A Virtual Reality Shopping Experience using the Apartment Metaphor

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ABSTRACT

In contrast to conventional retail stores, online shopping comes with many advantages, like unrestricted opening hours and is more focused on functionality. However, these pros often come at a cost of complex search and limited product visualization. Virtual Reality (VR) has the potential to create novel shopping experiences that combine the advantages of e-commerce sites and conventional stores. In this work, we propose a VR shop concept where product placement is not organized in shelves but through spatial placement in appropriate locations in an apartment environment. We thus investigated how the spatial arrangement of products in a non-retail environment affects the user, and how the actual shopping task can be supported in VR. In order to answer these questions, we designed two product selection and manipulation techniques (grabbing and pointing) and two VR shopping cart concepts (a realistic basket and an abstract one) and evaluated them in a user study. The results indicate that product interaction using pointing in combination with the abstract cart concept performs best with regard to error rate, user experience and workload. Overall, the proposed apartment metaphor provides excellent customer satisfaction, as well as a particularly high level of immersion and user experience, and it opens up new possibilities for VR shopping experiences that go far beyond mimicking real shop environments in VR.

CCS CONCEPTS

• **Human-centered computing → User studies**; **Virtual reality**; **3D Interaction**;

KEYWORDS

Virtual reality, shopping experience, immersive virtual environment, 3D user interfaces.

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Figure 1: Virtual shopping environment using the Apartment metaphor.

1 INTRODUCTION

Online shopping bypasses many disadvantages of conventional stores like limited opening hours and is more focused on functionality. However, this focus comes at a cost, leading to limited search functionality and product visualization [17]. Most online shops only present products using text and images, while customers of physical stores can interact with products and view them from every side. Virtual Reality (VR) has the potential to create novel shopping experiences that combines the benefits of on- and offline stores [24]. Most of the existing VR applications try to simulate conventional stores without addressing the limitations of those shops. In contrast to physical stores, for example, there is no need to display multiple instances of one product in a VR shop. Therefore, VR shopping concepts need to reconceptualized and designed from a different perspective. Most shopping trips already start at home when customers create a shopping list. This can be done by physically or mentally inspecting their supplies at home. Thus, we propose an apartment as a shopping environment, where products are located where an average buyer would expect them to be.

Based on a pilot study on product placement in a virtual apartment, we designed and evaluated a VR shopping approach using the *Apartment* metaphor. We investigated two different shopping cart representations for our prototype: an isomorphic shopping basket known from physical stores, and a non-isomorphic concept. Isomorphism is defined as a "natural" mapping between the real world and the virtual environment [6, 28]. Furthermore, we assumed that the basket would increase the feeling of presence, because of its intuitiveness and familiarity, whereas the virtual sphere as shopping cart representation would outperform on user experience, workload and performance, mainly because it has no physics and the products could be added faster. We further explored two different approaches for the product interaction, i.e. selection and manipulation of the products. The first one is based on the concept of the Virtual Hand technique, and the second method is based on Interacting by Pointing. This motivates the following research question: Does the isomorphic concepts provide higher user preference due to their familiarity, or can the user adapt to the non-isomorphic methods?

To answer this question, we conducted a study to evaluate the user experience using two isomorphic and non-isomorphic interaction methods and shopping cart modes with regard to the VRSE model [24], including task performance and user's preference. In this study, the task goal was to search for a product in the virtual apartment, select and manipulate the product using different techniques (*Grab* vs. *Beam*) and put it into different types of shopping carts (*Basket* vs. *Sphere*). For each search trial, task performance has been measured including task completion time and error rate. Furthermore, each participant had to complete multiple questionnaires for each combination of carts and methods to measure the user's preferences concerning immersion, motion sickness, workload and user experience. Based on those scores, we conclude that using the laser beam to select the product (*Beam*) and a virtual shopping cart (*Sphere*) was preferred regarding user experience and workload, as well as being more efficient concerning error rate.

Since many existing VR stores try to simulate conventional store interactions, we instead compared an isomorphic shopping basket representation and virtual 3D product manipulation techniques with non-isomorphic approaches. The isomorphic concept represents shopping in a physical store holding a realistic shopping basket in one hand and grabbing products with the other. The non-isomorphic concept is designed to use the capabilities of VR, e.g. providing users with a "magic" laser beam for product selection and manipulation. Nonetheless, the results of the study indicated that our application had an overall good user experience, which was best for the combination of both non-isomorphic concepts. Henceforth, we can assume that the user successfully adapted to the methods. Hence, the main contributions of this paper are:

- **Development of a novel VR shopping concept** using the *Apartment* metaphor.
- **A study of a VR shop prototype** using the *Apartment* metaphor was conducted and evaluated with respect to task performance and user preference.

2 RELATED WORK

The investigation and evaluation of a VR shopping environment can be approached from different domains. Specifically we address (1) interaction in virtual environments, as well as (2) prior research and (3) commercial applications in the field of VR shopping.

2.1 Interaction in Virtual Environments

In this work, we investigated whether VR shopping should portray the real-life experience in virtual form, or design a novel type of experience that builds on the affordances of the virtual medium. We thus created two VR shopping concepts, based on isomorphic and non-isomorphic interaction techniques. In this context, isomorphism characterizes the mappings between movements in the real world and their effect in the virtual environment [6, 22, 28]. An isomorphic technique uses one-to-one mappings and is considered the most natural approach. To overcome limitations in the tracking space or anatomical constraints, non-isomorphic techniques allow users to select and manipulate objects using "supernatural" metaphors. Virtual 3D manipulation tasks, like product interaction in a VR shop, combine target selection and manipulation [6]. For the isomorphic shopping experience we used a selection and manipulation technique based on the hand metaphor [21], whereas the non-isomorphic experience uses an adaptation of an interaction by pointing technique based on a laser tractor beam metaphor [6, 10, 15, 20].

The essential characteristics of VR are interactivity, immersion, and presence [17]. Bhatt [2] examines the feasibility of bringing VR to e-commerce sites and concludes that the balance between the three characteristics is necessary and dependent on the circumstances. For example, in the fashion industry immersion is more crucial, whereas in the financial sector presence is far more important. However, as we focus on types of goods found in conventional types of stores (groceries, electronics, clothes, furniture, etc.) immersion and presence could be combined into one characteristic, i.e. to what extent the customer's senses are isolated from the real and stimulated by the virtual world and the subjective experience of being in one environment, but physically situated in another [27]. Walsh et al. [25] concluded that VR could address limitations of web-based shopping applications, expanding the range of e-commerce possibilities, which indicates that VR has the potential to create novel and rich shopping experiences.

2.2 Shopping in Virtual Environments

It is claimed that shopping in VR offers a better shopping experience than two-dimensional e-commerce systems [9, 29] and that 3D applications are feasible for e-commerce [1, 19]. Although more and more VR shopping environments have emerged recently, they are still very simple and immature. In most instances, physical stores are merely virtualized and digitized, i.e. 3D models of the products are placed in a 3D representation of a typical existing store (e.g. ShelfZoneVR[1], eBay[2], Macy's VR[3]).

To legitimate the need of VR in retail, Lee et al. [17] compared the user interface of a VR shopping mall with an online shop. Their results indicate that online customers remain passive observers, whereas in a VR shopping mall customers are engaged in the inspection and control of the 3D visualized target products. Moreover, VR customers can experience the product dimensions and information more richly and engage in a more interactive shopping activity. Buffa et al. [8] describe further advantages of 3D virtual stores in comparison to physical stores. They state that customers benefit from less time-consuming shopping, 24/7 opening hours and more product information.

In Shop-WISE [11], the user can pick up 3D products and inspect them. This system allows searching for products by text input and moves the user automatically to the desired product after it has been selected from a result list. Here, the fact that all products

[1] https://invrsion.com/
[2] https://vr.ebay.com.au/
[3] https://goo.gl/h22ezQ

have static locations makes the shopping experience more realistic. However, in their approach the user chooses a product from a text list without product images or models and without knowing if the product is the desired one, except by its title. But if the products are named or described with an ambiguous term the user fails to find them, they are forced to browse through a large number of products. Moreover, listing 2D product images is also insufficient for checking details and comprehending dimensions [24]. Ogier et al. [18] converted a diegetic (stock-on-shelf) store, which offers potential advantages like increased immersion, to a non-diegetic (list based) store interface and compared them in a game-like setting. The major drawback of stock-on-shelf interfaces is that the in-game size of the purchasable stock needs to fit in the in-game spatial representation of the store's shelves. But the store size cannot be increased without affecting the narrative. So they conclude that non-diegetic shop interfaces are not appropriate for VR applications; even simple non-diegetic UI elements can be disruptive and cause motion sickness. Therefore, we used a diegetic shop interface, which avoids stock-on-shelf by placing only unique product items, and has as few UI elements as possible.

In large retail stores (e.g. supermarkets, brick-and-mortar stores, etc.), products of the same category are located in one area. Thus, they lack search functions, and one of the most mentioned disadvantages of physical stores is the issue of "not finding" a product [24]. Anecdotal evidence suggests that customers store products of different categories at similar places at their home, e.g. food and cutlery in the kitchen. Magic Home [26] introduces a concept prototype featuring a VR furniture store, where customers walk inside a local physical store and try out the furniture they want to buy. In addition, customers can get a preview of the furniture inside a virtual representation of their home, which is connected to the store. So the customers can decide how well the furniture fits inside their home using the advantages of the virtual world, while for example sitting on a couch in the physical store. This approach inspired our *Apartment* metaphor. We used a virtual apartment as the shopping environment, instead of just rendering a 3D representation of an existing physical store.

2.3 Commercial VR Shop Applications

Commercial solutions are also appearing on the market. A very recent example, albeit not yet market-ready, is the VR department store created by eBay[4] in collaboration with the shopping chain Myer. Customers can browse through eBay's product categories using head pointing in a mobile app and a mobile VR headset (e.g. Google cardboard). The products are represented by rotating 3D models, along with some side information (e.g. delivery date and price). The major drawback is the limited interactivity, as only head pointing with dwell time for selection is used, which can limit the shopping performance and experience.

Another commercial approach for a VR shopping application is ShelfZoneVR[5], which is a retail space simulator reproducing physical shops. Customers can freely move through the store using "Point and Teleport" [7] and grab the products with the HTC Vive controllers using the Virtual Hand technique [6]. Here, the shopping environment is an exact representation of a physical store, where the shelves are filled with products entities. As mentioned before, the presence of multiple items of the same kind (stock-on-shelf) makes the store more complicated and increases unnecessarily the needed virtual space and store size [18]. However, we adapted their realistic product selection to evaluate and compare it with a non-isomorphic selection technique (laser beam [5]).

[4]https://vr.ebay.com.au/

[5]https://invrsion.com/shelfzone

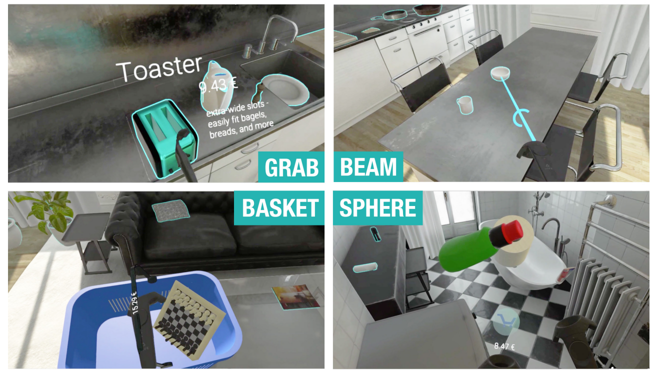

Figure 2: This figure shows the two implemented product interaction techniques (Grab, Beam), as well as the virtual shopping cart representations (Basket, Sphere).

3 CONCEPT

In this section, we describe the main parts of this work, including the implemented product selection and manipulation techniques, as well as shopping cart representations. Besides that, we describe system components like product representation, categorization and placement, navigation in the environment and the virtual apartment as the environment itself.

3.1 Product Interaction

In this paper, we present two implementations of interaction techniques to select and manipulate products in a virtual shopping environment. In the following we describe (1) the Grabbing the Product (*Grab*), as well as (2) the Laser Tractor Beam (*Beam*).

3.1.1 Grabbing the Product. Our isomorphic variant for selecting and manipulating a product in our VR shop prototype is based on the Virtual Hand technique [6, 21]. This concept utilizes a motion controller with a button, which triggers the interaction. In our case, the HTC Vive controller is held by the user's dominant hand and the grip button triggers the interaction. When the controller intersects with a product, it gets highlighted, which is visualized by a colored halo and by displaying the product's description and price (see Figure 2). Now, the user can grab the highlighted product by pressing the grip button, which hides the controller model. While the button is pressed, the product can be manipulated by moving and rotating the controller. The product can be dropped by releasing the button, and the controller becomes visible again. In summary, this is a classical example for isomorphic object selection and manipulation. Therefore, it should be intuitive and familiar for the user, because it represents everyday interaction with products in a store or at home. Nevertheless, the major drawback is that if objects are out of reach, it requires additional movement by the user and can therefore have a negative impact regarding performance and preference.

3.1.2 Laser Tractor Beam. The non-isomorphic counterpart uses the concept of interaction by Controller Pointing [14]. Here, the interaction is initiated by pressing the trigger button of the HTC Vive controller in the user's dominant hand. A product gets selected and highlighted when the blue laser beam intersects with it (see Figure 2). After a short dwell time (3s), visualized with a small indicator below the ray, the product is moved towards the controller analogously to the Tractor Beam metaphor [6, 20]. If the tractor beam phase has not been interrupted by releasing the trigger button, the product stops at some distance to the controller. Then, its position and orientation is now linked to the controller (see Figure 2), as in the grabbing technique, but here the controller remains visible. Here too, releasing the trigger button drops the product. The main advantage of this method is that the user can interact with products out of reach without extra physical movement. However, this method may be less familiar and intuitive to the user compared to the grab interaction. Furthermore, the pointing to the desired product becomes more complex the further away it is or when multiple products are close to each other or occluded.

3.2 Virtual Shopping Cart Representations

We also present two implementations of virtual shopping cart representations, in which the user can add selected products. In the following we describe (1) the Realistic Shopping Basket (*Basket*), as well as (2) the Virtual Shopping Sphere (*Sphere*) technique.

3.2.1 Realistic Shopping Basket. Concerning context-aware shopping experience [3], we claim that an integration of a virtual shopping cart is of crucial importance. The concept of our isomorphic cart representation is based on a real-world shopping basket. Here, a virtual basket is attached to the controller held by the user's non-dominant hand (see Figure 2). Products can be added to the basket by placing them inside the basket. The total price of contained products is displayed on the handle of the basket. Unfortunately, this representation is not fully realistic, because we had to overcome the problem of large products that do not fit into the shopping basket. So, larger products shrink in size when they come near the basket, which allows the basket to store many different products of different sizes (e.g. plants or televisions). The scaling is initiated when the product reaches a certain radius around the basket. Consequently, the product is scaled up to its original size when it leaves the trigger area. However, the number of products that can be stored inside the basket is still limited to its physical bounds. Nevertheless, this basket allows users to always have an overview of the current dimensions of their purchase, i.e. amount and sizes, in contrast to list-based carts in online shops. Furthermore, interaction with the products inside the basket is still possible, which allows the user to view the product information or remove a single product from the basket. We expect that this isomorphic concept of a virtual shopping cart representation will be more familiar and intuitive to the user, because of its similarity to an everyday shopping basket. Nonetheless, the physical properties of the basket may cause issues, such as accidentally losing products due to swinging of the basket.

3.2.2 Virtual Shopping Sphere. The non-isomorphic approach uses a virtual sphere object containing a shopping cart icon, which is placed above the non-dominant controller (see Figure 2). The "adding of a product" works differently than using the basket, where the user places the product physically inside the basket. In this method, the user places the product inside the sphere and releases the selection button to add the product to the cart. Then, if a product has been successfully added to the virtual cart, it loses its physical properties such as gravity (in contrast to the basket). The products inside the virtual cart are organized circularly around the sphere, where the radius is proportional to the number of products. Here too, products are scaled down when placed inside the cart, and the products remain interactive. The main advantage of this concept is the almost unlimited amount of products which can be stored and stacked around the sphere, because their sizes change dynamically if the number of products increases. Furthermore, the products are better organized than with the basket, where they are constantly "flying around" inside the basket because of their physics. Of course, the physics could have been disabled for the basket, but it should represent a realistic and isomorphic representation of a shopping basket. However, the non-isomorphic virtual shopping cart representation may be less intuitive and familiar for the user, which could affect immersion and user experience.

3.3 Virtual Environment

3.3.1 Product Representation. Each product in our prototype is visualized by a 3D model representing its real-world counterpart. To separate the interactive products visually from the environment, they are highlighted with a blue outline (see Figure 1). We used physics for every product, including gravity, and set appropriate parameters for every single product to increase immersion. To overcome accidental displacements, dropped products outside the cart "re-spawn" in its original location after five seconds. Every product offers detailed information like its name, a short description and its price, which is displayed if the user selects a product or uses an implemented info ray to allow the user to view product information from afar and without triggering a selection. The yellow info ray is triggered by pressing the touch pad button on the user's dominant hand controller.

3.3.2 Virtual Shopping Apartment. In the design of our VR shop concept, we wanted to improve search performance and maximize immersion. We thus focused on recreating the experience of a believable apartment. The apartment should create familiarity for the users to help them navigate through it and find the products faster than in a physical store. In order to navigate the environment, we used the current standard concept for movement in commercial VR systems, namely the "Point and Teleport" method [7]. All products are placed at locations inside the apartment based on the results of a short pilot study.

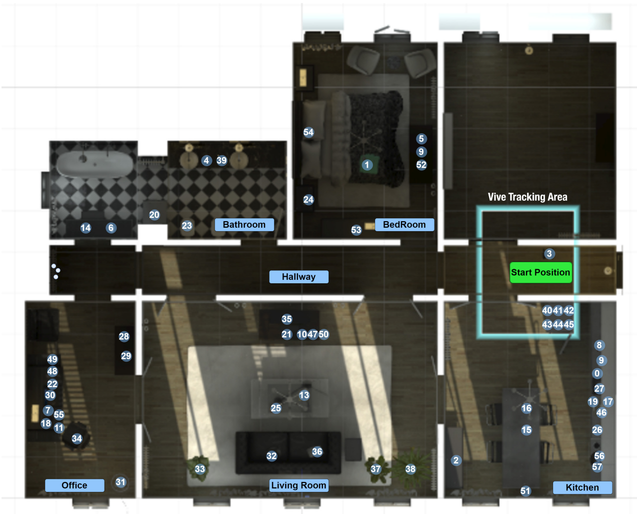

Figure 3: Apartment categorization and product placement.

3.4 Pilot Study: Product Placement

The aim of the pilot study was to develop a categorization scheme based on the Apartment metaphor to create a new shopping experience for future VR shop customers. This includes a standard apartment model as well as the product assignment. In addition, we wanted to overcome the everyday problem in supermarkets and online shops, namely searching for and finding of products. The pilot study ($N = 20$) was conducted as two short online surveys (5-10 min). In total, two iteration steps were conducted in order to successively create, review and refine the categories. In the first step, an initial apartment model was established, which was then revised and refined in the second step. Due to the results concerning product placement in a standard apartment, we addressed six room types as our shopping departments and distributed the products (the percentages indicate the number of times mentioned among the participants): bathroom (97.6%), kitchen (97.6%), bedroom (97.6%), hallway (88.1%), living room (83.3%), office (76.2%). Furthermore, a set of 60 products was assigned to our apartment model as part of the second step. This set of products is based on a dataset from a local retailer (on- and offline) of the current most searched products in a store. However, the pilot study indicates in which room and location (e.g. in the fridge or on the kitchen table) a product is expected in a virtual apartment. The participants' expected placement of products within a virtual apartment varies between different people, because not everyone has the same location in mind for each unique item. So to avoid multi-placement and to make the planned main experiment easier to replicate, we have chosen the most frequently mentioned product locations among the pilot study results (see Figure 3). The resulting apartment categories (or rooms) and product placements were used in the subsequent main experiment.

4 EXPERIMENT

We conducted an experiment to investigate VR shopping using the Apartment metaphor with respect to user performance, preference, and unmet needs. In this context, we evaluated two product interaction methods (*Grab* vs. *Beam*) and shopping cart representations (*Basket* vs. *Sphere*). Our main hypotheses were defined as:

- H_1 The task can be performed more efficiently using a tractor beam (Beam) and adding into a realistic shopping basket (Basket).
- H_2 Non-isomorphic interaction (Beam) is preferred over isomorphic interaction (Grab) with regard to user experience and task workload.
- H_3 Non-isomorphic cart representation (Sphere) is preferred over the isomorphic shopping cart (Basket) with regard to user experience and task workload.
- H_4 Non-isomorphic interaction (Beam/Sphere) is preferred with regard to user experience and task workload.

4.1 Participants

For the experiment 16 unpaid participants (4 female) were recruited from the university's campus; they were aged between 21 and 33 years ($M = 24.82$, $SD = 3.22$). The overall shopping frequency on different devices (PC, smartphone, tablet, supermarket), disregarding the type of goods, was rated on Likert scales from 0 (never) to 6 (several times daily). While they tend to shop more rarely on tablets ($M = 1.00, SD = 0.00$) or smartphones ($M = 1.80, SD = 0.75$), the majority prefer to shop in conventional stores ($M = 4.80, SD = 0.87$) or in online shops using a PC/laptop ($M = 3.60, SD = 1.11$). Furthermore, the participants were asked to rate the appropriateness of goods for VR shops on a scale from 1 (very relevant) to 6 (very irrelevant): furniture ($M = 2.20, SD = 1.17$), traveling ($M = 2.40, SD = 1.69$), real estate ($M = 2.40, SD = 2.16$), electronics ($M = 3.70, SD = 1.56$), clothes ($M = 4.30, SD = 2.06$), and groceries ($M = 6.00, SD = 1.35$). Finally, the average experience level with VR applications was rated rather low overall ($M = 1.9, SD = 0.88$).

4.2 Apparatus

The VR system used an HTC Vive and ran on a Windows 10 machine with Unity 5.5.4. A standard desktop computer was used with an i7 CPU, 16 GB RAM and Nvidia GeForce GTX 980Ti graphics. Besides experiment control, this PC was also used for filling out questionnaires by the participant. It is worth to mention that the frame rate of 60 fps was the same in all conditions. Two Vive controllers were used for interaction in the environment. The Vive lighthouses were installed about $2.5m$ above the ground in two opposite corners to span a maximum tracking area of approximately $4m \times 4m$. The participants were standing in its center while performing the tasks.

4.3 Design

The experiment used a within-subjects design with two independent variables having two levels:

- Product interaction (Grab, Beam)
- Shopping cart representation (Basket, Sphere)

Both conditions were counterbalanced using a Latin square. This amounted to 16 participants $\times$ 2 techniques $\times$ 2 carts $\times$ 10 product searches = 640 trials. Overall, 60 different products were evenly distributed all over the virtual apartment according to their most probable location, based on the results of our pilot study. In order to ensure equal conditions for every participant, all trials started at the same physical and virtual position. The participants received only minimal instruction about the functionality of the different interaction types, so that no explicit conceptual model was assigned to them. Performance (task completion time, error rate) and preference (task workload, user experience, motion sickness, immersion) were measured as dependent variables.

4.4 Task

In each task, the participant performed a product search using a combination of the two product interaction methods (*Grab*, *Beam*) and the two shopping cart representations (*Basket*, *Sphere*), see Section 3. The four tasks are consequently: *Grab/Basket*, *Beam/Basket*, *Grab/Sphere*, and *Beam/Sphere*. Each task starts with an exploration task followed by a search task. We chose an introducing exploration task without an explicit goal to browse the environment and obtain information about the rooms, orient the user to the world and build up knowledge. Besides that, in this training phase the user was able to get familiar with the interaction techniques and cart modes. Here, simple colored quads were randomly placed all over the environment to prevent memorizing the product locations. Each search task consisted of ten trials (product searches) in a row. Before each trial, the participant had to position herself in the center of the tracking area to ensure equal starting conditions. A trial was successfully completed when the target product was added into the cart within a time limit of 60 seconds, or counted as failed otherwise. The participant could travel through the apartment by using the standard Vive navigation techniques (natural walking within the tracking range, and teleportation).

4.5 Procedure

First, the participant was introduced to the experiment and signed an informed consent form. Then the experiment started with a 5-minute SteamVR tutorial to get familiar with the headset and the controllers, followed by a 5-minute exploration of the virtual environment, i.e. the apartment without any products, shopping carts or interaction functionality. In the main part of the experiment, the participant had to perform all four tasks in Latin-square order. Each task started with a short training phase of up to 5 minutes, in which the participant could familiarize herself with the selection and manipulation technique, as well as shopping cart. Then, in the actual task, ten search trials had to be performed. Before each trial, the name of the target product appeared for five seconds. Then the target had to be found and added into the shopping cart. After each task, the participant was asked to take off the HMD and fill out the post-task questionnaires to gather subjective feedback about the user's preferences, namely UEQ [16], NASA-TLX [13], MSAQ [12], and SUS [23]. Finally, a demographic questionnaire was filled out at the end of the study. The average duration of the whole experiment per participant was about 60 minutes.

5 RESULTS

We use the same abbreviations as in the concept: *Grab* and *Beam* for the product selection techniques; *Basket* and *Sphere* for the shopping cart representations; *Grab/Basket*, *Beam/Basket*, *Grab/Sphere*, and *Beam/Sphere* for the four tasks.

5.1 Performance

Task completion time was measured as the elapsed time in seconds to complete a single product search. The timer started when the countdown reaches zero and stopped automatically when the correct product has been added to the cart. We found no significant differences between the single tasks, the carts nor the selection techniques regarding speed: Basket lasted $16.84s$ ($SD = 10.11$) on average, whereas Sphere took $17.71s$ ($SD = 15.31$). Beam lasted $16.94s$ ($SD = 15.17$) and Grab $17.61s$ ($SD = 10.30$) on average.

All participants successfully completed all trials (finding and added all correct products into the cart within the time limit), regardless of the selection technique or cart mode. When looking closer into the number of corrections (i.e. the number of times a wrong product was added to the cart and corrected before trial ended), a univariate ANOVA analysis showed significant differences regarding the number of corrections between the cart modes ($F_{(1,636)} = 20.64, p < 0.01, \eta^2 = 0.05$), but none for the selection techniques. Sphere performed best with no corrections, whereas Basket caused 0.24 ($SD = 0.73$) corrections on average per trial.

5.2 User Experience

We chose the UEQ [16] as an end-user questionnaire to measure user experience (UX) in a quick and straightforward way. On a scale between -3 and 3 the overall UX was rated 1.40 ($SD = 0.64$) on average. Concerning the overall UX score, a univariate ANOVA showed significant differences between all four tasks ($F_{(3,636)} = 15.16, p < 0.01, \eta^2 = 0.06$). Beam/Sphere achieved the highest score ($M = 1.62, SD = 0.48$) and Grab/Basket the lowest ($M = 1.17, SD = 0.90$). Furthermore, cart modes ($F_{(1,636)} = 18.13, p < 0.01, \eta^2 = 0.03$) and selection techniques ($F_{(1,636)} = 27.28, p < 0.01, \eta^2 = 0.04$) also differed significantly regarding the overall UX score. Sphere was rated higher with an average of 1.50 ($SD = 0.54$) than Basket ($M = 1.30, SD = 0.71$) with respect to cart mode, whereas Beam was rated higher ($M = 1.53, SD = 0.46$) than Grab ($M = 1.28, SD = 0.75$) with respect to product selection technique.

However, the data was also subjected to a factor analysis, including the six UEQ factors Attractiveness (ATT), Perspicuity (PER), Efficiency (EFF), Dependability (DEP), Stimulation (STI), and Novelty (NOV); see Figure 4. Concerning these factors, a multivariate ANOVA showed significant differences between the cart modes with regard to ATT ($F_{(1,636)} = 13.53, p < 0.01, \eta^2 = 0.02$), DEP ($F_{(1,636)} = 68.63, p < 0.01, \eta^2 = 0.09$) and EFF ($F_{(1,636)} = 39.48, p < 0.01, \eta^2 = 0.06$), and in addition, between the selection techniques with regard to ATT ($F_{(1,636)} = 29.05, p < 0.01, \eta^2 = 0.04$), NOV ($F_{(1,636)} = 8.18, p < 0.01, \eta^2 = 0.01$), DEP ($F_{(1,636)} = 19.73, p < 0.01, \eta^2 = 0.03$) and EFF ($F_{(1,636)} = 69.56, p < 0.01, \eta^2 = 0.09$).

5.3 Workload

The task workload of the tested selection techniques and cart representations was assessed with NASA TLX [13]. Our system achieved an overall workload score of 32.42 ($SD = 20.38$) on average. Univariate ANOVAs showed no significant differences between the cart modes for overall workload, only between the single tasks ($F_{(1,636)} = 3.67, p < 0.01, \eta^2 = 0.02$) and selection techniques ($F_{(1,636)} = 9.05, p < 0.01, \eta^2 = 0.01$). Beam/Sphere was rated 29.77

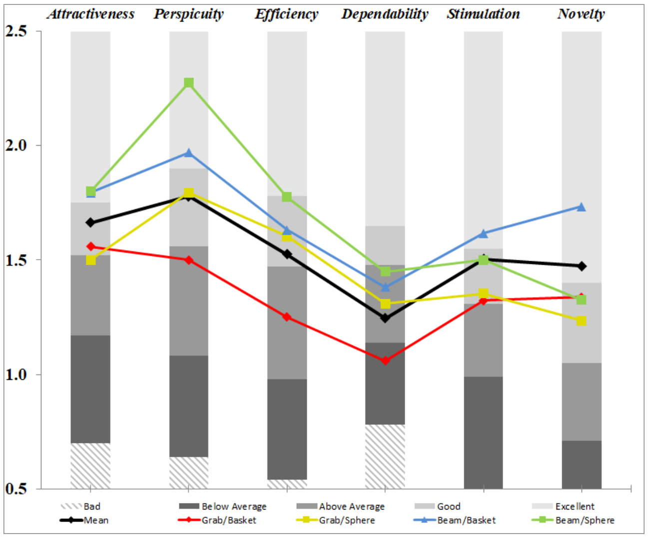

Figure 4: User Experience Questionnaire (UEQ) results with respect to comparison benchmarks (see shaded boxes). To make it easier to read, this figure shows a detail part between 0.5 and 2.5, while the original ranges between -3 and 3.

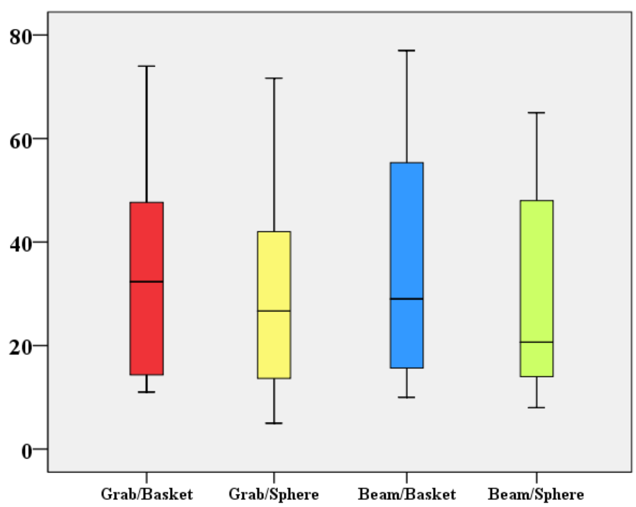

Figure 5: Results of the overall NASA TLX workload. In order to make it easier to read, this figure shows a detail part between 0 and 80; the original range goes from 0 to 100.

($SD = 19.44$) and Grab/Basket 36.26 ($SD = 22.49$) on average; (see Figure 5). As NASA TLX contains six subscales (MD: Mental Demand, PD: Physical Demand, TD: Temporal Demand, PF: Performance, EF: Effort, FR: Frustration), we conducted a multivariate ANOVA with regard to these factors. We found significant differences between the carts for FR ($F_{(1,636)} = 5.32, p < 0.01, \eta^2 = 0.02$), and between the techniques for PD ($F_{(1,636)} = 38.02, p < 0.01, \eta^2 = 0.05$), EF ($F_{(1,636)} = 14.17, p < 0.01, \eta^2 = 0.02$) and FR ($F_{(1,636)} = 21.66, p < 0.01, \eta^2 = 0.03$).

5.4 Motion Sickness

Motion sickness was measured with the well-established MSAQ [12] questionnaire. The system reached a total score of 16.83% ($SD = 6.53$) on average. There were no significant differences between the tasks (Beam/Basket: $M = 14.30\%, SD = 3.00$; Grab/Basket: $M = 15.00, SD = 4.20$; Beam/Sphere: $M = 15.14\%, SD = 3.00$; Grab/Sphere: $M = 15.28\%, SD = 4.13$) and the cart modes (Basket: $M = 16.71\%, SD = 6.31$; Sphere: $M = 16.95, SD = 6.74$) nor the selection techniques (Beam: $M = 16.89, SD = 6.00$; Grab: $M = 16.89, SD = 7.02$). A MSAQ consists of four categories (Gastrointestinal (G), Central (C), Peripheral (P), Sopite-related (S)); therefore, we conducted multivariate ANOVAs with regard to these factors. We found no significant differences between Basket and Sphere, but there was one between Grab and Beam for G ($F_{(1,636)} = 25.48, p < 0.02, \eta^2 = 0.04$). Moreover, interactions between the carts and techniques could be found for G ($F_{(1,636)} = 5.27, p < 0.03, \eta^2 = 0.01$).

5.5 Immersion

The immersion of the virtual environment was measured using the SUS questionnaire [23], where the participants were asked to answer six questions on a scale between 1 and 7. Here, SUS Mean is the average across all six questions (overall: $M = 5.06, SD = 0.95$), while SUS Count shows the amount of answers with 6 or 7 (overall: $M = 3.07, SD = 2.19$). For SUS Mean and SUS Count, no significant differences between the selection techniques or cart modes exist, nor are there any between the tasks. Regarding SUS Mean, Beam/Basket was rated with 5.13 ($SD = 0.76$) on average, followed by Grab/Basket ($M = 5.08, SD = 0.99$), Grab/Sphere ($M = 5.07, SD = 1.03$) and Beam/Sphere ($M = 4.96, SD = 1.00$), was considerably high. The SUS Count for Grab/Basket was rated 3.24 ($SD = 2.22$) on average, followed by Beam/Basket ($M = 3.12, SD = 2.00$), Beam/Sphere ($M = 3.06, SD = 2.24$) and Grab/Sphere ($M = 2.88, SD = 2.28$).

6 DISCUSSION

The study investigated two product interaction techniques (Grab vs. Beam) and two shopping cart representations (Basket vs. Sphere) in a VR shopping environment. In the following, we discuss the results with respect to task performance (task completion time, error rate) and user preference (user experience, task workload).

6.1 Performance

The experimental results showed that there was no significant difference between the selection and manipulation techniques or cart modes, so H_1 has to be rejected. Beam was expected to be significantly faster than Grab, because the participant does not need to navigate to the product. However, observations during the study indicated that Grab was slower when the product lay on the ground or above head level, because the participant had to stretch or bend. Moreover, we suspected the trigger volume as the main cause for Beam/Sphere being slower, although it could not be proved by the results. Observations and results indicate that the smaller trigger volume of Sphere might cause a speed loss, because the participant had to place the product inside the volume precisely, instead of just dropping the product into the basket. Consequently, when using the Beam/Sphere method the size of the sphere's trigger volume should be increased for a better task performance.

The analysis of the error rate metric showed that all search trials were successful, i.e. the participants collected all target products within the time limit. However, Basket caused more product corrections. Analyzing the affected product categories revealed that the corrections were caused by inconclusive product representations (e.g. similar-looking products like DVDs or books).

6.2 User Experience

Beam/Sphere achieved an "excellent" rating for Attractiveness, Perspicuity, and Efficiency, compared to the UEQ benchmark [16], as well as the highest overall user experience (UX) score (H_4). Nevertheless, this less realistic, non-isomorphic interaction performed slightly worse with regard to Stimulation and Novelty, in contrast to the excellent ratings for Beam/Basket. Overall, Beam was preferred over Grab (H_2). This could be explained by the notably better ease of use and the lower physical demand of the tractor beam interaction. In addition, Sphere was preferred over Basket regarding user experience, as expected (H_3). The gap in Dependability for all methods can be filled by introducing a conceptual model to the participant in the training phase or by clearer visual aids. These findings partly confirm that isomorphic interaction might be not the right choice for VR applications with regard to user experience (H_4), which is also attested to prior work [4, 6]. The fully isomorphic combination (Grab/Basket) even achieved good ratings regarding Novelty and Stimulation. The participants were obviously naive to this "natural" interaction technique in particular the representation of a realistic shopping basket and thus experienced it as uncommon, stimulating and novel in VR. Apart from that, Grab/Basket was rated just below average in Dependability, and even got the lowest rating in Efficiency. This could be explained by the participant's frustration when products are dropped unintentionally or unexpected behavior of the basket's physics.

Overall, Beam/Sphere had excellent ratings for Attractiveness, Perspicuity and Efficiency, and good ratings for Novelty and Stimulation. This indicates that the non-isomorphic conditions are the optimal combination for purchasing products in a VR shop with regard to UX (H_4).

6.3 Workload

As expected, Beam/Sphere had the lowest task load (H_4), and Basket turned out to be more frustrating than Sphere (H_3), whereas Grab was more frustrating and physically demanding than Beam (H_2). The NASA-TLX [13] results are in accordance with the UX ratings. The participants stated that using Basket was significantly more frustrating than Sphere, mainly because of the physics and limited space (or volume). So, as mentioned before, the physical behavior of the basket can cause unexpected behavior like unintended loss of products resulting in higher workload and frustration. Using Grab for product interaction was rated significantly more demanding and caused more frustration than Beam. The higher physical demand could be explained by the additional need to (physically) move to objects out of reach. Unintentional dropping of objects and picking them up from the ground additionally increased the frustration.

6.4 Limitations

As expected (see Concept 3), some participants had problem to find certain products, e.g. tissues were expected to be in almost every room in accordance with the pilot study placements. However, we decided to place the products at the most frequent locations in order to make the main experiment more controllable and reproducible. In addition, some participants remarked that the "Point and Teleport" technique negatively influenced the immersion. But they also admitted that this method might currently be the best option to address the limited walking space. For some similar looking products like DVDs or books, it was hard to decide which they had to choose. Here, the participants Nonetheless, these issues could be easily addressed in future work using multiple product placements and other travel techniques.

7 CONCLUSION & OUTLOOK

Current online shops may be functional and efficient, but do not provide an immersive shopping experience, whereas physical stores lack efficiency and functionality [24] (e.g. customers are often frustrated when searching for products in offline stores). This paper made an initial step towards more immersive virtual shopping environments. The proposed Apartment metaphor demonstrated the benefits of a combination of e-commerce, physical-inspired store environments and VR. In this respect, we investigated two product interaction methods (Grab, Beam) and two shopping cart representations (Basket, Sphere). The results show that Beam/Sphere outperforms the others in terms of error rate, user experience and workload, whereas Beam/Basket was the fastest.

Overall, the experimental results indicated that our system was rated high for immersion and user experience. To minimize motion sickness we would recommend to use Beam/Basket when designing a VR shopping environment, due to the better results regarding the gastrointestinal factor. Most of the participants enjoyed their experience with the VR Shop and showed interest in using it in the future. Thus, VR shopping has the potential to become a new shopping medium which combines the advantages of e-commerce and physical stores. However, this might not apply for all types of goods. The participants found the suitability for VR shops for electronics as above average, and very relevant for furniture, property or traveling. Moreover, a study comparing different settings, i.e. apartment, supermarket, outdoor, or office, as well as more focus on the product representation should be the next step in exploring interactive VR shopping experiences. While our concept for a VR shopping experience has the potential to improve the experience of consumers in electronic shopping environments, more research is needed in order to obtain a better understanding of the factors that determine the degree of usefulness of VR in retail.

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