The Influence of Human Factors on Olfaction based Mulsemedia Quality of Experience

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***Abstract*—With the aim to enrich users' perceived multimedia experience, the authors present the results of an empirical study which looked at user perception of olfaction based mulsemedia. The goal is to evaluate the influence of users' age and gender on user quality of experience (QoE) considering various scent types and categories (pleasant or not). The results present a complex relationship between these variables and how they influence user QoE. They indicate that different user groups report different perception of content level factors for olfaction based mulsemedia.**

***Keywords*— Mulsemedia, Olfaction enhanced multimedia, Olfaction-based mulsemedia, Quality of Experience, Sensory experience.**

I. INTRODUCTION

Recently, the multimedia community has begun to analyse and work with multiple sensorial media (mulsemedia) [1][2][3] (referred to as sensory experiences in some works [4]). This is based on the assumption that extending traditional media with tactile [5], gustatory [6] and olfaction [7][8][9] will result in enhanced user Quality of Experience (QoE) levels. Based on a working definition of QoE from a Qualinet white paper [10], is "(QoE) is the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and / or enjoyment of the application or service in the light of the user's personality and current state." Olfaction as a media component presents numerous challenges in terms of sensor, display development and in particular understanding. It has been employed alongside multimedia content across a variety of application domains [3][11]: entertainment (movies) [12], gaming [13], health [14][15][16], education [17][18][19] and tourism [20] to name a few.

A fundamental requirement to achieve enhanced QoE of olfaction-based mulsemedia for all these application domains is to understand the influence of lingering effects and synchronization [21][22][23]. This is because olfaction based mulsemedia applications should accurately present the various multimodal streams as they are presented in nature. In addition, user QoE is also affected by numerous other influencing factors (IF) [10]. The literature reports results on user factors such as effects of age, gender, culture [8][21], life experiences, emotions and mood [11], scent type [22] and temporal relations between olfaction and other media components [23][24][25]. To the best of the authors' knowledge no works have analyzed the influence the human factors of age and gender with respect to scent type on user QoE.

In this context, the results presented are the outcome of two experimental studies (referred to as experimental study 1 and experimental study 2, heretofore). The video sequences were enhanced with one olfactory and two olfactory components, respectively. The analysis reported here is from self-reported measures of 10 olfaction-based mulsemedia clips. The QoE levels of 138 assessors were captured. This paper is organized as follows: section 2 discusses related work, section 3 describes the components of the olfactory and video media display system used during the subjective testing. Section 4 outlines the assessment methodology employed, section 5 presents the results and analysis of the completed subjective testing with discussion on findings. Section 6 concludes the paper and highlights directions for future research

II. RELATED WORK

As mentioned, user QoE is influenced by numerous factors. In this section, we present an overview of existing works that considered such factors for olfaction based mulsemedia. Closely related to the work presented here, in [8][21] the influence of age, gender and culture on user perception of olfaction enhanced multimedia was studied. It was reported that age was not found to be as significant as gender and culture in terms of its influence on QoE. However, these works did not consider the scent type variable within the age/gender analysis. With respect to scent type as an IF, in [22] statistically significant differences were reported between pleasant and unpleasant

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scent types in terms of their influence on user QoE considering single and multi-scent presentations. However in this work, the influence of user factors of age and gender was not analyzed. In terms of the effect of synchronization error on olfaction based mulsemedia QoE, [8] studied it for olfaction enhanced visual media, if olfaction is presented 15s ahead of video or 10s after video, and noted that assessors found the experience as being synchronized. In [9], the effect of multiple olfactory streams on user QoE was presented. A minimum of 20s is required between consecutive scent presentations to ensure enhanced user QoE. It also reported that assessors did not enjoy mixing of scents. Again, the influence of scent type was not considered.

Considering these works, it can be concluded that no research has analyzed the combined human factors of age and gender with scent type. Considering the diverse factors that affect user perception of olfaction, there is a clear need for an analysis focused on the impact of scent type considering human factors on user QoE. This paper addresses this requirement.

III. EXPERIMENTAL SETUP

This section outlines the olfaction based mulsemedia presentation system, assessors, as well as video and scents used.

A. Olfaction-based Mulsemedia Presentation Equipment

The olfaction-based mulsemedia display system is shown in Fig. 1. The olfactory display (OD) used was the SBi4 – radio v2 scent emitter [26]. This OD can support four scents at any one time. The fans are controlled using the Exhalia Java-based SDK. The video content was played using the VLC media player 1.0.1 Goldeneye. The presentation of scents and video are controlled via a software framework. It presents synchronized and artificial skews between the olfaction and audiovisual media. The skew levels evaluated between the audio/visual and olfactory components were presented in step sizes of 5s. For experiment 1, the skew levels ranged from -30s to +30s and for experiment 2, from 20s to +20s. The range of test cases for experiment 2 was reduced based on the findings of experiment 1 where users reported significant decrease in QoE levels outside this range. Further discussion is provided in section V. In both studies, negative skew levels indicate olfaction presented before video whereas positive skew levels indicate olfaction presented after video. The time taken to deliver scent from the OD to the user was considered as part of the delivery process with detailed information presented in [8].

Fig. 1: Olfactory and video media display system [24].

B. Assessors Screening and Test Laboratory

Assessor Screening was employed according to the appropriate ISO standard [27] to *ensure assessors did not suffer from anosmia*. It was also employed as *part of training* in the *recognition of* the different *scents.* The test laboratory was designed in accordance with appropriate ISO standard [28]. Detailed information on the test lab design is provided for the interested reader in [8].

C. The Video Clips and Scents

In study 1, 6 video clips were used. The clips (90s in duration) were in form of documentaries, cookery programs and movies. The middle 30s block of each clip contain content related specifically to the scent being presented. The scents of fruity, flowery, spicy, resinous, foul and burnt were used. In experimental study 2, 4 olfaction enhanced multimedia clips were used. Each of the video clips was 120s in duration. Each of the video clips can be divided into four 30s blocks whereby the middle two 30s blocks contain content related specifically to the scent being presented. As mentioned, 2 scents enhanced the multimedia content for experimental study 2. The scent combinations were fruit-flowery, forest-burnt, fruit-foul, foul-burnt. For both study 1 and 2, the scents employed were selected so that a fair distribution of pleasant and unpleasant scent types were used.

D. Participants

A total of 138 assessors took part in this study (86 in study 1, 50 in study 2). These came from a variety of backgrounds: students, post graduate researchers and academic staff. They had excellent age and gender balance: (((53 between (20-30 years)), (43 between (30-40 years)), (42 between (40+ years))) with 62 females and 76 males. None of the assessors had any prior QoE knowledge nor had they any experience in multimedia quality assessments.

IV. Assesment Methodology

A. Test Protocol and Rating Scale

On arrival to the building, the assessors were brought to the waiting room where they were provided with an information sheet about the outline and procedure of the test. Any questions were addressed and assessors were required to sign a consent form. Once the consent form was signed, there were screened as according to section III.B.

A number of methodologies are available for subjective testing involving traditional multimedia components [29][30]. In terms of evaluating user perception of mulsemedia, the accepted approach to date has been to employ methodologies developed for subjective evaluation of traditional media components. With the variability of perception of olfaction and as a step to address the novelty of olfaction the degradation category rating (DCR) assessment methodology [30] was selected. In DCR (or Double Stimulus Impairment Scale method), participants are presented with two media samples. The first stimulus presented in each pair is always the reference, while the second stimulus is the stimulus under test. The reference sample was always a synchronized presentation of olfactory enhanced multimedia.

For experimental study 1 assessor's experienced one olfactory stream enhancing visual media. As mentioned and discussed in detail in [8], artificial skew sizes of 5s were simulated between the olfaction and video. Assessors were queried with respect their **detection** (statement 1) and **perception** (question 2) of skew as well as the impact of skew on user QoE (in terms of **enjoyment** (statement 3), **relevance** (statement 4) and **reality** (statement 5)). In the experimental study 2, two olfactory streams enhanced the audiovisual media. The assessors experienced the same skew levels for scent A and scent B in step sizes of 5s from -20s to +20s as per [9]. As done in the experimental study 1, assessors were queried with respect their **detection** (statement 1 & 2) and **perception** (question 3 & 4) of skew as well as the impact of skew on user QoE. The latter focused on **enjoyment** (statement 5), **relevance** (statement 6 & 7) and **reality** (statement 8 & 9)). The scales available to assessors to respond to the statements are presented in Table I.

B. Classification of Scent Types

As part of the experiments, assessors were asked to specify if they felt the scents presented were pleasant or unpleasant. The data was collected as part of the post test questionnaire i.e. assessors rated scents as pleasant or unpleasant based on the presentation of the scent along with the visual content. The results are presented in Table II. The results presented in this table were used to classify and group various scents as being pleasant or unpleasant for the results presented in Section V.

Table I: Assessor ratings scales available per statement Score	**Detection**	**Perception**	**Enjoyment / Relevance/ Reality**
5	Too Late	Imperceptible	Strongly Agree
4	Late	Perceptible, but Not Annoying	Agree
3	Neither Early or Late	Slightly Annoying	Neither Agree or Disagree
2	Early	Annoying	Disagree
1	Too Early	Very Annoying	Strongly Disagree

Table II: Assessor ratings of scents as being pleasant or unpleasant

Scent	**% that rated as pleasant**	**% that rated as unpleasant**	**Scent Classification: P=Pleasant U=Unpleasant UP= P or U**
Fruity	94.6%	5.4%	P
Flowery	81.96%	18.04%	P
Forest	75.3%	24.7%	P
Burnt	46.1%	53.9%	UP
Foul	9.3%	90.7%	U
Spicy	64.5%	35.5%	P
Resinous	67.5%	32.5%	P

V. Results and Discussion

In this section of the paper we present and discuss our findings on the self-reported measures via mean opinion score (MOS) on aggregate data from experiment 1 and 2. For all questions (on assessor sense of enjoyment, sense of relevance and sense of reality), the results are categorized firstly in terms of scent type i.e. pleasant or unpleasant (based on Table II) and secondly with respect to the human factors of age (users MOS were grouped within categories of (20-30 years), (30-40 years) and (40+ years)) and gender.

A. Results on User Sense of Enjoyment

Figures 2-5 show assessors' sense of enjoyment considering variables of scent type (pleasant/unpleasant) and the influence of age and gender for each category. In terms of Fig. 2, when an unpleasant olfactory component was presented before video, the male group reported lower levels of enjoyment from skew levels of -30s to -10s compared to the female group. The male and female groups reported similar levels of enjoyment when "almost" synchronized presentation took place i.e. skew levels of -5s to +5s. For unpleasant scent types, the male group was more sensitive in terms of their enjoyment to larger skew levels than the female group.

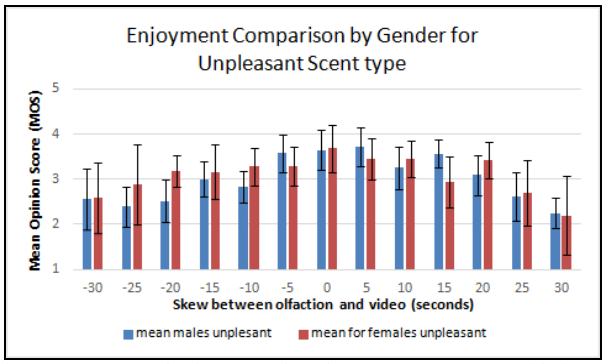

Fig. 2: User sense of enjoyment of unpleasant scent types considering gender with 95% confidence level.

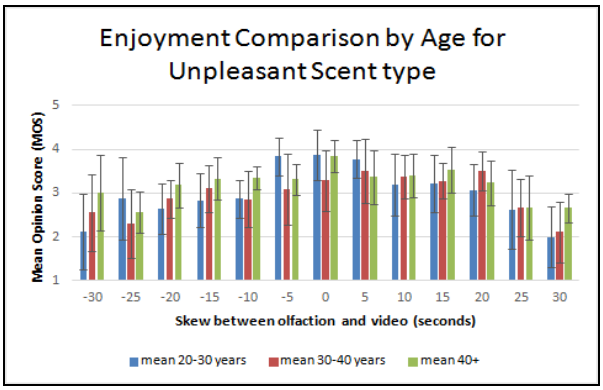

Fig. 3: User sense of enjoyment of unpleasant scent types considering age with 95% confidence level.

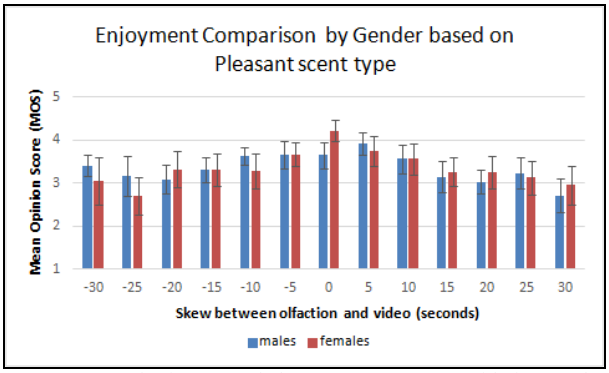

Fig. 4: User sense of enjoyment of pleasant scent types considering gender with 95% confidence level.

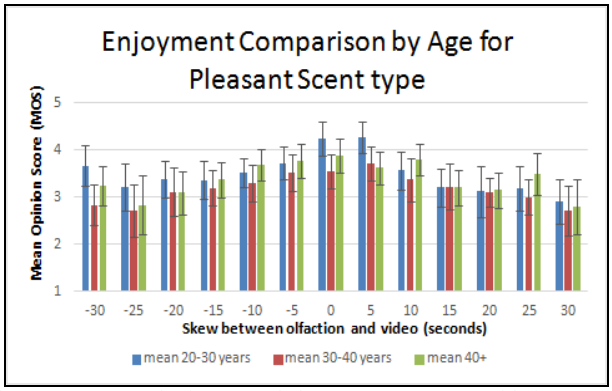

Fig. 5: User sense of enjoyment of pleasant scent types considering age with 95% confidence level.

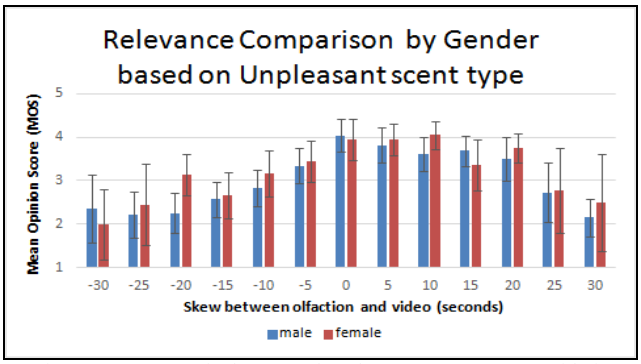

Fig. 6: User sense of relevance of unpleasant scent types considering gender with 95% confidence level.

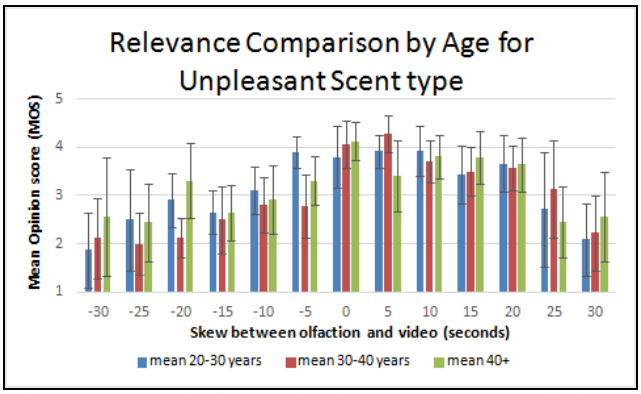

Fig. 7: User sense of relevance of unpleasant scent types considering age with 95% confidence level.

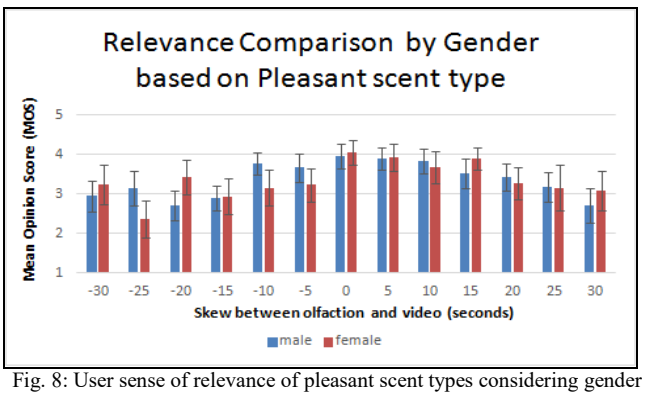

Fig. 8: User sense of relevance of pleasant scent types considering gender with 95% confidence level.

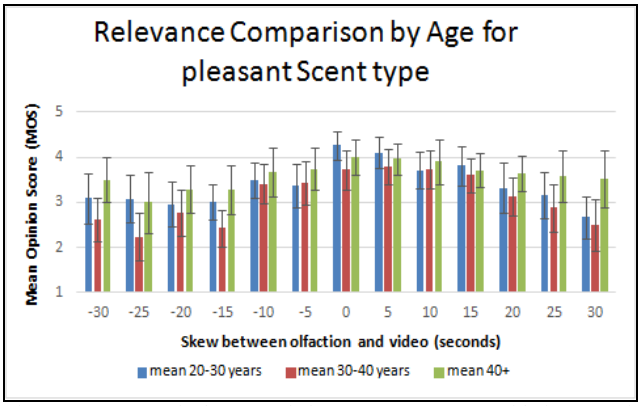

Fig. 9: User sense of relevance of pleasant scent types considering age with 95% confidence level.

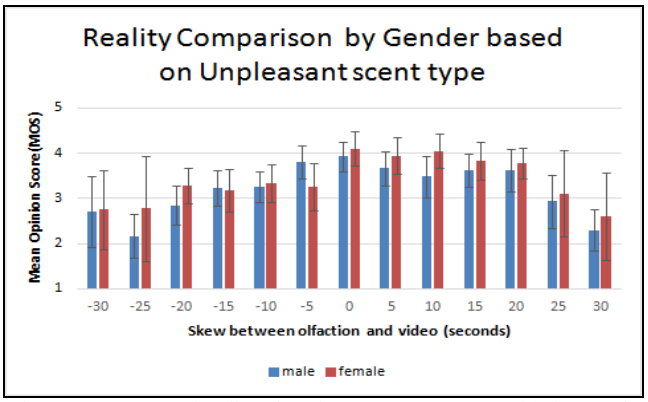

Fig. 10: User sense of reality of unpleasant scent types considering gender with 95% confidence level.

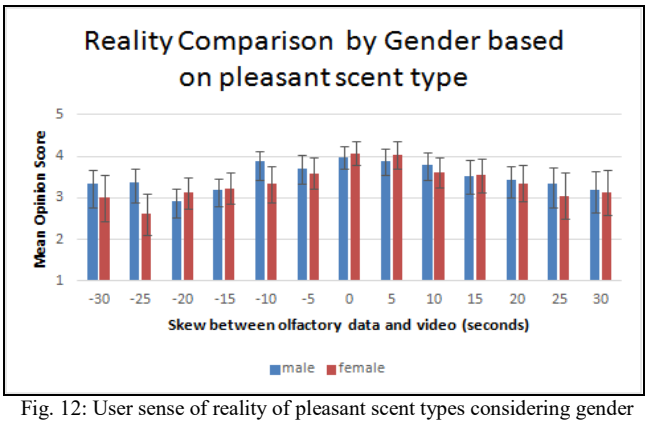

Fig. 12: User sense of reality of pleasant scent types considering gender with 95% confidence level.

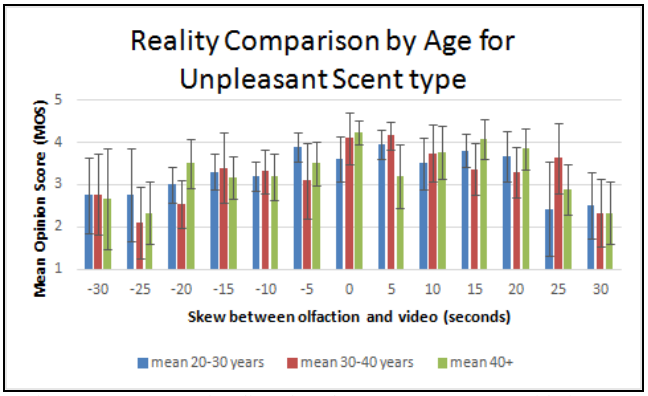

Fig. 11: User sense of reality of unpleasant scent types considering age with 95% confidence level.

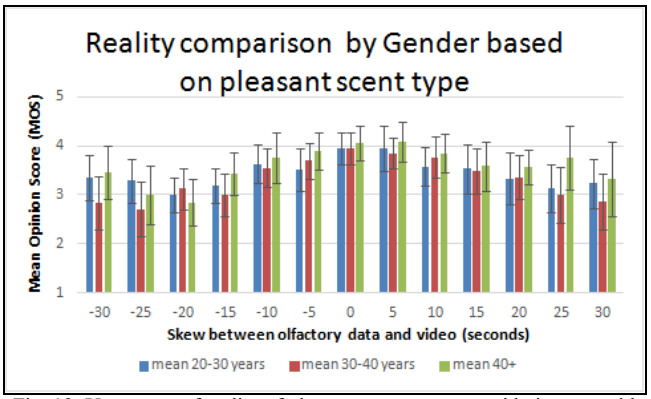

Fig. 13: User sense of reality of pleasant scent types considering age with 95% confidence level.

Fig. 3 illustrates the result analysis based on age categories for unpleasant scent types. The youngest group reported greater levels of sensitivity to skew levels when olfaction was presented before video with the older group being the least sensitive to skew across the majority of the skews. The youngest group had the highest enjoyment levels between presentations of -5s, 0s and +5s.

Fig. 4 presents the analysis based on gender for the pleasant scent types. The two groups reported similar findings across most of the skew levels with the females reporting higher levels of enjoyment when synchronized presentation took place. Comparing Fig. 2 and Fig. 4, both gender groups had greater levels of enjoyment for the pleasant scent types compared with unpleasant scent types.

Fig. 5 includes the analysis based on age categories for pleasant scent types. The youngest group generally experienced the highest level of enjoyment, particularly when olfaction was presented before video and up to skew levels of +5s. This supports the findings of [7], but it is a new finding within the context of this data set. In [8][9][22] where these variable combinations were not considered (age and pleasant scent type), generally users reported higher QoE when olfaction was presented after video.

B. Results on User Sense of Relevance

Figures 6-9 illustrate how relevant the scent was, when presented, to the video content.

Fig. 6 and Fig. 7 show a clear trend that male (in particular) and the older group assessors found the unpleasant scent presented after video more relevant than when olfaction was presented before video. This result is not as exaggerated for the unpleasant scent types as per Fig. 8 and Fig. 9 i.e. assessors were more prepared to accept a pleasant scent early then they were for unpleasant scents. It is also notable that a greater divergence in the reported measures exists based on age for both the pleasant and unpleasant scent types.

C. Results on User Sense of Reality

Figures 10-13 illustrate assessors' sense of reality considering variables of scent type (pleasant/unpleasant) and age and gender for each category. Similar to the findings for enjoyment, assessors reported higher sense of reality when olfaction was presented after video than before video. This is evident, in particular for the female group from the MOS ratings for reality of unpleasant scent types. The test participants were more willing to accept larger skew levels, and in particular olfaction before video if the olfactory component was pleasant as per Fig 12. In terms of the age variable, scent type appears to cause again greater divergence in self-reported measures when an unpleasant olfactory component is presented. Comparing Fig. 11 and Fig. 13, in the latter there is a greater consistency across the different age groups for the pleasant scent experiences.

VI. Conclusion

This paper presented the results of two subjective studies which analyzed user QoE of olfaction based mulsemedia considering diverse scent types and human factors (age and gender). These studies involved one and two olfaction stimuli enhancing multimedia content, respectively. The results highlight the significant influence of content level (scent type) and human factors on user QoE. As such, the authors propose that consideration of human factors is a key requirement for any recommender engine for olfaction based mulsedmedia. Future work will involve incorporating these factors into utility models for the definition of olfaction based mulsemedia as well as addition of additional mulsemedia components such as haptic media components to achieve our goal of a truly immersive multimedia system.

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