Modelling Human Factors in Perceptual Multimedia Quality: On The Role of Personality and Culture

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ABSTRACT

Perception of multimedia quality is shaped by a rich interplay between system, context and human factors. While system and context factors are widely researched, few studies consider human factors as sources of systematic variance. This paper presents an analysis on the influence of personality and cultural traits on the perception of multimedia quality. A set of 144 video sequences (from 12 short movie excerpts) were rated by 114 participants from a cross-cultural population, producing 1232 ratings. On this data, three models are compared: a baseline model that only considers system factors; an extended model that includes personality and culture as human factors; and an optimistic model in which each participant is modelled as a random effect. An analysis shows that personality and cultural traits represent 9.3% of the variance attributable to human factors while human factors overall predict an equal or higher proportion of variance compared to system factors. In addition, the quality-enjoyment correlation varied across the excerpts. This suggests that human factors play an important role in perceptual multimedia quality, but further research to explore moderation effects and a broader range of human factors is warranted.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems—*Human Factors, Software Psychology*; H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Evaluation/Methodology*

General Terms

Design; Experimentation; Human Factors

Keywords

Multimedia; Quality; QoE; Personality; Big-5; Culture; Hofstede; Enjoyment; Perception; Video

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1. INTRODUCTION

The success of multimedia content and service providers is often determined by the 'perceived' quality of the content that their customers, the viewers, use and enjoy. Typically, this perception is dependent on the 'nature' of content (i.e., the affective narrative) and the parameters controlling how that content is delivered. The nature of content can only be manipulated by content creators, however providers have the ability to stream the content at the 'right' parameters to ensure adequate viewer satisfaction.

While it might seem obvious that nothing less than the highest possible parameters would satisfy viewers, there are occasions which necessitate streaming at lower parameters. For example, in the case of mobile streaming where bandwidth and transmission form a bottleneck [39]. Additionally, there is research which shows that it is not mandatory to stream videos at high parameters to convey satisfying experiences [7, 12].

Suppose that two viewers are both shown a video sequence each at {25fps, 480p} and {15fps, 720p}. Is it possible that one viewer's perceived quality on a video sequence with a lower parameter setting is broadly equivalent to the other viewer's perceptive quality on another sequence with higher parameters? If yes, what are the factors influencing perception of quality? Which of these factors contribute positively and which negatively? These are some of the questions which motivate the research discussed in this paper. Finding answers to these questions would help content providers to maintain adequete customer satisfaction in a personalized manner while optimally utilizing resources such as bandwidth.

The challenges associated with such personalization are very subtle, owing to the complexity associated with individual differences. Moreover, these differences occur both at a micro-cosmic level (i.e., specific to the individual) and at a macro-cosmic level (i.e., cultural influences). While the microcosmic traits can be analysed with personality (a series of "internal properties" that relate to overt behaviours [27]), the macroscopic traits can be captured using cultural dimensions (representing "the collective programming of the mind distinguishing the members of one [nation] or category of people from others" which subsequently leads to a "broad tendency [for members of a group] to prefer certain states of affairs over others" [18]).

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Although a significant number of public video datasets for quality assessment exist, no dataset is suited to study the influence of the aforementioned human-factors. Without this subjective data, it is not possible to understand the impact of culture and personality on perceived quality and enjoyment, and whether it will be significant for practical applications. In addition, objective and subjective quality metrics are evaluated using existing public databases which do not take into account the human factors, or if they do they often draw participants from just the local population. This means that little is known about the generalisability of these quality metrics.

Therefore it is necessary to explore the impact that personality and culture has on Quality of Experience (QoE), as measured through the perceived quality of multimedia content and its associated subjective enjoyment. To answer this question, a novel video dataset consisting of 144 video sequences with a variety of movie-based content at different parameter settings is constructed (see Section 3.2 for detail). Then, a subjective experiment involving 114 participants is conducted to collect ratings on perceived quality and enjoyment. A set of regression models are developed to model the viewers' perception. Ratings on perceived quality and enjoyment (the dependent variables) are predicted given the movie excerpt, the quality parameters, and the participant's profile (the independent variables).

In summary, it is proposed that a model based on human factors could form the foundation for enabling multimedia content and service providers to optimise viewers' quality of experience under constrained conditions. As part of this work, the following research questions are addressed:

1. To what extent do human factors predict variance in ratings of quality and enjoyment?
2. What proportion of the variance attributable to human factors can be predicted by personality and culture (using the Big-5 and Hofestede models)?
3. Which aspects of the Big-5 Model and the Hofestede Model are key predictors of quality and enjoyment?
4. To what extent is quality related to enjoyment?

2. RELATED WORK

2.1 On Video Quality

Video quality and enjoyment evaluation has been widely investigated in the last few years, and numerous related video databases have been constructed. For example, the: VQEG HDTV database [13]; LIVE video database [36]; IVC video databases [23]; ReTRiEVED video database [31]; video enjoyment database [24], and aesthetic evaluation video database [29]. In these video quality assessment databases, the visual quality of videos derived from different distortion types (e.g., H.264 compression, packet loss and frame rate change) is evaluated by human beings. In video aesthetic evaluation databases, enjoyment (or appeal) levels are commonly given by participants. Generally, when performing the subjective tests, only four human factors (i.e., age, gender, vision and expertise levels) are reported. The obtained subjective scores are, then, analysed under the assumption that all participants have the same or similar perception to the visual quality of a video, irrespective of other human factors.

2.2 On Personality

We each possess traits which vary in systematic ways and these systematic differences can be explored. Consider personality, a series of "internal properties" that relate to overt behaviours [27]. Though there are many different theories which examine the predictive utility of personality, the Five Factor Model (FFM) [8] is one of the most parsimonious models. This consists of: openness to experience, conscientiousness, extroversion, agreeableness and neuroticism. These dimensions could map to perception of quality in many ways. For example, individuals with high neuroticism may be more sensitive to multimedia content that evokes negative emotions.

2.3 On Culture

The FFM can be considered as individual-level personality traits because they can be found to vary across a wide range of individuals [8]. However, there are also traits which are associated with the culture an individual is from. Perception and cognition are a product of the local environment in which someone lives and grows, which itself is shaped through shared conceptions and collective norms [20]. One theory in Psychology which studies such differences is the Hofstede's Six Factor Model (HM) [18], which includes: power distance; individualism; uncertainty avoidance index; masculinity; pragmatism; and indulgence [18]. Again, each of these dimensions could interact with the perception of quality and enjoyment. For example, individuals with high indulgence may become more critical of due to extended usage.

2.4 Background

It has been demonstrated that previous educational and socio-cultural backgrounds play important roles in such subjective rating [10, 34]. It has also been shown that cultural experience influences visual perception when viewing visual objects. In [30], it was found that there exists perceptual and attentional differences between Asians and Westerners, for example, Americans have more analytical visual perception (inclined to pay attention to details), while Asians have a more holistic visual perception (likely to be more sensitive to context). A more detailed investigation on the cultural differences in cognitive processes can be found in [28] where an analysis of the factors underlying the cultural differences can be found along with a multiple-level framework to integrate these factors to explore the cultural influences on cognitive processes. In [37], the cultural differences between American and Chinese individuals was studied on communication performance under audio and video conferencing conditions. In [9], the influence of culture on perception was investigated in many aspects, including optical illusion, colour perception, visual attention, and brain functioning. The correlation between culture and cognition was also studied in [1], by analysing the variation of word associations given by Japanese and American participants.

The experimental results across these studies indicate attentional variation in cross-cultural judgments. Previous research has also addressed factors which influence perception of quality (e.g. [4, 7, 32]) and emotions (e.g. [5, 25]). There has also been work which shows that personality influences media content preferences [3, 15].

As such, understanding, interpreting and evaluating content is dependent on previous experience, socio-cultural background, goals, and values. This may, consequently, influence what viewers consider to be of 'good' or 'bad' quality. Some works (for example [6, 21, 26, 32, 33, 38]) which do investigate the influence of above-mentioned human factors are often based on subjective tests applied to samples. However, it is seldom the case that samples are deliberately drawn from cross-cultural contexts.

Recently, there have been works which studied the influence of personality factors on perceived quality [40, 41]. However, one study involved about 59 users and their ratings on 6 YouTube videos covering three genres [41] and the other focussed on investigating the use of a multimodal remote control application in the context of IPTV [40]. However, such studies tend to draw their samples from only the local population.

Hence, it is meaningful to investigate, with a larger group of users from multiple demographic regions, the influences of individual and cultural variation with respect to the perceived quality and subsequent enjoyment video sequences, using a larger dataset, with various quality parameters. As such, it is important to involve participants from many different countries (as detailed in Section 3.5) in the subjective testing where culture and personality could potentially explain differences.

3. METHODOLOGY

3.1 Procedure

A lab-based subjective testing approach was taken. A set of video sequences were hosted on web server locally at each institution involved in the study (to avoid any latency issues over the Internet). Participants completed a questionairre and then watched several video sequences, rating the perceived quality and their enjoyment of each sequence immediately after viewing each. Informed consent and anonymity were assured at every stage of the study.

Participants started the survey by answering the VSM-2013 [19] and the BFI-10 [11] questionnaires to report cultural and personality traits respectively. Then each participant was shown 14 video sequences: 2 training video sequences (one at the beginning of the survey and another during the middle); and the 12 videos under assessment. The training video sequences showed participants what should be considered 'high' quality. They then had to respond to 12 further video sequences. Participants were randomly allocated quality parameters for each individual video sequence (except for the training videos).

Each participant was expected to rate all 12 video sequences. However, to maximise the ecological validity of participants' viewing behaviour, participants were left free and without any time-limit to complete the experiment. Of the 114 participants, 73.7% rated all 12. The minimum number of videos rated was 3, however the average was 10.8 ($\sigma = 2.56$). In total, 1232 ratings were recorded (90% of the maximum possible).

3.2 Video Dataset

This study is the first application of the CP-QAE-I video dataset (available from http://1drv.ms/1M1bnwU), after its validation in a previous study [16]. The dataset contains video sequences based on 12 excerpts from popular movies that were purposively selected to evoke different affects [35]. There were 3 ordinal parameters: bit-rate (384kb/s and 768kb/s); frame dimension (480p and 720p); and frame rate (5fps, 15fps and 25fps).

Thus, in the dataset, there were 144 conditions (resulting from the 3*2*2*12 settings of frame-rate, frame dimension, bit-rate, and content). Each video sequence has a length between 1 and 3 minutes. A review of the estimated marginal means show adequate distinction between the video sequences in terms of perceived quality and enjoyment as shown above in Table 1.

Table 1: Estimated Marginal Means of the Ratings for Each Movie Excerpt in the CP-QAE-I (z-Scores)

Movie Excerpt	Perceived Quality	Enjoyment
A_FISH_CALLED_WANDA	-.300	-.004
AMERICAN_HISTORY_X	-.121	-.560
CHILDS_PLAY_II	-.430	-.181
COPYCAT	-.022	-.443
DEAD_POETS_SOCIETY_1	-.105	-.437
DEAD_POETS_SOCIETY_2	.365	.782
FOREST_GUMP	.448	.747
SE7EN_1	.073	.402
SE7EN_3	-.229	-.312
SOMETHING_ABOUT_MARY	.220	.484
THE_PROFESSIONAL	.131	.330
TRAINSPOTTING	-.013	-.621

Covariates: Ext = 5.54; Agr = 7.22; Con = 6.55; Neu = 5.62; Ope = 6.75; PDI = -35.96; IDV = 18.73; MAS = -1.23; UAI = 44.61; PRG = 16.84; IVR = -16.97.

3.3 Measures

Participants responded to several measurement scales during the study in relation to: perception of quality; enjoyment; culture; and personality. These were previously validated and defined for participants.

3.3.1 Quality

To assess subjective perception of quality, the QoP-LoQ scale [14] was used. This consists of a single 5-point Likert-type rating item where participants indicate how they judged the quality of the video sequence. A low score indicates "no" satisfaction while a high score indicates "absolute" satisfaction.

3.3.2 Enjoyment

To assess enjoyment, a subjective measure was used. This consisted of a single 5-point Guttman-type rating item where participants indicated how much they enjoyed the video sequence. A low score indicates "no" enjoyment while a high score indicates "high" enjoyment.

3.3.3 Culture

Culture is a collective concept. Thus, when measured at the individual-level, traits associated with culture are being measured. The VSM-2013 questionnaire [19] was used to measure these traits according to the following dimensions: power distance (PDI); individualism (IDV); uncertainty avoidance (UAI); masculinity (MAS); pragmatism (PRG); and indulgence (IVR).

Table 2: Sample Descriptives

Human Factors	$\bar{x}(NTU)$	$\bar{x}(BUL)$	$\bar{x}(Pool)$	σ
Extroversion	5.61	5.46	5.54	1.689
Agreeableness	7.33	7.31	7.22	1.533
Conscientiousness	6.40	6.70	6.55	1.523
Neuroticism	5.56	5.68	5.62	1.716
Openness	6.60	6.91	6.75	1.424
Power Distance	-35.61	-36.32	-35.96	53.219
Individualism	25.79	11.67	18.73	50.619
Masculinity	3.68	-6.14	-1.23	53.483
Uncertainty Avoidance	52.54	36.67	44.61	47.182
Pragmatism	16.14	17.54	16.84	58.090
Indulgence	-22.63	-11.32	-16.97	65.522

$\bar{x}$: Sample Mean; σ: Standard Deviaton

3.3.4 Personality

To assess the personality of the participants, the BFI-10 [11] questionnaire was used. The personality is assessed according to the FFM [8], measuring: openness (Ope); conscientiousness (Con); Extroversion (Ext); Agreeableness (Agr); Neuroticism (Neu).

3.4 Sample Size

A power analysis was conducted, using G*Power 3, to determine the minimum sample size. Using the conventional error probabilities ($\alpha = .05$, $1 - \beta = 0.8$) while assuming that 'medium' effect sizes according to Cohen's benchmark will be detected ($f = 0.39$) and that the repeated measures will be correlated ($r = 0.8$), a minimum sample size of 64 was suggested. Due to the risk of error inflation associated with testing a large number of parameters, it was decided that a larger sample would be needed. A sample of 114 was obtained for this study.

3.5 Participants

The participants were 114 university students drawn from the two institutions the authors are affiliated with. Exactly 50% of the sample was drawn from each institution. In terms of nationality, there were: 43 British, 22 Indian, 16 Chinese, 15 Singaporean, 4 Nigerian, 2 Indonesian, 2 Pakistani, 2 Vietnamese, 1 Danish, 1 Dutch, 1 Latvian, 1 Myanmarian, 1 Polish, 1 Tanzanian, 1 Turkish, and 1 Zimbabwean. The proportion of female participants was 28.9% and the average age was 23.9 years ($\sigma = 3.68$).

Additional descriptives in terms of personality and cultural traits for each institution are shown above in Table 2. As would be expected, the means for the personality variables are consistent across the two institutions, following the expected normal distribution. However, several differences can be observed in terms of Hofestede's cultural dimensions. In particular, non-trivial differences can be seen in terms of: individualism; masculinity; uncertainty avoidance; and indulgence. It should be noted, however, that the full range of possible values were not observed for: extroversion (87.5% of expected range); openness (75% of expected range); and masculinity (67% of expected range).

These participants represent a non-probability sample. This sampling method tends to have two key weaknesses: lack of prototypicality (i.e., does the sample represent the target population?); and range restriction (i.e., is there sufficient variance in variables of interest to detect a relationship?). As the focus of this study is modelling rather than demography, only the latter presents a potential threat to validity. However, it can be seen that the participants varied in terms of personality and culture. There is little evidence of range restriction for most of the key variables of interest.

4. RESULTS

Analyses were conducted in PASW 18.0.3 for Windows. Due to the diverse range of nations represented in the sample and the overlap between each institution in terms of nationality of respondent, the geographic location of each institution could not be used as a proxy for culture. Hence, the two institutions are not compared. Instead, cultural variables were captured at the individual-level and a set of regression models are compared to examine differences in terms of these variables. Mixed linear regression has been used to account for repeated measures. The parameters in each model were estimated concurrently using the restricted maximum-likelihood method. Missing data was pair-wise excluded.

4.1 Baseline Model

The baseline model only considers system factors. In the context of the CP-QAE-I video dataset, there are 12 variations of the system factors which varied were: frame-rate (3 conditions); frame dimension (2 conditions); and bit-rate (2 conditions). Other system factors such as file format and delivery protocol were held constant as part of the experimental setup. Due to expected interactions between these conditions (e.g., an attempt to minimise bit-rate while maximising frame-rate and frame-dimension would likely create artefacts) these were modelled as factorial interactions. In addition, the movie excerpt itself is included as a parameter to reflect differences in cinematographic technologies and techniques used to create the movies. This was modelled as a main effect.

An analysis of this model can be seen in Table 3. It can be seen that all of the system factors and their interactions had a statistically significant effect on the perception of quality with the movie excerpt itself making a contribution. As expected, the movie excerpt itself had the largest impact on enjoyment. However, it is interesting to note that only a small number of the system factors had a statistically significant effect on enjoyment.

4.2 Extended Model

The extended model adds several fixed parameters to the baseline model as covariates with direct effects. These were cultural traits including: power distance; individualism; masculinity; uncertainty avoidance; pragmatism; and indulgence. Additionally, personality traits were also added, including: extroversion; agreeableness; conscientiousness; neuroticism; and openness.

Table 4 above show an analysis of the extended model. In addition, a more comprehensive overview of the parameters in the models can be found on the next page in Tables 6 and 7. It can be seen that several of personal and cultural traits are statistically significant predictors. Of particular interest are those which influence both perception of quality and overall enjoyment. These were:

Table 3: Baseline Model for Perception of Quality and Enjoyment

		Perceived Quality			Enjoyment		
Parameter	df_{num}	df_{den}	F	p	df_{den}	F	p
Movie Excerpt	11	191.387	8.880	.000	177.090	40.140	.000
Frame Rate (FR)	2	1152.788	23.540	.000	1131.230	5.173	.006
Frame Dimension (Dim)	1	1164.451	16.890	.000	1146.390	2.846	.092
Bit-Rate (BR)	1	1160.518	9.830	.002	1139.690	.474	.491
FR $*$ Dim	2	1150.910	3.070	.047	1130.961	1.663	.190
FR $*$ BR	2	1152.330	5.188	.006	1131.496	2.078	.126
Dim $*$ BR	1	1165.993	8.240	.004	1137.742	1.364	.243
FR $*$ Dim $*$ BR	2	1154.080	5.714	.003	1130.448	.002	.998

Table 4: Extended Model for Perception of Quality and Enjoyment

		Perceived Quality			Enjoyment		
Parameter	df_{num}	df_{den}	F	p	df_{den}	F	p
Movie Excerpt	11	191.490	9.070	.000	171.956	39.733	.000
Frame Rate (FR)	2	1142.880	24.075	.000	1136.577	4.695	.009
Frame Dimension (Dim)	1	1153.771	13.578	.000	1151.402	3.336	.068
Bit-Rate (BR)	1	1148.206	12.677	.000	1145.171	.257	.612
FR $*$ Dim	2	1145.057	3.748	.024	1145.206	1.057	.348
FR $*$ BR	2	1144.258	5.262	.005	1138.177	1.856	.157
Dim $*$ BR	1	1154.877	9.876	.002	1146.873	2.424	.120
FR $*$ Dim $*$ BR	2	1146.555	5.981	.003	1138.844	.057	.945
Extroversion	1	1151.392	.130	.718	1150.401	.024	.877
Agreeableness	1	1151.909	2.672	.102	1152.475	2.001	.157
Conscientiousness	1	1141.817	7.126	.008	1141.249	5.271	.022
Neuroticism	1	1149.100	11.708	.001	1146.479	.050	.823
Openness	1	1150.056	1.168	.280	1145.365	4.344	.037
Power Distance	1	1154.125	.290	.590	1152.465	9.138	.003
Individualism	1	1149.721	5.519	.019	1150.026	.674	.412
Masculinity	1	1147.422	5.578	.018	1141.312	3.312	.069
Uncertainty Avoidance	1	1144.686	.333	.564	1144.106	5.751	.017
Pragmatism	1	1152.021	4.889	.027	1160.700	.604	.437
Indulgence	1	1140.461	2.321	.128	1149.178	2.206	.138

Table 5: Optimistic Model for Perception of Quality and Enjoyment

		Perceived Quality			Enjoyment		
Parameter	df_{num}	df_{den}	F	p	df_{den}	F	p
Movie Excerpt	11	176.430	11.260	.000	179.877	46.990	.000
Frame Rate (FR)	2	1086.420	28.464	.000	1116.890	8.025	.000
Frame Dimension (Dim)	1	1100.669	17.950	.000	1120.818	3.130	.077
Bit-Rate (BR)	1	1092.200	13.052	.000	1121.960	.054	.816
FR $*$ Dim	2	1091.110	2.892	.056	1117.780	.719	.487
FR $*$ BR	2	1103.450	5.269	.005	1127.280	1.488	.226
Dim $*$ BR	1	1114.040	7.513	.006	1128.860	1.466	.226
FR $*$ Dim $*$ BR	2	1087.310	7.143	.001	1113.480	.020	.980

Table 6: Standardised Parameter Estimates in the Extended Perceived Quality Model

Source	Parameter	Estimate	$SE_{\bar{x}}$	*df*	*t*	*p*	95% CI		$\mathbf{r}_{y\lambda}$
							Lower	Upper	
System	5fps**	-.5568	.129	1086.514	-4.320	.000	-.810	.304	-.129
	384k**	-.8580	.134	1154.374	-6.377	.000	-1.122	-.594	-.184
	5fps * 384k**	.8026	.188	1145.181	4.268	.000	.433	1.171	.125
	15fps * 384k**	.7103	.182	1166.053	3.886	.000	.351	1.068	.113
	480p * 384k**	.8595	.191	1154.370	4.485	.000	.483	1.235	.130
	5fps * 480p * 384k**	-.8019	.262	1151.397	-3.061	.002	-1.316	-.287	-.089
	15fps * 480p * 384k**	-.7810	.260	1163.006	-3.003	.003	-1.291	-.270	-.087
Personality	Conscientiousness**	-.0747	.028	1141.817	-2.669	.008	-.130	-.020	-.078
	Neuroticism**	.0943	.028	1149.100	3.422	.001	.040	.148	.100
Culture	Individualism*	-.0636	.027	1149.721	-2.349	.019	-.117	-.010	-.069
	Masculinity*	.0659	.028	1147.422	2.362	.018	.011	.121	.069
	Pragmatism*	-.0653	.030	1152.021	-2.211	.027	-.123	-.007	-.065

Reference categories were: Frame Rate = 25fps, Frame Dimension = 720p, Bit Rate = 768k.
† *p < .10, * p < .05, ** p < .01*

Table 7: Standardised Parameter Estimates in the Extended Enjoyment Model

Source	Parameter	Estimate	$SE_{\bar{x}}$	*df*	*t*	*p*	95% CI		$\mathbf{r}_{y\lambda}$
							Lower	Upper	
Personality	Conscientiousness*	-.0601	.026	1141.249	-2.296	.022	-.111	-.009	-.067
	Openness*	.0528	.025	1145.365	2.084	.037	-.003	.103	.061
Culture	Power Distance**	-.0795	.026	1152.465	-3.023	.003	-.131	-.028	-.088
	Masculinity†	.0474	.026	1141.312	1.820	.069	-.004	.099	.053
	Uncertainty Avoidance*	-.0661	.028	1144.106	-2.398	.017	-.120	-.012	-.070

Reference categories were: Frame Rate = 25fps, Frame Dimension = 720p, Bit Rate = 768k. All system interaction effects are non-significant and so are not shown.
† *p < .10, * p < .05, ** p < .01*

masculinity and conscientiousness. The regression coefficients for these parameters show that they have positive and negative impacts on overall ratings, respectively. Individualism, pragmatism, and neuroticism had, respectively, negative, negative, and positive impact on perceived quality. However, openness, power distance, and uncertainty avoidance respectively had positive, negative, and negative impacts on enjoyment respectively. The magnitudes of the effect sizes are also comparable with some system factors.

4.3 Optimistic Model

While the goal of a model is to predict the value of a dependent variable as accurately as possible, not all of the residual variance can be solely attributed to human factors which have not been measured. A non-trivial proportion of the residual variance can also, to name a few, be attributed to: random error; measurement error; and the limitations of the modelling technique (in this case, generalised linear regression). As such, an optimistic model can be used to estimate the proportion of this residual variance which can be reasonably attributed to human factors (and, to a small extent because of limitations to experimental control, context factors). This is achieved by modelling each participant as a "random effect". That is, the repeated measurements were used to vary the intercept of the regression for each individual participant.

An analysis of the optimistic models is shown in Table 5. There is only a small number of differences between the baseline and the optimistic model. As expected, the F-statistics for the intercepts are much larger, showing that they explain a larger proportion of the variance. Additionally, the borderline significant interaction between frame rate and frame dimension has become non-significant. The most notable difference, however, is a large increase in the variance explained as a result of including participants as random effects.

4.4 Model Comparison

The models are compared using paired t-tests on the Mean Squared Residuals (MSR), shown in Tables 8 and 9, and the proportional reduction in overall mean squared error of prediction is examined (see [2]).

4.4.1 Models for Perception of Quality

In the baseline model, the MSR is 1.2636 ($\sigma = 1.77$). The optimistic model reduces the MSR to 0.9085 ($\sigma = 1.63$) ($p < .000$). This represents 24.2% of the overall variance predicted (compared to 37.9% overall). However, culture and personality only predict a small proportion of this variance. The extended model predicts approximately 9.3% of variance attributable to human factors, reducing the baseline MSR to 1.2311 ($\sigma = 1.77$) ($p < .014$).

4.4.2 Models for Enjoyment

In the baseline model, the MSR is 1.3684 ($\sigma = 1.63$). The optimistic model reduces the MSR to 0.9481 ($\sigma = 1.22$) ($p < .000$). This represents 23.0% of the overall variance predicted (compared to 47.8% overall). However, again, culture and personality only predict a small proportion. The extended model predicts approximately 9.3% of variance attributable to human factors, reducing the baseline MSR to 1.3290 ($\sigma = 1.58$) ($p < .001$).

Table 8: Paired t-Test Comparing Models for Perceived Quality on MSR

Models	$\Delta\bar{x}$	σ	$SE_{\bar{x}}$	95% CI		t	df	p
				Lower	Upper			
Baseline → *Extended*	.0325	.461	.013	.007	.058	2.472	1231	.014
Baseline → *Optimistic*	.3551	1.009	.029	.299	.412	12.350	1231	.000

Table 9: Paired t-Test Comparing Models for Enjoyment on MSR

Models	$\Delta\bar{x}$	σ	$SE_{\bar{x}}$	95% CI		t	df	p
				Lower	Upper			
Baseline → *Extended*	.0394	.430	.012	.015	.063	3.219	1231	.001
Baseline → *Optimistic*	.4199	1.129	.032	.357	.483	13.069	1231	.000

4.5 Quality and Enjoyment

Descriptive statistics for each movie excerpt and parameter setting are presented alongside a correlation analysis between quality and enjoyment in Figures 2,4 and Table 10. These show how the parameters, the content, and level of enjoyment interact when human factors are not controlled. It can be seen that the overall correlation between quality and enjoyment is significant, however this is not consistent across all of the movie excepts. Additionally, the 'highest' quality parameters do not consistently perform well.

5. DISCUSSION

The results suggest that human factors play an important role in the way perception of quality and enjoyment are rated. The analysis of perceptual quality, in particular, reveals that a greater proportion of the variance can be predicted by human factors (24.3%) than by system factors (13.7%); although, all the system factors and most of their interactions have larger effect sizes than any individual human factor. This suggests that perceived quality and enjoyment are determined by humans as much as they are determined by the system itself. This is in line with previous work in the area [7], but more importantly shows that "lower" system factors may not automatically entail lower quality or enjoyment. To illustrate this the parameter setting {25fps, 480p, 384k} was ranked 4^{th} for perceived quality and 1^{st} for enjoyment, despite having a low bit-rate. Indeed, performance varied across different movie excerpts and participants. As such, understanding these factors could be used to prioritise limited resources while aiming to maintain minimally acceptable quality for a broad range of viewers.

It is important to recognise that the human factors explored in this study, namely personality and culture, represent a small portion of the variance which can be attributed to human factors overall. For both variables, they represented only 9.3% of the variance. While this is an important proportion, further study is needed to discover other contributing factors, which could include sensory impairments and expertise.

Nevertheless, a key facet to consider is moderation. That is, where the magnitude (and sign) of a relationship (e.g., perceived quality on enjoyment) depends on the value of a third variable (e.g., personality). A correlation analysis of the relationship between quality and enjoyment shows considerable inconsistency in effect size. It is interesting to note that the excerpts with objectionable content (i.e., graphic murders) had non-significant correlations while excerpts with widely acceptable content (i.e., romance) had much higher effect sizes. Presumably, this is because people do not enjoy objectionable experiences and so experiencing something they do not like in higher quality actually detracts from their enjoyment. As viewers tend to object to different content, such interactions could be used as a basis for managing quality parameters.

It is interesting to note that the indulgence cultural trait did not predict either perceived quality or enjoyment. This is interesting because habituation and sensitization effect were anticipated. That is, those with high indulgence scores tend to concentrate on individual well being and leisure time and so would likely seek to immerse themselves in multimedia content to a greater extent than those with lower indulgence scores. It is possible, however, that the indulgence may not correspond directly with the use and enjoyment of multimedia content. As such, whether or not participants regularly use multimedia content and services may be an important factor to consider in future studies.

Previous work [40] reports that agreeableness was a predictor for perceptual quality whereas extraversion was a predictor for enjoyment and [41] reports that there were no significant influence of personality in perceived quality. However, it should be noted that these differences are expected due to several reasons like a) stimuli-oreinted interaction effects (YouTube videos [41], IPTV [40] vs. Affective movie clips in our work), b) measurement instruments used (TIPI [11] for personality in [41] vs. BFI-10 in our work), variation in samples and the sampling method (users from the same university and living in the same country [40, 41] vs. users from different universities in different countries), analysis technique used (linear classifiers in [41] vs. statistical modeling in ours) and so on. To address these differences, building a comprehensive QoE model involving data from multiple datasets is encouraged.

It should be noted that due to the international nature of the research presented in this paper, participants did not use the same laboratories and therefore did not use the same devices. As such, system and contextual factors such

Table 10: Correlation Analysis Showing the Relationship Between Perceived Quality and Enjoyment

	C-I	C-II	C-III	C-IV	C-V	C-VI	C-VII	C-VIII	C-IX	C-X	C-XI	C-XII	Total[b]
Spearman's ρ	.252	.170	.377	.161	.242	.447	.507	.439	.367	.269	.391	.369	.375
p	.007	.082	.000	.095	.011	.000	.000	.000	.000	.007	-.000	.000	.000

[b]This aggregate is based on non-independent data due to repeated measures.
Movie Excerpts:- C-I: A_FISH_CALLED_WANDA; C-II: AMERICAN_HISTORY_X; C-III: CHILDS_PLAY_II; C-IV: COPYCAT; C-V: DEAD_POETS_SOCIETY_1; C-VI: DEAD_POETS_SOCIETY_2; C-VII: FOREST_GUMP; C-VIII: SE7EN_1; C-IX: SE7EN_3; C-X: SOMETHING_ABOUT_MARY; C-XI: THE_PROFESSIONAL; C-XII: TRAINSPOTTING.

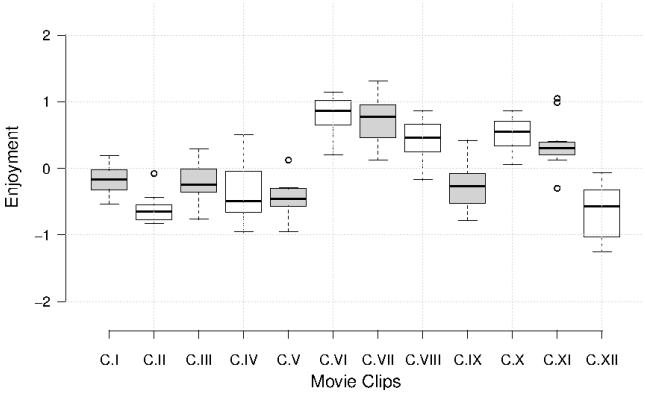

Figure 1: Box-Plot showing the distribution of Enjoyment of Each Movie Excerpt in the Dataset (z-Score)

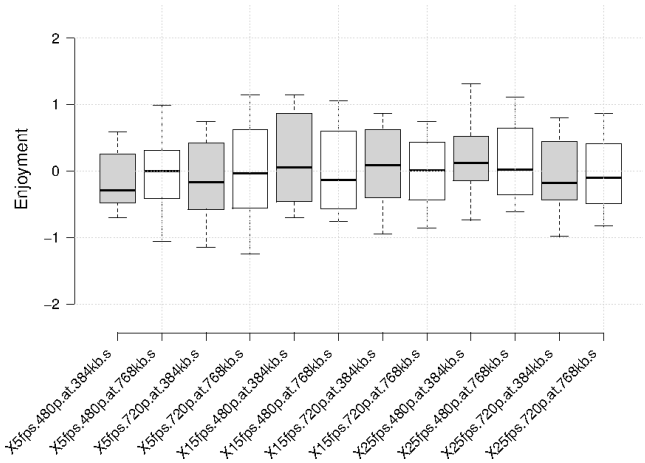

Figure 2: Box-Plot showing the distribution of Enjoyment of Each Parameter Setting in the Dataset (z-Score)

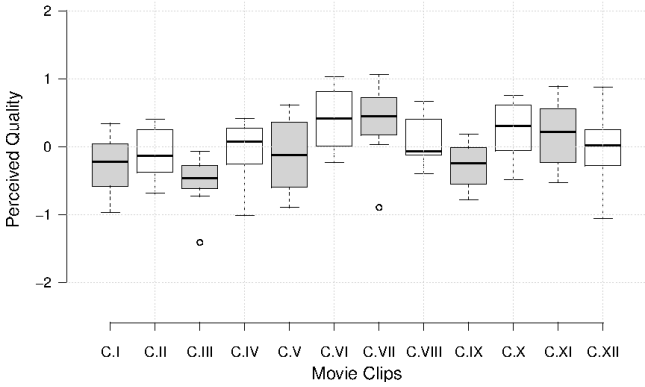

Figure 3: Box-Plot showing the distribution of Perceived Quality of Each Movie Excerpt in the Dataset (z-Score)

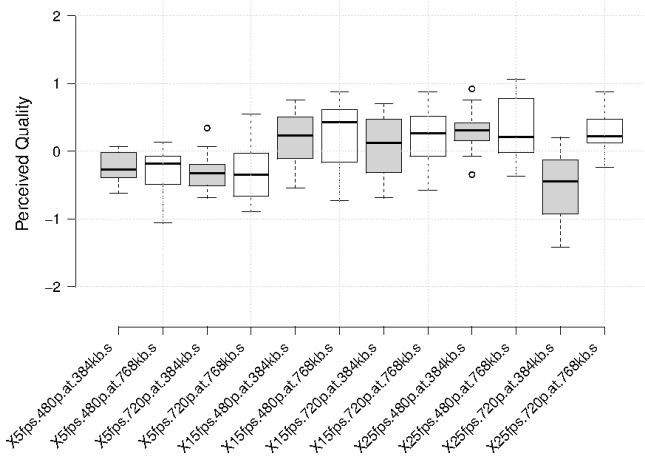

Figure 4: Box-Plot showing the distribution of Perceived Quality of Each Parameter Setting in the Dataset (z-Score)

as dead pixels, lighting conditions, and differences in computer hardware could have confounded any effect that has otherwise been attributed to the participants themselves. Consequently, this may over-estimate the variance attributable to human factors and so the relative 9.3% contribution of personality and culture may be an under-estimation.

6. CONCLUSION

Multimedia perception of quality and subsequent enjoyment is influenced by an intricate interplay between system, context, and human factors. Knowing the impact of these factors permits them to be exploited to optimise perceived quality and enjoyment under conditions where content delivery is constrained. As a step towards this goal, this paper presents a model of the role of human factors in perception of multimedia quality and its relationship to enjoyment.

Participants were drawn from a range of different nations to rate several video sequences under different conditions. It was found that: (i) approximately 13.7% of the variance in perceived quality could be predicted by system factors

while 24.3% could be predicted by human factors; (ii) approximately 24.8% of the variance in enjoyment could be predicted by system factors while 23.1% could be predicted by human factors; (iii) approximately 9.3% of the variance attributable to human factors could be predicted by personal and cultural traits (for both perceived quality and enjoyment); (iv) the traits of masculinity and conscientiousness were important predictors for both perceived quality and enjoyment; (v) individualism, pragmatism, and neuroticism were important predictors for perceived quality; (vi) power distance, uncertainty avoidance, and openness were important predictors for enjoyment; and (vii) the quality-enjoyment correlation varied in magnitude across the movie excerpts.

These findings confirm that human factors play a key role in perceptual multimedia quality and enjoyment. Of particular note, the variance attributable to human factors had an equivalent or greater impact on predicting the ratings compared to the system factors. This reveals that perceptual quality and enjoyment are as much human constructs as they are the result of objective technological differences. This offers several opportunities in terms of reducing bandwidth using human-centred quality of service algorithms. Based on the results of this study, such an algorithm could incorporate individualism, masculinity, pragmatism, neurotism and conscientiousness as paramaters (based on their ability to predict perceived quality) and individual preference for different genres (based on the differing correlations between quality and enjoyment across content).

However, further work is encouraged to model human factors because the personal and cultural traits selected in this study only represent a small proportion of the variance. Additionally, several limitations exist. Firstly, only the main effects of personality and culture were explored. It is possible that these traits interact with other factors and so more complex relationships could be identified. Secondly, the scope of the study was limited to a small subset of human and system factors. Broader investigations of system and context factors are needed. Thirdly, those recruited in this study were university students attending the authors' respective institutions. While there is no evidence to suggest that students are different to the general population in terms of quality of experience, additional work is encouraged to ensure that the full range of each human factor is considered (see [17, 22]) and any potential confounds are identified.

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