Understanding Retail Planograms through Virtual Reality-based Shopper Shelf Perception Analytics

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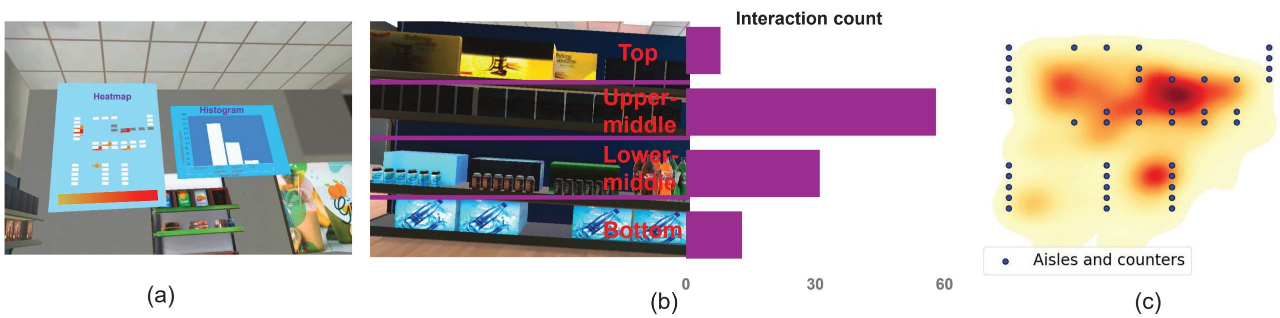

Figure 1: VR–based shopper shelf perception. (a) In-VR visualization of user interaction data combining a heatmap and histogram. (b) Interaction counts grouped by shelf level (top, upper-middle, lower-middle, and bottom) for all participants. (c) 2D heatmap showing user trajectories throughout the virtual store.

Abstract

This study explores how virtual reality (VR) can be used to evaluate the impact of planogram design on shopper behavior in retail environments. We capture multi-channel sensor data and build in-VR visualizations (spatial heatmaps and shelf-level histograms) to support rapid analysis of shopper behavior and inform planogram designs. The results show that product placement significantly affects shopper interaction. This suggests that VR-based shelf perception analytics can support strategic planogram design, particularly for improving the visibility and reachability of high-priority items.

CCS Concepts

• **Human-centered computing** → **Virtual reality; Interaction techniques**.

Keywords

Virtual Reality, Planogram, Virtual Retail Store, Shopper Behavior

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1 Introduction

A planogram guides how products are displayed on shelves to subtly draw shopper attention and influence purchasing decisions. Traditionally, the determination of the planogram is based on past sales data [2]. This process, however, is often time-consuming and labor-intensive, requiring repeated physical rearrangements of shelves. It also gives limited insight into how shoppers actually perceive products in real time.

Virtual reality (VR) offers a scalable alternative for planogram designs. It enables immersive simulations of retail environments where different planogram designs can be tested systematically. In VR, researchers and retailers can explore many layout variations without the manual effort of altering physical stores. VR also makes it possible to capture fine-grained behavioral data, such as dwell times and interaction patterns, which extend beyond what retrospective sales data can provide. However, existing studies on VR in retail often focus on shopper experience, presence, and engagement [3, 4]; VR's potential as a tool to study how planograms influence in-store behavior remains underexplored.

This study collects multi-channel sensor data from VR devices to investigate how users interact with products in a virtual retail environment. We present in-VR visual analytics (spatial heatmaps and shelf-level interaction histograms) to potentially support rapid interpretation of behavior patterns and planogram design iteration. The collected interaction data and pilot user study demonstrate that the layout of the virtual store significantly influences which products users notice and ultimately choose to purchase. These findings suggest that VR-based shopper shelf perception analytics can help retailers design strategic product placement, particularly for high-priority products that benefit from increased user interaction. A demo video for the study is available online.[1]

2 Methods and Experiments

10 participants (7 male and 3 female, aged 20–33) were recruited for our IRB-approved study. We chose a VR store with multiple aisles and racks to resemble the layout of a real-world grocery store [1]. Each rack contains 4 shelf layers, with products such as drinks, chips, and chocolate bars distributed across shelves. Participants used a Meta Quest 2 device running Meta Horizon OS Version 76.0.

Participants were instructed to freely navigate the store and interact with products displayed on the shelves. Each participant was randomly assigned a starting location in the virtual store. Throughout the study, we automatically recorded interaction data from the VR system. Specifically, we logged: (1) *headset pose data*, including position and orientation sampled once per second; (2) *grab interactions*, capturing both the event of a grab gesture and the identity of the product that was picked up; and (3) *controller pose data*, including the three-dimensional position of hand controllers, recorded once per second, which serves as a proxy for hand position to capture interaction attempts even when a grab is not executed.

We evaluate two VR locomotion modes for each participant: (1) *walking-in-place locomotion*, where participants navigated the store using controller thumbsticks, reflecting situations where retailers may not have a dedicated physical space for VR experiences, and (2) *real-walking locomotion*, conducted in a 3m $\times$ 3m lab space.

After participants completed the virtual shopping task, they were instructed to click the checkout button at the virtual counter. They were then presented with two complementary in-VR visualizations to summarize their interactions: (1) *Heatmap and histogram combination* appears as two floating panels (as shown in Fig. 1a). The left panel contains a 2D heatmap, overlaid on a schematic top-down layout of the store floor. Interaction density is visualized using a yellow-to-red color gradient, with red indicating higher interaction frequencies. The right panel displays a histogram, which shows the distribution of grab interactions across shelf levels (i.e., top, upper-middle, lower-middle, and bottom levels). (2) *Tabular summary* lists the total number of interactions for each product variant.

After the experiment, participants completed a post-study questionnaire. The closed-ended section uses a 7-point Likert scale, assessing the clarity and ease of interactions (e.g., grabbing and selecting products) and the perceived influence of the planogram on product discovery and purchase decisions. In addition to Likert-scale items, participants responded to preference-based questions regarding the effectiveness of locomotion modes (walking-in-place vs. real-walking), as well as preferred visualization of their interactions (heatmap and histogram combination vs. tabular summary). Finally, participants provided open-ended feedback.

3 Results

We first analyze the interaction data automatically collected during the virtual shopping task. On average, participants paused for 8.7 seconds in front of shelves before grabbing products, suggesting deliberate examination of products prior to interactions. From Fig. 1b, 80.9% of grab interactions of all participants took place on the lower-middle and upper-middle shelf levels, and products placed on the bottom shelf level accounted for only 7.3% of total interactions. This reflects users' preference for products positioned at or near eye level. From Fig. 1c, within the VR retail store, users' movements were concentrated in the center of the store and near the checkout counters, while the edges and corners were rarely visited. This helps identify regions that require additional advertising or other promotional measures. The results highlight the importance of planogram design, where product visibility and ergonomic accessibility play key roles in shaping consumer behavior.

Questionnaire responses show that 50% of participants strongly agreed and another 40% agreed that the layout of the virtual store influenced which products they noticed and decided to purchase. Most participants (90%) found the interactions (e.g., grabbing products and pressing checkout buttons) easy to understand and follow. In terms of interaction visualization, 50% of the participants favored the heatmap and histogram combination, 40% liked both formats, and only 10% preferred the tabular summary. This may be because the heatmap and histogram are more intuitive and visually informative, making it easier to interpret in-store behaviors at a glance. Open-ended feedback further supports these findings: "It showed which aisle I spent the most time in and what item I frequently looked at, giving insight into what grabbed my attention" (P7); and "I tend to choose products that are easier to reach, and the location of the products affects my shopping decisions" (P8).

4 Conclusion

This study investigates how VR-based shelf perception analytics can reveal shopper behavior in virtual retail spaces. Our results show that product placement greatly influences user attention and selection, and that intuitive in-VR visualizations help shoppers understand their shelf perception and highlight regions of high and low shopper engagement within the store.

Acknowledgments

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References

[1] Bright Vision Game. 2024. Grocery store environment. Available at: https://assetstore.unity.com/packages/3d/environments/landscapes/grocery-store-environment-hq-288645.
[2] Arun Chandramouli. 2019. Inventory analysis and planogram dashboard development: Retail industry insights. *International Journal of Science and Research* 8, 9 (2019), 1849–1858.
[3] Yu Sun, Luca Nivini, Gian-Luca Savino, Florian Mathis, and Johannes Schöning. 2024. Designing grocery shopping experiences for virtual reality. In *Proc. ACM AVI*.
[4] Nannan Xi and Juho Hamari. 2021. Shopping in virtual reality: A literature review and future agenda. *Journal of Business Research* 134 (2021), 37–58.

[1]https://youtu.be/gD1hg1Qw9FA