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# PERSONAL FACTORS AFFECTING THE AUDIO-VISUAL PERCEPTION OF THE URBAN PUBLIC SPACE

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## ABSTRACT

This paper summarises a continued analysis of a previously conducted experiment with a group of 71 normal hearing participants experiencing a virtual walk along an urban bridge over a highway by means of virtual reality technology. The pleasantness of crossing the bridge for each participant was surveyed during this virtual walk. In a companioning experiment, the participants performed an audio-visual attention test. Noise sensitivity was assessed by means of a short questionnaire. The aim of this analysis was to find out how personal factors like auditory or visual dominance, and noise sensitivity, can affect the individual perception of the urban environment. The analysis of the looking behaviour during the virtual walk was compared to the results of the attention tests and noise sensitivity. Significantly different pleasantness ratings were observed for people with different attentive abilities for a scenario with an unpleasantly rated visual and shielded traffic noise. The auditory dominated participants rated the experience more pleasant than the participants that are easily visually distracted. These two groups also showed a remarkably different looking behaviour when walking over the bridge: the auditory participants turned the head to look directly at the source and during a longer time than the ones that were visually dominated. These results showed a statistically significant difference. No statistical significance was found for other personal factors like age, gender or sensitivity to noise. As a conclusion, the analysis showed the important difference between auditory and visually dominated persons, strongly impacting their appreciation of the urban environment.

Keywords: Audio-visual interaction, Auditory-visual dominance, Virtual Reality, Road traffic noise, Urban public space.    I-INCE Classification of Subjects Number(s): 61.

## 1. INTRODUCTION

Since long there have been studies about the different responses between individuals to the same sensory stimulus. These differences in subjective responses are affected by stereotypes, fads, traditions, attitudes, norms and values (1). The consideration of personality has been an approach to understand perceptual differences (2). Personal values are demonstrated to be determinant of what the individual selects perceptually from the environment hence it is important to consider the process of selectivity in any perceptual theory (3).

The personality and values or the attentive capacity are not the only factors that can affect human perception, the interest and needs of each person can also be determining to estimate a perceived object (4). Also emotions can modulate the way we perceive our surroundings. It was found that both the loudness perception and the spatial auditory perception can be modulated by emotional significance

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(5). These findings have been applied in different fields. It has also been recently discovered in psychology that there is a high percentage of the population that is highly sensitive (an average of 15 to 20 percent). This implies amongst others, the ability to perceive stimuli with greater intensity (6). Noise sensitivity is one of the factors that can cause diverse reactions regarding the soundscape (7).

There is a large body of psychological research in the field of consumerism, where the different aspects of personality are studied because they affect the motivation to buy or use a product, as well as being convinced about an advertising message (8). These findings could be also applied in urban design to improve the quality of public space and attract people to use it, enhancing people's pleasantness and positive emotions.

The multisensorial characteristic of human perception is another factor that should be considered. This has been widely applied for commercial purposes, to improve the perceived quality of computer graphics and realistic rendering (9), and even in restaurants using the sonic environment to modify the taste of food (10). The multisensory aspect of human perception has also been studied in the perceived quality of urban public space. The auditory perception can improve when some visual cues are present (11) and similarly, sound can influence the perception of visual elements (12) (13) (14). Therefore, the audio-visual interaction in the urban environment can also be used to improve the quality of the perceived urban environment as a whole, improving visual quality to compensate a not so good sound environment and vice versa (15). From a physiological point of view, it has been shown that the integration of information from multiple senses occurs at a very early processing stage and might be directly related to the anatomical brain connectivity in humans (16). More specifically, the visual and auditory process demonstrate a very strong interaction. Giard and Peronnet found that humans are more accurate and rapid at identifying objects based on congruent auditory and visual features than with only unimodal information. They also found different perceptual characteristics between people. Therefore, people could be classified according to their audio-visual dominance, in auditory or visual dominant subjects (17).

In this paper, a continued analysis considering personal audio-visual aptitude was performed using a previously conducted experiment (15) that assessed different visual and audio designs of the same urban space by means of Virtual Reality Technology. 71 participants reporting normal hearing experienced different walks along an urban bridge over a highway with different audio-visual environments and rated their perceived pleasantness of the experience. The participants also performed an attention test afterwards to assess whether they were auditory or vision dominated. In addition, they answered a standard noise sensitivity questionnaire. These personal factors may contribute to a different perception of the urban environment. Oher personal factors like age or gender were also analysed.

Additional information is extracted from the use of the VR tool during the experiment. The visual behaviour of consumers is commonly measured to analyse different parameters like decision-making processes or attention and search. The information obtained from an eye tracking to trace a cognitive process can be generalised to natural situations (18). In this study, an eye tracking evaluation was used to assess the looking behaviour and the attentive tendencies of the participants in the VR experiment (15) by analysing the elements of the virtual urban environment they were directly looking at. The looking behaviour during the virtual walk was compared to the results of the audio-visual aptitude experiment and noise sensitivity questionnaire.

## 2. METHODOLOGY

This paper consist in a further analysis of the results from an experiment previously performed (15) taking into account the audio-visual aptitude and noise sensitivity classification of the participants as defined in Ref. (19). The aim was to find personal factors affecting the individual perception of the urban environment.

## 2.1 Personal factors

The aforementioned experiment consisted in the application of a methodology to compare the overall appreciation of different designs of an urban public space by means of Virtual Reality Technology (15). This method was applied to an urban bridge crossing a highway. Four different urban renovation designs of the bridge were proposed, considering both the visual and sonic aspects of the environment (Figure 1). Four visual designs and four sound environments were presented in different combinations resulting in 16 urban environments assuring that participants were exposed to a single sound environment each day of the 4 day experiment.

71 Participants experienced virtual walks along the bridge for each of the environments in a non-focussed context (non-informed experiment). Later, they experienced again the four visuals with their correspondent sound environment but this time they were asked to pay attention to the sound and visuals (informed experiment).

The ratings of pleasantness of the experience were grouped and analysed according to the different personal factors mentioned (visual or auditory dominance, sensitivity, age and gender) and compared to the overall ratings.

V1 - Conventional
S1 - Parapet

V2- Modern
S2 - 1.2 m barrier: LAeq reduction 7.9 dB

V3 - Vegetated
S3 - 2m barrier: LAeq reduction 11.3 dB

V4 - Whimsical
S4 - 3m barrier: LAeq reduction 12.4 dB

Figure 1 - Four visual designs of the bridge (V) and the description of their correspondent sound environment (S)

The audio-visual aptitude test was a sound-deviant detection test where 3 different videos were presented to the participants (19). One of the videos was the original recording, in a second one the sound of one of the elements on the scene was removed and in a third video the element was visually removed but the sound was still audible. The results showed that from the 75 participants, 32 of them made no mistakes in the auditory evaluation when the video was turned off and 43 of them made at least one mistake. This allowed to distinguish between participants who performed well in the blind auditory-deviant detection test (GA) and the ones that did not (BA).

From the group of 32 participants that made no auditory mistakes (GA), 18 participants never pointed at the visual-deviant and 14 made at least 1 mistake (Table 1). This subdivides the group in subjects either visually distracted (GA-VD) or not (GA-AD). This classification agrees with the study of Giard and Peronnet (17).

Table 1 – Participants classification based on auditory or visual dominance

| ***Auditory*** | **BA** *(error in auditory)* | **GA** *(no error in auditory)* | |
|---|---|---|---|
| Number of participants | 43 | 32 | |
| ***Visual*** | – | **GA-VD** *(visual dominant)* | **GA-AD** *(auditory dominant)* |
| Number of participants | | 14 | 18 |

To assess noise sensitivity Weinstein´s questionnaire was used (short Dutch variant). The details about how it was rated are described in (19). The results from the questionnaire classify the participants in 57 sensitive subjects and 12 not so sensitive. From the 75 participants 6 participants were discarded for different reasons.

Finally, a multi-factor analysis of variance was undertaken for each of the personal factors considered (audio/visual dominance, sensitivity, gender and age), first with the non-informed test (including the 16 combinations of visual and sound environment) and later with the informed assessment (including the 4 true combinations of visual and sound environment). The dependent variable was the pleasantness and the independent variables were the four sound environments (S), the four visual environments (V) and the person factors described above. Person ID is used as a random variable in the analysis.

## 2.2 Looking behaviour

The image projected on the Oculus of each participant – thus including their head movement – was recorded in a video for a later analysis of their looking behaviour. The main objective was to investigate possible additional differences between participants in the elements in the urban scene they were mainly looking at.

The virtual experience was visualized not only in the Oculus headset that provides the virtual experience to the participants, but also to a conventional screen. Participants could move their head around freely to inspect the virtual environment and the headset allowed to instantly relocate the virtual position within the virtual environment. The projection on the screen corresponded to the direction of view of the participant within the virtual experience, and therefore, to the areas and elements they were looking at during each moment.

Some reference lines were drawn on a transparent film located on the screen (Figure 2) to help to detect the elements in the urban scene attracting visual attention. The central area was considered as the area where the participant was directing the look at and the urban elements within the circle were considered most likely the focus of attention. The main perspective lines were the main references to detect the head movement with respect to the horizon line.

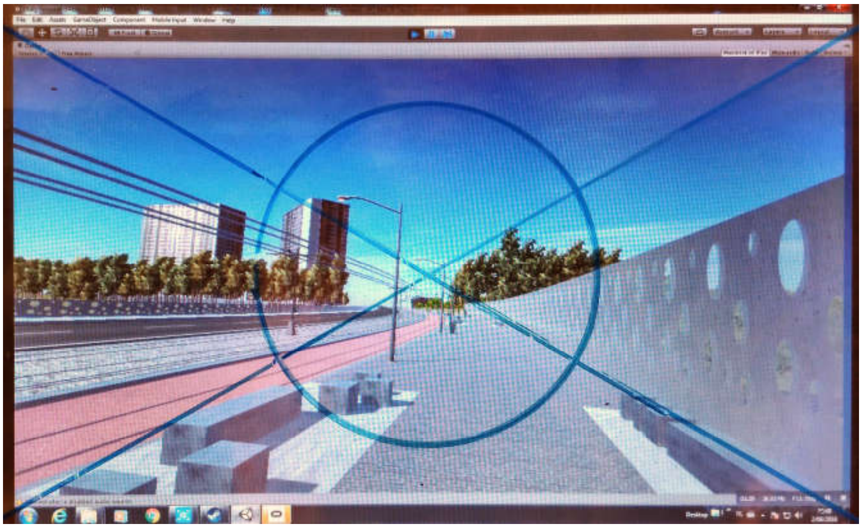

Figure 2 - Reference lines of perspective and central look for analysis of the looking behaviour of the virtual walk

The screen-recorded experiences of the participants making no auditory errors (GA) were analysed. Fom the 32 participants, 26 were succesfully recorded completely: 12 Visual dominant subjects (GA-VD) and 14 auditory dominant subjects (GA-AD).

In this paper only the looking behaviour in the Environment V4S4 under informed conditions is considered. The number of times the participants turned their heads to look at the cars driving on the highway was anotated, as well as the duration that any car on the highway would need to enter the designed circle and the intersection of the perspective lines. This procedure was executed once and the average values are shown in Table 2.

Table 2 – Looking behaviour: looking at the cars on the highway.

V4-S4 Environment. Informed condition

| | GA-VD | | GA-AD | |
|---|---|---|---|---|
| | **Duration (s)** | **Number of times** | **Duration (s)** | **Number of times** |
| **average** | 0:00:04 | 1.08 | 0:00:11 | 2.28 |
| **median** | 0:00:03 | 1 | 0:00:12 | 2 |
| **max** | 0:00:18 | 2 | 0:00:23 | 5 |
| **min** | 0:00:00 | 0 | 0:00:00 | 0 |

## 3. RESULTS AND DISCUSSION

### 3.1 Personal factors

The ratings of pleasantness for the 4 matching environments (AV, AV2, AV3 and AV4) under informed conditions are shown in (Figure 3) according to the auditory performance classification of participants: the ones that made an error (BA) and the ones that didn´t (GA). No differences are observed between both groups.

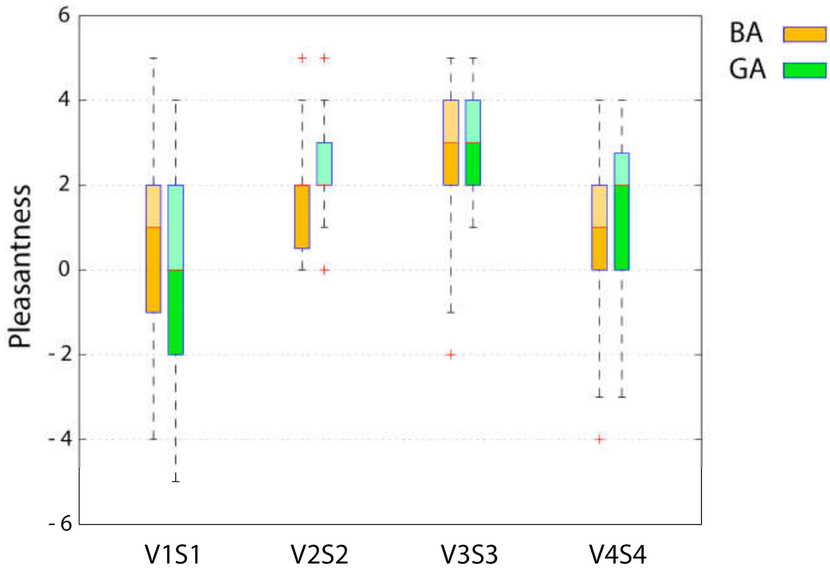


Figure 3 - Pleasantness ratings of the 4 matching virtual environments under informed conditions from participants making errors in the auditory test (BA) and the ones who didn't (GA)

Figure 4 shows the results after grouping by visual or auditory dominance. Results show similar ratings in all the environments except for the last one (V4S4), where a clear difference stands between the visually dominant subjects (GA-VD) and the auditory dominant subjects (GA-AD). The auditory dominant participants rated the experience two points more pleasant than the visually dominant participants. This difference is statistically significant. This result is consistent with the preference ratings of the environment V4S4, where the visual environment (V4) was rated the most unpleasant while the sonic environment correspondent to the quietest sound environment (S4) received the most pleasant rating.

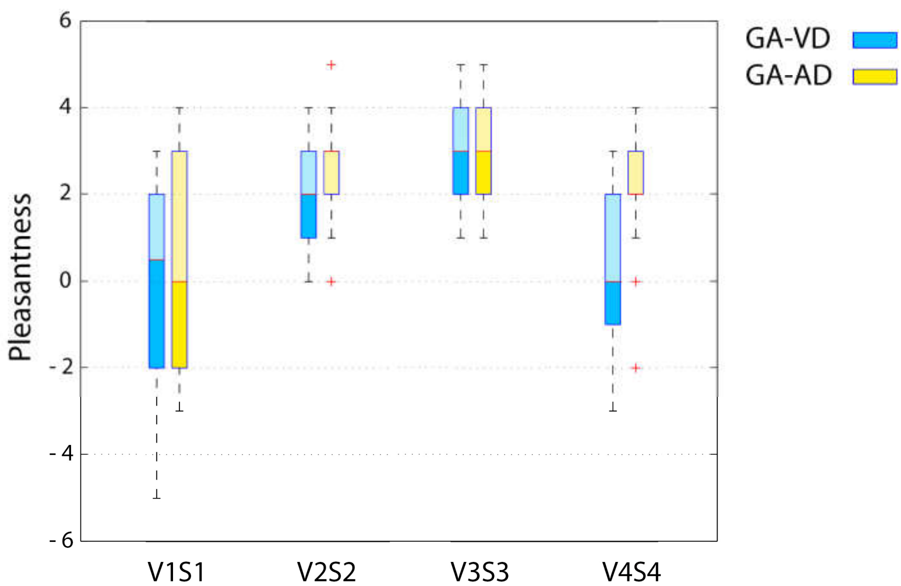


Figure 4 - Pleasantness ratings of the 4 matching virtual environments under informed conditions from participants with good auditory skills visually dominant (GA-VD) and auditory dominant (GA-AD)

Anova Analysis revealed that the personal audio-visual dominance (BA, GA-VD and GA-AD) affects the pleasantness rating of passing the bridge in a statistically significant way ($F=7.78$ $p<0.0004$). The sound and visual environment individually also have a statistically significant effect. A major influence of the visual setting was found ($F=71.93$ $p<0.00$). Sound has a smaller effect ($F=5.04$ $p<0.0018$). When considering interaction terms between this personal factor and the visuals, they are statistically significantly different from a zero interaction effect ($F=2.16$ $p<0.0445$). The people with different audio-visual dominance react differently to visuals in their pleasantness ratings. No statistical significance was found for the interaction between personal factor and sound.

Table 3 – Summary of the multi-factor analysis of Variance (ANOVA) test. The pleasantness is the dependent variable. Only the informed responses and true combinations between visual and sound are considered here. D includes the audio and visual dominance classification

| Source | Sum Sq. | d.f. | Mean Sq | F | Prob>F |
|---|---|---|---|---|---|
| **D: BA, GA-VD, GA-AD** | 53.31 | 2 | 26.654 | 7.78 | **0.0004** |
| **S: sounds S1 S2 S3 S4** | 51.81 | 3 | 17.272 | 5.04 | **0.0018** |
| **V: visuals V1,V2,V3,V4** | 739.46 | 3 | 246.488 | 71.93 | **0** |
| D*S | 20.94 | 6 | 3.49 | 1.02 | 0.4115 |
| **D*V** | 44.38 | 6 | 7.397 | 2.16 | **0.0445** |
| S*V | 15.13 | 9 | 1.681 | 0.49 | 0.8818 |
| Error | 4763.13 | 1390 | 3.427 | - | - |
| Total | 5921.84 | 1419 | - | - | - |

No statistical significance was found between either noise sensitivity, age or gender and pleasantness rating.

### 3.2 Looking behaviour

The number of times and total duration that participants with visual (GA-VD) or auditory dominance (GA-AD) looked at the cars on the highway during the virtual walk within the environment V4S4 under informed conditions is presented in boxplots in Figure 5. Results show that the number of times that auditory dominant subjects looked directly at the cars was approximately double of the visually dominant subjects. Additionally, they were watching the cars three times longer. These results indicates that auditory dominated people devote more attention to the sound source becoming more aware of the sound environment. These results agree with the different ratings of pleasantness of these two groups. For auditory dominant subjects the soundscape gains greater weight in the valuation of the overall environment increasing their self-reported pleasantness.

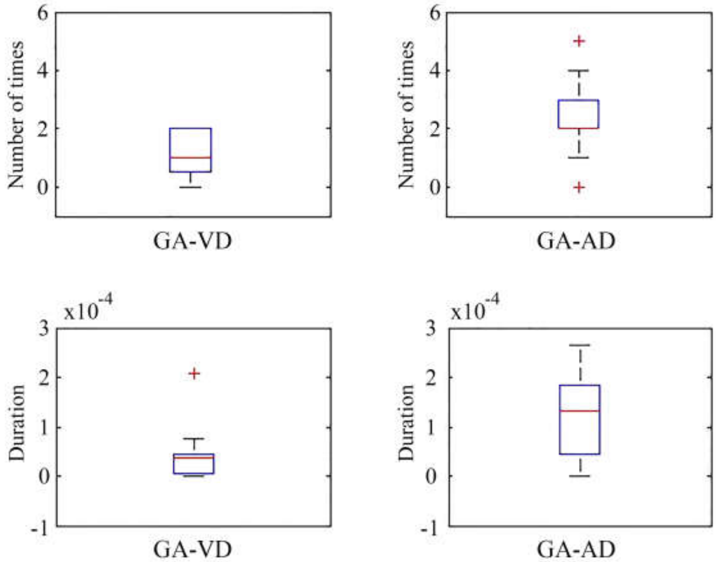


Figure 5 - Number of times and duration looking at the cars in the highway within the environment V4S4 under informed conditions by participants GA-VD and GA-AD

A general statistically significant difference between the results was found for the number of times participants looked at the cars on the highway ($F=7.06$ $p<0.0138$ in Table 4) and in the duration ($F=7.49$ $p<0.0115$ in Table 5) taking into account the Personal factor of audio-visual dominance.

Table 4 – 1-way ANOVA. Number of times looking at the cars

| Source | Sum Sq. | d.f. | Mean Sq | F | Prob>F |
|---|---|---|---|---|---|
| **Groups** | 9.3416 | 1 | 9.34158 | 7.06 | **0.0138** |
| **Error** | 31.7738 | 24 | 1.32391 | - | - |
| **Total** | 41.1154 | 25 | - | - | - |

Table 5 – 1-way ANOVA. Duration looking at the cars

| Source | Sum Sq. | d.f. | Mean Sq | F | Prob>F |
|---|---|---|---|---|---|
| **Groups** | $4.19101\ e^{-8}$ | 1 | $4.19101\ e^{-8}$ | 7.49 | **0.0115** |
| **Error** | $1.34366\ e^{-7}$ | 24 | $5.59858\ e^{-9}$ | - | - |
| **Total** | $1.76276\ e^{-7}$ | 25 | - | - | - |

## 4. CONCLUSIONS

A second analysis of the experiment of (15) is made with the objective to find personal factors affecting the perception of the urban environment. 71 participants experienced several virtual walks in different audio-visual urban designs of a bridge passing over a highway by means of Virtual Reality Technology. The pleasantness of crossing the bridge virtually is analysed as a function of personal factors.

Through an audio-visual aptitude test, participants could be classified in subjects that made errors in the auditory test (BA), and subjects that performed the auditory test correctly (GA). Within the last group with good auditory skills, a subgroup that made errors when visually distracted (GA-VD) and those that made no errors (GA-AD) was formed. Although the ability to analyse the complex auditory scene and auditory memory could contribute to the experience, we believe that the main factor that is observed here is auditory or visual dominance.

Important differences between the last two groups of participants (GA-VD and GA-AD) were found in the appreciation of the environment V4S4, where the visual V4 was rated as the most unpleasant and the sonic environment S4 was rated as the most pleasant. The auditory dominant participants rated the experience more pleasant than the visually dominant participants, showing consistency with the personal factor of audio-visual dominance. This difference valuation, showed statistically significant results in the multi-factor Analysis of Variance.

This difference was found only under informed conditions meaning that participants were asked to explicitly pay attention to visuals and sounds during their virtual walk. No difference was found for the non-informed part of the experiment. This implies that when people are not observant to sound or visuals they perceive the environment rather similarly, but when they are attentive to sounds and visuals, their pleasantness ratings vary according to their personal dominance to sound or visuals.

The looking behaviour revealed statistically significant differences between visual and auditory dominated subjects. The auditory dominant persons showed a remarkably different looking behaviour than the visually dominant subjects while walking over the bridge: they looked longer and more frequently at the cars on the highway. This shows that auditory people give more visual attention to the sound source becoming more aware about the sound environment than the visual dominant subjects and increasing the importance of soundscape in the assessment of the overall environment.

Noise sensitivity, age and gender did not affect the pleasantness ratings of the participants.

As a final conclusion, the attentive dominance to sound or visual elements strongly impacts the appreciation of the urban environment. This explains why personal factors make urban environments pleasant or not. The personal differences between people should be further understood to include them in urban design.

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