TOWARDS AUGMENTING MULTIMEDIA QOE WITH WEARABLE DEVICES: PERSPECTIVES FROM AN EMPIRICAL STUDY

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ABSTRACT

Wearable technologies and devices, including fitness trackers, smart watches, glasses, headgear and smart jewelry have been on the rise and are trending in the consumer market. Nonetheless, some wearable technologies have proven to be more successful and better received than others. The reasons behind this could be how users feel about the functionalities, features, aesthetics of wearables and their overall experience that are rarely considered. To address this, we present the results of an empirical study in which the Quality of Experience (QoE) and perceived usability of two wearable devices - a haptic vest and a heart rate monitor band – whilst watching multimedia content were explored. Results show enhanced user QoE when wearable devices were employed. Moreover, the usability and comfort of the two devices received positive feedback from users. However, participants were not so keen in wearing the devices regularly and in public.

Index Terms— *Wearables, Haptic Vest, Heartrate Monitor Wristband, QoE*

1. INTRODUCTION

In recent years wearables have grown and expanded. These gadgets do not only sense but communicate much more to a user [18]. Wearable devices - including watches, glasses, clothing, jewelry, and shoes - are used in many fields, such as healthcare, gaming, military, entertainment, education, commercial fields and leisure [20]. Wearing a computerized device involves many factors that include ease-of-use, how it looks (appearance) whether it is fashionable, lightweight, color and so forth. What is also important are the functionalities and what the device does, as is personal comfort since the design, material and weight of the device are also factors considered by users [12]. However, there has been limited amount of research done on user's experience of the usability of wearable devices. This is surprising, since exploring the ease of use and learnability of a device from a user's point of view would give developers insights into how users feel about the usefulness of such new devices, so they can meet their needs. Indeed, although usability has been applied in many fields [3] [4] [10], the perceived usability with wearables when experiencing multimedia has, to the best of our knowledge, not been explored and there is a gap which exists between the two concepts.

The aim of the experimental study reported in this paper is to explore how the use of wearables is perceived by users when viewing multimedia content. Accordingly, in our work we examined the QoE and usability of two wearable devices - a haptic vest and a heart rate monitor band. Users were asked to watch 7 multimedia clips and rate the devices in terms of functionalities, features, aesthetics of wearables and their overall experience. Accordingly, our paper is organized as follows: we present related research in section 2, then detail the methodology in section 3. Section 4 analyses the results obtained, whilst Section 5 draws conclusion and points out avenues for future work.

2. RELATED WORK

Wearable technologies are continuously being developed. Whilst devices themselves have been mostly aimed at expert wearers, research has examined wearables with the public in terms of their perception for everyday life and adoption of technology. Early work focused on gender and culture when carrying out their experiment and found that there were common interests with safety and comfort which were perceived positively [19].

Wearables have long been employed in the healthcare sector to assist people and make their life easier. One example of this is the work of Matthews et al. who looked at the usability of a wearable camera system amongst family caregivers of persons with dementia. From their study it was evident that caregivers found the device useful, easy to learn and accepted it despite having some concerns of privacy, and the device being perceived as obstructive and cumbersome. The system's usability of this device requires enhancement, but the functionalities were viewed positively [11]. In related work, Claudio et al. investigated the use of wearable sensor-based systems in emergency departments. The authors were interested in obtaining user feedback in terms of their attitudes towards wearable systems to predict the success of the technology. They found that both patients

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Table 1. Video Clips description

						
Clip 1: Beach Scene, blue waves lapping on the shore	Clip 2: Yellow sulphur springs, Danakil Desert, Ethiopia	Clip3: Red desert sands in Riyadh, Saudi Arabia	Clip 4: Bright sun shining upon the Arctic with bright snow	Clip 5: Solar Eclipse, sky turns dark and the moon appears	Clip 6: Angular Skyscrapers	Clip 7: Bouncing Balls

and nurses had positive responses and that the perceived usefulness of wearable sensor systems was higher than the ease-of-use. Also, patients' perceptions were more favorable as opposed to the nurses in terms of both ease-of-use and perceived usefulness [7]. Wearable camera systems have a greater acceptance amongst the general population when used for lifelogging purposes, as Ali et al. [17] have shown, but still have drawbacks in terms of privacy and comfort. Moreover, the same study suggested that the functions and quality of the images need to be improved to give a better satisfaction as well as acceptance.

Wearable technologies are not always accepted due to people's views and opinions which are always changing, and this is a challenge but, finding out how they feel in wearing the wearables is something that could aid developers in improving upon their designs or functionalities to meet their needs. To this end, many factors are perceived as being influential in accepting wearables. For instance, Ariyatum et al. highlighted that the physical appearance of a wearable plays a key role when it comes to acceptance. Moreover, the wearable device should fit the user's personality and lifestyle, and indeed the device's usability, functionality and price are also crucial factors when it comes to the device's acceptance [5]. Similarly, Bodine and Gemperle claim that the acceptance of wearables is based on perceptions of comfort and functionality; and that these dimensions should be considered by the developers early in the development phase [13]. However, developers tend to not always involve users in the early development stage and test wearables in iterations, which ultimately causes problems when it comes to using a device regularly and acceptance of the device [2].

Users' involvement is critical, as their experience confirms the success or failure of a product [9]. Accordingly, Stickel et al., and Hassenzahl have pointed out that user satisfaction is an important feature that determines whether the product has met a user's expectation [6] [15]. From this review of related work, it becomes clear that the potential of using wearable devices to enhance user QoE of viewing multimedia content has largely been ignored by the literature. In this context, a deeper understanding of user QoE is what inevitably would close the gap between designers and developers, helping them understand what users need and want from the product. Towards this goal, the focus of the experiment reported in this paper was twofold: to understand the user experience with wearable devices whilst viewing multimedia and to find out whether the users would incorporate wearables in their daily lives.

3. EXPERIMENTAL METHOD

3.1 Participants

Our study involved 24 participants (15 males and 9 females). Participants were aged between 18-41 years of age and hailed from a range of diverse backgrounds, nationalities, and education (undergraduate to postgraduate students and academic staff). All participants spoke English and were computer literate.

3.2 Experimental Material

3.2.1 Video Clips

In the experiment, participants watched 7 multimedia video clips, each of 120s duration. The view area is 1000x700 pixels. The resolution for each video clip is 1366 x 768 pixels. The frame rate is 30 frames per second. The original sound is generated from the original video content. The clips were chosen based on visual features: color, shape, spatial relations and texture. Accordingly, in 3 of the clips, the predominant color was blue, red, and yellow, respectively, a further 2 clips were chosen because one was mainly bright and the other dark, while the last 2 contained shapes that were almost exclusively angular or round, respectively (Table 1). These clips were chosen because they are based on natural scenes and contain low-level information that would offer a more interactive and engaging experience.

3.2.2. Wearable devices

Two distinct types of wearable devices were used in our experiments. The first was a Kor-FX gaming haptic vest (see fig.1). This device was chosen for this study because a user can get connected of what they are seeing on the screen, enabling them to have an immersive experience. Also, the haptic vest connects to the audio coming from any media content such as movies or games [14]. Applying the Kor-FX device in the experiment would provide different perceptions from users, because the vest has sensors that are meant to immerse the user and enhance sense of reality as well as giving a better experience.

The second device used in our study was a wearable heart rate monitor band (see fig.2). The second device used in our study was a wearable heart rate monitor band. Mio Go wearable band was chosen because it would help in monitoring the heart rate of a participant, especially seeing how fast or slow the heart beats for each video clip in relation to the haptic vest's vibrations. Mio Go has received positive reviews online from people who have purchased this product and use it regularly [16].

Fig. 1. Haptic Vest

Fig.2 Heart rate wristband

3.3 Experimental Preamble

The experiment took place in a quiet room, where the actual time of the experiment lasted between 30-40 minutes. The experiment had received ethics clearance from the local committee and each participant was asked for their consent in taking part in the experiment. Before the experiment every participant was introduced to the experiment with an explanation of the process and tasks involved. Each participant was provided with the previously described haptic vest and heart rate monitor band to wear. Once participants confirmed that wearing the devices was comfortable (e.g. not too tight/loose, in an awkward position) they then proceeded to view the multimedia video clips.

3.4 Experimental Process

Participants viewed 7 multimedia video clips on a laptop whilst wearing the Kor-FX haptic vest and the Mio Go band. The video clips were shown in a random order to ensure that order effects are minimized. After viewing each video clip, participants were asked to complete a short online questionnaire based on the haptic vest, indicating their views on a 5-point Likert scale (1= strongly agree, 2= agree, 3= neutral, 4= disagree, 5= strongly disagree) in respect of a number of statements concerning the device's usability (Table 2). When all 7 clips had been watched, participants were required to complete an extended paper questionnaire. The paper questionnaire consisted of questions split into two categories (Table 3 and 4), each targeting the haptic vest KorFX and MioGo wearable band, respectively. The questions were designed to capture a user's thoughts and their experience of wearing the devices. The widely used System Usability Scale (SUS) was incorporated when developing the questions to gather information and learn about a user's views of the product [1]. Once they had completed the experiment, participants were thanked for their time and effort.

Table 2. Questionnaire: Haptic Vest QoE whilst watching multimedia video clips

Q1: I enjoyed watching the video clip whilst wearing a Haptic Vest.
Q2: The Haptic Vest effects were relevant to the video clip I was watching.
Q3: The vibration was distracting.
Q4: The vibration was annoying.
Q5: The Haptic Vest effects enhanced the sense of reality whilst watching the video clip.
Q6: The Haptic Vest effects were necessary when watching a video clip.
Q7: The Haptic Vest effects enhanced my viewing experience.

Table 3. End of Experiment Questionnaire: Haptic Vest

Q1: The Haptic Vest is comfortable to wear.
Q2: I found the Haptic Vest bulky to wear.
Q3: The Haptic Vest starts to heat up after wearing it for a long time.
Q4: I found that the Haptic Vest has a range of functions that are well incorporated.
Q5: I would be confident wearing the Haptic Vest in public.
Q6: I would wear the Haptic Vest at work.
Q7: I would wear the Haptic Vest in my leisure time.

Table 4. End of Experiment Questionnaire: Heart Rate Monitor Wrist Band

Q1: Do you think Mio Go (wearable band) is a comfortable device to wear?
Q2: I think the activities available on the Mio Go band are helpful.
Q3: I would be confident wearing the heart rate monitor wrist band in public.
Q4: I would wear the heart rate monitor wrist band at work.
Q5: I would wear the heart rate monitor wrist band in my leisure time.

Table 5. Results of the Haptic Vest from the online questions (The cells in bold contain statistically significant results)

Haptic Vest	Video Clip 1	Video Clip 2	Video Clip 3	Video Clip 4	Video Clip 5	Video Clip 6	Video Clip 7
Q1	Mean: 2.63 Std: 1.13 *t* value: -1.619 *p*-value: .119	Mean: 2.66 Std: .868 *t* value: -1.881 *p*-value: .073	**Mean: 2.42 Std: .776 *t* value: -3.685 *p*-value: .001**	**Mean: 2.50 Std: .978 *t* value: -2.505 *p*-value: .020**	Mean: 2.92 Std: .974 *t* value: -.419 *p*-value: .679	**Mean: 2.25 Std: .847 *t* value: -4.338 *p*-value: .000**	Mean: 2.63 Std: 1.10 *t* value: -1.676 *p*-value: .107
Q2	**Mean: 2.46 Std: 1.02 *t* value: -2.600 *p*-value: .016**	Mean: 2.79 Std: 1.14 *t* value: -.894 *p*-value: .380	**Mean: 2.33 Std: .637 *t* value: -5.127 *p*-value: .000**	Mean: 2.58 Std: 1.10 *t* value: -1.856 *p*-value: .076	Mean: 3.29 Std: 1.08 *t* value: 1.320 *p*-value: .200	Mean: 2.71 Std: 1.16 *t* value: -1.232 *p*-value: .231	Mean: 2.58 Std: 1.06 *t* value: -1.926 *p*-value: .067
Q3	Mean: 3.46 Std: 1.28 *t* value: 1.748 *p*-value: .094	Mean: 3.08 Std: 1.06 *t* value: .385 *p*-value: .704	**Mean: 3.46 Std: .884 *t* value: 2.541 *p*-value: .018**	Mean: 3.46 Std: 1.10 *t* value: 2.037 *p*-value: .053	Mean: 3.00 Std: 1.22 *t* value: .000 *p*-value: 1.000	Mean: 3.29 Std: 1.23 *t* value: 1.159 *p*-value: .258	**Mean: 3.58 Std: 1.10 *t* value: 2.598 *p*-value: .016**
Q4	**Mean: 3.58 Std: 1.14 *t* value: 2.509 *p*-value: .020**	Mean: 3.29 Std: 1.04 *t* value: 1.372 *p*-value: .183	**Mean: 3.67 Std: .817 *t* value: 4.000 *p*-value: .001**	**Mean: 3.67 Std: .817 *t* value: 4.000 *p*-value: .001**	Mean: 3.29 Std: 1.16 *t* value: 1.232 *p*-value: .231	**Mean: 3.50 Std: 1.18 *t* value: 2.077 *p*-value: .049**	**Mean: 3.58 Std: 1.10 *t* value: 2.598 *p*-value: .016**
Q5	Mean: 2.63 Std: 1.01 *t* value: -1.813 *p*-value: .083	Mean: 2.75 Std: 1.07 *t* value: -1.141 *p*-value: .266	**Mean: 2.46 Std: .658 *t* value: -4.033 *p*-value: .001**	**Mean: 2.46 Std: .977 *t* value: -2.716 *p*-value: .012**	Mean: 3.00 Std: 1.22 *t* value: .000 *p*-value: 1.000	Mean: 2.54 Std: 1.14 *t* value: -1.967 *p*-value: .061	**Mean: 2.38 Std: .824 *t* value: -3.715 *p*-value: .001**
Q6	Mean: 2.92 Std: 1.21 *t* value: -.377 *p*-value: .739	Mean: 3.04 Std: 1.23 *t* value: .166 *p*-value: .870	Mean: 3.04 Std: .908 *t* value: .255 *p*-value: .824	Mean: 2.67 Std: 1.05 *t* value: -1.556 *p*-value: .133	**Mean: 3.46 Std: .932 *t* value: 2.410 *p*-value: .024**	Mean: 2.88 Std: 1.15 *t* value: -.531 *p*-value: .601	Mean: 2.92 Std: 1.02 *t* value: -.401 *p*-value: .692
Q7	Mean: 2.63 Std: 1.21 *t* value: -1.519 *p*-value: .142	Mean: 2.79 Std: 1.14 *t* value: -.894 *p*-value: .380	Mean: 2.67 Std: .817 *t* value: -2.000 *p*-value: .057	**Mean: 2.21 Std: .588 *t* value: -6.953 *p*-value: .000**	Mean: 3.13 Std: 1.12 *t* value: .549 *p*-value: .588	Mean: 2.58 Std: 1.02 *t* value: -2.005 *p*-value: .057	Mean: 2.75 Std: .989 *t* value: -1.238 *p*-value: .228

4. RESULTS

A significance level of 0.05 was adopted for the analysis. To check the effect that device type (haptic vest) has on QoE, IBM SPSS was used to undertake a one sample t-test. Our results indicate that specific multimedia content for the video clips significantly influences participants' QoE (Table 5). Throughout most video clips for question 1 there was no significant difference between participants' level of enjoyment. This suggests that participants' responses were balanced for most of the clips but, clips 3, 4, and 6 were the ones that they enjoyed most. The results for question 2 show that most participants felt that the haptic vest effects were only relevant to a certain extent to the video clips they were watching. However, some participants did feel that the effects were more relevant to video clips 1 and 3. This could be due to the video content or the audio. The results for the following two questions (3 and 4), whilst not statistically significant across the board (only responses for clips 3 and 7 for question 3 and video clips 1, 3, 4, 6 and 7 for question 4 were statistically significant), nonetheless show that users did not perceive the haptic vest's vibrations to be distracting or annoying. The results for question 5 show that in roughly half of the time, participants felt that the haptic vest effects did enhance the sense of reality whilst watching the video clips 3, 4 and 7, with responses being statistically significant. However, responses to this question for the rest of the video clips were not statistically significant, showing that not all participants felt that there was much difference with the effects enhancing the sense of reality; this could well be because of the video content. In respect of haptic effects being necessary to accompany video content, although for most video clips (except for video clip 5) responses were not statistically significant, participants' responses did however reveal a slightly negative attitude here. Lastly, responses to question 7 reveal that the use of the haptic vest did have an influence on the user viewing experience but only to a limited extent. Participants did, however, feel that the use of the haptic vest effects for video clip 4 were pleasing, with statistically significant responses being obtained in this case. Rounding up, what these experiments highlight is that the use of the haptic vest to impact QoE should be done judiciously and not across the board, considering the viewed content. Indeed, this is in

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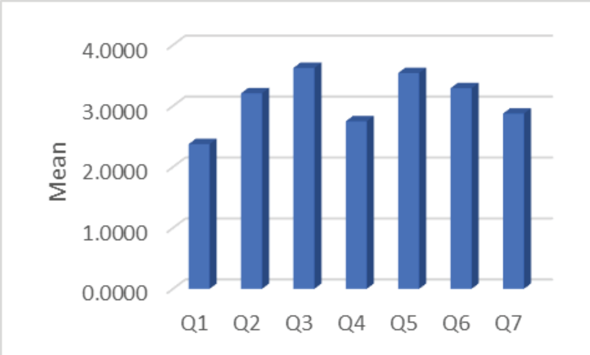

Fig.3. End of Experiment Questionnaire: Haptic Vest

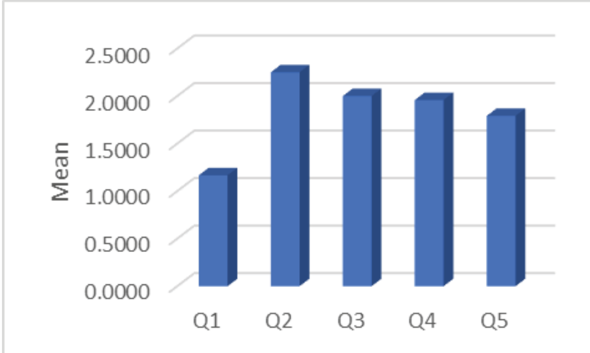

Fig.4. End of Experiment Questionnaire: Wrist Band

keeping with previous research which has highlighted the importance of the content itself on user QoE [9].

Results are shown in Table 6 for the end of the experiment questionnaire. The perceived comfort of the haptic vest reported by the participants had a statistically significant mean value of 2.38, emphasizing that participants found the haptic vest comfortable to wear. Moreover, the perceived comfort of the heart rate monitor wrist band reported by participants, displays an even stronger positive bias, with statistically significant responses' mean value of 1.17 (refer to figures 3 and 4.) Although not statistically significant, results show that participants did not perceive the vest to feel bulky when worn. Statistical significance was, however, obtained in user responses which highlighted that the device did not come across overly warm. Also, the perceived usability of the functions and activities in the vest by the participants was positive. It is also to be remarked that, on average, participants preferred the wrist band more than the haptic vest.

Table 6. Results of both wearable devices after the experiment (Boldface figures contain statistically significant results)

Haptic Vest	Mean	Standard Deviation	*t*	*p*-value
Q1	**2.38**	**1.01**	**-3.021**	**.006**
Q2	3.21	1.10	.926	.364
Q3	**3.63**	**1.24**	**2.460**	**.022**
Q4	2.75	.676	-1.813	.083
Q5	**3.54**	**1.10**	**2.407**	**.025**
Q6	3.29	1.08	1.320	.200
Q7	2.88	1.30	-.473	.641
Heart rate monitor band	**Mean**	**Standard Deviation**	***t***	***p*-value**
Q1	**1.17**	**.565**	**-15.906**	**.000**
Q2	**2.25**	**.532**	**-6.192**	**.000**
Q3	**2.00**	**.722**	**-6.782**	**.000**
Q4	**1.96**	**.624**	**-8.177**	**.000**
Q5	**1.79**	**.658**	**-8.996**	**.000**

Participants' statistically significant opinions of wearing the haptic vest in public were average, demonstrating that they were not so keen. Moreover, from the results the wrist band would be worn in public by users than the haptic vest, with expressed opinions again being statistically significant. The same could be said for wearing the devices at both work or in leisure time. Our statistically significant results also highlight that participants are keen on wearing the wrist band daily at work. Lastly, we wanted to know whether participants are likely to wear the devices in their leisure time. Here, the results for both work and leisure of the haptic vest were very similar. The statistically significant results for the wrist band had a mean of 1.79, which leans towards a categorical value of 'agree'. Again, the results for both work and leisure of the wrist band were very similar. Furthermore, participants are more comfortable wearing a wrist band than the haptic vest in their daily lives.

5. CONCLUSIONS

The aim of the experiment reported in this paper was to provide insights into users experience with wearable devices whilst viewing multimedia content. Although, the scale of our study was small from our results it appears that many users had a satisfying overall experience with the wearables. Both devices studied – a haptic vest and a heart rate monitoring wrist band - were perceived positively when it came to their comfort and usability. However, in respect of whether the users would incorporate these devices daily the results revealed that the heart rate monitor wrist band seemed more appropriate to be worn in public, work and leisure as opposed to the haptic vest. This could be because the wrist band is lightweight, small, compact, can be hidden and more appealing whereas the haptic vest is quite cumbersome and would be noticeable to wear.

In respect of user QoE, results show that the use of wearables whilst viewing the video clips did increase QoE. Also, it enhanced the enduring nature of the experience, at an average level. The user's interests in video content multimedia in most of the video clips varied as they had different expectations. Nonetheless, some video clips were more enjoyed, and this reinforces the primacy of content in multimedia QoE as evidenced by previous work [8].

Moreover, by applying the QoE concept we got an insight to the user's experience as well as learning which video clips were of interest to them and which ones were not it is something to consider in the future. However, whilst devices did enhance the overall QoE for most of video clips, the fact that this didn't happen across the board could be due to users not being acquainted with wearables whilst viewing multimedia or the content itself not matching up to their needs. All are avenues for future exploration.

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