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Personalised Adaptive Aisle (PAA) for Viewability and Reachability of Products in VR Shopping Environments

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ABSTRACT

To improve users' tendency towards shopping in Virtual Reality (VR), en-hancing the User Experience (UX) of the VR shopping environments is of primary importance. Product viewability, reachability, and personalisation are some of the primary UX factors in a shopping environment. This paper proposes and discusses three factors for a Personalised Adaptive Aisle (PAA) in a VR shopping environment to improve the shopping experience. They are 1) Shelf placement for viewability and reachability, 2) User view-point in VR, and 3) Personalised Product placement.

1. Introduction

Virtual Reality (VR) technology is used in several areas, such as entertainment, advertising, product design and display, construction, and tourism. Shopping and retail are among the most promising application areas of VR in a business context [20].

Although VR shopping still needs to be widely adopted, it could fill the gaps in standard online shopping using a web browser. VR shopping could improve customer satisfaction and experience and become a more popular online shopping method [1]. Global retail companies, e.g., IKEA, Nike, and BMW, have tried to embed VR into their online services and transform their shopping ecosystem [25].

In a physical offline store (brick and mortar), a good and consistent layout can attract customers to move around the store and buy more products than originally intended [2]. The store environment is a major factor influencing customer satisfaction [12]; however, a complex and inconsistent layout can increase customer dissatisfaction [2]. Design and placement of shelves are the primary considerations for a store design; hence, retailers pay close attention to shelf space. Retail shelves are adjustable by varying the number of shelf boards and the height and depth of each shelf board [7].

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The current VR shopping environments are pre-defined and do not consider customer's personalisation concerning their personality. Due to this, these pre-defined VR shopping environments affect the customer experience. Future VR shopping experiences should cater to adaptive experiences that change in real time based on customer preferences [7]. Since there is a lack of research concerning adaptive aisles in a VR shopping environment associated with customer's preferences, an adaptive aisle in a VR shopping environment would improve customer experience.

This paper is still a work in progress. It proposes and discusses three factors for a Personalised Adaptive Aisle (PAA) in a VR shopping environment to improve the shopping experience they are 1) Shelf placement for viewability and reachability, 2) User viewpoint in VR, and 3) Personalised Product Placement.

1.1 Shelf Dimensions

When defining the space for each product, retailers need to consider the op-tions with shelf dimensioning. A shelf rack consists of different shelf segments. Each shelf board's depth, height, and vertical level define a shelf segment. Figure 1 shows the shelf rack consisting of the shelf board and shelves. Shelf segments with a larger height reduce the total number of shelf levels possible on a shelf rack; the deeper a shelf segment, the more product units can be stored [7]. Figure 1 shows the shelf rack consisting of the shelf board and shelves.

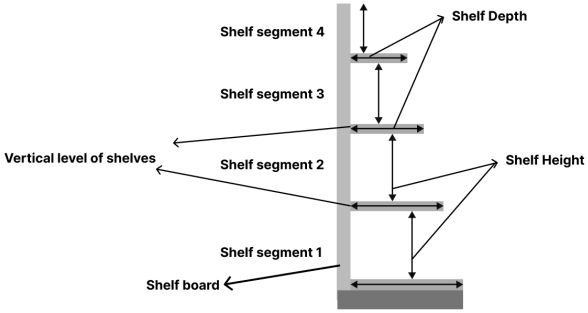

Fig. 1. The dimensions of a shelf rack

1.1.1 Shelf depth

An offline store shelf depth would differ from the VR shopping environment. The shelf depth in an offline store is deeper, so each shelf could store more product units, reducing physical restocking [7]. However, in a VR shopping environment, the shelf can have lesser depth as the virtual products can be programmed to restock by themselves.

1.1.2 Shelf height

Suitable shelf height is also important so customers can conveniently reach the products. In an offline store, based on the average user height of 1.6 metres, the maximum height for a customer to reach a product is about 1.8 metres. Anything higher than 1.8 metres may cause inconvenience to the customer and thus reduce their purchase intention. In an offline store, for a customer in a standing position, the height at which one can easily see most of the products on the shelf should be slightly lower than or equal to 1.8 metres. The shelf height most easily reached by hand is from the customer's waist to the chest. Therefore, it is observed that 1.5-1.7 metres is the most viable visible height of the products on the shelf, and 0.85-1.2 metres is the most convenient height to take

products from the shelves [26]. Figure 2 shows the standard aisle with the most viable visible and reachable heights.

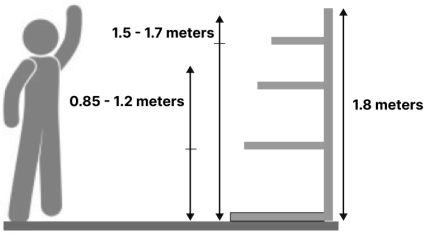

Fig. 2. Shelf height

1.1.3 Vertical level of the shelf board

The shelves are laid vertically on a shelf rack; the vertical level of the shelf is the segment's position (e.g., on eye level at 1.50 metres), and the total number of segments of each shelf rack is derived by selecting the height and vertical levels of the segments [1].

1.2 Customer viewpoint in VR

Similar to an offline physical store experience, customers in a VR shopping environment need to be able to view and reach out to products in the aisle. It has been observed that customers shop in a standing position in a physical offline store. However, in VR, customers can stand or sit [27] while shopping. In many computer and video games, a player, in most cases, will sit down on a couch while playing. The avatar's movements, such as walking and running in the game, are simulated even though the player is sitting [28]. Therefore, based on this premise, customers can be seated while shopping in VR as their avatar can simulate a standing position. This simulated standing position would have matched the standard aisle height above, which is convenient for viewing and reaching out to products in the VR shopping environment.

However, there will be an inconsistency between the customer's physical posture in the real world, i.e., sitting versus the simulated standing posture in the VR shopping environment. This inconsistency could impact the user's presence and sense of self-location in the VR shopping environment [18]. Therefore, to achieve a high presence in the VR shopping environment, the customer should be able to interact (or perform tasks) the same way as in the physical store, regardless of physical posture [10].

The standing position would affect the customer's comfort and satisfaction compared to a seated position. A seated position has been clearly shown to generate less fatigue, discomfort, and leg swelling than standing. A seated posture also provides more support and stability as it reduces imbalance and prevents falling over; hence, it is undoubtedly safer than standing while using VR. However, some customers would want to shop in the VR environment in a standing position, as standing improves alertness and is more active (28).

1.2.1 Seating versus standing in VR

Similar to an offline physical store experience, customers in a VR shopping environment need to be able to view and reach out to products in the aisle. It has been observed that customers shop in a standing position in a physical offline store. However, in VR, customers can stand or sit [27] while

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1.2.2 Influence of customer's physical height in VR

A point to consider is that a customer's viewpoint would vary for a standing and seated position with respect to the ground level due to the one's physical height (tall or short). Also, for a customer in a seated position, one's viewpoint would vary with respect to the ground level based on the height of the seat one is sitting on (high or low). This varying viewpoint would play a key role in the viewability and reachability of the products in the aisle.

There is quite a large height difference between a very tall person (183 cm) and a noticeably short person (140 cm) [15]. The chair's height depends on one's height, and the seat recommended for a customer 150 cm tall is 38 cm, and around 175 cm for someone 45 cm tall [22]. The height of a standing person to a seated one has a height ratio difference of around 54% [13]. For example, a short person 140 cm tall will have a seated height of around 76 cm. Based on this height factor, there will be variations in the customer's viewpoint in the VR environment. Figure 3 shows the customer's variation in viewpoint with respect to the shelves based on their seated or standing positions and their physical height difference.

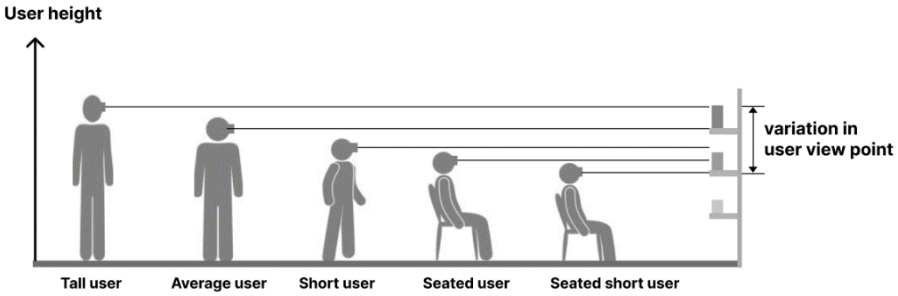

Fig. 3. Variation in customer's viewpoint

1.3 Personalised product placement

Based on the literature, products displayed at eye level are more visible, allowing more sales [23]. Products displayed at eye level are the most profitable buying location [3]. Figure 4 shows the customer's eye level standing in front of a standard aisle.

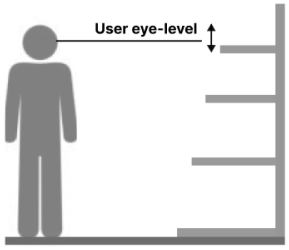

Fig. 4. Customer's eye-level

In a VR shopping environment, the topmost shelf at the user's first-person viewpoint level is considered a premium level. It should be used to display the personalised primary products based on the user's preferences, buying patterns and history. Other priority products can be displayed on the middle shelf, and the lower priority on the below shelf.

Also, in the VR shopping environment, the gap for grabbing must be considered for the customer to reach out to the shelves to pick products. The gap for grabbing allows customers to remove products from the shelf without disturbing the neighbouring products [7]. Hence, a standard gap between products on the shelf and a standard spacing between product clusters has to be maintained to improve customers' experience in a VR shopping environment.

2. Research Questions

This paper proposes three factors for PAA in a VR shopping environment. Some of the research questions are shown below to confirm the necessary factors. Experiments will be conducted where participants will navigate in the VR shopping environment, one with PAA and another without PAA, in a standing or seated position. The participants will view and reach out to the products in the aisle. Also, the participants will access their personalised products in the aisle. The participants will give their feedback through questionnaires concerning the product viewability and product reachability factors, presence factor and product personalisation after their exposure to the two VR environments.

2.1 Shelves placement for viewability and reachability

a) Can shelf placement in a VR shopping environment be improved for product viewability?

Experiment: The participants wearing an HMD will navigate the two VR environments (Non-PAA and PAA), and their product viewability factor will be measured in the experiment. The Non-PAA (Standard aisle) and PAA are the independent variables, and the product viewability factor is the dependent variable. Their product viewability factor will be measured based on the participant's exposure to VR shopping environments with the Non-PAA and PAA.

Hypotheses: The VR shopping environment with PAA will have a higher product viewability factor.

b) Can shelf placement in a VR shopping environment be improved for product reachability?

Experiment: The participants wearing an HMD will navigate the two VR environments (Non-PAA and PAA), and their product reachability factor will be measured in the experiment. The Non-PAA (Standard aisle) and PAA are the independent variables, and the product reachability factor is the dependent variable. Their product reachability factor will be measured based on the participant's exposure to VR shopping environments with the Non-PAA and PAA.

Hypotheses: The VR shopping environment with PAA will have a higher product reachability

2.2 Seating vs. standing in a VR environment

a) How can a customer in a seated position view and reach out to products in the aisle designed for someone standing?

Experiment: The participants wearing an HMD will navigate in the two VR shopping environments (Non-PAA and PAA); concerning the Non-PAA environment, the participants in a standing position will navigate in the standing position, and participants in a seated position will navigate in a standing position with their VR avatar and for a PAA environment, participants in a standing position will navigate in a standing position and a participant in a seated position will navigate in a seated position and will view and reach out to products in the shelves. Standing and seated positions will be the independent variables, and the product viewability and reachability factors will be the dependent variables.

Hypothesis: The participants navigating a VR environment with PAA will have higher product viewability and reachability.

b) How can a customer in standing and seated positions have an improved presence while viewing and reaching out to the products in the standard aisle?

Experiment: The participants wearing an HMD will navigate in the two VR shopping environments (Non-PAA and PAA); concerning the Non-PAA environment, the participants in a standing position will navigate in the standing position, and participants in a seated position will navigate in a standing position with their VR avatar and for a PAA environment, participants in a standing position will navigate in a standing position and a participant in a seated position will navigate in a seated position and will view and reach out to products in the shelves. Standing and seated positions will be the independent variables, and the participant presence factor will be the dependent variable.

Hypothesis: The participants navigating a VR environment with PAA will have a higher presence factor.

2.3 Personalised product placement

a) How can personalised products on the shelves be prioritised?

Experiment: The participants wearing an HMD will navigate in the two VR shopping environments (Non-PAA and PAA); concerning the non-PAA environment, the participants will navigate in the environment with the standard aisle without product personalisation on the shelves, and in a PAA environment, participants will navigate in the environment with PAA where the products in the

shelves will be personalised. Non-PAA without personalisation and PAA with personalisation are the independent variables, and the participant personalisation factor is the dependent variable.

Hypothesis: The VR shopping environment with PAA will have an increased personalisation factor.

b) How can products be placed on the shelves for easy picking?

Experiment: The participants wearing an HMD will navigate in the two VR shopping environments (Non-PAA and PAA); concerning the Non-PAA environment, the participants will navigate in the environment with the standard aisle, which would have the products placed on the shelves as per the standard product placement in offline stores and in a PAA environment, participants will navigate in the environment with PAA where the product placement in the shelves will have product gap for taking care of ease of picking in the VR shopping environment. The Non-PAA without a product gap in the shelves and PAA with a product gap for picking are the independent variables, and the ease of product picking is the dependent variable.

Hypothesis: The VR shopping environment with PAA will increase the ease of pick ability factor.

3. Design of the experiment

Based on the research questions in Section 2, two VR shopping environments, i.e., the Non-Personalized Adaptive Aisle (non-PAA) and the Personalised Adaptive Aisle (PAA), will be designed and developed as measuring instruments to measure the outcomes.

3.1 Non-PAA environment

The non-PAA environment will have a standard aisle height and shelves similar to the offline physical store. The customers will navigate through the VR environment in standing or seated positions. Based on the required first-person viewpoint for accessing the standard aisle, the customer will navigate in a simulated standing avatar relevant to the standard aisle, where one will view and reach out to products in the standard aisle.

3.2 PAA environment

The PAA environment will be based on the customer's first-person viewpoint from the ground level. The customer will navigate the VR environment in a standing or seated position and will view and reach out to personalised products in the personalised aisle.

Based on the literature review, we are adopting, from offline shopping environments, the best practices regarding shelf design for better product viewability and reachability for the VR shopping environment since the design and placement of shelves are the primary considerations for a store design [6].

In a VR shopping environment, a customer's eye-level standpoint would be the customer's first-person viewpoint. A shelf located at the customer's viewpoint as the topmost shelf would be ideal in the VR shopping environment. This is based on the abovementioned literature that 1.5-1.7 metres is the most easily visible height of the products, and 0.85-1.2 metres is the most convenient height to take products from the shelves [25]. Also, products displayed at eye level are the most profitable buying location [3].

As mentioned in the above paragraph, we propose the topmost shelf for the VR shopping environment from the customer's viewpoint. Two more shelves with equal vertical distance of 0.5

metres each below the top shelf with a total shelf height of 1.0 metres for better reachability as equal-looking shelves make orientation much easier and positively impact customer satisfaction and sales [6]. Figure 5 shows the customer viewpoint towards the PAA in the VR shopping environment.

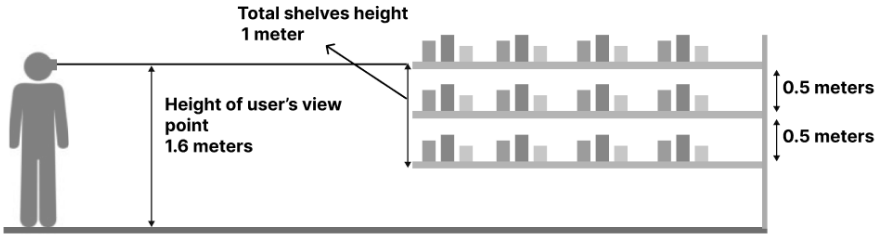

Fig. 5. Customer's viewpoint with PAA

3.3 Proposed shelf designs in the VR shopping environment

The proposed adaptive aisle with three shelves with a vertical height difference of 50 cm will be fixed to the shelf board. Based on the customer's viewpoint, the topmost shelf will align with one's viewpoint. The minimum viewpoint of the adaptive shelves, with the topmost shelf as the viewpoint, is 100cm with a maximum of 200cm.

Since the height of the shelf board will adapt to the customer's viewpoint, the topmost shelf attached to the shelf board will align with one's viewpoint.

Once set, the customer will be bound to this viewpoint while shopping in VR, and all the shelves will adapt to one's viewpoint. Figure 6 shows the shelf adaptiveness in the PAA in a VR shopping environment.

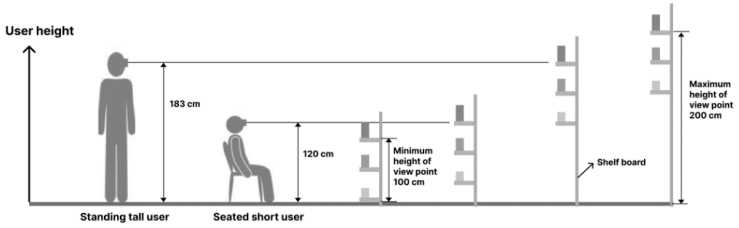

Fig. 6. Adaptiveness of the shelves in PAA

3.3.1 Shelves placement for viewability and reachability

Figure 7 shows the shelf placement in the PAA, three shelf segments with equal shelf heights, and the top shelf aligned to the user's first-person viewpoint. The total shelf height is 1m for easy viewability and reachability.

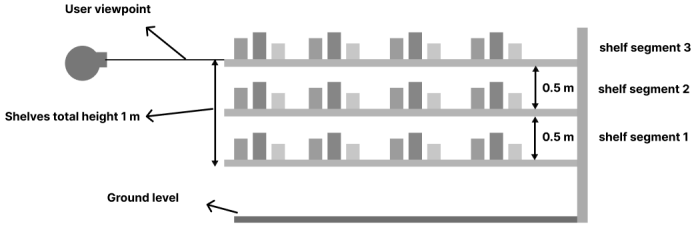

Fig. 7. Shelves placement for viewability and reachability in PAA

3.3.2 Seating vs. standing in VR (variation in user viewpoint)

Figure 8 shows the customers' standing and seated positions and varied height differences in front of a standard aisle height in a VR shopping environment (non-PAA).

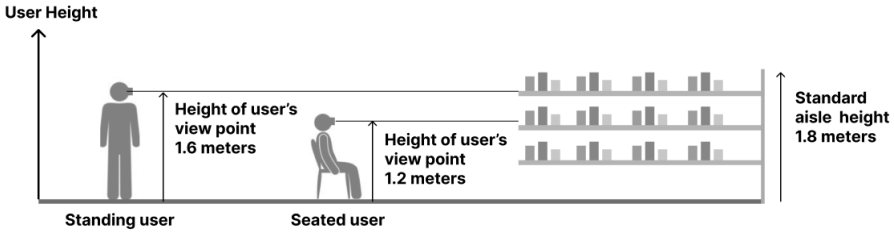

Fig. 8. Seating vs. standing in VR (variation in user viewpoint)

In Figure 9, the image depicts the users in standing and seated positions with their viewpoint height from the ground in front of the PAA.

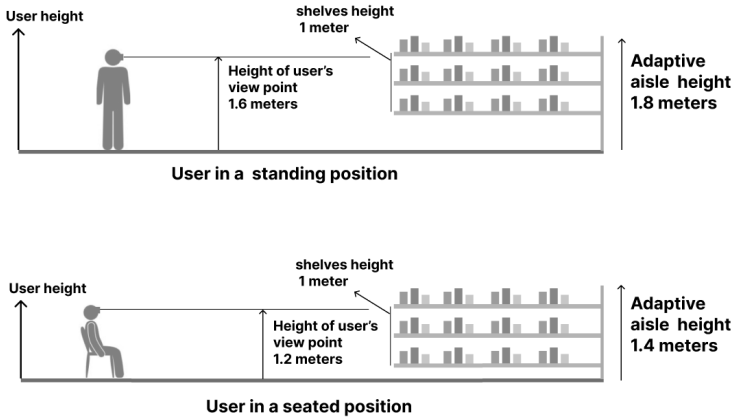

Fig. 9. Seating vs. standing in VR (variation in user viewpoint) with PAA

3.3.3 Personalised product placement

Figure 10 shows the depth of the shelves and the shelf segments with the priority shelf at the top for placing personalised products. Figure 11 shows the product placement on the shelves, depicting the spacing between product clusters and the gap between products for easy grabbing in a VR shopping environment with PAA.

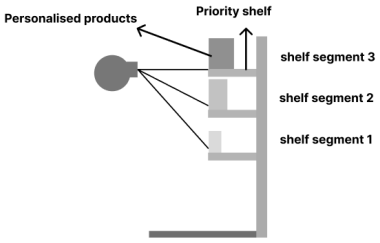

Fig. 10. Personalised Product placement (Priority product placement in PAA)

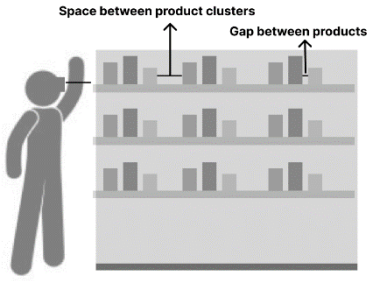

Fig. 11. Personalised Product placement (Product spacing in PAA)

4. The VR environment

In the experiment, two VR environments with suitable lighting and texturing are developed and displayed using the Meta Quest 2 head-mounted display (HMD). The products on the shelves are grabbable in the VR environment using the two Quest 2 VR controllers. Besides grabbing, the walking locomotion in the VR environment is done using the VR controllers. Figure 12 shows the user wearing a Meta Quest 2 HMD accessing the VR shopping environment in standing and seated positions.

The non-PAA environment is designed with the standard aisle with a shelf board height of 1.8m and four shelf boards with equal distance. Product viewability, reachability, and personalisation in the shelves are not considered in this environment.

On the other hand, in the PAA environment, the shelves adapt to the customer's viewpoint based on one's standing or seated position and physical height. In this environment, the shelves are reduced to three with equal distances to support product viewability and reachability. As discussed earlier, the products are laid on the three shelves to promote personalisation.

Fig. 12. A customer wearing the Meta Quest 2 HMD, standing (on the left) and seated (on the right), accessing the VR shopping environment

Figure 13 shows screenshots of the VR environment with the customer's first-person viewpoint at the centre of the standard aisle. It shows a difference between the customer's two first-person viewpoint positions in a non-PAA VR environment.

Fig. 13. VR shopping environment, standing (on the left) and seated (on the right) in the centre of the aisle, shows a difference between the customer's two first-person viewpoint positions in a non-PAA VR environment

Figure 14 shows screenshots of the VR environment with the customer's first-person viewpoint closer to the standard aisle. It shows a difference between the customer's two first-person viewpoint positions in a non-PAA VR environment.

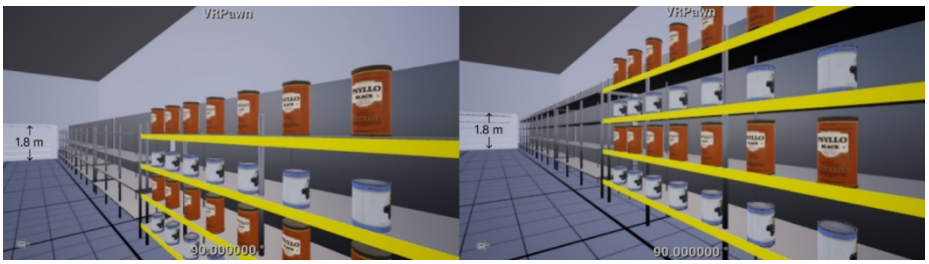

Fig. 14. VR shopping environment, standing (on the left) and seated (on the right) closer to the aisle, showing a difference between the customer's two first-person viewpoint positions in a non-PAA VR environment

Figure 15 shows screenshots from the VR environment with the customer's first-person viewpoint closer to the PAA VR environment.

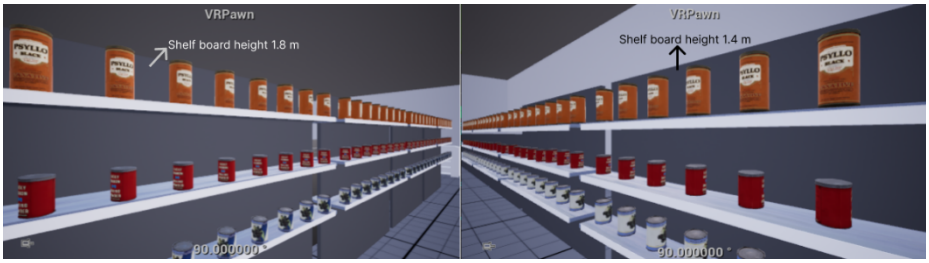

Fig. 15. VR shopping environment, standing (on the left) and seated (on the right), once the personalised adaptive aisle (PAA) is applied

5. Conclusion

This paper proposes three factors for a Personalised Adaptive Ailse (PAA) for a VR shopping environment by incorporating the best practices and user experiences from an offline shopping environment. The PAA offers the flexibility for the user to switch between standing and seated positions with improved product viewability and reachability factor and retaining the presence factor for either position. The user should be flexible in either position (standing/seated).

As discussed earlier, a standing position is recommended for an active state for improved health against illnesses linked to sitting for long times [27]. Also, many tracking systems propose users in a standing position [3]. On the other hand, the seated position has been shown to generate less fatigue, discomfort, and reduced motion sickness than standing, and the seated posture also provides more

support and stability [27]. Since the VR shopping environment is still evolving, this paper addresses the issues and concerns when trying to implement an aisle in a VR shopping environment where the aisle would be adaptive based on the customer's product viewability, reachability, and personalisation. We will continue with our work to add more factors that could affect the customer's experience in a VR shopping environment.

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