1:1 Scale Perception in Virtual and Augmented Reality

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Abstract

In this experiment, carried out at Renault, we studied size perception in virtual environments. Renault uses Virtual and Augmented Reality (VR and AR) technologies in the vehicle design process to visualize digital prototypes. Such simulations enable to take early decisions, in particular for vehicle architecture, which imply driver visibility performances and safety. We compared 1:1 scale perception of a cockpit through two different virtual reality systems: a Head Mounted Display (HMD), which can be used as virtual or augmented reality system, and a cylindrical screen vs. the physical 1:1 scale. We used HMD under three conditions. The first condition was basic virtual reality with head tracking. The second condition was identical, except for head-tracking which was turned off. Although this condition is not used in engineering simulations, we chose to study it in order to determine if head-tracking has an influence on size perception. As the HMD can be used as video see through augmented reality system (using video cameras), the third condition was augmented reality, to determine how body perception influences size perception. We used an adjustment task, to determine at which scale the cockpit must be displayed to subjects, to perceptually correspond to the 1:1 scale, i.e. the actual physical size. We show that differences exist between size perception using the HMD, and using the cylindrical screen. Underestimations seem to be more frequent when using cylindrical screen. Moreover, the level of knowledge of the vehicle and the virtual reality system also seems to influence subject's size perception.

1. Introduction

In order to assist decision processes during vehicle design, Renault has chosen to use virtual prototypes visualizations. These virtual assessments contribute to shorten decision loops concerning vehicle architecture, and to reduce the making of physical prototypes. But during these evaluations, observers do not always seem to be at ease with perception of dimensions, often judged off sized. Thus the question is: do observers in virtual environments perceive the 1:1 scale as they would in a physical prototype?
We address in this paper a method, which allows us to evaluate size perception in virtual environment to vehicle design. Virtual prototype of which we had evaluated this perception was displayed by a HMD or by a cylindrical screen. We compare 1:1 scale perception in these two devices in reference to physical 1:1 scale of the vehicle.

1.1. Previous and Related work

Size perception is an important issue for designers who have to evaluate a numerical mock-up by using virtual technologies. Consequently, it is a fundamental question to evaluate size perception when these kinds of technologies are employed. In a previous study, Kenyon *et al*. [8] explored approximately the same question as we asked, but they used a different virtual reality device. They worked with a CAVE - Cave Automatic Virtual Environment (i.e. a cubic room where images are rear projected on the walls; in this case it was a 4-sided Cave: 3 walls plus floor). They tested size perception of a virtual bottle in rich and sparse environments. They observed that size adjustments were closer to 1:1 scale when the object is presented in rich environment. In our experiment, we worked with two others types of virtual reality systems: a head-mounted display

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and a cylindrical screen. The virtual environment used is "richer" than that used in Kenyon *et al*. experiment, because it shows a road in a little town, with pavements, buildings, trees, pedestrians, etc.. According to Kenyon *et al*. results, size adjustments should be improved by the presence of this rich environment.

In a virtual environment, motion parallax is available in particular when the observer's head is tracked, by the way of a head-tracking system. Motion parallax corresponds to the range of objects' displacements while observer or environment is moving. This range depends on the distance between observer and objects. Luo *et al*. [9] carried out an experiment in which they tested the effect of motion parallax, on size perception in virtual environments, among other visual factors. They observed that motion parallax seems not to be a factor, which significantly influences size judgments. Therefore, is head-tracking necessary in our virtual reality system to evaluate the dimensions of virtual objects? Nevertheless Gogel and Tietz [6]showed that perceived motion concomitant with lateral head motion provide information permitting a recalibration of perceived distance. They suggested that motion parallax enables this recalibration and consequently a better understanding of egocentric distance. Paille *et al*. [11], also showed that in dynamic condition (i.e. with head-tracking) distance perception was improved. This better distance perception should improve size perception regarding to the size/distance invariance hypothesis. It is a hypothesis which proposes an invariant relation between perceived size and distance. Perceived size is supposed to be determined by the interaction of angular size and perceived distance such as tan(a)=S/D (where S is the perceived size, D the perceived distance, and a the visual angle subtended by the object at the eye's point; tan(a) is used to simplify this expression actually it is twice tangent of the half angle) (See Epstein *et al*. [5] for more details). According to this hypothesis, unfamiliar object's size can be determined accurately only when object's distance cues are available.

A study conducted by Rock and Harris [12] showed that body perception (i.e. visualization of the user's own body) could influence the user's size judgments if his body is visible during the size evaluation of an object. In their experiment, they accustomed subjects to perceive their body smaller than real with a reducing lens, and they observed that following size judgments are influenced by this body size adaptation.

1.2. Present Experiment

In order to study separately both previously described factors, we tested on the one hand the head-tracking influence on size perception (motion parallax influence), and, on the other hand the body perception influence on size perception of a virtual vehicle cockpit.

We measured by an adjustment method, the perceived 1:1 scale, in two different virtual reality systems: a HMD and a hemi cylindrical screen, and we compared it to the physical 1:1 scale. Using video cameras, the HMD can also be used as an augmented reality device, which allowed us to test body perception influence on 1:1 scale perception. In order to study the influence of head-tracking on size perception, we also tested the HMD without head tracking. Lastly, in order to determine the influence the display, we carried out tests on a cylindrical screen.

Our main hypothesis is that a difference exists between perceived 1:1 scale in virtual environment and real 1:1 scale. We suppose the more sensorial information there is, the easier it is to recognize the 1:1 scale. This implies two hypotheses to address:

- systems with head-tracking should involve better results than those with no head-tracking,
- in systems which allow body perception, results should also be better than those where body perception is not available.

Moreover, we suppose that, with the cylindrical screen, this difference will be overestimated. Indeed, the first sensation with this system is that displayed cockpits are too large, consequently we suppose that subjects will want to decrease the displayed cockpit size.

Figure 1. Seos 120x40 HMD

2. Method

We tested four conditions. Two actually take part in the vehicles' design process. The first one simply used virtual reality. In this condition subjects could actively explore the virtual cockpit. In particular, they had at their disposal two important visual distance cues: binocular disparity and motion parallax. The former was present because it was a stereoscopic system and the second because there was a head-tracking system. We named this condition VR-HT

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condition (Virtual Reality Head-Tracking).
The second condition which is used in vehicles design process was the augmented reality condition. In this case, in addition to binocular disparity and motion parallax, body perception was available. Body size information could be used as a relative size cue. We named this condition AR condition (Augmented Reality).
We tested two other conditions which are not used in vehicle design process. One condition used the HMD, but without head-tracking. Thus subjects could not actively explore their environment. They had to do without motion parallax, but binocular disparity was still present. We chose to test this condition in order to determine if head-tracking (motion parallax) influences size perception in virtual environments. We named this condition VR-NoHT condition (VR-NoHT stands for Virtual Reality No Head-Tracking).
The last condition we tested was the cylindrical screen because this system could be an alternative solution to the HMD. With the screen the visualization was stereoscopic, subjects were wearing active stereoscopy glasses. However they were not equipped with a head-tracking system. Consequently subjects could not use motion parallax, but as in VR-NoHT condition they could use binocular disparity. In fact with this system, subjects' body was visible, but it was not merged in the virtual environment as in the AR condition. We named this condition: Screen condition.

2.1. Participants

We distinguished four types of subjects according to their level of expertise with regard to the vehicle tested and related to the virtual reality systems used.
In the first, second and third groups, there were two participants per group. In the fourth one, there were three participants who actually were the three experimenters. We finally had 9 volunteers, including 8 males, all Renault employees. Their acuities have been tested before the tests, all had a normal vision.
The first group was composed of SCENIC II[1] usual drivers. We considered them "vehicle experts". Nevertheless they had never used any virtual reality nor augmented reality systems before, so they were considered "system non-experts".
In the second group, subjects were not SCENIC II drivers, nor especially familiar with virtual or augmented reality systems. They were "vehicle non-experts" and "system non-experts".
In the third group, subjects were not SCENIC II drivers but before each experimental session, they drove a SCENIC II during about 10 minutes. So they became "vehicle pre-exposed", and because they were not familiar with virtual reality systems, they were "system non-experts".
The fourth group was composed, like the third one, of "vehicle pre-exposed" subjects. They did not actually drive the vehicle, they just seated in the vehicle for about 10 minutes before each experimental session. With regard to the system, they were considered as "experts", because they were familiar with these virtual and augmented reality systems.

[1]SCENIC II is a vehicle of Renault's range.

2.2. Apparatus

2.2.1 HMD VR

Mused the head mounted display SEOS HMD 120/40 (Figure 1) (www.seos.com). Its field of view is 120 horizontally with a central overlap of 40and 67 vertically. It has two optics (one for right eye and other for left eye). Each of both optic has a field of view of 80X67, and it's resolution of 1280X1024 pixels. A dioptric correction of 4 dioptries is possible. The image generator was driving simulation software SCANeR II (one PC per optic). In order to track observers' head movements, the HMD was equipped with an infrared optical tracking system. Two infrared cameras flashed to illuminate the tracking targets, and the software Dtrack (A.R.T., www.ar-tracking.eu) calculated the 6 degrees of freedom targets position and orientation. We used a dedicated PC for this head-tracking system. For the condition without head-tracking, we only turned off the head-tracking system.

2.2.2 HMD AR

The SEOS HMD can be adapted for augmented reality use. Two cameras are fixed on the HMD, providing an indirect vision (video see through) augmented reality system. The cameras' resolution is 768X582 pixels. The video images are merged to the virtual environment by chroma key technique (software D'Fusion, Total Immersion, www.t-immersion.com).

Figure 2. Experimental Device

Figure 3. Cylindrical Screen

2.2.3 Cylindrical screen

We used a 3m radius cylindrical screen. Three projectors (Barco Galaxy 1280X1024, www.barco.com) display the virtual environment, and we used active stereoscopy to provide observers with stereoscopic visualization. With this display system there is only one position of the observer for which the projection is correct. Therefore, the observer position was set 3m far from the screen center and 1.20m high (actually the eye's height depends on the participant's size, approximately 1.20m). The global display's field of view is 210X50. This system is not equipped with a head-tracking system.

2.2.4 Experimental device

HMD sessions, the seat was positioned in front of a green material (for chromatic acquisition, see Figure 2). Thus in augmented reality, the observer could only see his own body and the virtual environment. For the screen sessions, the seat was positioned in front of the screen so that the observer's eyes were 3m far from the screen and 1.20m high (Figure 3).

2.2.5 Plug-in

To allow subjects to interactively adjust the size of the virtual cockpit, we imagined a new functionality in SCANeR© II (SCANeR© II: driving simulation software developed by Renault, Technical Center of Simulation). The plug-in was developed by Oktal, company which is SCANeR© II co-owner with Renault. This plug-in allows applying a 3D proportional transformation to the cockpit (only without modify the outside environment), choosing the center of transformation and the increment step. Because we wanted to minimize the distance variation between the observer and the cockpit, we chose the center of the steering wheel as center of transformation. Therefore when subjects adjusted the cockpit size, it was the angular size of the cockpit which varied. For the increment step, we choose 0.005, i.e. 0.5% of the physical size of the cockpit (physical 1:1 scale).

2.2.6 Virtual Environment

In this experiment, we only used a SCENIC II virtual cockpit, represented with a high level of details. This cockpit was positioned in a static road situation in Guyancourt village (FRANCE, 78) (Figure 4). The virtual eyes of the observer were positioned in the virtual cockpit, in the same position as in the real cockpit. Thus, before experimental sessions we had measured the eye's position of all subjects in driving position.
The virtual cockpit in 1:1 scale has been created on the basis of the SCENIC II CATIA model developped by Renault.

2.3. Procedure

Volunteers participated in the 4 experimental sessions. All sessions had equivalent procedures. Subjects were seated in a vehicle seat in front of the screen or wearing the HMD. The experimental task was explained or recalled if it was not the first session. In the case of sessions with the HMD, subjects performed adjustments of the optics and interpupillary distance, visualizing a vehicle cockpit, but not a SCENIC II cockpit.
The task consisted in adjusting the size of a SCENIC II cockpit, in which the observer was immersed. The progress of the experiment was entirely automated. The cockpit was displayed during 25 seconds, available time lapse for each adjustment. Then a black screen was shown for 2 seconds, and new cockpit was displayed for a new adjustment. The task was explained in these words:
"You'll be immersed in a SCENIC II cockpit. The cockpit scale will not be necessary correct, i.e. correspond to the physical size. The goal of the exercise is to adjust the cockpit size until you reckon it corresponds to the physical size. You have to say us "more" if you want to increase, and "less" if you want to decrease the size. You have 25 seconds to perform this task, and five seconds before the end, you will hear a beep announcing the close end. Then a new cockpit will appear and you will have to perform exactly the same task."
Subjects started with a training session, composed of three cockpits. The first was at 1:1 scale, but it was not announced to subjects. The scale of the second was 1:0.98 (i.e. 98% of the physical size). The third cockpit was displayed at 1:1.02. If subjects did not feel at ease with the task they could have a second training session (the same as the first).
The experimental session was composed of three blocks. Each block contained five cockpits. There was a short break between two blocks, where in the HMD conditions, subjects took off the HMD. Initial sizes at which cockpits were dis-

Figure 4. Virtual cockpit - Size variation. Center: 1:1 scale, Left: scale lower than 1, Right: scale higher than 1

Conditions	Body Perception	Head-tracking
Screen	Yes	No
AR	Yes	Yes
VR-HT	No	Yes
VR-NoHT	No	No

Table 1. Experimental Conditions

Conditions	Means adjusted sizes	Std-Er
Screen	1.055	0.013
AR	0.96	0.035
VR-HT	0.98	0.029
VR-NoHT	1.02	0.024

Table 2. Means adjusted sizes & Standard Error

played were 0.9, 0.95, 1, 1.05, and 1.1. In each block, the five initial sizes were used. For one subject, in each session, the order of initial sizes was different. Moreover, when it was possible, initial sizes orders were different from subject to subject.
This experiment was composed of four conditions, one using the cylindrical screen and three using the HMD. For the screen condition it was in virtual reality even if subjects could see their own body. For HMD conditions, both of them were in virtual reality, one of which was without head-tracking. The last HMD condition was in augmented reality (Table 1).

3. Results

Virtual cockpit is displayed with an initial size. Subjects varied the cockpit's size (by saying "more" or "less") until they reckoned it was at 1:1 scale. We call this final size "adjusted size". An adjusted size higher than 1 means an underestimation of the cockpit size, because the subject needs to see a larger cockpit than the physical size to perceive it as the 1:1 scale. Thus the real 1:1 scale is underestimated. On the contrary, an adjusted size lower than 1 shows an overestimation of size. In this case, the subject needs to see a smaller cockpit than the physical size to perceive it as the 1:1 scale. The real 1:1 scale is overestimated.

3.1. Means observations

The condition which led to the largest adjusted sizes is the Screen condition. The mean adjusted size for all subjects is 1.055 (standard error 0.013). This means that in average, subjects underestimated the 1:1 scale by 5.5% (with regard to the physical size, see Figure 5 for the graph, Table 2 presents mean values of adjusted size, over all subjects).
The second condition which generated underestimations is VR-NoHT. In this case, we observed a mean adjusted size of 1.02 (standard error 0.024). This value corresponds to an underestimation of 1:1 scale by 2%.
On the other hand, we observed overestimations for AR and VR-HT condition. For the latter, the mean adjusted size is 0.98 (standard error 0.029), which corresponds to an overestimation of 1:1 scale by 2%. For the former, the mean adjusted size is 0.96 with a standard error of 0.035. This value represents an overestimation by 4%.

3.2. Statistical study

We performed statistical tests over all subjects. These tests reveal that the difference between the mean adjusted size in Screen condition and the reference value 1 is significant (test T, p value < 0.05). This reference value of 1 corresponds to the ideal adjustment, i.e. the physical size. Screen condition involved a mean adjusted size 5.5% underestimated. There is a second significant difference: the difference between the mean adjusted size in Screen condition and in AR condition (test T, p value < 0.05). In both conditions, body's observer was visible. But in spite of this common characteristic, there is no head-tracking in Screen condition, whereas there is in AR condition. This difference seems to have a great impact on size perception, because, in average, Screen condition involved size underestimations when AR condition involved size

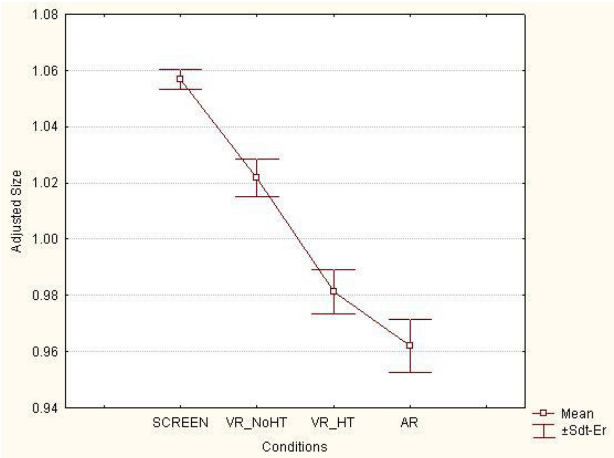

Figure 5. Mean adjusted sizes per conditions

overestimations.
A one way variance analysis carried out to all subjects, reveals a significant effect of condition of visualization on adjusted size (F (3.516) = 34.7, $p < 0.001$). We performed the same analysis for each subject and the result shows the same significant effect of condition of visualization (p value < 0.01).
As a conclusion, we observed that the vehicle's cockpit size is perceived differently according to the type of system used. We used the Mann Whitney U test to compare estimations of each subject to the reference value 1. All following means are individual means. All significant differences presented below have a p value of 0.05 (Table 3).
In Screen condition, the mean adjusted size is higher than 1, for every subject except one. For this latter, the mean adjusted size is not significantly different from 1. This means that for the majority of our subjects the 1:1 scale has been perceived too small. They underestimated the cockpit size.
In the case of the VR-HT condition, for 6 subjects out of 8 (one subject could not pass VR-HT condition), the mean adjusted size is significantly different from 1. For half of them, the mean adjusted size is higher than 1. For the other half, the mean adjusted size is lower than 1, thus these subjects overestimated the cockpit size.

In AR condition, for 6 subjects (out of 9) the mean adjusted size is significantly different from 1. For 4 of them, this mean is lower than 1. Majority of the 9 subjects performed size overestimation when body perception was available.
It is in VR-NoHT condition that we observed the greater amount of means adjusted size non-significantly different from 1. Among the 4 subjects which presented results significantly different from 1 , we observed mean adjusted size higher than 1 for 3 of them. It is the only condition in which the majority of our subjects presented results non-significantly different from 1.

4. Discussion

In this exploratory experiment, we compare 4 experimental conditions, which allows us to explore 4 possible sources of influence on size perception. The first possible source we approach is the influence of the type of display (i.e. HMD Vs Cylindrical screen). Secondly, we examine how the presence or absence of head-tracking influences cockpit's size perception. Then body perception's influence on size perception in our experiment is discussed. Finally, we expose what we observed about the influence of participants' vehicle or system competence.

4.1. HMD or Screen ?

Considering the fact that Screen condition is without head-tracking, we have to compare it to VR-NoHT condition. We observe that for the majority of our subjects (7 out of 9), mean adjusted sizes in Screen condition are higher than those in VR-NoHT condition. And for 5 of them, it is in VR-NoHT condition that the adjustments were nearest to 1 while Screen condition was significantly different from 1. Thus sizes appear to be more underestimated when the cockpit is visualized with the cylindrical screen than with the HMD. With this latter, estimations seems to be closer to 1.
The HMD seems more adapted to assess dimensions of near objects in virtual reality than the cylindrical screen. To confirm this observation, we could carry out another test in which we would mask the real environment (with no change on the field of view) in the Screen condition. Indeed in this condition a part of the real environment remained visible, which is not the case in the HMD condition. Moreover the head movement while there is no head-tracking could have an impact on size perception. Thus, to be exactly in the same condition with Screen as in the VR-NoHT condition, we would have to fix the subject head in a chin rest in addition to masking the real environment.
Like most of 3D displays, the cylindrical screen and the HMD we used, create a conflict between accommodation (focus) and vergence cues. When using the screen, subjects accommodated on the screen plane, which is at a fixed 3m distance from the subject's eye during the whole experiment, whereas vergence cues varied with the depth of the fixated object of the virtual scene. In the present study, the object of interest is the virtual cockpit, which was displayed to appear around 1m. We can consider that usually subjects'vergence is at this distance. Similarly in the HMD, vergence distance is variable, but focus distance is fixed at

Conditions	Underestimation	1:1 scale	Overestimation	n=
VR-NoHT	3	5	1	9
AR	2	3	4	9
VR-HT	3	2	3	8
Screen	8	1	0	9

Table 3. Distribution of subjects' means adjusted size

the optical infinite (i.e. beyond 5-6m). The same conflict between focus and vergence cues exists in both systems, but with different parameters. Using the novel 3D display they have developped, Hoffman *et al*. [7] explored the impact of this conflict. Their 3D display has three different focal distances, and consequently focus cues are correct or nearly correct with the virtual scene. They observed that the conflict between accommodation and vergence increase the time required to fuse a stereoscopic stimulus and to interpret it. Moreover, they confirmed results of Watt *et al*. [13] that focus cues influence depth constancy and contribute to estimate 3D scene.
What is the impact of the accommodation-vergence conflict on size perception in our systems ? And to what extent the difference between the conflict in the cylindrical screen and the conflict in the HMD influence size perception ? To answer these questions, further experiments in which this conflict is isolated, are required.

4.2. Head-tracking Influence

We designed the VR-NoHT condition to compare it to the VR-HT condition, in order to investigate the influence of head-tracking. We observe that the difference of the mean adjusted size between VR-NoHT and VR-HT condition is positive for 6 of 8 subjects (one subject could not participate the VR-HT session). We observe more overestimation with head-tracking than without. In addition, 5 of these 6 subjects gave estimations closer to 1 in VR-NoHT condition than in VR-HT condition. It seems that, for the majority of our subjects, the perceived 1:1 scale has been closer to physical size with no head-tracking than with head-tracking. It can be noted that the VR-NoHT condition is the condition for which there was the less mean adjusted sizes significantly different from 1. This result signifies that it is in the VR-NoHT condition that our subjects have recognized the more easily the 1:1 scale.
Why adding head-tracking, results have not been improved ? Perhaps it is due to the fact that head-tracking implies latency (time delay). Latency is the time between a head movement and its visual consequences in the virtual environment. An experiment conducted by Allison *et al*. [1] show that tolerance of temporal delay in a virtual environment depends on the head movement velocity. For rapid movements (90°/s), subjects report a world instability after 60ms of delay. When the movement is slower (22.5°/s) instability is detected after a 200ms delay. These values represent the point of subjective equality (PSE) of subjects. Another study showed that subjects are sensitive to delays as small as 10ms (Ellis *et al*. [4]). In this study, Ellis *et al*. performed JND measure, i.e. just noticeable difference. Their PSE was equal to 30ms. Could our delay system disturb size perception considering that there is a theoretical delay of 33ms?
Considering a study concerning hand afterimages[2] conducted by Mon-Williams *et al*. [10], we can think that latency could have an effect on size perception. In this study, they suggested that in virtual reality systems, illusory size changes may occur when hand image is not correctly updated relatively to hand position during an observer's movement. Indeed hand afterimages seem to change size while the hand, which is unseen, moved. This illusion has already been observed by Carey and Allan [2]. The interpretation suggested by Mon-Williams *et al*. concerning virtual situation implies a commonly encountered problem in virtual reality systems: latency. This time lag generated by images treatment and head-tracking system, can induce spatial discrepancy between hand image and hand position.
We observed in this experiment that better results are obtained without head-tracking than with head-tracking. This observation, even if we have been surprised to not observe judgments improvement with head-tracking, is consistent with the Luo *et al*. [9] in which they recorded that motion parallax might not be a significant factor in determining size judgments.
Nevertheless in studies such as Paille *et al*. [11] and Creem-Regehr *et al*. [3], distance estimation seemed to be improved when head movements were permitted (by decreasing underestimations). Consequently head movements might, according to these studies and to the SDIH, improved size perception. This is not what we observed in this experiment.
These observations suggest that distance and size estimations may correspond to different evaluation processes.

[2] An afterimage is an image that persists after the stimulus is disappeared. It is possible to create an afterimage in the darkness by dazzling the subject with a short bright flash of light, for objects between the flash and the subject's eyes an image will persist on the retina.

4.3. Body Perception Influence

To estimate body perception's influence on size perception we can compare AR condition to VR-HT condition. For 5 subjects (among 8) the difference (of mean adjusted sizes) between AR and VR-HT condition is positive. That means that sizes have been perceived smaller with body size information than without this information for the majority of our subjects. If we consider the general mean over all subjects we do not observe this positive difference, because one subject presents an important inversion (he gave very large size overestimations in AR condition). AR condition does not really improve 1:1 scale perception. Actually there were as many subjects that presented mean adjusted sizes significantly different from 1 in AR condition as in VR-HT condition.
In order to reach a better understanding of body perception's influence on size perception, we could suggest complementary experiments. Why does presence of body size information not improve size estimations? Is the video scale coherent with the vehicle 1:1 scale? To answer this latter question we could vary the video scale and measure with which video scale, subjects correctly reckon vehicle's 1:1 scale. If the video scale is not equal to 1, video treatment might imply scale modification which influences size perception. Then it could be considered, according to our results, to modify video scale to improve judgments done in augmented reality. If we do not observe any influence of video scale variations on 1:1 scale perception, we might conclude that body perception has no influence on size perception. But this result would be contrary to previous studies, such as the Rock and Harris [12] one. In their study, they observed that if a subject is adapted to see his body smaller as real (with a reducing lens), his size estimations given while perceiving his body will be influenced. Nevertheless, at present time with our system we cannot carry out such an experiment in an entirely automated way as is the present experiment.

4.4. Participant Type influence

We have identified 4 subjects' groups according to their level of competence with regards to the vehicle tested and to the virtual reality system used.
"Vehicle non-expert, system non-expert" group presents the most dispersed results, while pre-exposed groups, i.e. "vehicle pre-exposed, system non-expert" and "vehicle pre-exposed, system expert" subjects, present more constant results over conditions, and results closer to 1. Therefore pre-immersion in the assessed vehicle, or a vehicle of the same size if the assessed vehicle does not physically exist, seems to improve size estimations. Indeed pre-immersion seems to be necessary even if subjects are "vehicle expert", as "vehicle expert" results are more distant to 1 than "vehicle pre-exposed" results.
System competence seems to improve size estimations, decreasing results dispersion over conditions. Indeed fourth group results, i.e. "vehicle pre-exposed, system expert", are more constant than those of "vehicle pre-exposed, system non-expert".
In Screen condition, the size is always underestimated whatever the vehicle or system competences are.

5. Conclusion

In this paper, we have presented a method to assess the impact of virtual and augmented reality technologies on visual perception and more particularly on size perception. These experimental conditions help us to estimate factors that influence the 1:1 scale perception in virtual environment.
Considering our results we notice that our principal hypothesis is verified in our conditions of experimentation: there is a difference between perceived 1:1 scale in virtual environments and real 1:1 scale. Moreover this difference is not the same according to the system used to display the virtual prototype. However two of our three hypotheses are not confirmed. Indeed we do not observe overestimations in the Screen condition but underestimations. In this condition, we observed an underestimation of 5.5% (with regard to the physical size), which is an important size perception distortion for an industrial use.
Body perception does not seem to improve size estimations in our virtual and augmented reality systems. There might be a discrepancy between video scale (i.e. body scale) and numeric scale which would have an influence on vehicle 1:1 scale perception.
The experimentations presented in this article are slightly unusual as the experimentations found in the literature. Most of these experiences are related to evaluate size perception of an external object (i.e. object in front of the subject). In our case, the observer is in the assessed object (i.e. the subject is immersed in the object). Perhaps these both situations are based on different judgment processes?
A first step has been done for the estimation of visual perception (and size perception) via virtual and augmented reality technologies for the automotive numerical process and above all at a very early stage of design. This experiment highlights the contribution of the Virtual Reality technology to design and assess vision in our future cockpits.

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