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Raumsynth:

An experimental setup for investigating the relationships between urban form and spatial experience based on Fechner’s Method of Production

Johannes Frölich
Bauhaus Universität Weimar
johannes.frölich@uni-weimar.de

Sven Schneider
Bauhaus Universität Weimar
sven.schneider@uni-weimar.de

Saskia Kuliga
University of Freiburg, Center for Cognitive Science
saskia.kuliga@cognition.uni-freiburg.de

Martin Bielik
Bauhaus Universität Weimar
martin.bielik@uni-weimar.de

Dirk Donath
Bauhaus Universität Weimar
dirk.donath@uni-weimar.de

Abstract

By extending Fechner's Method of Production, we investigate the relationships between urban form and spatial experience using an experimental Virtual Reality setup that allowed participants (N=102) to create three-dimensional, environmental scenes in real time. Participants could adjust five independent parameters (building height, building width, amount of buildings, space between buildings, and street width) to arrive at a scene that felt pleasant or unpleasant to them. Participants were also asked to estimate certain sizes in the virtual environment. A streetscape and an urban square were used as contextual scenarios for the participants’ preference ratings. This article describes an approach for analyzing the resulting, highly complex data in three steps: First, the correlations between direct spatial features were calculated. Second, the participants’ answers were combined into clusters. Third, these clusters were imported as a data source for investigating more advanced spatial features, such as amount of visible sky, and visible vertical and horizontal surfaces, and linked to the participants’ ratings for pleasure and dislike. We found that ratios in both distances and amounts of visible sky, vertical and horizontal surfaces of the streetscape and urban square scene used in this study are clearly distinctive between (what participants rated as) unpleasant and pleasant scenes.

Keywords

Spatial experience, empirical study, method of production, urban form, visuo-spatial properties.

1. Introduction

Architectural planning and design needs to understand the effects that the spatial features of the environment have on (future) users. Especially in urban design, it is crucial to know what impact urban form (shape, dimensions and allocation of streets and buildings) has, because once streets and buildings are built, they are hard to change, and thus have a relatively long lasting impact on the inhabitants and future development of a city. Research has indicated that urban form has measurable effects on movement flows (Hillier & Iida, 2005), on the use of space and distribution of functions (Sevtsuk, 2010; Porta, 2009) and on orientation and navigation (Meilinger, 2008).

In order to investigate the influence of certain features and stimuli on the participants' emotional response, contemporary research usually presents several systematic variations of the same stimulus to participants in different groups; or studies different scenarios within groups. Different variants are then either rated separately on a scale (e.g. a Likert-Scale from pleasant to unpleasant), or are presented simultaneously to participants with the aim of attaining preference ratings, a method that can be traced back to Fechner's *Method of Choice* (1876). For architectural research, however, arriving at a set of *systematic* variations of the same stimulus poses a challenge: By having to choose from a large variety of *possible* stimulus variations that best fit the context of certain hypotheses, architects risk overlooking certain configurations, which makes this process, to some extent, subjective. If architects are interested in ascertaining holistic responses to various scenarios, and to precisely identify thresholds for configurations of parameters that cause certain emotional responses, then *all* possible configurations should at least be considered. On a practical level, though, this would seem to be all but impossible, at least for the fine-grained level of *all* possible variations.

Instead of the a-priori definition of a set of isolated variants, Fechner (1876) proposed the *Method of Production,* in which participants themselves are asked to create objects or sets of variants that relate to or cause a certain emotional reaction; e.g. feeling pleasure. Researchers can then analyze the structural properties and features of these bottom-up generated variants. In contemporary research, the *Method of Production* has mainly been applied in two-dimensional scenarios, such as for preference studies on the proportions of rectangles (Westphal-Fitch, 2013; Green, 1995; Davis & Jahnke, 1991), cropping photographs (McManus, 2009), or reproducing famous works of abstract art (McManus, 2014). Westphal-Fitch et al (2013) argued that this method is suited for such research, because it is not constrained by any preconceptions experimenters might have. Relationships between three-dimensional spatial configurations and spatial experience using Fechner's *Method of Production* have not been studied so far; probably because it is challenging for researchers to analyze data sets that contain numerous possibilities of the same parameters.

By extending Fechner's *Method of Production*, and following in the footsteps of work by Westphal-Fitch et al (2013) and McManus (2014), we aim to develop an innovative method for investigating the impact of spatial configuration and form on user experience and environmental appraisal by assessing bottom-up user-generated spatial preferences of various architectural street configurations. In the following sections, we will first introduce our experimental setup and then test it using two contextual scenarios: an urban square and a streetscape. Moreover, we develop an approach for evaluating the resulting data by using cluster analysis, with the aim of studying possible relationships between visuo-spatial properties (such as the amount of visible sky, horizontal and vertical surfaces) and user preference.

The main goal of the study is to test if our experimental setup can be usefully applied for the study of relationships between urban form and emotional response. The research questions were formulated as: A) Is the full range of the five possible spatial parameters used? B) Are there any correlations between these parameters for the participants' ratings of pleasant/unpleasant? C) Do the pleasant results coincide with unpleasant results? And D) how do these preferences relate to visuo-spatial properties?

2. Methods

2.1 Requirements and Experimental Setup

In this study, participants were asked to create objects that cause a pleasant or unpleasant feeling. The creation of a three-dimensional spatial configuration is a challenging task, because of the multitude of parameters that can be varied. Furthermore, experts (such as urban designers and architects) may have learned certain strategies for the production of spatial artifacts and these may strongly influence the results. On the other hand, non-expert participants generally do not have sufficient modelling or drawing skills, making it hard to realize what they intend to do. To begin with, we therefore had to create an easy-to-use tool that standardizes the creation of variants and enables users to create solutions directly, without needing extensive training in how to use the tool. Furthermore, as participants needed to be able to change all spatial parameters continuously, no unexpected transitions from a scene to another should occur, and changes in parameters must have an immediate impact on the setting that the participants experience (rather than a delay). For displaying data we decided to use a 3D-solution, allowing the participant to explore the three-dimensional space while presumably being more immersed than with traditional methods such as 2D-illustrations/renderings or even displaying 3D-scenes on a 2D-screen. To meet these requirements, we developed an experimental setup, which we call *RaumSynth* (a combination of the German word "Raum" (room, space) and synthesizer).

This setup consists of three main components:

1. Head-Mounted-Display (*Oculus Rift Development-Kit-2*).

2. Our custom-developed software *RaumSynth,* for the parametric generation of spaces; using a combination of the Game engine *Unity3D*, the database system *MySQL*, and the statistical program *IBM SPSS Statistics.*

3. A self-made controller with which the user can change parameters to change the spatial configuration.

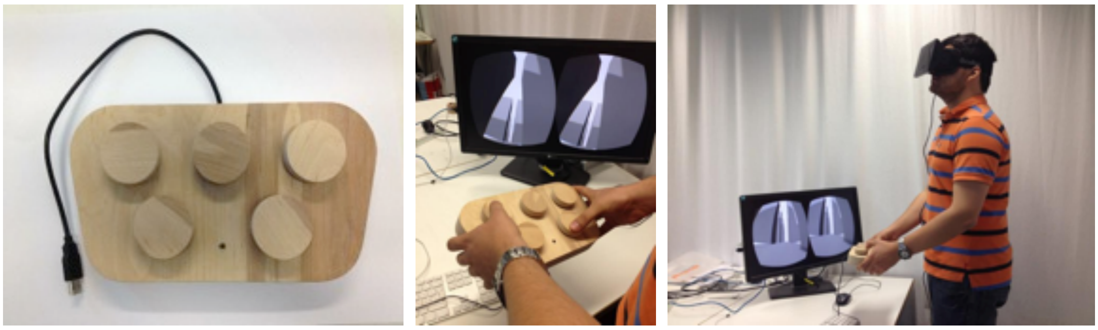


Figure 1: Self-developed, CNC-milled Controller (left); using controller and interacting with software (middle, right).

The *Oculus Rift DK2* (https://www.oculus.com/dk2/) was selected, because it uses a 3D-gyroscope to read positional information and a simple tracking unit to locate the goggles in a room. Participants are able to modify the displayed scenes using a custom-designed controller with five large rotating dials (variable potentiometers) and one button, attached to the computer via the usb port (Figure 1). A small open source development board (*ArduinoUNO*; www.arduino.cc) was used to convert the positions of every single potentiometer to a serial data stream that is interpretable by *Unity3D*. *Unity3D* uses the serial data stream from the controller to calculate the changes in the geometry, based on the parameter settings in real time. When the user finishes adjusting the geometry for one scene, he or she then moves on to the next scene by pressing the button on the controller. A software script was also written to store all available data in a *MySQL* database, e.g. position of the user, line of sight (rotation); plain geometry as 3D-file (https://collada.org), all parameter settings, and metadata about the participant.

To summarize, the custom-developed *RaumSynth* setup, it is possible to conduct studies in which users can change three-dimensional scenes using different parameters in real time.

2.2 Modeling the Contextual Scenarios

To test the experimental setup described above, we created two test scenarios: one illustrates a streetscape and the other an urban square. In both scenes all elements were solid white. No textures were used at all, so that users could focus purely on the geometry of the spatial configuration. However, to increase the plasticity of both scenes, a screen space ambient occlusion and a drop-shadow simulating a sun were integrated into the scenes.

The streetscape (Figure 2) consisted of regularly spaced houses along a straight road. On both sides of the street there was a 5 metre wide sidewalk. The following five parameters were freely adjustable with the controller:

- the height of the buildings (HB), ranging from 3 – 120 metres
- the width of the street (WS), ranging from 15 – 70 metres
- the width of the buildings (WB), ranging from 8 – 68 metres
- the spacing between the buildings (SH), ranging from 0 – 32 metres
- the number of buildings (NB) ranging from 3 – 17 on both sides.

The participant is positioned on the pavement on right-hand side of the scene. To ensure comparability of the results, the participant was not able to move around in the scene, but could freely look around (the resulting line of sight was stored in the database).

The urban square scenario consists of four rectangular cuboids which enclose the square (Figure 2, right). The following parameters were freely adjustable with the controller:

- the width of the square (SW), ranging from 8 – 150 metres
- the length of the square (SL), ranging from 8 – 150 metres
- the height of the buildings (BH), ranging from 3 – 50 metres
- the width of the buildings (BW), ranging from 3 – 50 metres
- the shift of the buildings clockwise or counter clockwise (SB), ranging from -5 – 5 metres.

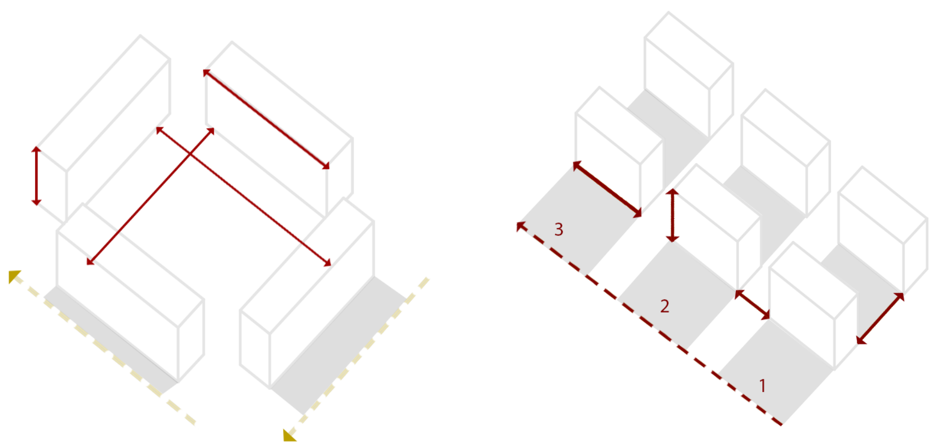


Figure 2: All the variable parameters in an urban square situation (left) and streetscape (right).

The participant is positioned at a fixed location in one corner and per default looks into the middle of the square. In both scenes, participants were first asked to state their body height, and this height (minus 7 cm for eye level) was then used to calculate the viewpoint so that participants would experience a realistic position of his or her own field of view.

2.3 Study Procedure

As the main goal of the study was to test if this experimental setup can be usefully applied for the study of relationships between urban form and emotional response, we formulated several tasks in which participants were asked to first create a scene that elicited positive feelings, and second that induces negative feelings, for each of the two scenarios (street or urban square) described above.

Tasks and Ratings for Pleasure or Dislike.

The three tasks were formulated identically for the streetscape and the urban square scenario: "Create a scene that feels pleasing to you" (*task 1*), "Transform the scene you created to a scene that starts to feel unpleasant to you" (*task 2*) and "Create a scene that feels unpleasing to you" (*task 3*). While other descriptions could certainly have been used, the concept of perceiving pleasure or dislike was selected based on the findings by Hershberger & Cass (1988) that pleasure was one of the most often referenced categories for describing architectural space. In addition to these two (potential) extremes, we were interested in a "between-state" and therefore introduced the third intermediate task, which we call the "nearly unpleasant" task.

Size Estimation in the Virtual Environment.

The order in which the tasks were presented was the same for every participant. After the three tasks (for the streetscape and the urban square scenario separately), a fourth task was posed to test the participants' ability to estimate sizes in the virtual environment. In the streetscape scenario, participants were asked to set the height of the building to 10m and the width of the street to 30m. In the urban-square-scenario, participants were asked to set the width and depth of the square to 30m and the height of the buildings to 10m. All parameters not relevant to the fourth task were locked to a default setting to ensure that all participants had the same configuration to deal with. All tasks were displayed directly in the VR-goggles (see Figure 3, left). To signalize that the participants had read the task and wanted to proceed to the production part, or had finished their task, they pressed the button on the controller. Before starting the first task in each scenario the participant had time to get used to the function of the five dials. The tasks each had a time limit.

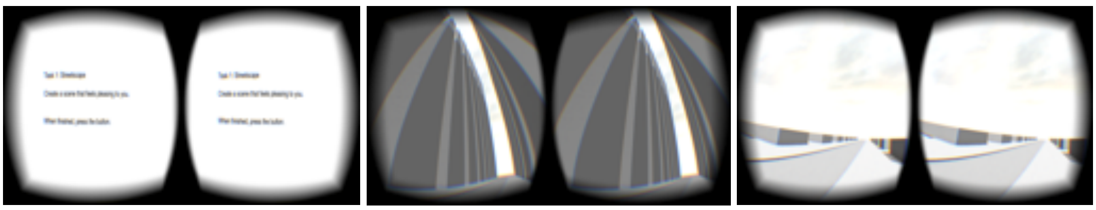


Figure 3: Task description in the HMD (left); streetscape scene showing max and min building height (middle, right).

In addition to the data already mentioned, the following data was also stored in the database: height, gender, size of hometown as well as prior experience with virtual worlds (on a Likert-scale from 1 to 10) and their ability to imagine the scenes as real scenes (on a Likert-scale from 1 – 10). No pictures, screenshots or other relevant information for the test was shown to the participants in advance, and participants did not receive an incentive for taking part in the study.

3. Results

3.1 Participants

In order to find meaningful patterns in the large number of possible results, we needed a large number of participants. 102 persons participated in the study (Mage=25.4, SD: 6.7 years, 43% female), most of them (91%) either students or staff at Bauhaus-University Weimar, which teaches design and architecture. Most of the participants therefore had at least a basic understanding of design and spatial configuration.

The study was carried out in December 2014. None of the participants reported experiencing any trouble in understanding the tasks when asked after the test. The same applied to using the interface for controlling parameters. Participants estimated the degree of realism as very high (M=7.8, SD=1.5). The average time taken to complete the test was 17 minutes.

3.2 Distribution of parameter settings

In order to evaluate to what degree the participants made use of the range of the parameters, we plotted the distribution of settings for each parameter in each task (Table 1 and Table 2).

The distribution of four of the five parameters (building height, building width, space between buildings, and street width) in the task for creating pleasant scenes is unimodal and skewed to the right, whereas the in the task for creating unpleasant scenes the distribution is mostly bimodal. The distribution of the fifth parameter (amount of buildings) is similar in all three tasks, where most participants set a high number of buildings.

On account of the distribution of parameters we conducted pair-wise correlations for the parameters building height, building width, space between buildings, and street width. The highest correlations were found between building height and street width (R^2=.259), as well as the height and width of buildings (R^2=.205). The mean ratio between building height and street width was 1.33 (SD=.75; Median=1.47), which is a slightly smaller value than the golden section (1.618).

Table 2 shows similar results: the distribution of building height, square width and square length when creating a pleasant scene is mostly unimodal, whereas the distribution of these values is mostly bimodal. When creating unpleasant scenes, more extreme values are used. The most significant correlations were found between length and width of the square (R^2=.65) as well as width of the square and the distance between the houses (R^2 = .63). The ratio of width and length of the square in Task 5 was set to an almost quadratic square with 1.1 (SD=.31) and had an average size of 373 m².

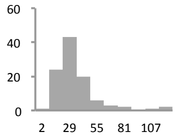
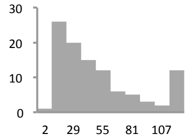
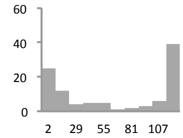
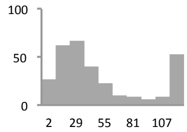
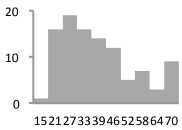
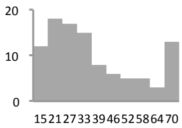
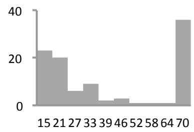
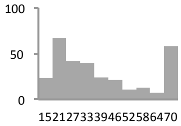
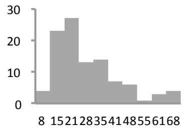
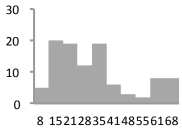
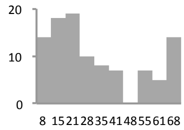
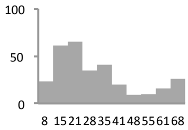
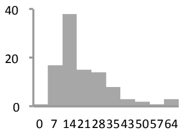
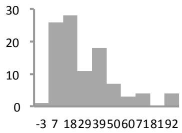
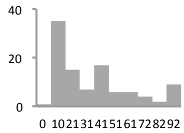
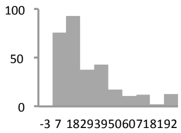
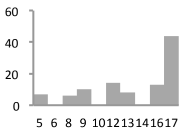
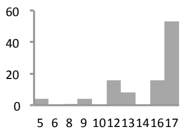
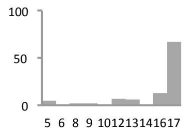
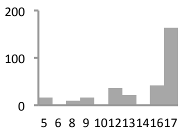
	task 1; pleasant	task 2; nearly unpleasant	task 3; unpleasant	task 1+2+3
BH	 height in m	 height in m	 height in m	 height in m
WS	 width in m	 width in m	 width in m	 width in m
WB	 width in m	 width in m	 width in m	 width in m
SH	 spacing in m	 spacing in m	 spacing in m	 spacing in m
NB	 number of bld.	 number of blg.	 number of blg.	 number of bld.

Table 1: Histograms showing the distribution of parameter settings in the streetscape scenario.

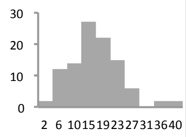
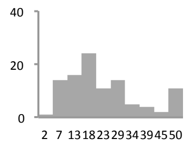
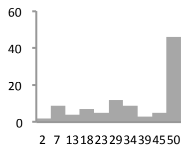
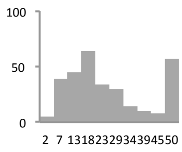
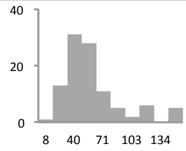
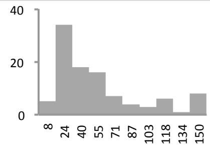
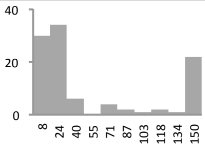
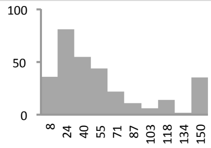
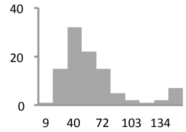
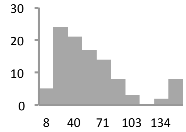
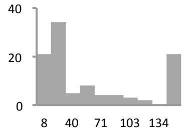
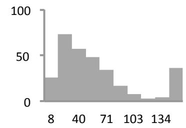
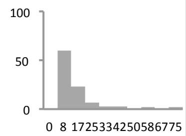
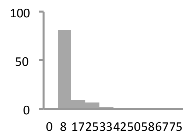
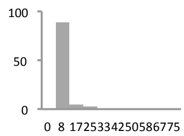
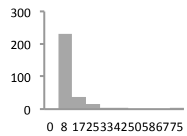
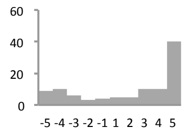
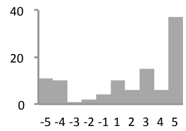
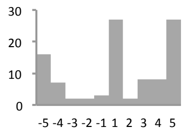
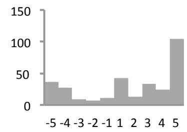
	task 5; pleasant	task 6; nearly unpleasant	task 7; unpleasant	task 5+6+7
BH	 height in m	 height in m	 height in m	 height in m
SW	 width in m	 width in m	 width in m	 width in m
SL	 length in m	 length in m	 length in m	 length in m
BW	 width in m	 width in m	 width in m	 width in m
SB	 shift in m	 shift in m	 shift in m	 shift in m

Table 2: Histograms showing the distribution of parameter settings in the urban square scenario.

3.3 Clustering the results

In a second step, we clustered the range of results produced. In order to find out how strongly differently rated results differ we clustered a combined set of variants containing both pleasant and unpleasant results as well as pleasant and nearly pleasant results. For this purpose we used the Hierarchical Clustering Method based on all five generative parameters. The clustering algorithm is based on calculating the Euclidian distance in five dimensional space. In order to avoid biasing the results towards variables that use higher ranges of absolute values (length of the street vs. gap between the houses), we used the standard score as input for the clustering method. The threshold for the analysis (desired number of cluster) was defined after evaluating the clustering dendrogram as a function of stability and homogeneity.

Figure 4 shows the results of clustering for each scenario and the two combinations of differently rated results. The clusters (ranging from 8 to 11 clusters depending on the scenario and combination of results) are represented as bars along the x-axis, whereby the number of results that belong to each cluster is represented by the height of each bar. This enabled us to differentiate between results that were rated positive (pleasant), colored blue, or negative (unpleasant / nearly unpleasant), colored red.

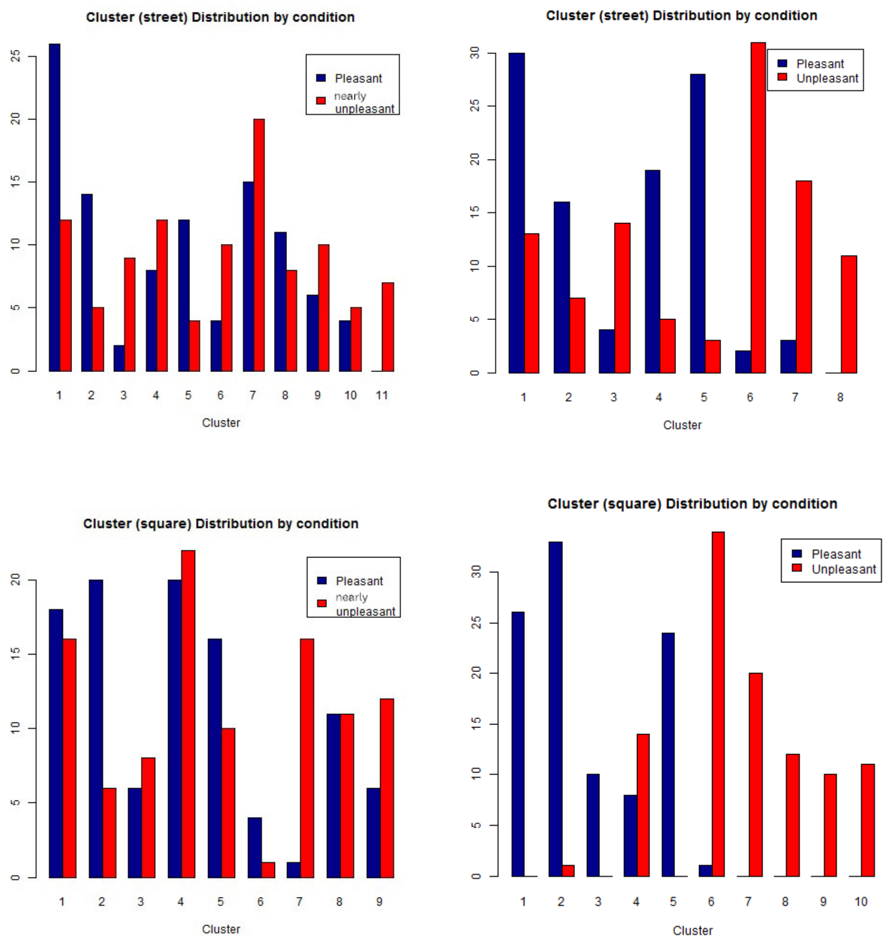


Figure 4: Distribution of pleasant/nearly pleasant (diagrams on the left) and pleasant/unpleasant (diagrams on the right) results in the identified clusters.

Looking at the distribution of positively and negatively rated results after clustering the combined set of *pleasant* and *nearly unpleasant* variants, one can see that they are well mixed in almost each cluster. In contrast to this result, the clustering of the combined set of *pleasant* and *unpleasant* variants shows highly separated clusters. This indicates that the pleasantly and unpleasantly rated scenes differ greatly in the five parameters. To illustrate this we plotted the three most positively and negatively rated scenes graphically in Table 3 (streetscape) and Table 4 (urban square). To generate the images, we calculated the average setting of the five parameters in each cluster.

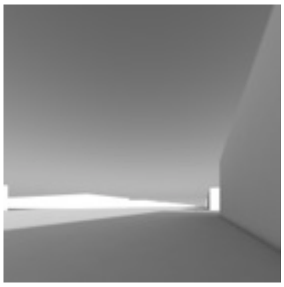
	Rank	2. Rank	3. Rank
Pleasant Streetscap e	Cluster 1 (30 participants) 	Cluster 5 (27 participants) 	Cluster 4 (19 participants) 
	HB: 22.7; WS: 28.11; WB: 23.23; SH: 10.95; NB: 16	HB: 16.9; WS: 24.49; WB: 15.52; SH: 12.55; NB: 10	HB: 33.08; WS: 51.87; WB: 23.09; SH: 15.61; NB: 17
Unpleasant Streetscap e	Cluster 6 (34 participants) 	Cluster 7 (19 participants) 	Cluster 3 (14 participants) 
	HB: 114.78; WS: 23.82; WB: 19.14; SH: 9.8; NB: 16	HB: 43.32; WS: 23.82; WB: 16.8; SH: 76.92; NB: 15	HB: 9.4; WS: 69.9; WB: 54.28; SH: 38.82; NB: 17

Table 3: The three highest and lowest rated clusters in the streetscape scenario.

Table 3 shows clearly that the scenes belonging to the three most pleasant clusters are very similar and homogeneous in most parameters. Proportions between building height, width of the street, building width, as well as the distance between the buildings are almost the same. Only the absolute dimensions differ. The average ratio between building height and street width was 1.43, which is, again, very close to the golden ratio.

The scenes that belong to the three most unpleasant rated clusters present distinctive geometries: all three of them have extreme values in different parameters. Cluster 6 presents a very narrow, high streetscape with very little visible sky. The second most unpleasant scene (Cluster 7) exhibits large distances between high buildings (43.32m). The third most unpleasant streetscape shows flat and wide buildings (9.4m, 54.28m) and a street width of 69.9m.

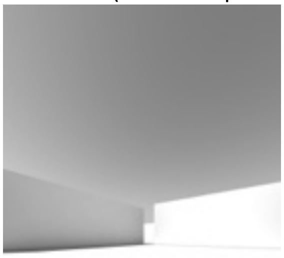
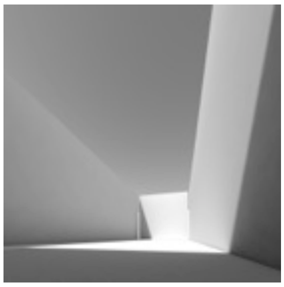
Pleasant Urban Square	Cluster 2 (33 Participants) 	Cluster 1 (26 Participants) 	Cluster 5 (24 Participants) 
	SW: 35.01; SL: 29.35; BH: 10.4; BW: 5.4; SB: 3.6	SW: 52.46; SL: 71.76; BH: 18.35; BW: 10.2; SB: 3.7	SW: 49.07; SL: 42.72; BH: 15.11; BW: 6.03; SB: -4.2
Unpleasant Urban Square	Cluster 6 	Cluster 7 	Cluster 4 
	SW: 26.63; SL: 19.21; BH: 45.47; BW: 1.94; SB: 0.1	SW: 133.74; SL: 46.39; BH: 42.33; BW: 3.5; SB: 0.01	SW: 13.35; SL: 11.77; BH: 16.56; BW: 1.16; SB: -3.3

Table 4: 3 Highest and lowest rated clusters in the urban square scenario.

As with the streetscape clusters, the clusters representing the three most pleasant scenes from the urban square clusters *(Table 4)* differ greatly from the three most unpleasant scenes. At the same time, the three most often used clusters show a very similar looking scene. The three pleasant cases appear similar, but vary strongly in their absolute metrics. The length of the square, for example, differs between 71.76m and 29.35m, and the settings for the height of the buildings is very mixed ranging from 10.4m to 18.35m.

Looking at both the streetscape and the square scenes, the three pleasant clusters in the streetscape and the square scene appear similar. Both show a homogeneous scene with consistent proportions. Looking at the unpleasant clusters, one can see similarities between the clusters in the streetscape and the urban square: all six clusters were created using at least one or more extreme parameter settings, resulting in a scene where at least one parameter dominates the scene.

3.4 Correlation with visuo-spatial properties

In the last step, we investigated whether the produced results relate to visuo-spatial properties. Several studies suggest that such properties correlate with perceived enclosure (Stamps, 2005), spaciousness and complexity (Franz, 2005) or else landscape-openness (Weitkamp et al, 2014). The appeal of these properties is that they can be used to characterize spatial situations based on their visual appearance and without the need to introduce additional abstract categories such as height or width.

In this setup, we automatically determined the amount of visible sky, the amount of visible horizontal surfaces and the amount of visible vertical surfaces in every scene. This was done, using a self-developed grasshopper definition that used data from the *Collada*-3D-file of every scene. In order to calculate the measures, we decided to limit the field of view to 120°, according to the field of view in the *Oculus Rift*. 400 × 400 evenly distributed rays were used to calculate intersections with the geometry. Intersections with vertical and horizontal surfaces were filtered and split. All remaining rays represent the rays to the sky. The sum of vertical, horizontal and sky rays total 100%.

	Cluster 1	Cluster 5	Cluster 4
Pleasant streetscape	RS: 0.354; RV: 0.425; RH: 0.22	RS: 0.406; RV: 0.372; RH: 0.221	RS: 0.375; RV: 0.394; RH: 0.231
	Cluster 6	Cluster 7	Cluster 3
Unpleasant streetscape	RS: 0.06; RV: 0.719; RH: 0.22	RS: 0.507; RV: 0.236; RH: 0.257	RS: 0.597; RV: 0.157; RH: 0.246

Table 5: Amount of sky (RS), amount of vertical (RV) and horizontal (RH) surfaces for the three most pleasant and most unpleasant rated clusters in the streetscape scenario.

Table 5 shows that the three most often generated clusters are very similar in terms of their ratios. The only slight difference appears in the amount of visible vertical surfaces, which varies from 37.2% to 42.5%. Compared to the ratios in the three pleasant clusters, the three unpleasant clusters show very diverse ratios. The amount of visible sky differs from 6% to 59.7%. The amount of vertical elements varies from 71.9% to 15.7%.

	Cluster 2	Cluster 1	Cluster 5
Pleasant urban square	RS: 0.673; RV: 0.2; RH: 0.127	RS: 0.678; RV: 0.178; RH: 0.144	RS: 0.667; RV: 0,194; RH: 0.138
	Cluster 6	Cluster 7	Cluster 4
Unpleasant urban square	RS: 0.014; RV: 0.875; RH: 0.11	RS: 0.378; RV: 0.491; RH: 0.13	RS: 0.076; RV: 0.873; RH: 0.049

Table 6: Amount of Sky (RS), amount of vertical (RV) and horizontal (RH) surfaces for the three most pleasant and most unpleasant rated clusters in the urban square scenario.

As with the findings in the streetscape, the ratios in the urban square (*see Table 6)* show the same trends. In the three most often generated clusters the ratios are very similar. The amount of visible sky ranges between 66.7% and 67.8%. The biggest difference here again is the amount of vertical elements, varying between 17.8% and 20%. The ratios of the unpleasant streetscape are almost completely applicable to the ratios of the unpleasant urban square: the amount of visible sky varies between 0.14% and 38.8%, and the vertical surface ratios vary between 49.1% and 87.3%.

Evaluating both the streetscape ratios and the ratios resulting in the urban square scenario, one can see a tendency in which, independent of the absolute distances in the 3D scenes, the ratios are constantly distributed in a similar way when looking at each pleasant scene. In the unpleasant scenes at least at one parameter tends to be very extreme, either minimized or maximized. Since these ratios do not describe absolute distances, they are more generalizable and can possibly be used and confirmed in future research.

3.5 Estimation of sizes in the virtual environment

In general, estimating absolute sizes in Virtual Reality systems is reported as being very challenging (Loomis & Knapp, 2003). In our study, however, the participants' average estimation was almost accurate: the average width of the street was 36 metres (SD=8). The average height of the building with 13.3m (SD=4.6) was also only slightly underestimated. 48% of the participants were able to set the width of the street between 28 metres and 32 metres, 46% of all participants were able to set the height of the buildings between 9 metres and 11 metres.

It was slightly more challenging to set height, width and length in the urban square scenario. In contrast to the streetscape scenario the participants needed to change three parameters for the urban square scenario instead of just two. The ratio width and length of the urban square was on average precisely set to 1.01 (SD=.09). The average size of the square was set to 41 metres (SD=9.7m) width and 40.03 metres (SD=8.9m) length.

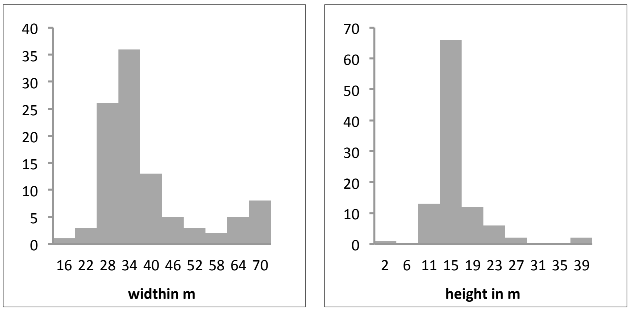


Figure 6: Distribution of streetscape width and distribution of building height in task 4.

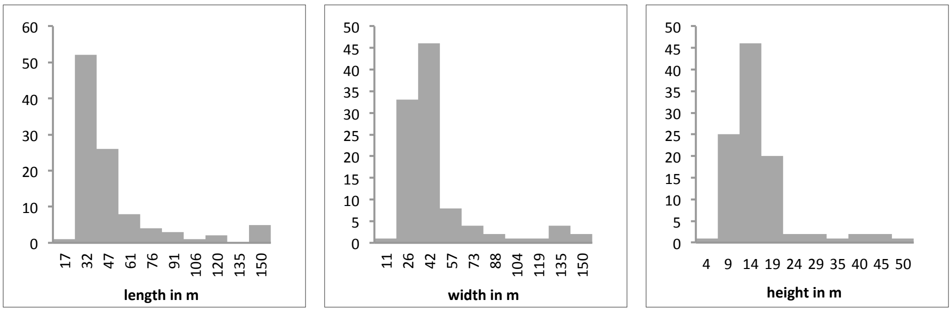


Figure 7: Distribution of length and width as well as building height of the urban square scene in task 8.

The height of the square was slightly underestimated, and was on average set to 13.3 metres (SD=5.9). Nevertheless, 36% of all participants were able to set the height between 9 metres and 11 metres. Interestingly, neither in the streetscape nor in the urban square was there a noticeable correlation between the ability to estimate sizes in the virtual environment and prior experience with 3D computer games.

Whereas during the rating tasks there was no noticeable connection between the resulting scene geometry and gender of the participants, in task 4 and 8, female participants succeeded far better in estimating absolute sizes. Female participants set the average dimensions of the urban square to 35.1m × 35.6m × 11.1m, whereas male participants were only able to set the dimensions to 47.2m × 44.2m × 12m. Similar results could be seen in the streetscape scenario, where females set the dimensions to 34.1m × 12.3m, whereas males were only able to set the dimensions to 38.5m × 15.2m.

4. Conclusions & Outlook

We conducted an empirical study based on Fechner's *Method of Production* to investigate the relationships between urban form and spatial experience. In order to achieve this, we created a new experimental setup allowing participants to easily create three-dimensional scenes in real time by adjusting five independent parameters. The setup was tested in two scenarios: a streetscape and an urban square. In this setup we showed an approach for analyzing the resulting complex data in three steps. After analyzing the distribution of the parameters for changing the scene we applied a clustering method to find similar parameter settings.

Results showed that there was a clear separation between pleasant and unpleasant scenes. Pleasant scenes appeared to be very homogeneous in all available parameters, while in unpleasant scene configurations one or more parameter was set to an extreme setting resulting in either a flat large scene, a narrow but extremely high or other extreme proportion. We were able to reproduce these outcomes by analyzing the relationships between the ratios of vertical surfaces, horizontal surfaces and the amount of visible sky. Our results also showed that the participants were able to more or less correctly estimate absolute distances in the VR System used, with only a slight tendency to underestimate.

Although, we have shown that the method presented here to provide useful, valid and reproducible data, there are some aspects we would consider for future investigations using this method: Firstly, it is only possible to analyze one item per scene. Compared to more traditional investigations that, for example, use surveys, we cannot ask the participant to create a scene based on more than one feeling at a time (here: pleasant-unpleasant). If we were to ask participants to answer more diverse questions, it would greatly increase time needed for participants to complete the test, which could result in other problems such as concentration fatigue. Secondly, we present only one possible way of analyzing the data. Other methods might be helpful in discovering more relationships between parameters. The results presented are also bound to the specific case and parameters used.

Future research should not only address these problems, but also investigate a way to validate the resulting data in more detail; for example by selecting scenes from this study, presenting them to another group of participants and asking them rate the particular scenes.

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