Factors affecting the sense of scale in immersive, realistic Virtual Reality space

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Abstract. In this study, we analyze and identify a proper scale value when presenting real world space and everyday objects in immerse VR. We verify the impact of usage of reference points in the form of common objects known to the user such as windows, doors and furniture in the sense of scale in VR. We also analyze user behavior (position, rotation, movement, area of interest and such) in the scale setting task. Finally, we propose optimal scale values for single objects presentation, architectural space with many points of references and a large scale space with less to no points of reference. The experiments were conducted on two groups: the Experts (architects) and Non-experts (common users) to verify the translation of real-world object size analysis skills into the same capacity in the virtual world. Confirmation of the significance of the pre-immersion in VR for a sense of scale accuracy is also described.

Keywords: sense of scale · Virtual Reality · sense of scale factors

1 Introduction

In recent years, Virtual Reality (VR) has been popularized mainly thanks to the computer games market, but more and more industry companies see the potential in this technology. It opens up huge opportunities for the architecture, allowing exploring the space of the building long before it is built. Still, there are many negative factors including disorientation or dizziness, which prevent correct reception in the virtual world [9]. For VR architecture-related applications, one of the main problems now is the distorted aspect ratio and scale. Allowing the user to fully adapt to a world in which a sense of depth, scale and spatial awareness is mapped, will give VR a huge advantage over traditional forms of information transfer, such as renders, 3D models and animations.

The purpose of the research was to verify the existence of disproportions in the reception of the size of architectural objects in virtual reality in relation to the given real dimensions and subjective assessment of the user. It involves

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examining the impact of various factors (such as pre-immersion[4], the size of the interior and the presence of a reference point in the form of common objects known to the user) on the sense of scale and user's behavior in the VR. The study will be conducted on two groups: Experts (the architects) and Non-experts (common users) to further explore the translation of real-world object size analysis skills into the same capacity in the virtual world.

The contributions to research concerning sense of scale, immersion as well as comfort in Virtual Reality presented in this article are:

- Confirmation of significance of the pre-immersion in VR for sense of scale accuracy.
- Analysis of user's motion (movement and rotation as well as areas of interest - AOI) during the VR scale evaluation task.
- Tests verifying the impact of usage of reference points in the form of windows, doors and furniture on the sense of scale in VR.
- Tests verifying whether the user's professional experience affects the sense of scale in VR (Experts versus Non-experts).
- Tests verifying the impact of view continuity or lack of it in on VR application comfort of use.
- Proposition of optimal scale values for single objects presentation, architectural space with many points of references and a large scale space with less to no points of reference.

We start with a related work overview in the next section. Then the factors affecting the sense of scale detailed description is given. This is followed by an evaluation method along with an information about study group and gathered data overview. Next, test results and their discussion are presented in total for both of the test sessions. Finally, ideas for further development and final conclusions will be given.

2 Related work

Interesting example of the influence of various factors on the perception of the size of objects in VR is an experiment conducted by Renault to visualize the car's design before the production [3]. The task used in this study was to adjust the interior of the car cockpit. In order to avoid unnatural enlargement of the object in front of the user, a black screen was displayed whenever the scale changed. The study was conducted on four groups made of people who use the selected car model or not and with previous experience with VR or not. Some of them were also allowed to spend a certain time in the cockpit of the real car before the test (pre-immersion). The results of the group with pre-immersion were more consistent, unlike people who could not be inside the car. Also, seeing car before

[4] Pre-immersion - the user's sense of immersion in digital reality and separating him from the real world extended by the possibility of earlier experiences of a fragment or the whole of the virtual world through its representation in the real world.

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the test had a much greater impact than even everyday use of a given car model. Finally, the authors propose a factor for the correct perception of the scale in the virtual reality environment: for goggles with the head movement tracking 1:0.98, while for devices without head tracking about 1:1.02.

The authors of another study observed not only the disproportion in the perception of real objects, but also the influence of their own body on the perception of the environment [15]. At the start of the study the participants were given a plastic cube for one minute to remember its size. Then they were asked to assess and properly adjust the size of his own hand and a plastic cube in four variants: cube size only (no interaction), the hand only, both with free interaction with the cube, both but sequentially - first the cube, and then the size of the hand. The study showed that users of the VR perceive their own hands as larger than they are in reality, while other objects appear to be smaller. The positive impact of the interaction on the perception of the scale was also proven (third variant).

Another interesting study focuses on the importance of the order and type of environment in which the user is located [7]. The participants were asked to adjust the size of the chair, which they could previously observe and analyze its dimensions in the real world. The subject was introduced to three VR scenes in order: the virtual equivalent of the room in which the experiment was conducted (full pre-immersion), then a futuristic visualization showing the large-size structure and chairs arranged in it and finally the interior of the museum with preserved real proportions. Results showed that it was much easier to determine the scale of object in known space (the worst results were observed in the futuristic interior). By transporting the user from a large-scale world to a much smaller world (or the other way around), his or her perception of the scale of the whole environment changes drastically. For the subjects, the futuristic environment seemed much larger than it actually was.

3 Factors affecting the sense of scale in VR

The sense of scale in Virtual Reality is a sum of many factors. We have to consider physiological and anatomical features of the eye structure as well as elements of psychology of vision. The most important of them are: ability of stereoscopic vision (including IPD - interpupillary distance), parallax effect, Field of View (FOV), Body Base Scaling (BBS), objects known to the user, number of frames per second (FPS), objects out of focus or bad Depth of Field (DOF) and visual aspect. All of those factors have been taken into account by the authors in the experiments described in this article.

Ability to stereoscopic vision is the ability to perceive depth and distance binocularly. Knowing the viewing angle and IPD, the visual cortex calculates the distance to the observed object. However, this only works on objects that are close to the observer (within the convergence phenomenon). At distances greater than about 6 meters, the angular differences are too small to detect [8] [4].

Parallax effect is a phenomenon based on the incompatibility of images of the same object that is observed from different points. Objects further away seem to

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move in the same direction as the observer when the objects being closer seem to move contrary to the observer's movement and faster than those that are at distant. Mapping the parallax effect in the virtual world is possible thanks to motion tracking devices.

Field of View (FOV) is a space that a person perceives simultaneously with the fixation point of the pattern. The field of view can differ for each individual due to factors such as the depth of the eye socket, lowered eyebrow or even a drooping eyelid. For VR applications, two separate *FOV* types should be considered: *FOV* of virtual cameras and the second that results from the construction of the VR goggles.

Body Base Scaling (BBS) is the ability to use parts of the body (most often hands) to assess the size of objects in the surrounding environment [12]. Gibson [6] even emphasized that people do not perceive the environment per se, but the relationship between their body and the environment. Additionally, Gedliczka in [5] presents anthropometric measures and their application in functional design.

Object that is known to the user can be used to assess the size of unknown objects. Researchers recognize the role of the module in the always-present architectural elements, such as doors and windows, whose dimensions, dictated usually by a clear functional need, are widely recognized [16].

Frames per second (FPS) or specifically the reduction of the number of displaying frames can affect negatively not only the perception of the scale, but also the entire immersion and cause discomfort. This phenomenon can primarily disturb the parallax effect and the assessment of the distance of objects based on head movements. It can also cause frustration or even malaise and should be assured in value recommended by VR equipment manufacturer [14].

Depth of filed (DOF) represented as blurred objects outside the focus area are widely used in computer graphics and video production. For a VR application that may negatively affect the perception of the scale and create the unwanted impression of movement, thus causing the users to feel unwell. Therefore, setting a photographic DOF effect in VR is not recommended.

Visual aspect understood as providing correctly displayed lights and shadows can significantly improve the perception of space. For objects that are far away, when stereoscopic vision no longer works, the brain recognizes their size and distance thanks to, among others, shadows and perspective.

4 Evaluation

The study was divided into two sessions (named accordingly A and B). The hypotheses in individual sessions were as follows:

First session (A)

1. Task A1: Displaying a black screen between each change of the scale factor will reduce the impression of unnatural magnification of objects in front of the subjects, making it easier for users to adjust the size of the objects.

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2. Task A2: The possibility of experiencing the phenomenon of partial pre-immersion on a real object will make it easier for users to adjust the size of its virtual counterpart.

Second session (B)

3. Task B1: The impact of pre-immersion as well as user's behavior is the same regardless of the ability to analyze the size of objects in the real world (Experts vs Non-experts).
4. Task B2 and B3: The absolute real size of the room affects its perception in the virtual world.
5. Task B3 to B5: The existence of a reference point in the form of windows, doors and furniture positively affects the sense of scale in the virtual world.
6. Task B1 to B5: There is a translation of real-world object size analysis skills into the same capacity in the virtual world.

4.1 Test tasks

All respondents were first familiarized with the purpose the study and individual tasks as well as the principles of control (increase / decrease the scale and display of the architectural plan using the controller). Then, for each participant the eye distances from the ground and pupil spacing were measured [2]. After that, the participant was given a specific task regarding the study session.

First session (A)

Task A1 The aim of the first task was to change the scale of the rectangular cardboard box sized 50x50x100 centimeters displayed on the screen with initial scale 1:0.4 (Fig. 1 c)) until it reaches a size subjectively corresponding to the dimensions given in the technical drawing (displayed in the virtual space). Two variants were used: one with a black screen appeared for 0.2 seconds with each object scale change and the other without the black screen. Ten subjects were randomly and evenly assigned to two groups, where each group saw one of these variants first (with or without black screen). We assumed that the use of a black screen with each change of scale forces the user to assess the size of the object with each step again. Thanks to this, the decision on the next step (enlargement or reduction of the object) is more thought-out by the user. In addition, the fact of enlarging the object unnaturally in front of the user may lead to an assessment of its size based on the previous size of the object. The secondary goal of this task was to observe a basic user behaviour during scale assessment task. Scale change, subject position as well as subject rotation was recorded for that purpose.

Task A2 The aim of the task was to determine whether partial pre-immersion will affect the final result of the scale parameter set by users and what impression it will cause for users. The task and participant's distribution to two groups were identical to A1 with the difference with black screen variant was replaced by the possibility of seeing the real box before and during the task (Fig. 1 a) and

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Fig. 1. The participant of the study during the task consisting in adjusting the scale of the box in a variant with the possibility of experiencing pre-immersion, a) during the first session (task A2); b) during the second session (task B1). c) A1, A2 and B1: box visualization in VR.

b)). The second variant included the same task, but without real object (users had only a drawing available with the dimensions of the tested object).

Second session (B)

Task B1 The purpose of this task is identical to the A2 task, with the difference that it is carried out by both: ordinary users and experts (Fig. 1 b)). The user has a minute to look at the object and remember its subjectively felt size. The user can also at any time remove the glasses and recall the size of the item. In addition, it can display the box's projection with dimensions at any time.

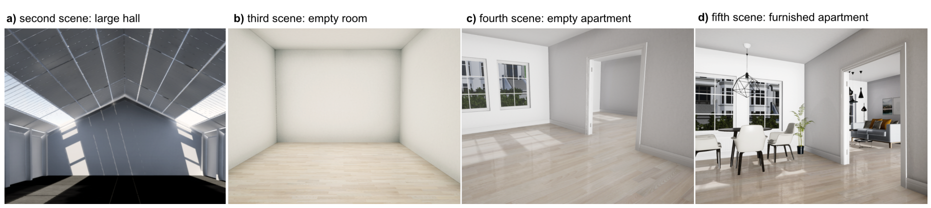

Fig. 2. Scenes used in the second session. a) B2: a large hall with a sloping roof. b) B3: an unfurnished room of standard dimensions, without windows and doors. c) B4: several-room, unfurnished apartment of standard sizes. d) B5: a several-room, furnished apartment of standard sizes.

Tasks B2 to B5 During all further tasks in this session the participants were asked to adjust the size of the room to the dimensions given on the architectural plan. Initially, each room was significantly reduced, relative to its actual size. The examined person has the opportunity to view an architectural plan with selected dimensions at any time and any number of times. The plans were displayed right in front of the user's eyes, while completely obscuring the view of the examined interior in order to avoid the effect of scaling the room relative to the page with the drawn plan. The plans were made in accordance with the basic principles of

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creating a technical construction drawing. The users were transferred to (Fig. 2):

- Task B2: large hall with initial scale of 1:0.3. The subject will focus only one dimension - height. The 8-meter high building with an area of 615 square meters is characterized by a large number of windows that prevent the feeling of overwhelming.
- Task B3: a rectangular empty room without doors or windows of about 12 square meters and a height of 2.7 meters with initial scale of 1:0.75.
- Task B4: empty apartment with doors and windows and a view of the street and neighboring buildings with initial scale of 1:0.75. The door size was adopted in accordance with standard dimensions as for study participants, adopted because of human anthropometric features [5].
- Task B5: apartment from previous task, but fully furnished with initial scale of 1:0.75. It was extended with standard-size furniture such as kitchen, table, chairs or sofa and a number of accessories (flowers, paintings).

At the end of the test users were asked to complete a short survey regarding the ease and convenience of the tasks performed.

5 Results and analysis

In total, 40 people of different sexes and ages participated in the study. The number of study participants was selected in accordance with [13, 17, 11]. Twenty Non-experts (with an average ability to analyze spatial relations) participated in the first study session. The second study session was conducted on two groups, ten people in each: The architects (Experts, characterized by their acquired ability to analyze space in terms of its dimensions and the ability to read architectural plans and compare them with real space) and ordinary users (Non-experts, people unfamiliar with architecture from a professional point of view).

5.1 First session

Task A1 We did not observe the significant difference between variant without black screen and with it in case of scale value with mean scale values accordingly 0,852 and 0,846 with same Confidence Interval equal 0,1 for p=0,05[5] (Fig. 3). Participants presented similar behaviour by increasing the scale up to satisfactory value rather than passing this value and decreasing. Also, the plan with box size values was opened only in the first half of this process (mostly at the start of the test). The subjects presented similar movement pattern by moving towards the box and back several times (gray lines on Fig. 4) and looking at the object from different angles from time to time. With no other objects or points

[5] All of the Confidence Intervals (CI) for all of the experiments shown in this study were calculated for p=0,05. Therefore, we will omit that information in a later description writing just CI value.

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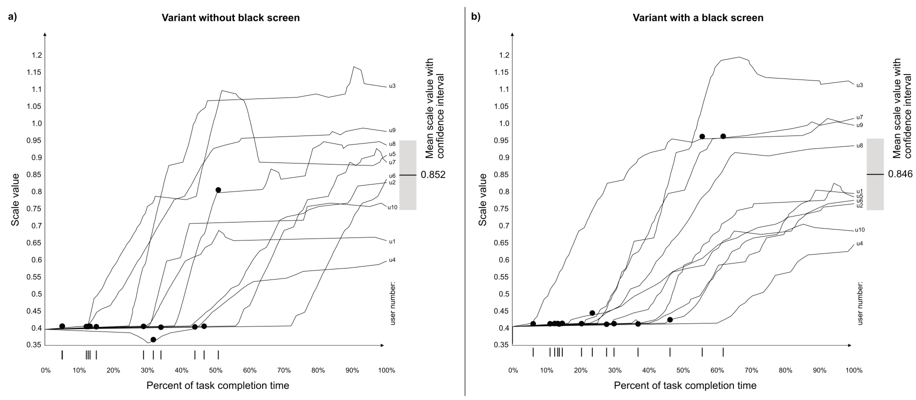

Fig. 3. Scale value and plan opening times for both variants (without black screen on the left, with a black screen on the right). Lines represent scale value change for each participant, with final value on the far right. Also, the mean value with CI is presented. A moment in which the subject displayed architectural plan is marked as dot on a corresponding scale value line as well as vertical line above X-axis. We did not observe the significant difference between those variants in terms of final scale value, scale change process or moments of viewing the plan.

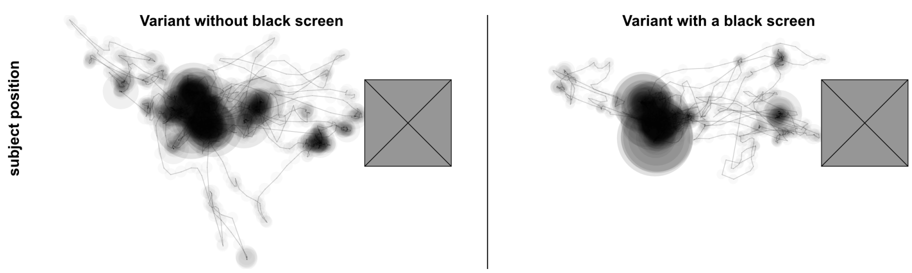

Fig. 4. Cumulative heatmap of the subject's position for both variants (without black screen on the left, with a black screen on the right) gathered five times on the second. The darker the circle, the more participants visits that spot. The bigger the circle, the more time was spent on specific spots. Movement path is presented as connected lines. The position of the box that's been scaled is presented as a grey rectangle with "X" in it. We observed more diverse movement in variant without the black screen.

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of reference in the 3D scene they try to measure object by movement. The black screen variant affects the participant movement being more stationary than in the other variant (less deviation from the center position, Fig. 4). There was no significant difference in subject rotation between both variants.

Even we observe no gain in scale nor the task time (66,9 seconds ± 20,4 CI for variant without black screen and 54,2 seconds ± 15,5 CI for black screen variant) all of the participants pointed the black screen variant as more difficult and inconvenient. Seven participants answered in the post-task survey that the black screen *"Made it difficult for me to judge the size of the item"*. Other frequently selected answers were *"It made me feel unwell"*, *"It was irritating"*, *"It made it difficult to focus on the task"* (three people for each answer). Therefore, we decided not to use the black screen in further tasks.

Task A2 Participants have achieved more consistent results with pre-immersion variant (when they can interact with the physical box at the start of the test) with mean final scale value of 0,98 with CI=0,057 rather than 0,885 with CI=0,101 in the variant without physical box (Table 1). Even the Confidence Intervals overlap a bit, the difference is clear with two times lower CI and final scale value much closer to actual object scale in the real world (which was equal 1). Also, without a physical object reference the value of one meter was considered much smaller than it actually was. After pre-immersion in second variant results has improved significantly in most cases, placing close to proper box scale value. On the other hand, the group that starts with pre-immersion achieved much more consistent and closer to real value results with mean difference value at only 0,01 ± 0,03 (rather than 0,18 ± 0,18 in the other group). In the post-task survey all of the participants found the ability to see the real object easier than the one with the plan with dimensions only (regardless of whether the variant with the pre-immersion was used as the first or as the second). Most often, in the open question responses, users emphasize the possibility of comparing the box with their own body as a feature that made it easier for them to complete the task. They were also more confident of their answers. On the other hand, without pre-immersion it was hard for them to imagine the size of 1 meter.

5.2 Second session

Task B1 We did not observe a significant difference between Experts and Non-experts in case of final scale value (Table 2), scale change process nor behaviour (movement, rotation). At the same time, the benefit of using pre-immersion was once more confirmed both in the results of the survey. The participants pointed this task as one of the easiest from whole study (Fig. 7) and a possibility to see the real object as a helping factor. The mean final scale value oscillates around the actual value of 1 (1.02 ± 0,04 CI for Experts and 1.03 ± 0,06 CI for Non-experts).

Task B2 This task showed the least consistent results (highest standard deviation and CI). This scene was often felt by users to be much smaller than it

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Table 1. Scale value for both variants (with and without pre-immersion). Participants have achieved better results with pre-immersion variant. Also the group that starts with pre-immersion achieved much more consistent and closer to real value results. $FSVpre$ - the final scale value in pre-immersion variant when users can interact with the physical box at the start of the test; $FSVno$ - final scale value for variant without a physical box; $Sdiff$ - final scale value difference between variants; $MSdiff$ - mean scale value difference in each group; $SDdiff$ - standard deviation of the scale value difference in each group; IF group - pre-immersion-first group, users who could see the real box as first variant; NIF group - No-immersion-first group, users who could see the real box as second variant; $Mean$ - mean scale value for all the participants; SD - standard deviation of the scale value; CI - Confidence Interval for the mean scale value.

	User number	$FSVno$	$FSVpre$	$Sdiff$	$MSdiff$	$SDdiff$
NIF group	1	0,68	0,96	+0,28	0,18	0,18
	2	0,83	1,07	+ 0,24		
	3	1,07	1,01	- 0,06		
	4	0,64	1,07	+ 0,43		
	5	0,8	0,79	- 0,01		
IF group	6	0,85	0,91	+ 0,06	0,01	0,03
	7	0,94	0,95	+ 0,01		
	8	0,99	0,99	0		
	9	1,05	1,03	- 0,02		
	10	1,0	1,02	+ 0,02		
$Mean$		0,885	0,98			
SD		0,142	0,079			
CI		0,101	0,057			

Table 2. Mean scale value and task time for tasks B1 to B5 and both groups (Experts and Non-experts). B1: cardboard box, B2: large hall, B3: empty room, B4: unfurnished apartment, B5: furnished apartment. For scale, the least consistent case was marked (B2: large hall). For time results, the tasks with the longest task time was marked (B2: large hall and B4: unfurnished apartment). M - mean scale value for all the participants in a particular group; SD - standard deviation of the mean scale/time value; CI - Confidence Interval for the mean scale/time value. The difference between the mean values and the median were in the range 0,0-2,7% (giving 0,0-0,03 in the case of scale value) so they are omitted from the results.

		B1		B2		B3		B4		B5	
		M	CI	M	CI	M	CI	M	CI	M	CI
scale	Experts	1,03	0,04	**0,96**	0,12	1,02	0,03	1,12	0,06	1,10	0,03
	Non-experts	1,02	0,06	**0,96**	0,22	1,10	0,06	1,18	0,05	1,17	0,05
time [s]	Experts	61,4	10,5	**87,0**	34,5	59,9	18,3	**89,2**	35,8	45,9	13,5
	Non-experts	57,4	10,2	**59,2**	11,1	56,5	12,2	**64,0**	22,0	44,9	12,7

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actually was in real world and smaller than apartments in further tasks (Table 2). For example, two of the participants from the group of Non-experts indicated that the correct size of the hall was almost half the size of the actual scale. What is more, this was one of the two tasks (along with an empty room) in which it took the participants the most time to set the final scale value (Table 2). Also, they made the most changes to the scale parameter in this scene with the median value of 86 changes (increase and decrease combined) and CI equals 23 (much higher than tasks B3-B5 with a median value respectively of 38 ± 10 CI in B3, 47 ± 7 CI in B4 and 46 ± 8 CI in B5).

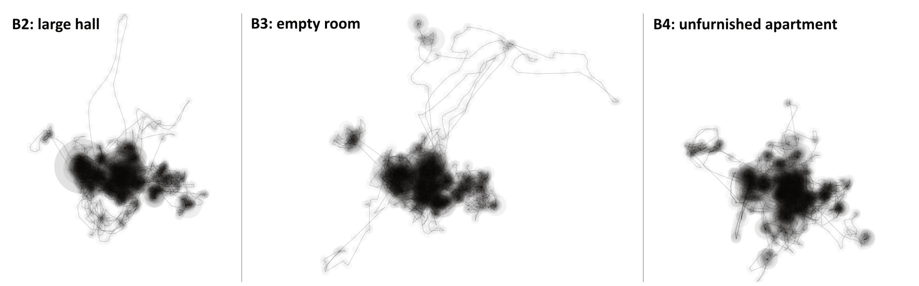

Fig. 5. Subject's position for tasks B2: large hall, B3: empty room and B4: unfurnished apartment gathered five times on the second. Each of visualization presents cumulative heatmap of the subject's position. The darker the circle, the more participants visits that spot, the bigger the circle, the more time was spent on specific spots. Movement path is presented as connected lines. We observed more diverse movement in task with a little or no point of visual reference (B2 and B3) than in a scene with apartment with doors and windows (B4).

We observed more movement in this and following task than in others (Fig. 5). Once again, participants tend to measure the space with continuously moving back and forth from center position. Same type of behavior of even bigger scale can be observed during task B3 (empty room). We conclude that a little or no point of visual reference forced the participants to make an assessment based on movement.

Tasks B3 to B5 In those scenes participants used mainly the doors and windows as referencing points (Fig. 6). That was confirmed in a post-test survey where 16 out of 20 users pointed that out. This scene was also selected as the second easiest in whole test (after cardboard box one, Fig. 7). It is also worth noting that after the appearance of doors and windows in scene four and furniture in scene five, users rated the room as larger than before (Table 2).

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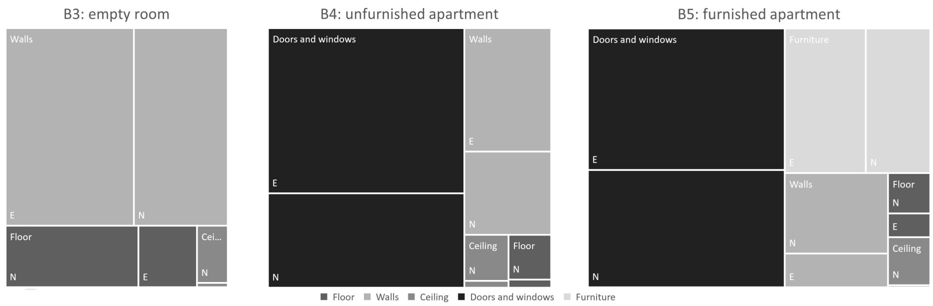

Fig. 6. Areas of interests (AOI, objects being in the center of the view at the time) in tasks with apartment (B3 to B5). Both groups tended to favor (the Experts even more) know objects such as doors and windows over looking up and down on the floor and ceiling. In all three scenes ceiling was observed almost exclusively by Non-experts. E - group of Experts, architects; N - group of Non-experts, common users.

5.3 Experts vs Non-experts

We observe no significant difference between those groups in case of final scale value (Table 2). However Experts tend to set lower and closer to real world scale value for tasks with architectural space. In the other hand, the common users tend to recognize the space size smaller in VR than it was in real life (scale values higher than 1 and closer to 1,1-1,2 for tasks B3-B5 with apartment setting). Expert results were also more coherent with lover CI than Non-experts in most cases. There was also a difference in the frequency of displaying the plan. The architects remembered the given dimensions faster than the Non-experts group, and they recalled the plan less frequently.

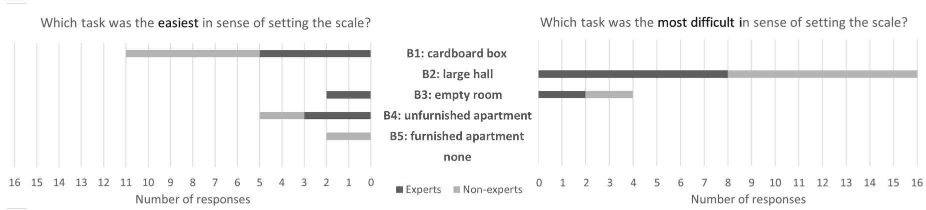

Fig. 7. Posttest survey. On the left: the easiest task; on the right: the most difficult task. Both Experts and Non-experts indicated the task with a cardboard box (B1) and empty apartment, but with doors and windows (B4) as the easiest tasks. Dimensions given to a plan as well as furniture in the scene were considered helpful mostly by the Experts.

Both groups considered a large hall (B2) and a room without doors and windows (B3) to be the most difficult ones (Fig. 7). These opinions are confirmed in the results, as they are the least convergent with each other and frequent

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changes of scale value were made. Some of the participants tried to obtain information about the surrounding space with their own steps - similar behavior to the one observed in the first test session (we can call it "movement based scaling"). Both groups indicated the task with a cardboard box (B1) and empty apartment, but with doors and windows (B4) as the easiest tasks. They emphasized the advantage of being able to see the actual object and a reference point in the form of doors and windows. At the same time, the overall sense of difficulty in determining the scale differed between the groups (considered more difficult by Non-experts. The mean score of difficulty on a ten-point scale, where 1 means the easiest and 10 the most difficult, for Expert was 4 $\pm$ 3,2 CI and 5,3 $\pm$ 6,1 CI for Non-experts.

6 Conclusion

The aim of this study was to investigate the disproportion in the perception of the size of virtual architectural objects in relation to the given real dimensions and subjective assessment given by the subjects. The study also analyzed the influence of various factors on increasing the spatial awareness of the respondents. The benefit of using pre-immersion in VR was confirmed. The final scale value of the task with the possibility of seeing a real box was more consistent between all users and oscillated around the actual value of 1 (scale equal to 1:1). Surveys showed that users also found the pre-immersion variant easier. We did not observe a significant impact of the presence of a black screen between each change of the scale on the results. At the same time post-test survey showed that the black screen was received negatively by participants and made it difficult to assess the object's size. Although, we did not observe any significant difference between the Experts and Non-experts in case of final scale value, there were noticeable differences in user behavior during the study. Architects viewed a plan with dimensions less often and set lower and closer to real world scale value in tasks with architectural space. Their results were also more coherent with lover CI than Non-experts in most cases. Such factors as doors, windows and furniture causes that the users perceived the space as larger than when it consisted only of the floor, walls and ceiling. The scene with a high hall and a room without doors and windows seemed to be the most difficult for users to assess. The respondents in these tasks tried to measure the room with their own steps. In those scenes, with a little to no known points of reference, we observed behavior that can be called "movement based scaling" (participants tried to measure a space with their steps).

The problem raised in the work has a further, wide field of development. Survey results have shown that it would be a good idea to extend the study to include *BodyBaseScaling* or the human figure as a module helping to determine the size of the object. This element may turn out to be crucial in the case of very high rooms, such as a hall. Another possible development of the study would be to extend it with an Eye-tracker device developed for VR (to track the exact movement of the eyeballs rather than center point AOI) or the automatic image

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analysis in search of elements affecting the user's sense of scale [10]. We are also considering combining these studies with impression curve study [1] to verify scale impact on computer dame level design process.

To sum up, the study has shown that one can use 1:1 scale when presenting single objects in immerse VR to them being perceived by users as in proper scale. We propose a little bigger scale of 1:1,1 for architectural space with many points of references such as doors, windows and everyday objects. For large scale spaces with less to no points of reference (as empty hall presented in this study) we recommend a bit smaller scale of 1:0,96.

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