MICRO-SPATIAL ELEMENTS AND THEIR IMPACT ON SOCIO-SPATIAL BEHAVIOUR: A STUDY IN VIRTUAL REALITY

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Abstract. In the Global South, complex and multilayered urban public spaces rarely allow for an empirical understanding of the role of small, micro-spatial elements (such as raised thresholds, plinths etc) in social uses of public space. However, through the use of Virtual Reality (VR) systems and virtual environments, combinations of such elements can be tested and analysed with users to ascertain their relative ease of allowing socio-spatial interactions. Using a VR simulation of a public space in Delhi, the study examines the inter-relations of micro spatial urban elements on optional and social activities, and also assesses the relative importance of these elements in contributing to a person's ability to pause in a public space. The study documents socio-spatial interaction in a commercial neighbourhood market space through timelapse videography and identifies spatial patterns of congregation and the elements contributing to such. The space is then re-created as a 3D virtual environment, and different micro-spatial configurations are assessed by participants. Through a quantitative and qualitative analysis of such assessments, the research attempts to reveal how these elements may be used in combination to design robust and socially resilient public spaces.

Keywords. Micro-Spatial Elements, Assisted Design, Virtual Reality, Socio-Spatial Behaviour

1. Introduction

Urban spaces, especially in the global South, are characterised by complex and layered relationships between spatial form and social behaviour. These relationships have developed over time and through specific urban spatial typologies and configurations. They have, historically, responded to prevailing social dynamics, while also playing a major role in shaping the same. From the 'otlas' of North India to the courtyards of the Mediterranean- form and space have always acted as anchors of socio-cultural configurations and have perpetuated them in ways that have made the a-posteriori separation of the two realms very difficult.

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Given the complexity of such socio-spatial dynamics, the empirical analysis of such relationships has always remained an elusive task, and the act of designing such spaces has traditionally remained an intuitive act. Designers have relied upon their personal experiences and their own implicit understanding of the complex links between spatial form and social outcomes, in the context of such layered environments. With the increasing pace of urbanization in the South, it is important to have an empirical understanding of how even small urban spatial elements may exert significant influence on socio-spatial interaction.

There exists a large body of research relating to social activities and urban spaces (Whyte, 1980; Gehl 2011; Rapoport 1977) as well as research linking urban form with social linkages (Dempsey et al 2011, Mouratidis 2018). At the same time however, there exists relatively little research in empirically establishing the relationships between micro-spatial elements (such as raised thresholds, fixed seating alcoves, plinths etc) and social interaction, especially in the complex conditions of Southern urbanism. For this research, 'micro-spatial elements' were defined as immoveable, non-reconfigurable, non-structural urban elements which cover a larger surface area as compared to their depth or height. For example, while a wall covers a larger area comparative to depth, is structurally necessary for the building and hence not covered as 'micro-spatial' while a raised, extended plinth or steps in front of a building is fixed, non-configurable, non-structural and covers a larger area comparative to their height, making it a micro-spatial element. Material or Textural elements such as paving materials were not included in this research, due to their minimal volumetrics.

Recent advances in Virtual Reality (VR) systems have opened up powerful methodological avenues for controlled experimentation in this regard (Van Leeuwen et al. 2018, Meenar et al. 2020, Yu et al 2022). Immersive virtual environments allow for the systematic investigation of the impacts of specific micro-spatial elements on perceived socio-spatial interactions and pause spaces through simulations of urban spaces. Such simulations also allow for isolating these elements from the surrounding urban form, while showing them in various combinations within the same urban space. This allows one to get a user's assessment of the space specifically related to combinations of elements which has been difficult to do in past field studies) as well as exploring and assessing combinations not present at the site.

Using a virtual reality simulation of public spaces in Delhi, the study examines the inter-relations of micro spatial urban elements on specifically 'optional' and 'social activities' (Gehl 2011) as well as assessing the relative importance of these elements in contributing to a person's ability to pause in a public space. The study documents spatial interaction in a commercial neighbourhood market space through video documentation throughout the day. Spatial patterns of congregation and the elements contributing to the use of such spaces by people are identified. The space is then further documented and re-created as 3D virtual environments, and different micro-spatial configurations are assessed by participants who do not regularly interact with the spaces in question. Through a quantitative and qualitative analysis of such assessments, the study attempts to reveal how these elements may be used in combination to design robust and socially resilient public spaces where emergent activities can flourish.

2. Data and Methods

2.1. IDENTIFYING SOCIO-SPATIAL ELEMENTS IN PUBLIC SPACES

3 public spaces in New Delhi: a neighbourhood community center, a plaza at a retail mall and an urban village street, were chosen and documented through field visits, timelapse videos and participant observation. Timelapse videos allowed easy identification of urban elements which are conducive to pause as well as spaces of circulation and movement (Fig. 1) while field visits were used to document dimensions of urban elements, built-edge conditions and space enclosure. Based on the video documentation, the community center was found to offer the most diverse combination of micro-spatial elements and was thus selected as the test case for control experimentation.

Figure 1. Screengrabs from the timelapse videos collected at public spaces in New Delhi showing pause elements as well as movement spaces

From the field studies, movable elements such as benches, chairs etc were ignored as this study concentrated on permanent elements in the urban space which cannot be modulated, changed or re-arranged by users of the public spaces. From the documentation, 4 urban elements were identified to formulate combinations: **(a) Raised Plinth (b) Raised Planter Seating (c) Trees (d) Food Kiosks.** Further, 3 building edge conditions were identified at the ground floor, which also worked in conjunction with these elements: **(a) No Setback (b) Ground Floor Setback (c) A Colonnade.** These elements and built edge conditions were further modelled in Rhinoceros 6.0 to form a family of micro-spatial urban elements which could be added or removed in various combinations from the rendered VR space.

2.2. DATA COLLECTION FRAMEWORK AND TOOLS

2.2.1. 3-Dimensional Modelling and Virtual Reality Environment

The elements and the built environment were modelled (Fig 2) to form a 3-dimensional environment wherein the built features such as building height, enclosure ratio, façade elements and signages were kept constant and only the element combinations changed.

4 Element combinations were used for the experiments across 3 built edge conditions making a total of 12 micro-spatial combinations which were used for the experiments. The 4 element combinations were: **(a) No Elements (b) Only Raised Planter Seating (c) Raised Planter Seating with Trees (d) Raised Planter Seating, Trees and Food Kiosks.** The raised plinth was used as a part of all experiments but were only noticeable in the conditions with a colonnade or a ground floor setback. The model also simulated crowds in the physical environment through the addition of 2D representations of people in the movement spaces.

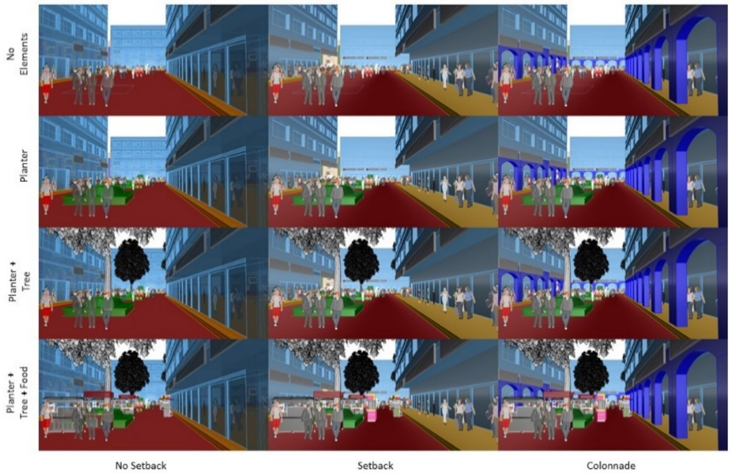

Figure 2:3D models of the 12 combinations urban elements across 3 built edge conditions

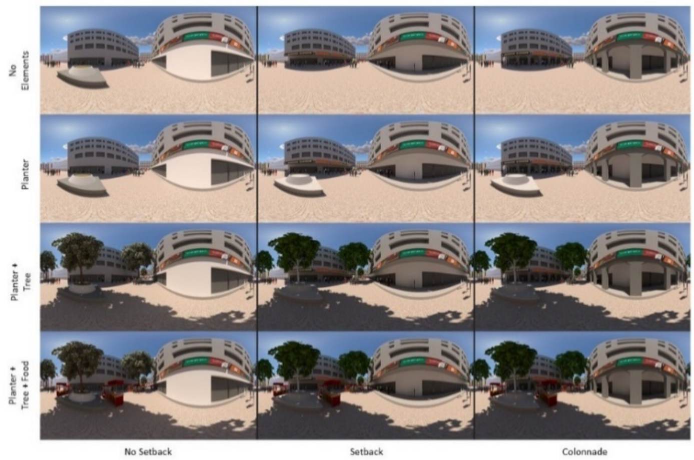

Figure 3: Spherical Renders for the Virtual Environment of the urban elements

Following this, each micro-spatial element combination was rendered as a spherical, 360-degree, stereoscopic Virtual Environment (Fig. 3) in a daytime setting, keeping the same viewing angle and eye height (1750 mm). The Virtual Environment simulated sunlight angles and intensities as per the average climatic conditions of New Delhi to closely simulate the experience of being outdoors in the city.

2.2.2. SCENARIO BUILDING

The methodology introduced 2 scenarios to participants in order to test the inter-relationships of these element combinations with (a) optional activities, and (b) social activities (Gehl, 2011). Participants were introduced to Prompt1 (Scenario 1) and asked to rate the micro-spatial combinations accordingly. Following a small break to counter VR-induced nausea or other adverse effects, participants were given Prompt 2 (Scenario 2) and asked to respond accordingly. The prompts were as follows:-

1. It is a lovely, clear, pleasant day. You are meeting your friend and have arranged to meet in this public space. You'll have not made any fixed plans or finalised any formal indoor space to meet in. However, upon arriving, your friend sends you a message that they will be delayed by 15 minutes.

If you are in this space, what will you do to spend the next 15 minutes? Where will you do it? How would you rate the space for this activity?

2. Now, your friend has arrived and they want to spend some time with you. Your friend suggests that, as it is a pleasant day, they would prefer to be outside.

Where and how will you spend your time with them? How would you rate the space for this activity?

The 2 scenarios outlined above were synthesised through the lens of Gehl's (2011) frameworks of 'necessary', 'optional' and 'social' activities. In the first prompt, the 'necessary activity' was initiated as the act of waiting. The participant would then have to describe the 'optional activities' they would do while waiting, which element (if any) is conducive to that and rate the space for the ease of doing the activity in. In the second prompt, with the addition of the 'friend', the activities became 'social' and the same questions were asked to analyse if any changes in rating are observed for the combinations. Through the phrase " a lovely, clear, pleasant day", the participant was informed of the assumed climatic conditions of the experimental space.

2.2.3. DATA COLLECTION

Figure 4: Head-mounted VR Displays used for the experiment.

15 students (8 male and 7 females), from a variety of regional backgrounds, participated in the study and were asked to rate a variety of element combinations, using the 3 built edge conditions noted. The participants are all recently migrated to the city and were not typically familiar with public spaces in New Delhi. This reduces 'familiarity' as a factor when taking ratings of socio-spatial behaviour with differing urban element combinations. Participants were also given time to familiarise themselves with the VR display and environment using a practice test before beginning the actual experiments. As shown in Fig 4, a head-mounted VR Display (Procus One) system was used to engage participants with the virtual urban environment and participants were asked to rate each combination of elements on a scale of 1.0 - 5.0, 1.0 being the least likely to be used for their particular activity and 5.0 being the most likely.

Qualitative, semi-structured interviews were conducted during the VR experiment with each participant to further discuss and analyse their experience, their behaviour in the experiment space and their interactions. The interviews were done at the same time as the participants were viewing the space to enable them to give their reasoning while viewing the virtual space. These interviews allowed for further qualitative input from the participants on their virtual experience as well as qualifying the reasons behind their ratings. Each environment was analysed by the participant for 60 seconds and the total time for each participant was approximately 30 minutes.

3. Discussion

3.1. PRELIMINARY DATA ANALYSIS

For a preliminary analysis of the preferences of subjects with regards to both scenarios, rating matrices (Fig. 5) were generated for the 2 prompts to map out the user evaluations of the micro-spatial element combinations. The matrices were compiled for the mean ratings for all participants, for all configurations across both scenarios. The initial condition (wherein no element is present in a space with no setback) was removed from the test scenarios, as initial interviews with participants revealed dependencies on façade elements, shop types, frontage porosity, architectural aesthetics and other subjective conditions beyond the scope of this study.

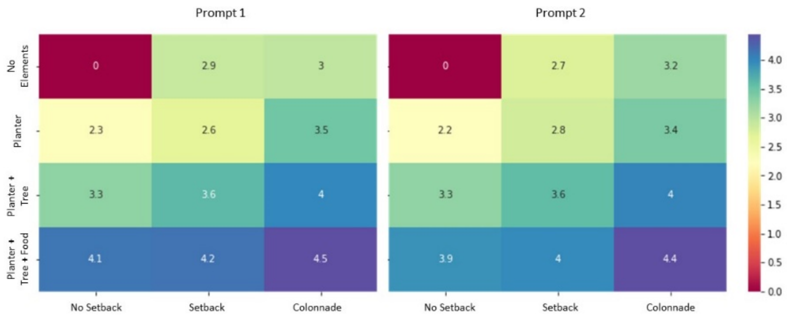

Figure 5: Correlation Matrices for Scenario 1(left) and Scenario 2(right)

The matrices revealed a clear pattern, whereby subjects assigned higher ratings to conditions which included multiple co-occurring elements, as compared to others with fewer ones. For both scenarios, a colonnaded built edge along with raised planters with trees and food stalls received the highest ratings out of all conditions. On the other hand, a built-to edge condition (no setback) without trees or food stalls received the lowest ratings.

The distribution of ratings across all conditions were also examined, to understand the degree of consistency and agreement across subjects for each condition (Fig. 6). This revealed that while some conditions (such as no-setback with only planter) had a very high consistency (low standard deviation), others such colonnades with planter had much lower agreement. There were also cases such as colonnades with planters and trees, where the degree of agreement was much higher in scenario 1, as compared to scenario 2.

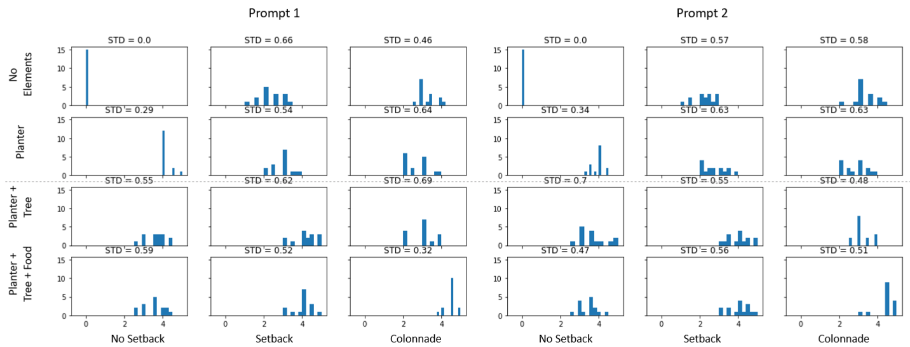

Figure 6: Rating distribution for Scenario 1(left) and Scenario 2(right)

On this note, preliminary analysis was also conducted to understand the degrees to which the same spatial conditions were rated similarly for both prompts. This was done to examine the extent to which different conditions were perceived to

be conducive for both scenarios. The ratings for the two scenarios across subjects were plotted against each other for all conditions, and regression analysis conducted to examine their coefficients of correlation (R values) (Fig 7).
The analyses revealed that while the built edges with setback showed consistent and significant correlations in ratings between the two scenarios (R = 0.51 - 0.67), the correlations for colonnaded built edges were much lower (R = 0.0 - 0.17). For the no-setback edge condition, the correlation appeared to depend on the presence of micro-spatial elements. The condition with food carts corresponded to a much higher correlation (0.65) as compared to the other conditions without them.

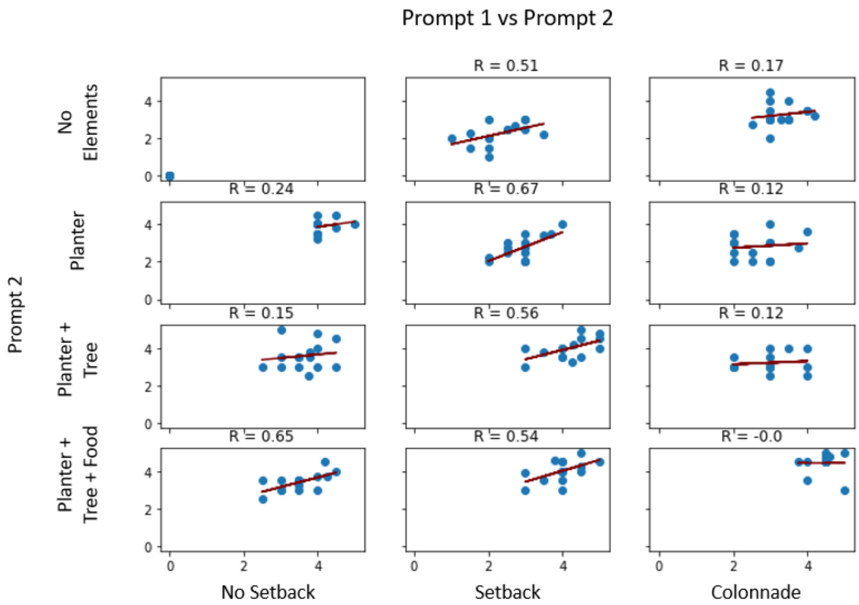

Figure 7: Scatter plots for ratings for scenario 1 vs scenario 2

4. Key Findings

From the collected data, the highest rated and most consistent combination of elements (across both scenarios) was the **Colonnaded Edge with a Raised Seating Planter, Trees and Food Kiosks**. Participants consistently qualified this space as "comfortable", "multi-functional" and a "variety of activities to do". The consensus was that **"it would be a space I would gladly spend time in".** Interestingly, a few participants (N=2) gave lower ratings to the combination when they were with friends ('social activity') as compared to their ratings when alone ('optional activities'). Their qualifying answers of "too many elements" and "appears too busy to sit with a friend" suggests that, for certain individuals, social groups and activities would change their perceptions of "pause space" and comfortable socio-spatial combinations.

Similarly, the lowest rated combination was **No Setback Edge with Raised Seating** element. This combination did not have Trees with the Seating Element. Participants consistently identified this space as a **"walkthrough"** space rather than a pause or waiting space. The primary reason given was often "lack of shading" and "not comfortable to spend time in". When analysed combined with 'social activities, this rating drops further, with **most participants responding that they would leave the space with their friend or go indoors to one of the retail shops** shown in the façade. This is a strong indication that seating elements, by themselves, are not conducive to socio-spatial interactions. The Standard deviation values for both the lowest and the highest rated combinations show high consistency across responses. (STD=0.23 to 0.32)

On average, for setback built-edge or colonnaded conditions, the collected data show higher ratings (ranging between 3.0 - 5.0) on element combinations involving trees, indicating that trees and their shading effect are important when considering pause spaces in this urban environment. This is further confirmed through their answers wherein "shading" and "shaded spaces" recur consistently. However, in a no-setback condition, these ratings become more dispersed and less clustered (ranging from 2.0 - 4.5). This indicates that the ability of micro-spatial urban elements to induce pause may be related to their proximity of the perceived primary movement paths (in this case, other combinations clearly showed a shaded walking path on the edge of the building, either in the form of a setback or a colonnade.)

On comparing the scatter plots (Fig 7) for both prompts, certain combinations such as Raised Planter Seating, Trees and Kiosks show strong correlations across both 'optional' and 'social' activities, regardless of the built edge condition. This indicates that this tri-partite combination of urban elements is particularly impactful towards making interactive, "pause spaces" and fostering socio-spatial interactions. However, other combinations of elements show a wide variation when compared as 'optional' to 'social' activities. While the correlation matrices show a general rating trend across combinations, the regression analysis for consistency across both prompts show us that many combinations have a wider dispersion between optional activities and social activities. While unspoken by the participants, this is indicative of perceptual differences in element combinations when people use public spaces for differing activities.

5. Opportunities, Challenges and Way Forward

Though in an initial stage of development, this paper attempts to empirically analyse the socio-spatial interaction qualities of micro-spatial elements within a VR-assisted mixed-methods framework. Due to the limited sampling size, this experiment may be regarded as exploratory rather than a confirmatory study. The indicative trends established in this study could be further explored and expanded upon by follow-up studies with a larger sampling size. Follow-up studies within common socio-cultural contexts could suggest further consideration of socio-cultural elements such as festival spaces, religious and cultural elements. Also, this study is limited to demonstrating people’s preferences for design elements through static VR environments. More immersive and interactive Virtual

Reality environments would allow for more diverse combinations of elements to emerge and create a more comprehensive family of micro-spatial elements.

In complex urban environments and diverse communities, such as in Indian cities, robust public spaces need to cater to a multitude of urban communities and need to be flexible while simplistic. However, design practices and planning strategies for urban experiences often run the risk of homogenising experience and relating them with singular urban elements while, often, ignoring combinations of elements that may lead to a more positive urban experience. Also, with the variety of informal systems and informal urban interactions which occur in Indian cities, formal design tools and strategies tend to be highly reductive. Most qualitative studies on informality in Indian public spaces tend to ignore the physical urban elements which foster or strengthen the informal uses of space.

Thus, an empirically established family of micro-spatial elements would be of immense relevance to contemporary design practices and demonstrate the importance of small, heterogeneous socio-spatial elements to larger urban planning and design bodies. This framework adopts contemporary assisted design methods to address this very issue in complex urban environments where the influence of groups of urban elements is often greater than the sum of their parts. As VR technology is getting more sophisticated over time, the experimental framework demonstrated here has a great deal of relevance in reaching and communicating with diverse, non-design communities in India and other areas of the Global South. Given the relatively realistic and immersive qualities of Virtual Reality, collecting and analysing user-specific behaviour through such a mixed-methods framework has immense potential for co-design and participatory processes in urban communities in Indian cities.

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