Measuring Quality of Perception in Distributed Multimedia: Verbalizers vs. Imagers

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Abstract

This paper presents the results of a study which investigated the impact of cognitive styles on perceptual multimedia quality. More specifically, we examine the different preferences demonstrated by verbalizers and imagers when viewing multimedia content presented with different Quality of Service (QoS) levels pertaining to frame rates and color depth. Recognizing multimedia's infotainment duality, we used the Quality of Perception (QoP) metric to characterize perceived quality. Results showed that in terms of low and high dynamisms clips, the frame rate at which multimedia content is displayed influences the levels of information assimilated by Imagers. Whilst black and white presentations are shown to be beneficial for both Biomodals and Imagers in order to experience enhanced levels of information assimilation, Imagers were shown to enjoy presentations in full 24-bit colour.

1. Introduction

Notions of quality are of paramount importance in distributed multimedia systems – simply stated, a user will not invest time, money or, indeed, other resources if (s)he does not believe that (s)he is getting quality commensurate with expectations. Whilst efforts to characterize distributed multimedia quality have been forthcoming along the years (Apteker et al., 1995; Cranley et al., 2003; Steinmetz, 1996; Wilson and Sasse, 2001), the proliferation of multimedia applications, display devices and – last but certainly not least – users, have led researchers to investigate novel ways of exploiting perceptual quality measures to transmit bandwidth-intensive multimedia content over fixed size pipes to an increasing numbers of users.

The trade-off between perceptual multimedia quality and traditional measures of quality – such as those characterizing *Quality of Service* (QoS) – is not always straight-forward and can be counter-intuitive. For instance, the asymptotic property first put forward by Apteker et al. (1995) holds that relationship between perceived multimedia quality and bandwidth allocated to the corresponding multimedia applications is non-linear – as such significant bandwidth savings can be achieved if notions of perceptual quality are taken into account in the design of distributed multimedia systems. In related work, Ghinea and Thomas (1998) have shown that, if multimedia's *infotainment* characteristic (i.e. that multimedia content is situated in an informational-entertainment spectrum) is taken into account, then users tend to assimilate more information when such video content is presented at low frame rates than at higher ones, since the information tends to present itself longer at lower frame rates. Such work again provides support to the counter-intuitive observation that bandwidth - a scarce resource in distributed multimedia systems - is not the sole arbiter of quality in this context.

Information transfer constitutes, in most cases, an important side of multimedia applications. Nonetheless, a dimension that is often overlooked in such cases, particularly in respect of quality considerations is the one of *cognitive style* (an individual's characteristic and consistent approach to organising and processing information (Weller et al., 1994)), especially since it affects the ways through which people organize and perceive information. Accordingly, in this paper, we offer a characterisation of distributed multimedia quality according to the *Verbalizer/Visualizer* facet of cognitive styles, because distributed multimedia content boasts multiple presentation dimensions, including text, preferred by Verbalizers, and graphics, favoured by Visualizers. This paper is thus structured as follows: Section 2 presents the research rationale behind our study, the methodological design of which is given in Section 3. Results and their discussion are then presented in Section 4, while conclusions and possibilities for future work are identified in Section 5.

2. Research Rationale

2.1 Perceptual Distributed Multimedia Quality

Distributed multimedia applications have a variety of service requirements which will need to be supported by both host platforms and communication networks. These requirements can themselves change dynamically depending on the applications and the media they support. Furthermore, as mobile communication systems proliferate, the services offered by the communication networks will also vary.

The layered communication architecture based on the OSI reference model as well as many of the network protocols in use today are ill-suited for supporting such applications. On the one hand, traditional protocols such as TCP/IP were conceived at a time when the emphasis was laid on providing functionality for data transfer over unreliable networks and not, for instance, on synchronisation between the audio and video streams of a multimedia application. On the other hand, while the OSI reference model has a number of QoS parameters describing the speed and reliability of transmission, these parameters apply to lower protocol layers, and are not meant to be directly observable or verifiable by the application. As regards legacy communication architectures themselves, they provide no support for negotiation and maintenance of applications' QoS, nor for its re-negotiation should the applications' requirements change. Moreover, there is no facility for the reservation and allocation of system and network resources needed by multimedia applications.

In order to meet multimedia QoS requirements and to take full advantage of the services provided by the underlying networks, it is therefore necessary that new approaches are elaborated for the distributed multimedia applications of the future. One such approach is the use of perceptual quality considerations in distributed multimedia systems.

The communication goals of informational multimedia are to entertain, inform and teach (Garrand, 1997). The literature, however, contains few references dealing with how these goals of informational multimedia are affected when multimedia applications are presented with varying QoS levels. Indeed, the focus has been predominantly on the entertainment aspect of multimedia, with users being consistently polled on their satisfaction (or annoyance) with impairments contained in multimedia presentations. Such work is at the core of the perceptual quality metrics, be they subjective or objective, and also forms the basis of Steinmetz's work on media synchronisation (Blakowski and Steinmetz, 1996; Steinmetz 1996), of work done on perception of frame rate variation (Apteker et al., 1995, Fukuda et al., 1997; Gulliver and Ghinea, 2004; Wang et al., 2001) and of research into perception of media loss (Procter et al., 1999; Wijesekera et al. 1998, Wilson and Sasse, 2000, 2001), as well as delay and jitter (Claypool and Tanner, 1999; Cranley et al., 2003; Song et al., 2002). What is striking is that, with the possible exception of Procter et al. (1999), who use ‘ease of understanding’, ‘recall’, ‘level of interest’, and ‘level of comprehension’ as quality measures, little or no consideration at all has being given to how the other two sides of informational multimedia, namely to inform and to teach, are affected when the presentations are done with varying QoS levels. It is also worthwhile remarking that, even in the case of Procter et al. (1999), these goals were examined with limited multimedia content (a bank’s annual report and a dramatized scene of sexual harassment).

User satisfaction, perception and understanding of multimedia should be the driving force in networking and operating systems research. Currently, research in these areas is driven mostly from a purely technical perspective, with little analysis of the benefit to the user. The focus of our research has been the enhancement of the traditional view of QoS with a user-level defined *Quality of Perception* (QoP). This is a measure which encompasses not only a user’s satisfaction with multimedia clips, but also his/her ability to perceive, synthesise and analyse the informational content of such presentations, thus providing a more complete characterisation of the communication goals of multimedia. With it users are asked to indicate, on a scale of 1-6, how much they enjoyed the multimedia presentation (with scores of 1 and 6 respectively representing “no” and, “absolute” user satisfaction), while their knowledge of the informational component is examined via a series of questions, and expressed as a percentage measure reflecting the proportion of correct answers received (Ghinea and Thomas, 1998). QoP thus represents, to the best of our knowledge, the only metric for perceptual quality evaluation which takes into account multimedia’s *infotainment* characteristic, and in this paper we study the effect of individual differences, as given by a user's cognitive style, on QoP, when multimedia is affected by quality variations.

2.2 The Verbalizer/Visualizer Dimension of Cognitive Styles

Cognitive style, originally proposed by Allport (1937), is defined as the degree of the thinking complexity of the individual in assimilating, interpreting, and reacting to the stimuli of information environmental (Craft, 1984). The other definition given by Riding and Rayner (1998) suggests that cognitive styles can be used to describe strategies of information processing and information representation used by different individuals. There are different types of cognitive styles, summarised in Riding and Cheema (1991). Among these, Riding's (1991) Visualizer/Verbalizer dimension is particularly related to multimedia systems because it concerns *presentation* of information (Paivio, 1990). More specifically, it describes the tendency for individuals to represent information being processed in the form of text or in the form of images (Riding and Cheema, 1991). Their different characteristics are:

- Imagers: Imagers tend to be internal and passive. Imagers perform better if the environment presents text and also pictorial material such as pictures, diagrams, charts, and graphs. Visualizers prefer to process information by seeing and they will learn most easily through visual and verbal presentations, rather than through an exclusively verbal medium.
- Verbalisers: Verbalisers tend to be external and stimulating. Verbaliser individuals perform better if the environment presents only information in the form of text. Verbalizers prefer to process information through words and find they learn most easily by listening and talking (Laing, 2001; Liu and Ginther, 1999).

This dimension also defines Bimodal individuals as the ones that can represent and process information equally well both in the form of text and images. In other words, they are equally comfortable using either modality (Jonassen and Grabowski, 1993). Previous research has highlighted the relevance of this dimension with computer-based learning. For example, Riding and Sadler-Smith (1992) investigated the relationships between cognitive styles and presentation modes. Their study was conducted in a computer-based instructional system, which includes various presentation modes. The results showed that the presentation modes have important influences upon learning performance. Specifically, students on the Visualizer dimension improve most in learning due to the inclusion of more pictorial presentations about certain types of content.

This dimension has also received attention in the area of information retrieval. For instance, Ford et al. (2001) examined how different cognitive style groups interact with AltaVista search engine. Their study found that generally imager individuals had poor retrieval success in information seeking environments. However, there is a lack of work to investigate the preferences of Visualisers and Verbalisers in multimedia systems in general, and specifically in distributed multimedia systems, where quality fluctuations can occur owing to dynamically varying network conditions. As the QoP metric is one which has an integrated view of user-perceived multimedia quality in such distributed systems, it is of particular interest to investigate the impact of cognitive styles on QoS-mediated QoP, as it will help in achieving a better understanding of the factors involved in such environments and ultimately help in the elaboration of robust user models which could be used to develop applications that meet with individual needs.

3. Methodology Design

3.1 Participants

This study involved 39 participants, which turned out to be quite evenly distributed in terms of cognitive styles. On the basis of Riding's Cognitive Style Analysis (see Section 3.2.2), the participants include 10 Verbalizers, 14 Biomodals, and 15 Visualizers. All users tested were inexperienced in the content domain of the multimedia video clips visualized as part of our experiments, which will be described next.

3.2 Video Clips

A total of 12 video clips were used in our study. These 12 clips had been used in previous QoP experiments (Ghinea and Thomas, 1998), and were between 30-44 seconds long and digitized in MPEG-1 format. The subject matter they portrayed was varied (as detailed in Figures 1 and 2) and taken from selected television programmes, thereby reflecting infotainment sources that average users might encounter in their everyday lives. Also varied was the dynamism of the clips (i.e., the rate of change between the frames of the clip), which ranged from a relatively static news clip to a highly dynamic Space movie, the degree of dynamism of a clip being established through user tests, as detailed in Ghinea and Thomas (1998).

3.3 Cognitive Style Analysis

The cognitive style dimension investigated in this study was Verbalizer/Visualiser. A number of instruments have been developed to measure this dimension. Riding's (1991) Cognitive Style Analysis (CSA) was applied to identify each participant's cognitive style in this study, because the CSA offers computerised administration and scoring. In addition, the CSA can offer various English versions, including

Australasian, North American and UK contexts. The CSA uses two types of statement to measure the Verbal-Imagery dimension and asks participants to judge whether the statements are true or false. The first type of statement contains information about conceptual categories while the second describes the appearance of items.

There are 48 statements in total covering both types of statement. Each type of statement has an equal number of true statements and false statements. It is assumed that Visualizers respond more quickly to the appearance statements, because the objects can be readily represented as mental pictures and the information for the comparison can be obtained directly and rapidly from these images. In the case of the conceptual category items, it is assumed that Verbalisers have a shorter response time because the semantic conceptual category membership is verbally abstract in nature and cannot be represented in visual form. The computer records the response time to each statement and calculates the Verbal-Visualizer Ratio. A low ratio corresponds to a Verbaliser and a high ratio to an Imager, with the intermediate position being described as Bimodal. It may be noted that in this approach individuals have to read both the verbal and the imagery items so that reading ability and reading speed are controlled for. Riding's (1991) recommendations are that scores below or equal to 0.98 denote Verbalizers; scores of 1.09 and above denote Imagers; individuals scoring between 0.98 and 1.09 are classed as Biomodals. In this study, categorizations were based on these recommendations.

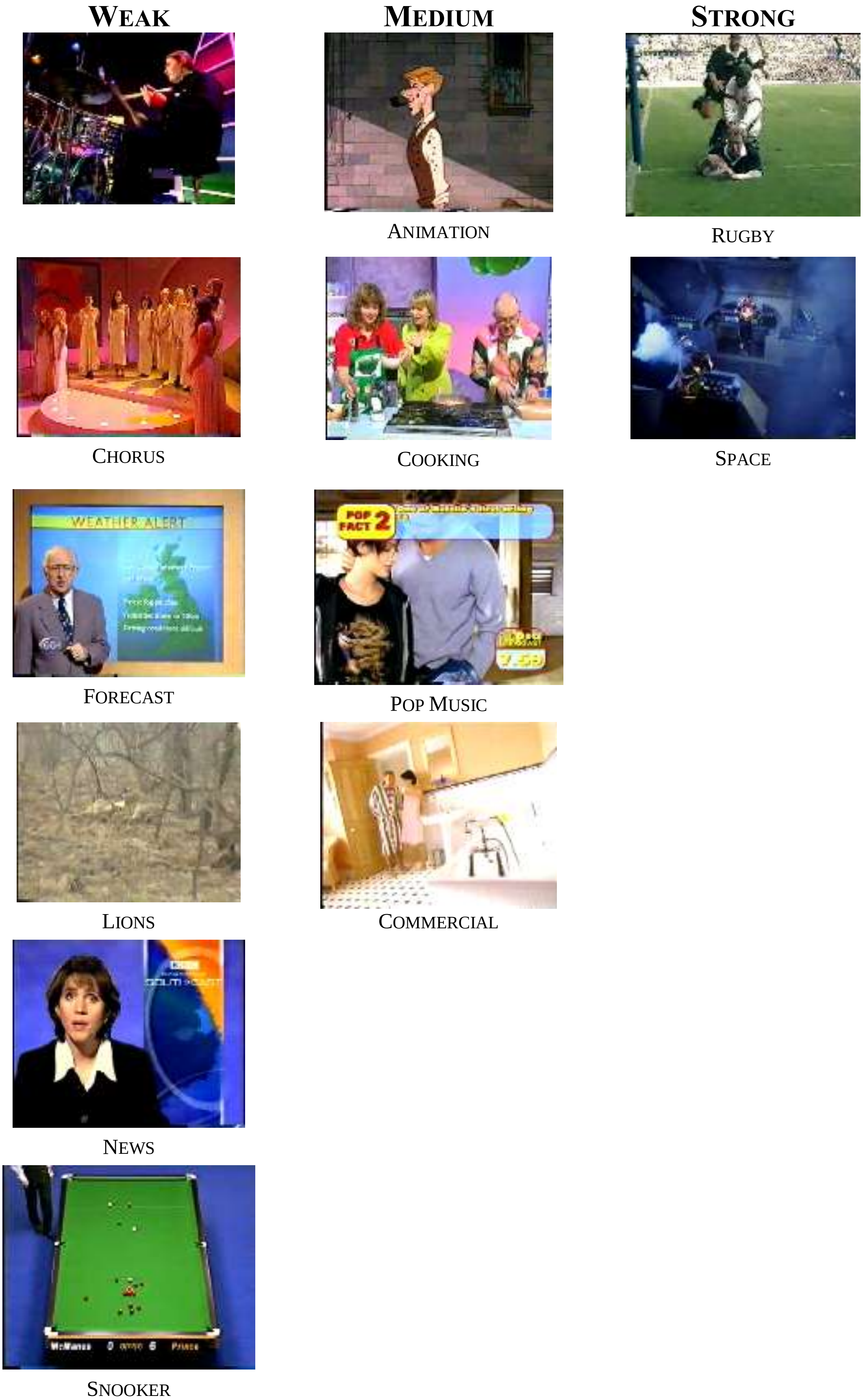

Figure 1: Clip breakdown according to dynamism

3.4 Quality of Perception

User perceptual multimedia quality was assessed using the Quality of Perception measure. Consistent with its ability to poll infotainment quality, this metric has two components – one which measures the ability of users to understand and assimilate the informational content of clips, denoted by QoP-IA, with the other, QoP-LOE, measuring the subjective level of enjoyment with the multimedia quality. The first is expressed as a percentage measure reflecting the proportion of answers correctly given to a series of 10 clip-specific questions that users had to answer after watching each clip in our selection, whilst the second is expressed on a Likert scale of 1-6 (with scores of 1 and 6 representing the worst and, respectively, best perceived qualities possible).

3.5 Procedure

In the opening screen, participants were given an overview of the process that was to proceed (Figure 1). The following screens were those of the computer-presented CSA to determine the individual participant's cognitive style. Once this was done, users moved onto the 'Test Movie' Screen, where they were given a chance to become familiar with varying levels of QoS delivery, by visualizing appropriately parameterized probes of multimedia material. Accordingly, users could select multimedia probes which exemplified playback at three different frame rates (25, 15 and 5 frames per second) and two different color displays (24-bit color and black and white, respectively).

Having become familiar with the varying levels of QoS delivery, users were then requested to select their preferred choice of QoS delivery for the 12 video clips of our experiments. Users were told that their particular choice would impact upon their final scores, in an inversely proportional relationship to their specified quality levels. The final stage of the experiments involved participants watching the twelve video clips. After each video clip was seen, participants answered the QoP-IA questions and indicated their QoP-S ratings for the respective clip. In order to counteract any order effects, the order in which clips were visualized was varied randomly for each participant.

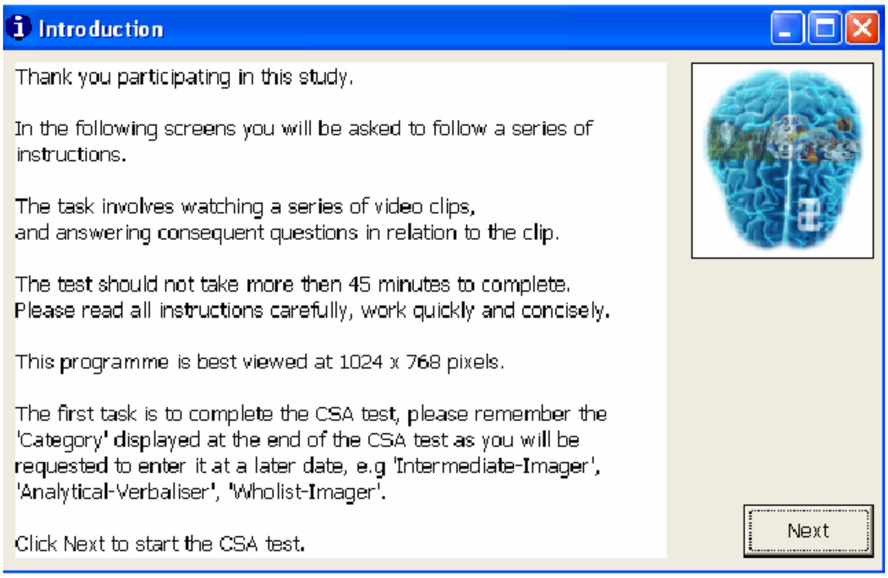

Figure 2: Introductory Screen

3.6 Data analysis

In this study, the independent variables include the participants' cognitive styles, as well as clip categories, and degree of clip dynamism. The dependent variables were the two components of Quality of Perception, QoP-IA and QoP-LOE. Data were analyzed with the Statistical Package for the Social Sciences (SPSS) for Windows version (release 9.0). An ANalysis Of VAriance (ANOVA), suitable to test the significant differences of three or more categories (Stephen and Hornby, 1997), was applied to analyze the participants' responses. A significance level of $p < 0.05$ was adopted for the study.

Since in real-life quality often comes with a hefty price tag, in our experiments we scaled participants' QoP-IA scores through a user *preference coefficient*:

$$\text{preference coefficient} = 5*(\text{color} * \text{fps})^{-1} \qquad (1)$$

The main role of the preference coefficient was to incorporate the impact of user QoS choices on their QoP-IA score (the higher the frame rate and the better the color quality requested, the lower the scaling coefficient) and, as opposed to previous studies in the area (Apteker et al., 1995; Cranley et al., 2003; Ghinea and Chen, 2003; Wilson and Sasse, 2001, Wijesekera et al., 1999), which have exclusively ignored the issue, also reflects the extent to which personal entertainment considerations ('*I want the highest possible multimedia display quality…*') are balanced by informational ones ('*…but do I really need it if information capture is also my aim?*') in the context of multimedia infotainment.

Accordingly, in our experiments *color* = 1 for black and white presentations and 2 for 16-bit color presentations, while *fps* is the numerical value of the desired frame rate. The preference coefficient thus also gives a relative indication of bandwidth resources required by the chosen multimedia presentation (a value of 1 corresponding to a low bandwidth, black and white, 5fps, presentation, with the lowest value of 0.1 corresponding to a full quality 25fps, color presentation).

4. Discussion of Results

4.1. Frame Rate Impact

Analysis of our results revealed that the particular frame rate at which a multimedia clip is viewed has a statistically significant impact ($F=3.036$; $p< 0.05$) on Imagers' QoP-IA levels in the case of content which is either of *low* or *high* dynamism (see Figure 1). In these cases, multimedia clips which were shown at the highest possible frame rate of 25fps were those that resulted in Imagers getting the highest QoP-IA scores (Table 1).

Frame Rate (fps)	Mean QoP-IA (%)	Std. Deviation
5	40.8542	18.33984
15	40.1307	19.12235
25	45.4421	18.86389
Total	42.2905	18.88076

Table 1: QoP-IA means for Imagers viewing clips of low and high dynamism

This result can be explained through the fact that clips shown at 25fps capture visual information at the highest temporal resolution (among the set of frame rates considered in our experiments), and so the visual element in them has a wealth of detail which lower frame rates could potentially miss. Thus, it comes as no surprise that Imagers, who tend to absorb information from visual sources, have high QoP-IA scores for clips presented at high frame rates. Whilst a high temporal resolution is certainly beneficial for high dynamism clips - where the potential of losing out on information is high if clips are captured at low frame rates - it is also certainly true in the case of low dynamism clips. Here the static nature of such clips can lead to user boredom when viewed and capturing visual information at a higher frame rate overcomes to some degree the static nature of the clip, which are presented with a greater temporal visual detail, and are thus of particular use to Imagers.

Whilst frame rate was shown not to influence Imagers' QoP-IA levels in the case of medium dynamism clips, our results did reveal that in certain cases of clip content it did significantly influence (from a statistical viewpoint) Verbalizers' and Biomodals' QoP-IA levels (see Table 2), although no particular patterns could be identified as why this is the case.

Clip	Verbalizer	Biomodals
Animation	F = 4.1783, p< 0.05	F =3.976, p< 0.05
Chorus	F =3.835, p< 0.05	Not significant
Forecast	F= 6.318, p< 0.01	Not significant
Pop Music	F =8.966, p< 0.01	F =3.865, p< 0.05
Space	Not significant	F =5.788, p< 0.05

Table 2: Impact of clip content on Verbalizer and Biomodal QoP-IA

Our findings also revealed that, with the exception of a few isolated cases (Table 3), the particular frame rate at which a clip is run does not influence participants' level of subjective enjoyment with the clip content, ie. QoP-LOE levels. This finding complements those of previous research (Apteker et al., 1995; Ghinea and Thomas, 1998; Wilson and Sasse, 2000), which showed that when viewing content purely for entertainment purposes, frame rate does impact QoP-LoE scores, and shows that when participants have an infotainment task at hand, they will predominantly ignore any degradations in frame rates, and concentrate on the informational nature of the exercise.

	Verbalizers	Biomodals	Imagers
Animation	F = 5.113, p< 0.05	F = 7.812, p< 0.01	Not significant
Chorus	Not significant	F = 3.889, p< 0.05	Not significant
Forecast	F = 9.454, p< 0.01	Not significant	F = 6.122, p< 0.01
Lions	F = 5.021, p< 0.01	Not significant	F = 3.918, p< 0.05
Pop Music	F =6.194, p< 0.01	F = 4.222, p< 0.05	Not significant
Snooker	Not significant	Not significant	F = 4.939, p< 0.05
Space	F = 6.512, p< 0.01	F = 4.855, p< 0.05	F = 7.245, p< 0.01

Table 3: Impact of frame rate on participant QoP-LoE levels

4.2. Impact of Colour Depth

Our experiments have highlighted that the particular colour depth at which a clip is shown is statistically significant in the case of Biomodal individuals' QoP-IA scores. Moreover, what is interesting is the fact that the highest QoP-IA scores in these cases were obtained for clips which were displayed in black and white. This result

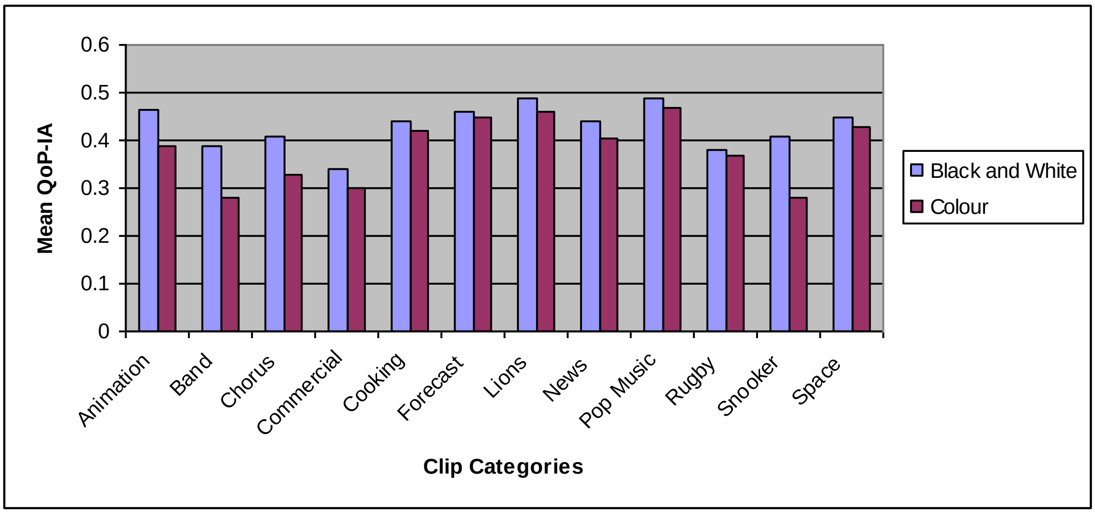

Figure 3: Impact of Colour Depth on Biomodals' QoP-IA

complements those of previous studies which have showed that Biomodal users tend to take versatile approaches and can easily adjust their media preferences for receiving information (Riding and Rayner, 1998) and shows that when the particular mode of media delivery is fixed (as was the case of our experiments) Biomodals will prefer lower quality multimedia colour resolution (Figure 3).

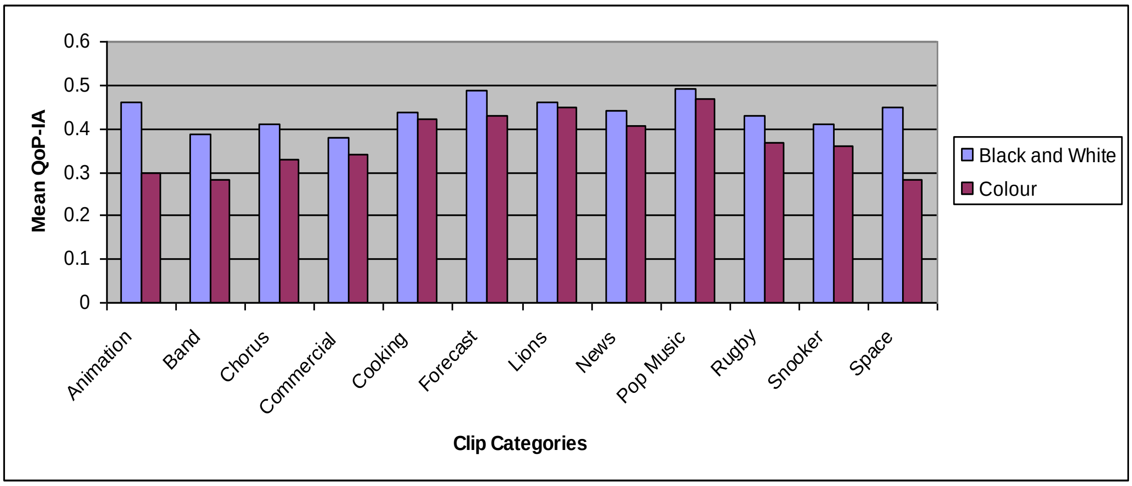

Figure 4: Impact of Colour Depth on Imagers' QoP-IA

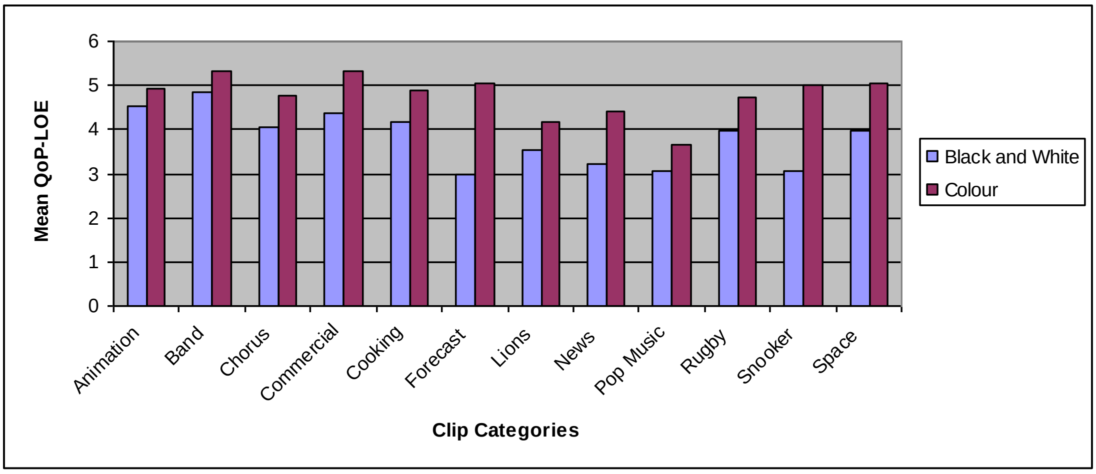

Figure 5: Impact of Colour Depth on Imagers' QoP-LoE

Another interesting result obtained is that Imagers performed better in terms of QoP-IA when clips were presented in black and white, but had higher QoP-LoE scores when those clips were presented in full 24-bit colour (Figures 4 and 5). This finding is certainly different from those of previous studies (Chen, 2002; Ford and Chen, 2001), and suggests that users' perceptions may influence their performance - in other words, what users like may not be what they need. This observation, coupled with that of the previous section which highlighted that users tend to ignore degradations in frame rates if there is an informational aspect to their task, suggests that the infotainment duality of multimedia has a symbiotic effect on user perceived multimedia quality.

5. Conclusions

Perceptual quality is an important facet of the user multimedia experience; recognising that multimedia comprises an infotainment duality, user cognitive styles represent another important aspect of this experience. The study reported in this paper brings together these two dimensions and investigates multimedia perceptual quality as experienced by different cognitive styles, when the underlying Quality of Service varies. We used the Quality of Perception measure and its two components, information assimilation (QoP-IA) and level of enjoyment (QoP-LOE), to characterise user perceived quality. QoS parameters considered in our experiment are the presentation frame rate and colour depth. Moreover, as opposed to previous work in the area, in our study users were actually allowed to choose their preferred presentation parameters, knowing however that there was a cost implication in choosing higher quality settings.

Our results revealed that, in terms of low and high dynamisms clips, the frame rate at which multimedia content is displayed influences the QoP-IA of Imagers. On the other hand, frame rates can have, for specific multimedia content, significant effects on the QoP-IA of Verbalizers and Biomodals. In respects of colour depth, black and white presentations are beneficial for both Biomodals and Imagers in order to experience higher levels of QoP-IA. Nonetheless, Imagers were shown to obtain a higher degree of QoP-LoE from clips presented in full 24-bit colour.

Our study has, of course, limitations: the sample size could be increased, the influence of task (and indeed of multi-tasking) could also have been explored, as indeed could the impact of more varied multimedia content. In addition, other dimensions of cognitive style could also be investigated. All represent worthwhile avenues for future work.

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