Research of the Dependence of the Sensitivity of the Visual System on the Geometric Dimensions of the Stimuli in the Perception of a Typical Multimedia Content

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Abstract—**Increasingly, television content is available to viewers on various types of screens. It is considered that the geometric dimensions of the screen for displaying video sequences affect the formation of a subjective assessment of the quality of perception of multimedia content on various devices. The impact of physical screen size with signal artefacts effects on perceived visual quality and the relative depth of field is still unclear. Users may judge the size of objects with artefacts differently, even when objects appear the same on the retina. The work aimed to study the effect of the physical size of popular televisions on forming a subjective quality assessment. The proposed method allows for the dynamic change of the visual quality of typical media content depending on the physical size of the television display. Using a sample of more than 10,000 stimulus perception thresholds for the frame, controllable factors influencing the formation of a subjective assessment of the quality of perception were found. The unique contribution of the present work is that, for the first time, we will research the impact of streaming video with compression and streaming artefacts on human vision system with cognitive processing of information for various physical display sizes with fixed screen parameters and displaced user position. Provided a methodology for large-scale testing of streaming video with compression and streaming artefacts for various screen sizes. New data can be used for scientific purposes related to practical applications for visualization technologies, signal reception and processing in information technology devices, and related areas such as marketing, advertising, and the film industry.**

I. Introduction

Today, watching videos in movie theatres, on personal computers, and home televisions has become an integral part of everyday life for many people. [1].

Modern television and video content companies increasingly need to follow their audience to different screens to ensure they reach their target markets with an effective level of impact. Media content companies must better understand the likely impact of stimulus perception on a display screen to plan their media graphics in the new world of multiple screens. In this work, the influence of the physical dimensions of the display on the formation of a subjective assessment of the quality of perception of multimedia content by a typical user is considered.

Previous research has focused primarily on the ability to display different videos on devices with varying types of screens and the impact of different types of content [2]. Only a few studies have compared video content viewed on different screen sizes with the same content [3]. Has been assessed viewer attention and arousal in response to 3 different screen sizes [4]. Viewers responded to video images from TV and movies that displayed different emotions. Attention was measured by slowing the heart rate in response to images, and arousal was measured by skin conductance while browsing [4] either on an iPod or a 32-inch. Participants saw a 10-minute fast-paced action sequence (multi-cut) or a 10-minute slow (long) conversation sequence from a feature film. Screen size affected the reported sensations of spatial presence in participants who looked at larger screens, reporting higher levels. Several interactions have been found between screen size, content tempo, and audio playback. However, previous studies did not consider several important factors, namely the perception of the effects of video sequence artefacts during signal transmission, fixed parameters of screens of various sizes, such as clarity, colour reproduction, and environmental conditions [2]. Environmental conditions are the cognitive processing of information when the human body is displaced. For example, on a large screen, users can not look away and match the size of an object. However, if a user is watching on a medium-sized TV, it is possible to turn your head and judge the size of an object (in the video) in relation to other objects in the room.

Another problem with previous research is that the main goal of the vast majority of research in the field of visual psychophysics is to gain knowledge about the human visual system, and its relationships to video quality were not discussed in such studies.

By fixing the viewing angle and intensity of light, we were able to test the effect caused by the user's perception of video distortions for different screen sizes. In the proposed research, the most frequently used home cinema screen sizes are 50 inches to 80 inches. We used a lab experiment to control the viewing angle and the impact of physical display dimensions on users viewing videos with artefacts. We found an acceptable minimum threshold for perceiving video content for each screen size. The approach proposed in this work considered the real effects on the screen, such as reduced video quality due to bandwidth changes. Also, the proposed method complements previous studies on the impact of physical screen sizes on user perceptions. Using a typical user environment brings our research closer to the real conditions of users' perception of media content. To generalize our results to most media content studies, we used pre-processed video sequences from video databases with typical content such as NETFLIX [5], [6].

In this work, we measure, for the first time, the impact of screen size and compression artefacts on visual quality when viewing streaming video and the relative depth of field in real conditions. The proposed work opens up opportunities to improve the understanding of the perception of media content and, as a result, the work of video quality assessors, media companies, the film industry, marketers, and advertising specialists.

II. Literature review

The user perceives media content through early vision and cognitive processes. Early vision refers to those stages of vision that involve capturing, preprocessing, and encoding visual information but do not include the interpretation or other cognitive processing of visual information [7]. The process of perception of video sequences can be divided into three segments: filtering, encoding and interpretation. Filtering and coding are related to early vision and the interpretation of cognitive processes. Filtering determines what information is captured and what is lost, either system-wide or within a specific stream or channel. Encoding describes how specific visual mechanisms represent certain components of visual information. Interpretation describes how encoded information, possibly from multiple sources, including memory, is used to determine the state of objects in the visible world. The viewer's ability to allocate cognitive resources to process mediated messages is always limited. When the means of providing the information is a video sequence displayed on a screen, the viewer usually does not control the rate at which new information is introduced. Most of the available resources of the human visual system are devoted to storing information to keep up with the flow of content and significantly reduce cognitive processing of the details of the transmitted information [8]. Screen size is a factor in the automatic allocation of processing resources. Larger screens increase stimulus displays and the size of responses to those stimuli. The proximity of objects displayed on the screen induces a stronger response of behavioural responses to "high arousal" stimuli [9]. In previous studies, user response to a large screen is significantly higher than that of small screens. It does not decrease significantly from medium to small screen when using user arousal stimuli [10]. Therefore, from the above information, it can be concluded that studies focusing on evaluating the quality of video sequences comparable to users' perception should begin with the study of early vision and minimally consider the interpretation component.

The viewing angle is determined by the type of screen, its physical size, and the viewing distance. The viewing angle affects user reactions even if the physical screen width does not change [10]. Similarly, large screens increase user responsiveness when the screen size and screen type are varied while maintaining a constant viewing angle [11]. Previous studies have compared the physical dimensions of screens with different types. Factors such as clarity, colour reproduction, and environmental conditions were different for different types of devices. Regardless of the screen's physical size, the change in viewing angle matters in explaining the increase or decrease in motivational relevance and emotional effects for users [12]. Research with a fixed viewing angle and screen parameters has not been conducted. However, the relative depth of field of HVS can be flexible. Since the eye's lens is focused on objects, different processing algorithms may be needed for objects of different sizes in the video sequence. Therefore, from the above information, can be concluded that studies related to the study of the impact of the physical size of the screen on typical users of media content in the framework of early vision should be carried out with a fixed viewing angle and fixed parameters of the screen.

To the best of our knowledge, this is the first study that compared the perceptual effects of video sequences with artefacts on signal transmission at different physical display sizes with fixed screen sizes in a single experiment. The following section details the methods used to conduct the experiment and analysis. What follows are the results of the experiments and a discussion of the results. The data will allow for improving the analysis of predicting the response of a person when viewing content from television screens of various types.

III. Participant Methodology

Twenty-five participants aged 20 to 40 with normal vision were recruited through the Moscow Technical University of Communications and Informatics. In this work, normal vision is defined by typical user content (in the Russian Federation, students 16 years of age are required to undergo a general medical examination, including an eye test) participants do

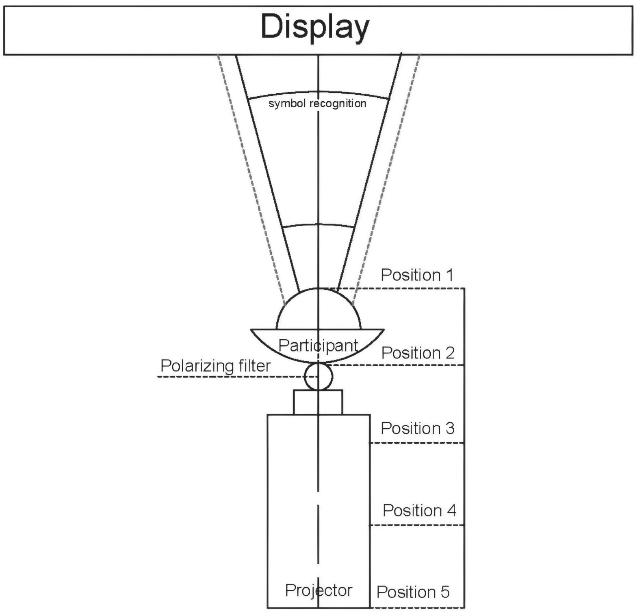

Fig. 1. Scheme of the structure of the equipment

not use glasses, lenses, or other medical devices for vision correction in normal daily activities. Most participants have no experience with the human perception of visual information. Informed consent was obtained from all participants. Most of the participants were third-year undergraduate students, which is a good balance between three important parameters: physical maturity of the eye, daily use of typical user-generated content, namely watching videos and images on the Internet, and no experience with the visual perception of information. Of these three parameters, the lack of experience with visual perception is especially important since such experience leads to improved detection of artefacts [13], [14].

IV. Stimulus and apparatus

The proposed device consists of a screen, a projector, an external source of stimulus transmission, a manipulator for finding the minimum acceptable video quality threshold for one video [15], and a lens with a polarizing filter. The participant and projector are on the platform and can be moved with the platform to different distances. The scheme of the structure of the installation is shown in Fig. 1.

The Christie DHD800 projector projects information from an external source onto a large screen. The external source is a computer capable of playing 8 video sequences simultaneously. The projector provides a fixed clarity, colour reproduction, and background load to fix the screen parameters in each experiment.

The platform distance from the screen is x. The point on the projected image on the screen is described by coordinates (u, v) with the origin at the intersection of the optical axis with the screen. Projected image width is then $2w$ (i.e. from $u = -w$ to $u = w$) and height is $2h$ (i.e. from $v = -h$ to $v = h$). β be a half field of view (i.e. for the field of view of 30^0 used in paper $\beta = 15^0$). Then:

$$w = x \tan \beta, \tag{1}$$

$$h = \frac{9}{16} w = \frac{9}{16} x \tan \beta, \tag{2}$$

$$A = (2h)(2w) = \frac{9}{16} x^2 \tan^2 \beta, \tag{3}$$

where A is the area of the projected image. A_s is the area of the lux meter sensor. It is fixed and independent of x. The lux meter measures intensity I_s, which is held constant. The total light emitted by the screen is, therefore,

$$I = \frac{A}{A_s} I_s = \frac{I_s}{A_s} \frac{9}{16} x^2 \tan^2 \beta, \tag{4}$$

The light leaving the screen towards the participant is diffusely emitted over a half hemisphere. Let the participant's pupil be radius a, thus area πa^2. The fraction of light Ω emitted by a patch at location (u, v) on the screen and received by the pupil into the eye is the area of the pupil divided by the area of the half-hemisphere of the radius of the eye from the patch. The participant's eye is at the distance $\sqrt{x^2 + u^2 + v^2}$ from a patch of screen at location (u, v). Hence:

$$\Omega = \frac{\pi a^2}{2\pi(x^2 + u^2 + v^2)}, \tag{5}$$

The light from a differential patch $dA = du dv$ located at (u, v) on the screen arrives obliquely to the surface of the pupil at an angle ϕ to the optical axis. The light received at the pupil is, therefore, attenuated by

$$\cos \phi = \frac{x}{\sqrt{x^2 + u^2 + v^2}}, \tag{6}$$

The intensity of light collected by the pupil of the eye (and therefore projected onto the retina of the participant) is given by:

$$I_e = \frac{I_s}{A_s} \iint_A \Omega \cos \phi \, dA \tag{7}$$

Then:

$$I_e = \frac{I_s}{A_s} \iint_A \frac{\pi a^2}{2\pi(x^2 + u^2 + v^2)} \frac{x}{\sqrt{x^2 + u^2 + v^2}} dA, \tag{8}$$

$$I_e = \frac{I_s}{A_s} \iint_A f(x, u, v) \, dA \tag{9}$$

if

$$f(x, u, v) = \frac{\pi a^2}{2\pi(x^2 + u^2 + v^2)} \frac{x}{\sqrt{x^2 + u^2 + v^2}} \tag{10}$$

The participant has been shown the processed video sequence in multiple instances, each with a different bitrate. Initially, video playback starts at the worst bitrate. The participant had the manipulator for changing the quality of perception of video content, which serves as the manipulator for improving

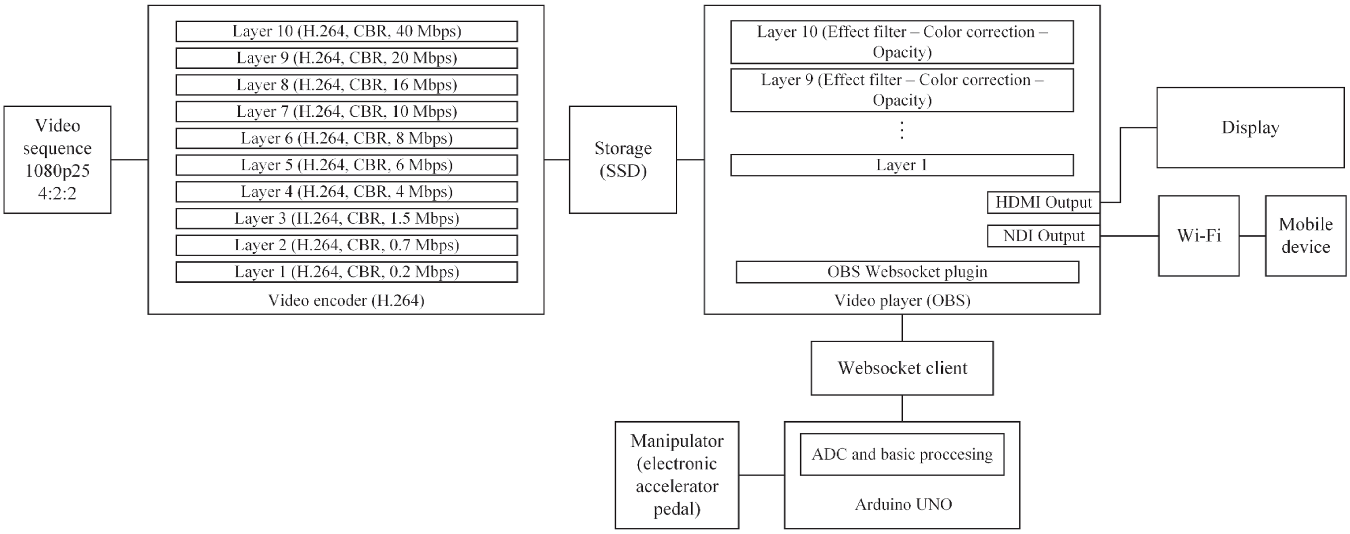

Fig. 2. The block diagram of the input signal processing algorithm

the bitrate. The manipulator was made from the electronic pedal of a Lada Priora car, which has satisfactory ergonomics [15]. It is assumed that the experiment participant will press or release the pedal to adjust the quality of the video with different strengths. To avoid stepping in quality with a limited number of levels, setting intermediate quality values using the pedal ensures that neighbouring levels are synthesized proportionately, determined by how hard the pedal is pressed. When projecting a video, the participant must observe the absence of distortions/artefacts of the video sequence on the screen at his discretion. The block diagram of the input signal processing algorithm is shown in Fig. 2.

When the projector moves, the image changes not only in size but also in brightness. A variable density neutral density filter was made based on two polarizing filters to normalise the screen's brightness. The filter's optical density variation occurs by changing the angle between the structures of the crystal lattices. According to Malus's law, the intensity of the flow after passing through 2 filters of the polarization plane, which are rotated at an angle, is:

$$I = I_0 \cos^2 \theta \tag{11}$$

A special film, an iodine crystal pickled between 2 thin layers of polyvinyl alcohol, was used as polarizing filters. The crystal of the isotope iodine 127 has the following structure: Fig.3.

In the frontal projection, the crystal's anisotropic properties are most noticeable since the substance consists of paired molecules with a covalent, non-polar single bond, which is much denser in the vertical direction. Pronounced misanthropy allows the iodine crystal to transmit light radiation only linearly polarized radiation. Applying the filter reduces the light output from the projector, but the projector's initial value of the luminous flux can deliver the 100nit (cd/m2) in a controlled environment. It is enough for high-quality

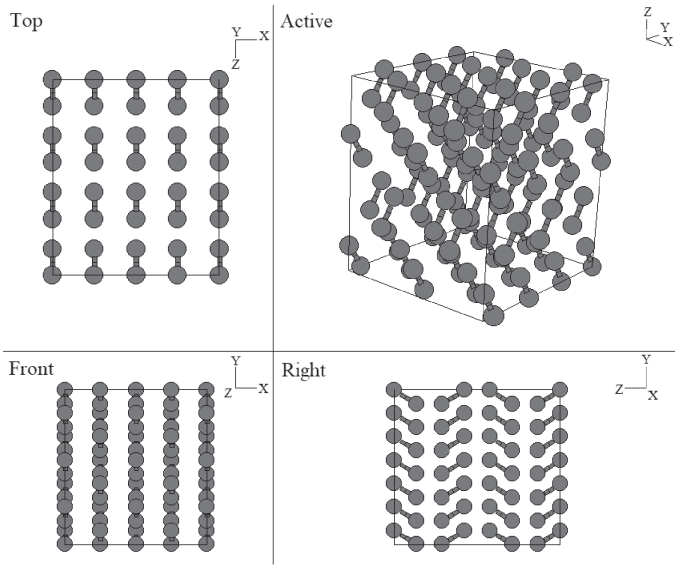

Fig. 3. The structure of isotope iodine 127

reproduction of content produced according to the ITU-R 709 standard for all screen sizes used in the experiment [16]. When the projector's position was changed, the screen's surface was measured with a luxmeter Testo-540 and the filter was adjusted to the illumination value adopted in the experiment, 162 lux. No matter the distance of the projector/viewing platform from the screen, the intensity of the projector is adjusted so that the intensity of light measured at the screen is constant. As the projector is moved backwards, the image formed on the screen increases in size as the field of view remains constant. Therefore, from the above, the distance from the screen to the participant increases by k when changing positions. Also, the point of the projected image on the screen is described by the coordinates (u, v) increases by k times:

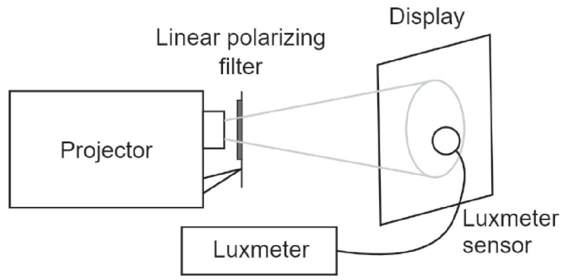

Fig. 4. The structure of complex to ensure uniform display illumination

$$I_2e = \frac{I_s}{A_s}\iint_{A_2} \frac{\pi a^2}{2\pi k^2(x^2+u^2+v^2)}\frac{kx}{k\sqrt{x^2+u^2+v^2}}\,dA_2, \tag{12}$$

where A_2 is the area of the projected image, I_2e the total intensity of light collected by the pupil of the eye in position 2:

$$A_2 = (2kh)(2kw) = k^2A, \tag{13}$$

Then:

$$I_2e = \frac{I_s}{A_s}\iint_{A} f(x,u,v)\,dA, \tag{14}$$

Therefore, the light reaching the retina is not inversely proportional to the platform's distance from the screen. Fig.4 shows a schematic representation of the complex to ensure uniform display illumination.

A side camera was used to measure viewing distance, and data from this camera was combined with data from a camera mounted behind the participant. We chose the minimum and maximum distance from the participants from the display screen and averaged these parameters to create one distance indicator for each position. The distance was measured by overlaying a grid on each keyframe to coincide with the centre of the screen being viewed and then counting the number of grid lines between the screen and the viewer's eyes. For testing, we used video sequences, database NETFLIX [5], [6], ITU, and a database created in the Moscow Technical University of Communications and Informatics laboratory [17]; each video sequence had ten different bitrates. The content of the video sequence is shown in Fig.5. All video sequences were separated by a grey background lasting 2 seconds.

V. Procedure

The setup is placed in a separate room, where the light is adjusted in advance to avoid distortion of the stimulus display. The room is completely objects, and the participant sees not only the screen but also notices the change in the size of the projected image when the platform is moved back. Before testing, the brightness is measured and recorded using a polarizing filter installed on the projector lens. During the experiment, only 1 participant and the researcher are present in the room. The participant started the test by pressing the provided control pad. The participant notes and holds the required test stimulus by pressing the manipulator with his foot. The participant is not limited in time when watching a test video sequence. We simulate a normal environment for content consumption as closely as possible. Hence, the experiments represent a non-classical approach. Therefore, we do not use a head holder or any viewing aids such as lenses. There were no differences in viewing comfort (M = 8.21 on a 10-point scale) or enjoyment (M = 8.3).

The participant is invited to view the preprocessed video sequence in several instances. Each instance has a different bitrate from 5 different distances (203, 233, 263, 293, 323 cm) with fixed angular dimensions of the screen and adjusts the quality of the video sequences. Guidelines from the Society of Motion Picture and Television Engineers of the Russian Federation recommend sitting at a distance where the viewing angle fluctuates around 30° [18]. This will make viewing the displayed stimulus on the screen as good as possible and is suitable for most viewing modes.

When projecting a video, the participant must observe the absence of distortions/artefacts of the video sequence on the screen at his own discretion. The minimum acceptable threshold for the user is found; if the quality of the video sequence is unsuitable for perception, according to the subjective perception of the user, the pressure on the manipulator increases, and thus, the level of video quality improves. As soon as the set of video sequences ends, the setting is shifted to the next mark (+ 30 cm), and the experiment starts anew. Data collection occurs automatically by logging readings to a file. Minimum perception thresholds were measured for five different distances for 25 participants. A total of 12000 frame-by-frame thresholds were obtained from the experiment. Testing took about 10 minutes per participant. The trials were run at the participants' own pace to reduce any side effects of fatigue, and the participant was allowed to take a rest break at any time. It should be noted that not a single participant took advantage of the rest break. For our data, a 95% confidence interval was used. The standard deviation for estimating the confidence interval for each representation is specified in Rec. ITU-T Bt.500-11 [19]. The standard deviation σ_k to evaluate the confidence interval for each position is given by:

$$\sigma_k = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(s_k-\bar{s}_k)^2}, \tag{15}$$

where $\bar{s}$ the arithmetic mean, k is the subjective evaluation of minimal threshold for each video in 5 position. All experiments were continued until the confidence interval was below 5% of the current mean. During the processing of experiments, participants who did not respond to a grey background with a manipulator were excluded from the general analysis, Fig.6. There were minor differences among participants between average viewing angles for each physical screen size.

Fig. 5. The content of the video sequence

VI. Results

A. Correlation of participants' answers for each position

A sample of 25 participants provided more than 10,000 thresholds for frames. Fig. 7 presents the results of the participants' responses for 1-5 positions of the stimulus display with the minimum acceptable quality, or in other words, the perception threshold for the entire duration of the video sequence.

As can be seen from the figure, users noticed artefacts better in the video, which shows the main object of observation with a stable background.

B. Perceptions of subjective quality by users for all stimulus display positions.

Fig.8 shows the values of all positions with users' perception of quality depending on screen sizes averaged over the frame number and all subjects and frames of the video sequence.

The figure shows that users perceive Position Display Screens 3 and 4 more clearly; in other words, the sizes of these screens are more comfortable for users. Participants notice better artefacts on positions 3 and 4; therefore, these positions determine the ideal screen size for user experience in this experiment. However, since the difference in average values ranges from 0.515 to 0.600, it can be concluded that users' perception of artefacts is not significant for providing video content from various typical TV sizes.

VII. Discussion

The presented results describe the effects of video streaming artefacts and effects on HVS for various physical display sizes with fixed screen parameters. The present work has potential practical applications to supplement video quality assessments based on psychophysical vision models. These models can explain image and video quality well, often outperforming metrics based on manual functions, statistics, or machine learning [20]. The results herein show that screen size is not important for the perception of distortions in video streaming; it can be an important parameter in video quality evaluation for television displays.

The experiments in this work use the threshold method, where the stimulus starts with poor quality. Then the participant gradually increases the intensity until the threshold of satisfactory perception of the stimulus is found. Finding

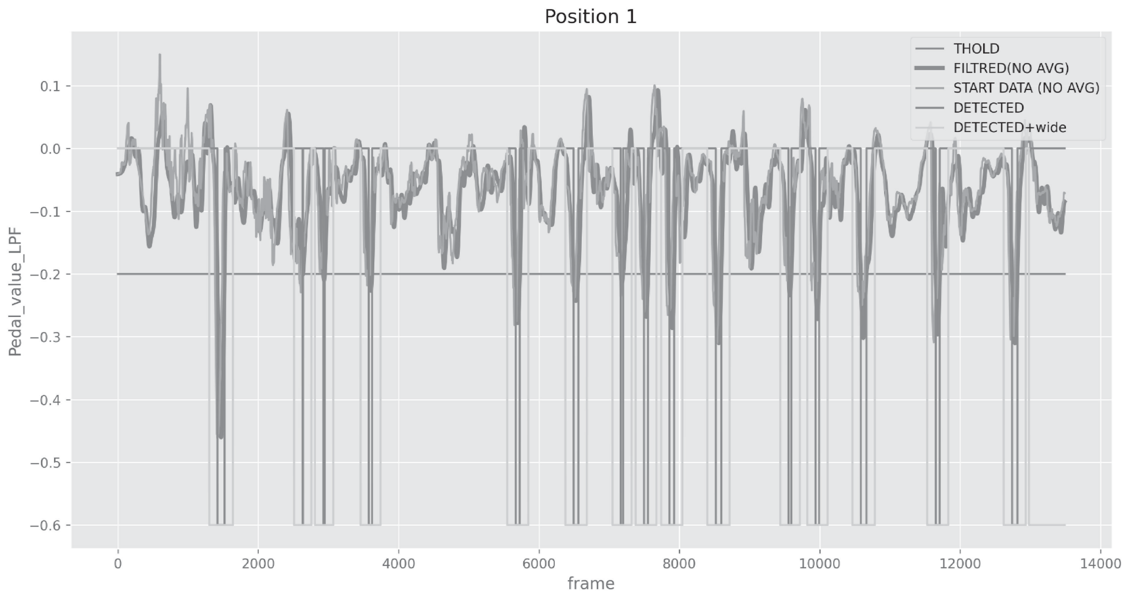

Fig. 6. The results of the participants' responses for position 1

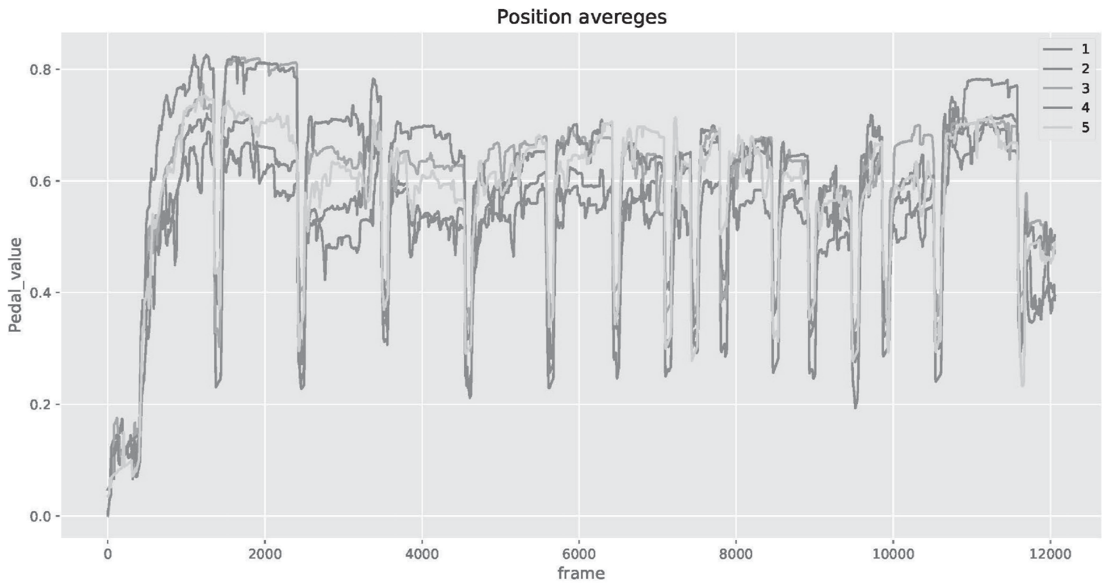

Fig. 7. The results of the participants' responses for 1-5 positions of the stimulus display with the minimum acceptable quality

this threshold is comparable to how quality evaluation metrics work when video content providers use solutions that only allow users to see videos of acceptable quality [5]. The reverse threshold was not measured with the transition from high quality to unsatisfactory since there is a possibility that the user will set the perception threshold at the most satisfactory level, or in other words, at a high bitrate and will not lower the manipulator to the perception threshold of video sequence artefacts [21]. Unlike most previous studies on the effects of screen size, we gave participants the freedom to watch video sequences as they felt comfortable without using a head holder. Despite this, participants were asked to keep their heads in a fairly narrow range of positions, and therefore, any head movement is compensated for by large-scale experiments.

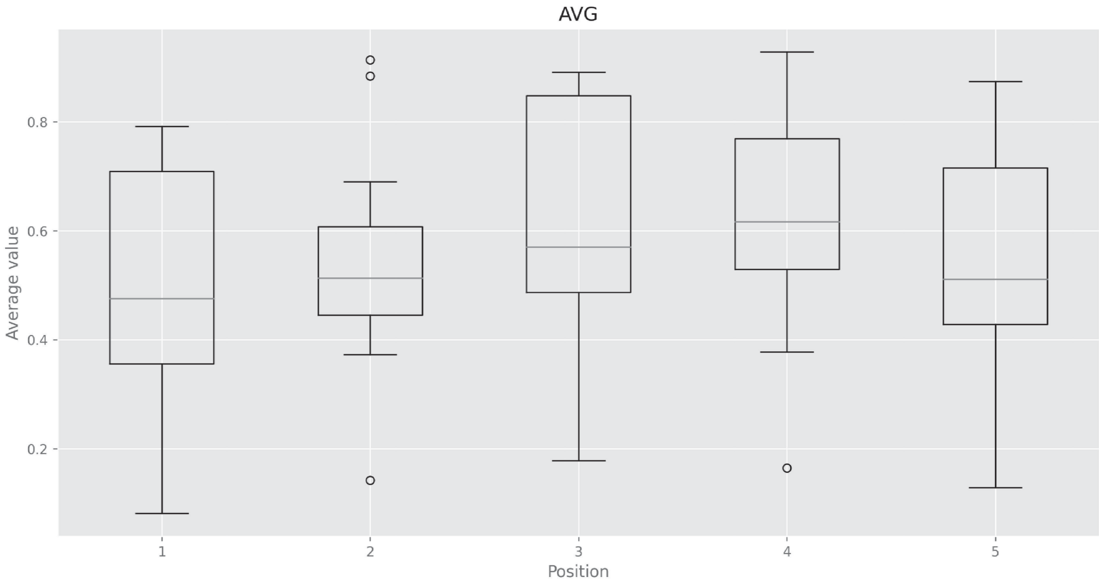

Fig. 8. The values of all positions with users' perception of quality depending on screen sizes

Participants did not change the viewing angle, which makes our results representative of a typical audience for each screen type, but are questionable for typical user-generated content conditions. The most likely explanation for our results is that people with short video sequence content of fewer than 10 minutes can comfortably view the video on display devices from 50 to 80 inches [22]. It's also worth noting that a typical offer on video download sites like Instagram and YouTube is less than 15 minutes long. For this reason, we have prepared a video sequence of 10 minutes. However, a future experiment may complement the current one by lengthening the video sequence.

The most important limitation of the proposed work was that it did not examine screen types smaller than 50-inch videos, such as tablets and mobile phones. The presented methodology and procedure will allow for large-scale tests with a minimum number of participants and time spent on the experiment (10 minutes per participant per screen size). Future research may find that on very small screens, users will be affected by factors such as the shallow depth of field of the optical part of the visual system at short focusing distances, which allows remaining involved even in the presence of interfering visual stimuli, or, on the contrary, information about the focusing distance of the lens when viewing content on very large screens. Another limitation is that we haven't tested screens larger than a typical home TV. Larger screens will show more life-sized objects, which may increase the likelihood of participants experiencing cognitive responses.

VIII. Conclusion

The purpose of the work was to the first time research the impact of streaming video with compression and streaming artefacts on the human vision systems with cognitive processing of information. In this work, we measure, for the first time, the impact of screen size and compression artefacts on visual quality when viewing streaming video, and the relative depth of field. The method and analysis of experiments allow for dynamic change in the visual quality of a specific media content depending on the physical size of the television display. New data on the artefacts perception of users for the provision of video content on various TV sizes can be used for scientific purposes related to practical applications for visualization technologies, signal reception, and processing in information technology devices, as well as related areas such as marketing, advertising, and the film industry.

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