Measuring Stereoscopic Image Quality Experience with Interpretation Based Quality Methodology

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ABSTRACT

Stereoscopic technologies have developed significantly in recent years. These advances require also more understanding of the experiential dimensions of stereoscopic contents. In this article we describe experiments in which we explore the experiences that viewers have when they view stereoscopic contents. We used eight different contents that were shown to the participants in a paired comparison experiment where the task of the participants was to compare the same content in stereoscopic and non-stereoscopic form. The participants indicated their preference but were also interviewed about the arguments they used when making the decision. By conducting a qualitative analysis of the interview texts we categorized the significant experiential factors related to viewing stereoscopic material. Our results indicate that reality-likeness as well as artificiality were often used as arguments in comparing the stereoscopic materials. Also, there were more emotional terms in the descriptions of the stereoscopic films, which might indicate that the stereoscopic projection technique enhances the emotions conveyed by the film material. Finally, the participants indicated that the three-dimensional material required longer presentation time, as there were more interesting details to see.

Keywords: Stereoscopic quality, stereoscopic film, image quality

1. INTRODUCTION

Developments in stereoscopic technologies have made better quality stereoscopic displays possible\textsuperscript{1}. The technological developments have created a situation in which there will be an increasing amount of hype about the possibilities of stereoscopic technologies. There are already experts who predict that home entertainment, movie theaters and game playing will be completely transformed by stereoscopy. However, the current technological situation is not entirely unique. There has been a hype period in which stereoscopic images have been considered a critical breakthrough in entertainment and education in almost every decade since the 1860s when the stereoscopic entertainment first broke through due to the innovations in stereoscope design and photography\textsuperscript{2-4}. In 1860s the stereoscopic entertainment consisted of photographic pairs which were viewed with a hand-held stereoscope. The images consisted of an educational image series of foreign cities or natural sights. With the development of stereoscopic movies, the expectations regarding the breakthrough of stereoscopic images became even stronger.

A common thought during each of the stereoscopic hype periods has been that stereoscopic viewing is somehow more exciting and appealing for the viewers and consequently ordinary movies and images will be quickly superseded by the stereoscopic technology. For some reason this has never happened during the last 150 years and stereoscopic images and movies have remained a marginal phenomenon. There are probably many technological, economic and societal reasons for the unsuccessful attempts to introduce the stereoscopic 3D\textsuperscript{5,6}, but one important factor is probably related to the viewer experience with stereoscopy. In many cases stereoscopic presentations have been uncomfortable or even impossible to view due problems in content creation or film projection and thus the viewer experience has not been good enough. Furthermore, there have been very few serious trials to use stereoscopic imaging in artistic and expressive sense.

Stereoscopic images can also induce adverse symptoms and physiological aftereffects in the viewers as they produce conflict between the convergence and accommodation systems of the eye\textsuperscript{7-12}. Because the possibility of having adverse symptoms is critical for the acceptance of the stereoscopic technologies, the viewer experience studies have mostly focused on measuring the negative experiences. However, there are probably also positive experiences created by
stereoscopic imagery. It is usually thought that stereoscopic images are somehow more exciting than ordinary images. If this is the case, then one should be able to define the nature of the positive experience and the specific factors in 3-D that are the true causes of the enhanced experience. These could be for example increased fun and excitement, increased feeling of reality or solidity, feeling of presence or maybe aesthetic experiences like being awed by the beauty or sublimity of stereoscopic images. Although there are studies related to the positive experiences, they have been based either on questionnaires or different types of psychophysiological measurements. There has been only a few explorative studies regarding experiences with stereoscopic displays. Freeman and Avons conducted a focus group study, in which the features of presence experience with three-dimensional television were investigated. Their main finding was the feeling of being transported to the three-dimensional scene during the experiment. In our study we wanted to explore the viewer experience in individual level with paired comparison approach so that more specific results could be obtained.

1.1 Experience formation

When a stereoscopic film or an image is viewed, the resulting experience is formed by factors related to stereoscopic materials, the cognitive-emotional factors related to the viewer, the perceptual-physiological limitations of the viewer’s visual system, the viewing context and the culture. The interaction of these factors affect the viewing experience that is formed in a specific situation.

The stereoscopic materials can be either static images, like photographs, or moving images, like stereoscopic films. The most significant factor related to stereoscopic materials is the contents and the way stereoscopy is related to contents. For example, stereoscopic films have often been stereoscopic effect parades without significant interest in creating high quality narrative.

The technology that is used to watch the materials has also significant impact on the viewer experience. Firstly, there can be a number of artifacts in the images, like keystone distortion, ghosting, flicker, cardboard effect, puppet-theater effect, image flipping or feelings of artificial clarity. Secondly, different image sizes and styles in a mobile device and in a film projection will probably direct the viewers attention to different aspects of the images. Thirdly, image processing, like compression, scaling or 2D-to-3D conversion can produce significant errors and distortions in the material.

The cognitive and emotional state of the viewer is probably one of the most significant factors affecting the viewer experience. First of all, the viewer has reasons to watch the material. These reasons can vary from choosing entertainment to the evening to reviewing stereo photography collection. Secondly, the viewer might have some prior experience with stereoscopic images and materials. Having more experience with stereoscopy probably increases the negative impact of errors or distortions, as the initial excitement of stereoscopic materials has already passed and the viewer might pay more attention to deficiencies in the material. Thirdly, the user may have different expectations of the material. This type of viewer experience evolution has already taken place during the introduction of larger displays and better audio surround. For example, seeing a film in a theater probably creates more expectations of quality than watching a short news cast in a mobile device. Fourthly, the viewer might have certain attitudes towards stereoscopy and new technologies in general. Being skeptical of new technologies or expecting distorted images make any image errors more visible when compared to a situation in which the viewer is enthusiastic about the new technology.

Physiological limitations are set by the convergence and accommodation systems that tolerate only limited amount of depth or depth change in the images before the images become blurry or diplopic. The perceptual limitations are related to the maximum depth level in which an object can be viewed as a single image, i.e. Panum’s fusional area as well as to the tolerance limits for mismatch in convergence and accommodation. If these limits are violated, images might be difficult to view and eye strain might be present. Both physiological and perceptual aspects of stereoscopic perception have received a lot of attention in the ergonomics research related to stereoscopic images, but they cannot be fully interpreted if higher level cognitive and emotional factors are not taken into account.

The perceptual-physiological and cognitive-emotional processing levels can interact in multiple – and also in artistic — ways. For example, viewing emotionally significant stereoscopic photograph of a grandchild might override minor inconveniences produced by stereoscopic errors in the image. Similarly, a teenager might forget eye strain created by too high depth magnitude when watching a highly anticipated stereoscopic film. Thus, measuring only diplopia thresholds or eye strain without considering the more complex factors might not produce usable results.
There has been several studies, which have attempted to define the added value of stereoscopic images. For example Lambooij\textsuperscript{14} describes experiments in which the task of the participants was to rate the naturalness, viewing experience, presence, image quality and depth of the stereoscopic images produced by different 2D-to-3D algorithms. The results indicated that naturalness ratings correlated significantly with the quality ratings suggesting that it might be the relevant stereoscopic quality factor.

Another approach to stereoscopic images is to measure the degree in which the viewer feels to be inside the scene depicted by the stereoscopic image. The feeling of being transported from the actual environment to the virtual world is described as presence or immersion experience\textsuperscript{20, 32-34}. Presence experiences have usually been categorized to two main categories, physical and social presence\textsuperscript{35} which refer to the transportation to the virtual world and the feeling of being together with other persons.

1.2 Interpretation Based Quality approach to stereoscopic image quality

The examples in the previous paragraphs have indicated that stereoscopic image quality is affected by multiple factors ranging from emotions to restrictions created by the oculomotor system of the eye. In order to deal with the complexity of the problem, we approach the stereoscopic viewer experience first with top-down approach and then bottom-up. We start the research by using a novel image quality research method developed at the Department of Psychology, University of Helsinki. This method, Interpretation Based Quality (IBQ), combines existing approaches to image quality and form a research approach in which the perceptual attributes of the viewer are derived from a combination of quantitative and qualitative data. These perceptual attributes reflect different levels of viewer experience\textsuperscript{36-40}.

Conventional subjective image quality studies use psychometric methodologies like paired comparison or quality ratings to measure the impact of image features or errors to the viewer. Although these methodologies are well established and very useful in many cases\textsuperscript{41}, they have some shortcomings especially when comparing high-quality images or completely new image types. Using the conventional methodologies gives information about the detectability of errors or allows to select the best quality images but they do not tell why the viewers rated one image type as better than another. Furthermore, rating images based on predefined rating scale, like image quality, presence or naturalness might leave significant experience dimensions unmeasured, as it might not be possible to guess, what kind of experience dimensions are relevant with a new image type.

In the IBQ approach the conventional methodology is complemented with a qualitative part in which the participant is interviewed about the reasons he used when viewing the materials. The interviews are analyzed and the occurring experience attributes are systematically coded based on grounded theory principles. The resulting codes are combined with the quantitative data and this combination is statistically analyzed. This approach has been successfully applied in studies related to paper quality\textsuperscript{36, 37}, consumer photographs\textsuperscript{38} and video camera quality\textsuperscript{40} with over one thousand experimental participants. The main benefit of the IBQ methodology is that we obtain the real experiential dimensions from the viewers and thus are able to construct measurement scales that truly reflect the experiences of the viewers.

In the current study we have used the IBQ methodology with stereoscopic materials and conducted a paired comparison experiment in which the viewer watches the non-stereoscopic and stereoscopic versions of the same material and reports her preference. In this article we report the attributes used by the viewers, which indicate the most significant experiential dimensions of stereoscopic movie watching.

2. METHODS

2.1 Participants

68 participants from participated the experiment. The participants came from the Faculty of Behavioral Science of the University of Helsinki. 62.5 % of the participants were females and their mean age was 24.9 years (range 18-33 years). The vision of the participants was checked before the experiments with visual acuity, contrast sensitivity and stereoscopic acuity tests. All the participants had normal or corrected to normal vision.

2.2 Materials

There were eight twenty second film clips that were used in the experiment. The materials were filmed by Kasimir Lehto and Sami Laitinen from Stereoscape Ltd. (www.stereoscape.net). The filming was done with Sony HDV cameras with a resolution of 1440 x 1080 pixels. The cameras were synchronized with LANC control unit. There were eight contents:
**Content 1.** A girl standing and watching a billboard. The scene is fairly stationary but the camera moves slowly to the top left direction (Figure 1).

**Content 2.** A boy playing football in the rain. In this stationary and rainy scene there is a wet road in front and a boy playing football in the background. The heavy rain is visible in the foreground (Figure 2).

**Content 3.** A bridge with cars and pedestrians. A group of persons walks slowly on the bridge. Several cars go quickly below the bridge (Figure 3).

**Content 4.** A boy running quickly. A boy is running quickly on a street. Camera follows the boy who is occasionally occluded by a parked car (Figure 4).

**Content 5.** A sleeping boy. The face of a sleeping boy fills the whole screen (Figure 5).

**Content 6.** A girl brushing her teeth. A girl is watching herself on the mirror and brushing her teeth (Figure 6).

**Content 7.** A tree. There is a tree in the middle of the scene and apartment buildings in the background. The camera goes slowly up and follows the trunk of the tree (Figure 7).

**Content 8.** Dancers under a bridge. A group of young people is watching while two young men dance under a bridge (Figure 8).

### 2.3 Projection equipment

The film clips were presented with a 2.40GHz HPxw4400 computer equipped with two Seagate ST373455SS hard disks and nVidia QuadroFX 1400 display card. The film clips intended for the left eye were on a separate Seagate hard disk and the film clips for the right eye were on a second Seagate disk. The resolution of the film clips was 768 x 432 pixels. The film was shown with Inition 3DVidBoxHD player without a soundtrack and projected with InFocus DepthQ projector on a projection screen and viewed with NuVision AG100 Active Glasses. The viewing distance was 280 cm and the projected image size was 113.5 x 151.0 cm.

### 2.4 Procedure

Before the experiment we checked the vision of the participants and ensured that they had sufficient stereoscopic vision as well as visual acuity and contrast sensitivity. The participants filled in a background questionnaire before entering the experiment. In the experiment they saw a pair of film clips containing the stereoscopic and non-stereoscopic version of a specific content. The order of contents in the whole experiment as well as the order of stereoscopic and non-stereoscopic version in each case were randomized. After seeing both versions of contents the participants indicated which one of them did they prefer. After indicating their preference we asked the participants to tell the experimenter the reasons for their choice. The participant then told freely about their reasons.

During the interview the experimenter asked additional questions. The questions were formed in such a way that the experimenter used only the terms introduced by the participants. If the participant used abstract descriptions (e.g. "It was beautiful") of the film, the experimenter formulated a question in which she tried to find out the concrete reason for the specific description ("What in the image looked beautiful?"). If the participant referred to a concrete attribute (e.g. "I noticed the eyes of the sleeping boy"), the experimenter formulated a question in which tried to find out the experiential consequences of the content that took the attention of the viewer ("What kind of atmosphere did the eyes of the boy create?"). The interviews were taped and transcribed to text. The text was then analyzed with Atlas.ti program in which experiential attributes and locations were identified and marked. In this paper we report the most frequency of the subjective attributes that were mentioned in the interviews.
Fig. 1. Girl and billboard.
Fig. 2. Boy playing football.
Fig. 3. Bridge with pedestrians.
Fig. 4. Running boy.
Fig. 5. Sleeping boy.
Fig. 6. Girl brushing her teeth.
Fig. 7. Tree and houses.
Fig. 8. Dancers under a bridge.
3. RESULTS

In the text analysis were divided the resulting codes into four main categories. The first category contained the image locations that were mentioned by the participants (e.g. pedestrian, eye, tree, rock; N=1266). The second category contained physiological sensations experienced by the participant (e.g. eye strain, nausea, vertigo; N=100). The third category included the experience attributes that referred to a specific experience attributes (e.g. three-dimensional, nice, cool; N=1914). The fourth class referred to camera movements mentioned by the participants (e.g. camera went up, camera moved to right, camera was stationary; N=90). In this analysis we describe the locations, the symptoms and the experience attributes.

3.1 Location descriptions

A total of 1266 location descriptions were collected from the experimental data. Table 1 shows the frequency of location reference types in stereoscopic (3D) and non-stereoscopic (2D) versions of the contents. The column labeled significance indicates whether there were significant differences in the number of location references between the stereoscopic and non-stereoscopic versions. Most of the descriptions were related to the stereoscopic versions of the movie clips, although references to people were also fairly common with the non-stereoscopic film clips. Other commonly referred locations were trees and plants. Complex natural objects were regarded as interesting and the participants would had liked to have more time to explore them. Also the mirror of scene 6 was found to be compelling, as the mirror image had depth and thus did not look like an ordinary mirror image. Other categories included “A location in a scene” that refers to miscellaneous stationary objects in the scene (e.g. traffic signs, rocks, bridge) and “Moving objects” which refers to miscellaneous moving objects in the scenes. Category “Background” indicates comments related to objects seen far in the background of the film clips. Category “Face and face parts” refers to content with the sleeping boy, which elicited a lot of references to the chin, nose and eyes of the boy. “Light sources” were street lamps and car lamps. “Ground in front of a scene” is a group containing references to the front part of the scene that was regarded as significant in many scenes.

<table>
<thead>
<tr>
<th>Descriptions</th>
<th>3D</th>
<th>2D</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>281</td>
<td>75</td>
<td>ns.</td>
</tr>
<tr>
<td>Trees and plants</td>
<td>168</td>
<td>14</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Mirror</td>
<td>160</td>
<td>15</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>A location in a scene</td>
<td>140</td>
<td>13</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Moving objects</td>
<td>127</td>
<td>8</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Background</td>
<td>110</td>
<td>11</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Faces and face parts</td>
<td>60</td>
<td>0</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Light sources</td>
<td>53</td>
<td>8</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Ground in front of a scene</td>
<td>22</td>
<td>1</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1121</td>
<td>145</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Symptoms

Adverse symptoms were not mentioned often when describing the films, as can be seen in Table 2. The table shows the frequency of symptoms in stereoscopic (3D) and non-stereoscopic (2D) conditions. The significance value on the rightmost column shows whether there is a significant difference in the frequencies between the 3D and 2D situations as given by the Chi-square test.

Approximately five percent of the all experience descriptions referred to adverse symptoms created by the stereoscopic film. The most common symptom was “Troublesome feeling while watching”, which refers to all kinds of eye-related symptoms mentioned by the participants (e.g. eye strain, tired eyes, weird feeling in the eyes). The total number of quotes for eye strain was 37, which is 2.1 % of the all stereoscopic experiences mentioned by the experiment participants. Almost as common was symptom cluster “Focusing difficulties”, which contains descriptions of symptoms indicating accommodative difficulties (e.g. “It was difficult to make the consecutive images sharp, my eyes did not work right”). Other symptoms that were mentioned were “Dizziness”, “General discomfort” and “Perceiving double images”, but the frequency of these symptoms was very small.
Table 2. Symptoms.

<table>
<thead>
<tr>
<th>Descriptions</th>
<th>3D</th>
<th>2D</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troublesome feeling while watching</td>
<td>37</td>
<td>1</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Focusing difficulties</td>
<td>36</td>
<td>1</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Dizziness</td>
<td>9</td>
<td>1</td>
<td>ns</td>
</tr>
<tr>
<td>General discomfort</td>
<td>9</td>
<td>0</td>
<td>ns</td>
</tr>
<tr>
<td>Double images</td>
<td>5</td>
<td>1</td>
<td>ns</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>96</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Subjective attributes

Depth impression

The subjective attribute descriptions in table 3 describe the arguments the participants used when comparing the stereoscopic and non-stereoscopic versions of the films. The significance value indicates the significance of difference between stereoscopic and non-stereoscopic conditions. The most commonly mentioned impressions were related simply to the depth of the stereoscopic film (frequency=365). A typical quotation in this category was:

"When you watched the three-dimensional version, you checked the images and noticed that the three-dimensionality worked really well in the foreground" (Content 2/Footballer, Participant 2, lines 68-76 in the interview).

Life-like vs. artificial

Interestingly, the secondly and thirdly most common experience attributes were contradictory: many participants felt that stereoscopic movies were better because they looked more real and life-like (frequency=220), but there were almost as many references to artificiality (frequency=144). A typical comment in the life-likeness category was:

"In the three-dimensional images it felt like I was able to touch the scene, there more atmosphere and it felt that it was more near and more life-like". (Content 1/Girl with billboard, Participant 11, line 208 in the interview).

Typical comments in the artificial category referred the stereoscopic image as unreal or computer like:

"I noticed the light in the three-dimensional version, the lights and shadows, the way that the contrasts were larger in the stereoscopic one and you had the feeling that you were more in the scene. The dancers looked more like dolls in stereoscopic version, or like printed scraps, but they made a weird sympathetic impression". (Content 8/Dancers, Participant 12, line 49 in the interview).

"There was this weird but comfortable feeling of unreality in the stereoscopic version" (Content 6/Girl brushing teeth, Participant 32, line 60 in the interview).

There are two important details in these categories. Firstly, being artificial did not necessarily mean that the viewer regarded the image quality as bad. Artificiality was often regarded as a style effect that created a specific atmosphere in the scene. Thus, real-unreal continuum does not necessarily reflect an image continuum from good to bad quality. Secondly, the same participants used the real-unreal attributes in a different way with different contents. Consequently, the validity of reality-likeness as a quality attribute might differ according to the content qualities.

Presence in the scene

Stereoscopic videos elicited many references to being part of the scene (Table 3):

"It was so real, I mean the boys head, it looked so realistic and I felt like I was present in the situation" (Content 5/Sleeping boy, Participant 11, line 119 in the interview).

The presence attributes were very homogenous, they consistently described the stereoscopically depicted scene as a place to which it is very easy to move into. This finding confirms earlier suggestions that presence is a significant experience factor with stereoscopic contents.\(^{15, 20}\)
Table. 3. Subjective attributes.

<table>
<thead>
<tr>
<th>Descriptions</th>
<th>3D</th>
<th>2D</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth impression</td>
<td>365</td>
<td>11</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Real and life-like</td>
<td>220</td>
<td>22</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Artificial, looks like a computer game</td>
<td>144</td>
<td>3</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Dynamic, lots of movement</td>
<td>116</td>
<td>6</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Presence</td>
<td>107</td>
<td>5</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Some locations blurry and difficult to see</td>
<td>94</td>
<td>15</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Disturbing</td>
<td>84</td>
<td>2</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Not enough time to look at everything</td>
<td>57</td>
<td>30</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>You notice more details</td>
<td>57</td>
<td>4</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Threatening, scary</td>
<td>56</td>
<td>2</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Weird</td>
<td>46</td>
<td>1</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Looks bad</td>
<td>45</td>
<td>26</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Interesting</td>
<td>43</td>
<td>0</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Difficult, exhausting</td>
<td>43</td>
<td>1</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Exciting and stimulating</td>
<td>40</td>
<td>3</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Feeling of space</td>
<td>30</td>
<td>0</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Glossy, light</td>
<td>30</td>
<td>0</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Boring, melancholic</td>
<td>29</td>
<td>43</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Messy</td>
<td>27</td>
<td>1</td>
<td>p&lt;0.01</td>
</tr>
<tr>
<td>Peaceful</td>
<td>24</td>
<td>38</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Ordinary</td>
<td>11</td>
<td>33</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Total</td>
<td>1668</td>
<td>246</td>
<td></td>
</tr>
</tbody>
</table>

Emotional and atmosphere related experience attributes

Stereoscopic movies elicited also a wide variety of emotional reactions and impressions of changes in the scene atmosphere (Table 3): some scenes were regarded as more exciting and stimulating, but other scenes appeared as threatening or even scary. Objects that were in front of the screen were sometimes regarded as scary, as the following quote indicates:

“It was really a messy scene, somehow the atmosphere was pressing, the mirror jumped out of the picture too strongly, and the girl’s mirror image was changing in mirror and it felt like the girl was in the same room with you, not in the movie” (Content 6/Girl brushing her teeth, Participant 11, line 46 in the interview).

On the other hand, many participants regarded the stereoscopic image more exciting:

“Somehow, when you looked at the running boy, it felt like the boy was running away from something… In the stereoscopic scene you paid more attention to the boy… the stereoscopic scene was more intensive and engaging in that sense.” (Content 4/Boy running, Participant 13, lines 152-174 in the interview).

The wide range of emotional reactions visible in the subjective attribute list indicates that the emotional messages of stereoscopic contents are enhanced. The fact that two dimensional scenes were more often regarded as boring, ordinary or melancholic (Table 3) verifies this observation.

Too much to see

Many participants complained that there was not enough time to watch all the details of the stereoscopic scene. It was often mentioned that stereoscopic scene contained more interesting details compared to the two-dimensional scene. These comments were categorized to “You notice more details” category in Table 3. On the other hand, the fact that there
were more details to watch created a situation in which the viewer did not have enough time to check everything and even felt stressed and exhausted by this. Typical comment from “Not enough time to look at everything” category describes this kind of situation:

“.. you just wonder about the stereoscopy, and it feels that you need more time to see the whole situation.”
(Content 5/Sleeping boy, Participant 27, line 141 in the interview).

“.. somehow all the time to went through all the things that were in front of mirror. You just looked at these things and went through them one by one, which you do not usually do as you look at the scene as a whole.”
(Content 6/Girl brushing her teeth, Participant 31, line 260 in the interview).

4. CONCLUSIONS

Stereoscopic movies create a wide variety of experiences for the viewers. We could also find systematic experience clusters in the data that reflect the most significant experience dimensions. Based in the qualitative analysis of the interview data we can see that many viewers saw the stereoscopy to change the life-likeness of the contents. This confirms earlier findings which show that naturalness ratings are connected to image quality ratings in stereoscopic images. However, the change was not as simple as could be expected, i.e., that the depth sensation would create only increase in the life-likeness of the stereoscopic scene. Although this happened to many participants, there was also a strong tendency to see increased artificiality or unreality when the stereoscopy was present. The result indicates that rating the images based on the subjective life-likeness of the images might not be optimal in every situation. This effect is probably content dependent and further analysis in which the specific contents and content details are correlates with the experiences may reveal more about the reasons for these experiences.

Adverse symptoms were almost completely absent in our interview data, as only two percent of the experience attributes in stereoscopic conditions indicated eye strain or other symptoms. The absence of symptoms is quite interesting, as the majority of current human factors research has been focused on sickness studies. However, the low frequency of symptoms might be related to the extremely short duration of the stereoscopic film clips in our experiment, which might have prevented the buildup of any strain or sickness symptoms. Still, it is interesting that the viewers characterize their viewing experience mostly on positive terms.

Feeling of presence, i.e., being in the film scene, was a common way of describing the preference for stereoscopic contents. This finding is in agreement with previous suggestions about the relevance of presence with stereoscopic technologies. Interestingly, none of the participants use the terms presence or immersion, but consistently referred to being transported to the film world. Our result is quite consistent with the findings of Freeman and Avons who also mention that focus group participants mentioned the subjective transportation theme during the group sessions. It is also interesting that presence experiences occurred in our results, as the stereoscopic film clips were very short. It seems that subjective transportation to the film world can occur already within first twenty seconds of viewing. However, our current definition of presence includes only single experience attribute and it is known that presence has more complex experiential structure. Thus, further analysis of data regarding the other known components of presence experience is needed so that the total role of presence in our data can be understood.

There were also enhanced emotional reactions to the scenes with stereoscopy. Previously psychophysiological studies have shown that stereoscopic images increase the arousal of the viewer, but in this case we can show that the effect is related to the intended emotional message of a scene. With the close-up image of the boy the intimate feeling of the situation is increased significantly and the scene depicting the boys dancing under the bridge, the slight menacing themes of the scene become more scary. At the same time, the ordinary two-dimensional contents were viewed as boring and ordinary. It seems that the ability to enhance the atmosphere and emotional themes in the materials is one of the significant criteria of stereoscopic image quality. The enhanced reactions are similar as the concept of enhanced viewing experience used by Lambooij, whose results indicate better viewing experience with stereoscopic images. Our finding probably reflects the content dependent fine structure of the viewing experience concept.

Many participants emphasized the fact that the stereoscopic contents contained so much to see that it was stressful to try to grasp all the details of the see. The implication of this finding is that there might be a need to have longer scene lengths in stereoscopic materials. Editing too short scenes might miss the aesthetic potential of stereoscopic contents and
create stress for the viewer. Furthermore, image scaling or 2D-to-3D conversion might significantly reduce the structural fine details in stereoscopic images and thus affect this aspect of viewing experience.

Our results indicated that Interpretation Based Quality (IBQ) methodology can be successfully used to probe the experiential dimensions of stereoscopic material. The results show that determining the experiential dimensions by qualitative methodology is a fruitful way of approaching the stereoscopic contents. This paper presents only an initial analysis of our data, as only frequencies of experience categories were reported. We plan to extend the analysis by exploring the relations between experiential dimensions as well as by statistically measuring the correspondences between specific experiental reactions and properties of the contents that were documented in the form of location codes in our experiment. We hope that this will enable us to understand the relationship between contents, stereoscopic structures and viewer experiences.

REFERENCES

14. M. T. M. Lambooij, "What is the most appropriate attribute to measure 3D quality?" Eindhoven University of Technology, 2005.


38 G. Nyman, J. Radun, T. Leisti, and T. Vuori, "From image fidelity to subjective quality: a hybrid qualitative/quantitative methodology for measuring subjective image quality for different image contents," presented at 12th International Display Workshops (IDW '05), Takamatsu, Japan, 2005.


