order to extend the range of supported sensory effects the AmbientLib provides the possibility of invoking so-called device drivers. A device driver is responsible for rendering parsed sensory effects on the corresponding devices with respect to the present hardware setup. Currently, AmbientLib provides a device driver for rendering sensory effects on the amBX system [14].

Table 1. Web Video Sequences.

Sequence Name	Genre	Bit-rate (Kbit/s)	Length (sec)	Wind/ Vibration
2012	Action	2186	29.1	6/8
Prince of Persia	Action	2114	24.89	7/6
Tron Legacy	Action	2379	25.08	7/4
STS131 Launch	News	2812	30.09	7/5
Tornado	News	1299	31.03	4/12
Etna erupts	News	3165	40.07	19/13
GoPro HD Th. Racing	Commercial	2429	30.09	8/3
Verizon	Commercial	1819	30.15	4/4
Audi	Commercial	2245	30.19	9/5
Volcano Britain	Documentary	2133	33.1	10/4
African Cats	Documentary	2562	19.1	6/1
The Last Lions	Documentary	1850	37.04	25/6
GoPro HD Berrecloth	Sports	3552	32.08	11/23
Travis Pastranas Rally	Sports	2619	32.08	8/8
GoPro HD Ronnie R.	Sports	2245	23.16	7/7

2.2 Participants and Stimuli

For the user study we invited 26 students (18 female and 8 male) aged between 20 and 57 who participated at AAU Klagenfurt, Austria. Only one participant already took part in a similar user study. For the user study at RMIT University, Australia, 21 students and staff were invited (12 female and 9 male) aged between 22 and 58. None of these participants had previously taken part in a similar user study. For the user study at UoW, Australia, 21 students and staff were invited (6 female and 15 male) aged between 22 and 63 and none of the participants took part in a similar user study.

The assessment was designed as a Web site with an introduction at the beginning, where the whole assessment was provided in English. Thus, each participant had the same test conditions. The user study consisted of 15 Web video sequences from five genres. Table 1 lists the Web video sequences including the genre, bit-rate, length, and number of wind and vibration effects. Please note that light effects are generated automatically as described in Section 2.1. All Web videos are presented with a resolution of 720p, where the SEM descriptions were generated with the open-source tool Sensory *Effect Video Annotation (SEVino)* [12]. The annotation of the video sequences was done internally. Since the process of annotating sensory effects is subjective, we introduced a review process which ensured that all necessary effects are covered and, in our opinion, best fitting for the presented scene.

2.3 Test Setup

The three experiments were conducted in a controlled environment and under the same ambient conditions as described in [4]. For each session we ensured that all non-

Table 2. Hardware and Software.

AAU Klagenfurt	RMIT University	UoW
amBX Premium Kit (Fan, Vibration Panel, Light, Sound); 24" Monitor with a resolution of 1400x1050 Mozilla Firefox 6 & 8 in full-screen mode Ambient Library 1.5 & Web browser plug-in 1.5 amBX Software (amBX System 1.1.3.2 and Philips amBX 1.04)		
Dell Optiplex 655: Pentium D 2.8 GHz w/ 1 GB RAM & ATI Radeon HD 5450	HP Z400: Intel Xeon Quad Core 3.33 GHz w/ 6 GB RAM & Nvidia Quadro FX 1800	Intel Quad Core 3 GHz w/ 3GB RAM & Intel Q35 384MB
Windows XP SP3	Windows 7 64-bit	Windows XP SP3

essential electronic devices were turned off. Additionally, the room was darkened to gain better light contrast for the light effects.

Table 2 presents the hardware and software used for conducting the subjective tests in both countries. The amBX Premium Kit was used to render the sensory effects according to their definition within the SEM descriptions. All available devices were used during the user study, i.e., the left and right light-speakers which combine a LED light and a speaker (including the subwoofer), the wall washer (consisting of three lights), the left and right fans, and the wrist rumbler.

The user study itself was structured into three parts: an introduction with pre-questionnaire, the main evaluation, and a post-questionnaire. The overall duration for the user study for each participant was around 20 minutes.

The introduction was used to explain the test procedure to the participants and to advise them to turn off all electronic devices. Additionally, the introduction advised the participants to not take part in the experiment if they are visually or aurally impaired. The pre-questionnaire included demographic questions (e.g., age, gender, country of residence, nationality, occupational field, education).

The main part of the test is described in detail in Section 2.4. The third part of the subjective test was a post-questionnaire which was presented at the end of the experiment to the participants for feedback on the user study itself with the following questions:

Q1. Have you ever participated in an experiment similar to this one?

Q2. Which sensory effects would you like to have in addition?

Q3. Any other comment about what you liked or did not like, or things that should be changed during the course of this experiment?

With the question Q2 a list of sensory effects was provided, i.e., fluid (water), temperature, aroma, and fog. The participants could select one or more of these additional sensory effects to indicate which other sensory effects they would like to experience. Furthermore, the list of additional effects included sensory effects that were already present in the user study (i.e., vibration, wind). This should give the participants the possibility to state whether they would like to have these sensory effects to be stronger or weaker.

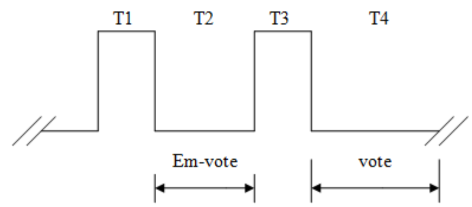

Figure 1. Evaluation Method.

2.4 Test Method and Experimental Design

For the user study we modified the *Double-Stimulus Continuous Quality-Scale (DSCQS)* as defined by ITU-R Rec. BT.500-11 [11]. Due to the objectives of this experiment we added a voting possibility for emotions between the presentation of the reference sequence (i.e., without sensory effects) and the presentation of the test condition (i.e., sequence with sensory effects). Figure 1 depicts the presentation structure of the adopted DSCQS.

In Figure 1, *T1* represents the presentation of the reference sequence. The reference sequence is a randomly selected Web video sequence from Table 1 presented without sensory effects. *T2* depicts the voting for emotions. We used the emotions from [7] as ground truth for our test. A list of emotions with their scope was presented to the participants (e.g., anger, worry, fun, etc.), where the participants chose one or more emotions from this list. After the selection of an emotion the participants were asked to rate the intensity of the selected emotion for the reference sequence. The rating was presented with a slider with a continuous scale ranging from 0 (very weak) to 100 (very strong).

After rating the emotions, the same Web video sequence was presented but this time with sensory effects, depicted by *T3*. During *T4* the participants were asked again to select and rate the intensity of the emotions they experienced during the Web video sequence with sensory effects. Afterwards, the participants rated the enhancement of the QoE for the Web video sequence with sensory effects in relation to the Web video sequence without sensory effects. The continuous rating scale for the enhancement of the QoE ranged from 0 to 100, where 100 represented a big enhancement and 0 indicated that sensory effects were very annoying. It has to be mentioned that DSCQS uses an impairment scale which was not suitable for our test. Thus, we adopted the original scale and transformed it into an enhancement scale which consists of the following levels: *Big enhancement (100 – 80)*, *Little enhancement (80 – 60)*, *Imperceptible (60 – 40)*, *Annoying (40 – 20)*, and *Very annoying (20 – 0)*.

During the presentation of the Web video sequences the background color of the screen was set to black, as other colors would have interfered with the video and the light effects. During the voting the background color of screen was set to mid-grey as proposed in [11]. Finally, there was no time limit during any of the (emotion) voting processes.

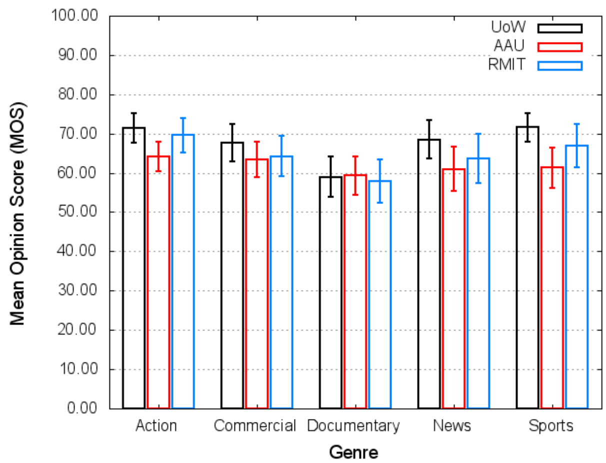

Figure 2. Enhancement of QoE for each Genre for all three user studies.

3 RESULTS

The aim of conducting the same user study in different countries was to identify if there are differences in the enhancement of the QoE among different user bases. Furthermore, we were interested in whether or not users' emotion responses are influenced by sensory effects. The intensity of an emotion may provide information on whether sensory effects have an increasing or decreasing influence on the user's elicited emotions.

3.1 Evaluation Methods

The evaluation for the enhancement of the QoE, including the screening of outliers, was conducted as proposed in [11]. This includes the calculation of the Mean Opinion Score (MOS) and the 95% confidence interval for all Web video sequences and genres. Outliers were screened once for all Web videos and participants for each country, which resulted in no outliers in the three user studies. The enhancement of the QoE was subdivided into five levels during the evaluation.

To identify differences between the means of the intensity of an emotion without (M_{WoE}) and with sensory effects (M_{WE}) we used a one-sided Student's *t*-test for independent samples. The Student's *t*-test was done twice under the following two hypotheses:

$$H_{0_1} = M_{WoE(active)} < M_{WE(active)} \quad (1)$$

$$H_{0_2} = M_{WoE(passive)} > M_{WE(passive)} \quad (2)$$

Hypothesis (1) was used to test if active emotions (e.g., anger, worry, fun, etc.) are increased in their intensity when using sensory effects. Hypothesis (2) was used to test if passive emotions (e.g., tiredness, boredom, passiveness, etc.) are decreased in their intensity when using sensory effects. For more details on active and passive emotions the reader is referred to [15]. To screen outliers, the modified *z*-score with the median absolute deviation (MAD) estimator with a threshold of 3.5 was used [16]. The advantage of this method in relation to the standard *z*-score is that it uses the median of the absolute deviation of x_i and $\bar{x}$. Thus, the modified *z*-score is more robust than the standard *z*-score. Furthermore, the outliers were only screened once for each emotion without sensory effects and with sensory effects.

3.2 QoE Results for Australia and Austria

Figure 2 depicts the MOS and the 95% confidence interval for each genre of all three user studies. The results for the user studies conducted at RMIT and at UoW are very similar in terms of the five-level enhancement scale. In both cases the highest enhancement of QoE can be observed for the genres action and sports. The results for the genres action, commercial, news and sports are in the range of 60 to 70 for the user study conducted at RMIT which is in the area of *little enhancement*. The results for UoW state that the genres action and sports are rated slightly above 70 which is in the upper area of *little enhancement*. The participants state the influence of sensory effects for the documentary genre as imperceptible.

For the user study conducted at AAU, Austria, Figure 2 illustrates the same trend as in the results of the Australian studies. It can be observed that the genres action, commercial, news and sports are in the range of 60 to 70. Moreover, it can be observed that again the same four genres as in the RMIT user study are in the range of *little enhancement*. However, the results for the genres news and sports are slightly lower compared to the results from the Australia studies. Again the documentary genre has the lowest score. In contrast to the Australian studies, the highest degree of enhancement can be observed for action and commercial.

Comparing the results from the three user studies it can be observed that in all cases the genres have the same tendencies with respect to their MOS. In particular, the genre action and sports have the highest enhancement of QoE in the studies conducted. ANOVAs revealed that there exists a significant difference between the genres action and sports for the user studies conducted at AAU and UoW (p-values: 0.0086 for action and 0.0023 for sports).

3.3 Results for Emotions for Australia and Austria

Due to space constraints, Figure 3, Figure 4, and Figure 5 depict only emotions for which the Student's *t*-test revealed a significant difference over all Web video sequences. The alpha value for accepting the appropriate hypothesis was 5%. The *p*-values which represent the significance of the results are given with the name of the emotion. To visualize the difference between the intensity of emotions without and with sensory effects the mean of the intensity for Web video sequences without and with sensory effects is plotted as a bar chart.

Figure 3 depicts the results for the emotions of the user study conducted at UoW. All emotions were significantly increased in their intensity with sensory effects. Moreover,

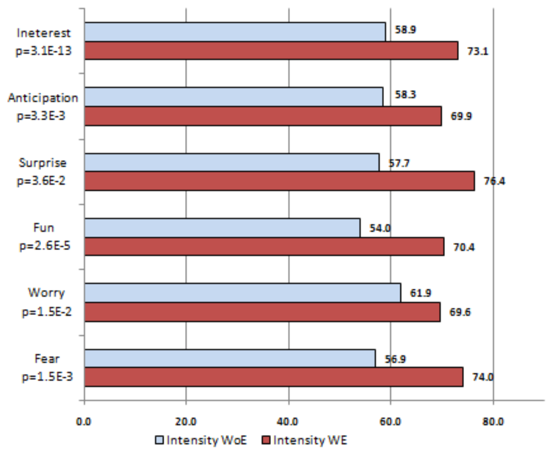

Figure 3 Emotions with significant differences between with and without sensory effects for UoW, Australia.

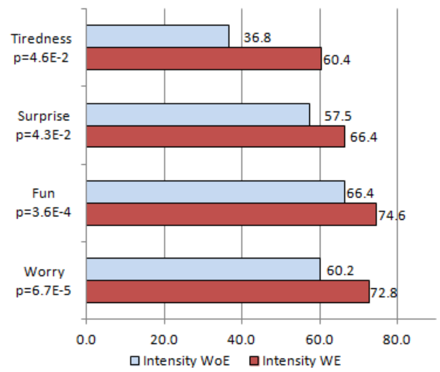

Figure 4. Emotions with significant differences between with and without sensory effects for RMIT, Australia.

only emotions are significantly influenced which can be referred to as active emotions [15]

Figure 4 illustrates the results for the emotions of the user study performed at RMIT. An interesting observation can be made regarding emotions which can be referred to as active emotions (i.e., surprise, fun and worry). These emotions are significantly increased in their intensity with sensory effects in relation to their intensity without sensory effects. The emotion tiredness, which can be referred to as a passive emotion, is also increased.

Figure 5 depicts the results for the emotions of the user study carried out at AAU. In comparison to Figure 4, a lot more emotions show a significant difference in their intensity. However, the same tendency as in the Australian user studies can be observed: active emotions are increased significantly. Furthermore, it can be observed that the intensity of the passive emotion boredom is decreased.

The two emotions fun and worry are present in each set of results from Austria and Australia and in all cases the intensities of these two emotions are significantly increased with sensory effects. This suggests that sensory effects increase active emotions. Regarding passive emotions, no assumptions can be stated so far as the only two passive emotions tiredness (cf. Figure 4) and boredom (cf. Figure 5) exhibit contradictory results.

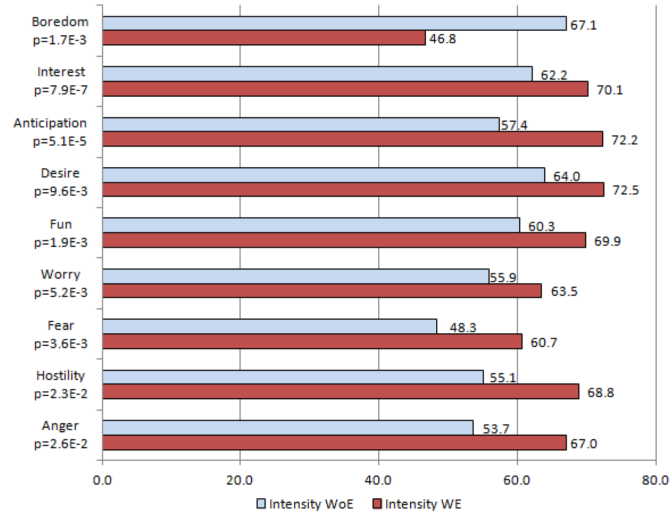

Figure 5. Emotions with significant differences between with and without sensory effects for AAU, Austria.

3.4 Post-Questionnaire Results

The results of the post-questionnaire for the user study conducted at RMIT indicated that none of the participants had previously participated in a similar study (i.e., Q1). For the question on which sensory effects should be additionally added or if the available sensory effects should be stronger (i.e., Q2), 48% of the participants stated that they wanted to have stronger wind effects, 43% voted for having stronger vibration effects, 71% would like to have temperature added and 62% want to have aroma as additional effect. Only 29% voted for adding fog and 10% indicated that fluids like water should be added. The last question of the post-questionnaire (i.e., Q3) gave the participants the possibility to give feedback and comments. 24% stated that the lights were distracting and 10% said that the wind effect gave a false sensation because the temperature was not varied according to the video content e.g., hot wind to correspond to lava flow from a volcano explosion. 19% of the participants perceived a higher involvement with sensory effects.

The results of the post-questionnaire for the user study performed at UoW are as follows. For Q1, the results show that none of the participants have already participated in a similar user study. The question on which sensory effects should be additionally added or if the available sensory effects should be stronger (i.e., Q2) revealed that, 62% of the participants would like to have temperature added. 52% want to have aroma in addition, 33% would like to have stronger wind effects, and 29% would like to have stronger vibration. Only 14% would like to have fog and 10% can imagine that fluid are added as sensory effects. Regarding Q3, 19% of the participants stated that sensory effects enhance the QoE and 14% said that the effects were not appropriate with some video sequences.

The results of the post-questionnaire for the user study carried out in Austria are as follows. For Q1, one person stated that he/she had participated in one of our previous studies [4]. Q2 revealed that 46% of the participants would like to have stronger wind effects, 50% voted for having stronger vibrations, 54% would like to have temperature added and 46% can imagine having aroma added to the palette of available sensory effects. Similar to the Australian user study, fog (27%) and fluids like water (15%) were also less desired as additional effects. Regarding Q3, 15% of the participants stated that the light was distracting. Furthermore, approximately 8% said that they were mentally overloaded and 8% found that sensory effects to be disturbing during the documentary video sequences. 19% of the participants commented that sensory effects enhanced the experience.

4 DISCUSSION

Regarding the enhancement of the QoE for the three user studies it is clearly outlined that some genres are more suitable for sensory effects than others. In particular, the action genre, which has the highest rating in terms of MOS, seems to be very suitable for additional sensory effects. Due to the entertaining nature of action sequences, there are more possibilities to annotate sensory effects such that they are engaging for the user. Surprisingly, in all three studies the results for the documentary genre are rated the lowest. In comparison to our previous studies [4], the documentary genre was rated the highest. This can be due to the different content used in both user studies.

Comparing the results of the user studies regarding the intensity of emotions, results indicated that active emotions (e.g., worry, fun) are increased in their intensity with sensory effects (H_{0_1}). Only two passive emotions are present in the results: from the Austrian user study, the passive emotion boredom is significantly decreased in its intensity. In contrast, the RMIT user study indicated that the passive tiredness emotion is surprisingly increased in its intensity. Thus, it is not yet possible to derive a general conclusion on passive emotions from the results (H_{0_2}).

5 CONCLUSIONS AND FUTURE WORK

In this paper, we presented the results of three formal subjective quality assessments conducted at different locations, i.e., RMIT University, University of Wollongong both in Australia and AAU Klagenfurt in Austria, evaluating how Web videos enhanced with sensory effects affected users' emotional responses and QoE.

The results show that, in general, sensory effects enhance the QoE. Furthermore, the results indicate that some genres are more suited for sensory effects than others. The emotions and their intensity verify these results and in addition to the QoE they show which emotions and how these emotions are influenced by sensory effects. In general, it can be concluded that active emotions are increased in their intensity. The results obtained for the passive emotions do not yet allow for a general conclusion on whether passive emotions are decreased or increased in their intensity.

Future work includes identifying the influence of single sensory effect (e.g., wind) on the QoE by conducting further user studies. A further research task is to investigate users' elicited emotions and their intensity by using an electroencephalography (EEG) device to automatically identify the user's emotions when watching a video.

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