VRtangibles: Assisting Children in Creating Virtual Scenes using Tangible Objects and Touch Input

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ABSTRACT

Children are increasingly exposed to virtual reality (VR) technology as end-users. However, they miss an opportunity to become active creators due to the barrier of insufficient technical background. Creating scenes in VR requires considerable programming knowledge and excludes non-tech-savvy users, e.g., school children. In this paper, we showcase a system called VRtangibles, which combines tangible objects and touch input to create virtual scenes without programming. With VRtangibles, we aim to engage children in the active creation of virtual scenes via playful hands-on activities. From the lab study with six school children, we discovered that the majority of children were successful in creating virtual scenes using VRtangibles and found it engaging and fun to use.

CCS CONCEPTS

• **Human-centered computing → Interaction devices**; • **Social and professional topics → Information science education**.

KEYWORDS

virtual reality, tangibles, touch input, children, education

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1 INTRODUCTION

Young children are commonly mentioned as examples of creative thinkers who create their own worlds and play with imaginary friends, which allow them to develop new skills or compensate for the skills they cannot demonstrate in the real world [15, 38]. Today's virtual reality (VR) technology allows a transfer of these imaginary worlds from imagination into an outside world of virtual reality. However, the process of creating new virtual worlds requires a technical background, which restricts the user group of active virtual world creators primarily to software developers.

The issues of a technical barrier are particularly challenging for children, who are usually exposed to virtual reality as passive users and miss an opportunity to become active creators. Although there has been a big body of work done to facilitate children's entry point into technology using physical computing toolkits [8, 32], tangible [3, 30, 36] and visual [13, 29] programming environments, and wearable computing platforms [20, 28], there has been little to support children's active participation in creating virtual reality scenes.

In this work, we aim to provide an intermediary step towards familiarization with VR as active creators by allowing non-tech savvy users, e.g., children, to create virtual scenes playfully without writing a code, and instead focus on creative expression. To facilitate the fun and quick creation of virtual scenes, we developed a virtual environment, where children can create virtual scenes while being inside the virtual world. From the interaction perspective, we have employed two interaction techniques to facilitate direct manipulation of virtual objects, known to children from daily interaction: (1) tangible input (from playing with toys) and (2) touch input (from playing with smartphones). We combined the virtual space and the interaction techniques in the system called VRTangibles, which includes a tablet, a set of tangible objects, and a virtual reality environment shown in the headset. Children can create virtual scenes by placing tangible objects on the tablet while wearing VR glasses and the virtual objects will instantaneously appear in the virtual world. To evaluate the effectiveness of the proposed system in facilitating children's familiarization with VR via hands-on activities, we collected preliminary findings from a user test with six children. We found that children were successful in creating virtual scenes using VRtangibles and found interaction with the system to be fun.

In this paper, we provide two primary contributions:

- We present the design and implementation of VRtangibles – a system aimed at lowering the barrier of entry to primary school children's in creating virtual reality scenes.
- We present and discuss preliminary findings from an empirical evaluation with six school children that offers a view into the future improvements for VR educational systems for children.

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2 RELATED WORK

Although there has not been much work about creating virtual scenes focused on children, researchers have designed support systems to create VR environments in general. In this section, we outline existing work related to (1) tangible objects and (2) touch input for VR content creation, followed by (3) educational technology for children.

2.1 Tangible Objects for VR Content Creation

Tangible user interfaces emerged a link between the digital and physical world, which in particular enabled the manipulation of digital objects using physical proxies [18, 33]. It was previously shown that people can better comprehend the manipulated information, when they physically interact with it, for instance, using tangible user interfaces [10]. Moreover, from the interaction perspective, tangible interfaces are faster for 3D manipulation tasks and more intuitive than mouse or touch interaction [5], which benefits spatial memory tasks [9].

In recent years, researchers facilitated the interaction in the virtual environment using tangible user interfaces, such as LEGO-proxies and 3D-printed objects, to extend the limited interaction experiences with standard VR controllers. A good example of physical manipulation in a virtual environment includes VirtualBricks. It is a LEGO-based toolkit that facilitates physical manipulation in VR by offering a set of feature bricks, which emulate and extend the capabilities of default controllers [1]. Using this toolkit users can build a proxy of a virtual object using LEGO bricks and operate a virtual object using its physical proxy.

In another toolkit, called TanGi, Feick et al. [12] added more flexibility to the interaction with tangible objects by introducing stretching and bending of 3D-printed objects in addition to translation and rotation. They showed that the 3D-printed proxies were quicker and more accurate in completing matching tasks, which required manipulating different parts of a proxy, compared to traditional controllers. Muender et al. [27] took a step further and compared LEGO-based proxies of virtual objects to their 3D-printed models. In the task of building and exploring virtual scenes aimed at architects, film, and theater-makers, they found that both 3D-printed and LEGO-based representation showed similar results in perceived grasping accuracy, performance, and haptic impression. Although the experts from their experiment mentioned a high benefit of the system and saw great potential for non-technical users, tangible objects have a limited precision for selection and manipulation of virtual objects, which we aim to overcome with touch input.

2.2 Touch Input for VR Content Creation

Virtual content creation is often a tedious and time-consuming task. To turn this task into a more joyful activity, Billinghurst et al. [6] introduced 3D Palette, which combines pen and tablet to create virtual scenes by drawing primitives on a tablet and visualizing them in 3D space, using widgets for parameter adjustment. Many recent works used a tablet as a supporting plane for sketching in virtual reality [2, 11] or as a slicing volume for 3D data selection [37]. However, usage of a tablet in a virtual environment was not only restricted to a single touch input in sketching tasks and was recently explored as a multi-touch device for 3D modeling tasks, such as selection, position, orientation, and specifying a path [26]. In our work, we aim to build on the successful usage of touch input combined with tangible objects, which together facilitate tactile feedback and precise object manipulation.

2.3 Educational Technology for Children

There is a broad body of work on educational technology for children, which includes several computational toolkits and programming environments [7, 21]. However, only a small subset of these is aimed at primary school children, despite the quick growth of the area [41]. Programming environments typically employ block-based interfaces, such as Scratch Jr. [13] and KidSim [35], tangible physical manipulatives, e.g., KIBO [36] and IoT toolkit [39], or hybrid environments [16] like Strawbies [17] in the design of these programming environments. Another group of toolkits, such as Cubelets [30], and LittleBits [3], have been increasingly popular with younger children due to the immediate sensory engagement [42], visibility, and concreteness [4]. More recent works employed VR environment to teach children programming [19, 31], however, they lack empirical evaluation with younger children and tangible interaction.

Compared to previous works which focused on toolkits for learning programming, we aim to provide children an introduction to the process of creating virtual scenes in real-time without writing a code. We focus on the encouragement of children's creative expression rather than learning a new programming environment and see it as a pre-step for programming. Perhaps the work closest to our own is CoSpaces Edu for kid-friendly 3D creation and coding [1]. It uses a drag-and-drop metaphor to place 3D objects in the virtual scene using a mouse and keyboard. After creating a scene, a child can put on VR glasses to see the results of her effort in the 3D space. With this, CoSpaces requires constant switching between scene creation and seeing a result in VR, and lacks the playfulness necessary to engage children in the creative process. This is where we see a benefit of VRtangibles, which we describe in detail in the following section.

3 VRTANGIBLES

VRtangibles facilitates an immersive interaction with a virtual world by allowing a user to be located in a virtual scene while creating it. It is enabled via a VR headset, a set of tangible objects, and touch input. In the following two subsections, we describe in detail both interaction concepts and the implementation of VRtangibles.

3.1 Interaction Concept

From the interaction perspective, VRtangibles consists of one output (virtual environment) and two input (tangible objects and touch input) components (Figure 2). The VR headset, which users wear throughout the whole time of interaction, plays a role in the instantaneous output for the input provided by tangible objects and a tablet. Tangible objects are used to create virtual objects in the scene and can be further granularly modified using touch input.

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[1] https://cospaces.io/edu/

Figure 1: Inputs of the VRtangibles: three tangible objects on the 3D-printed platform (left) and a tablet as an interaction surface (right). The tablet is overlaid with a VR interface. The tangible objects and a tablet are tracked in the virtual space using VR trackers.

3.1.1 *Tangible Objects.*

We employed tangible objects due to their learning benefits. As pointed by Klahr et al. [22, 23], using physical objects in a learning task might change the nature of the knowledge relative to that gained through interaction with virtual objects. Moreover, 3D shapes might ease the perception and understandability through the haptic and proprioceptive perception of tangibles compared to visual representation alone [14, 25]. Thus, we implemented the following interaction with tangible objects while creating virtual scenes.

After putting a VR headset on, a user is located in a virtual world, where she can add static, e.g., trees, and dynamic objects, e.g., cars, to the virtual scene using tangible objects. A user can create a new virtual object by touching the tablet's touch surface with a 3D-printed tangible object, e.g., an abstract tree, house, and car. For exploratory purposes, we chose these three types of tangibles to facilitate their combination into a single context of urban environment familiar to children. The initial instance of a virtual object looks like a tangible object and its properties can be modified using touch input. Virtual objects appear instantaneously after placing a tangible one on the tablet, similar to interaction paradigms in Nintendo [2], Lego Dimensions [3], and AwareKit calendaring system [24]. When placing multiple objects with the same properties on different locations, a user can use a tangible as a "stamp" and tap at multiple locations.

3.1.2 *Touch Input.*

The tablet's surface is mapped to the rectangular area with red borders in VR and represents an interaction surface and employs four modes of interaction: (1) scene control, (2) object modification, (3) trajectory creation, and (4) object deletion. A user can switch between the modes by tapping soft buttons on the physical tablet, which are mapped one-to-one in VR and are placed in the corners of both physical and virtual tablets (Figure 1 right).

Scene control. In the scene control mode, similarly to interaction with Google Maps [4], a user can move the virtual scene using single-finger swipe gestures or zoom in and out using two fingers. Moving the scene also allows the selection of a virtual object. The selected object is marked with a semi-transparent cube placed next to the object, which represents the middle point of the interaction area (red rectangle in the virtual scene) (Figure 3 right). To change the position of a virtual object in a scene, a user has to move the scene and change the middle point of the interaction area.

Object modification and deletion. When the object is selected, a user can change its color and type by tapping on the up-down and left-right buttons respectively (object modification mode), specify a trajectory for dynamic objects by drawing a path with a finger on the touch surface (trajectory creation mode) and delete it by tapping on the delete button (object deletion mode) (Figure 1 right).

Trajectory creation. We employed trajectory creation to allow the movement of virtual objects on the 2D surface. With this, we aimed to showcase one possibility to interact with dynamic elements in VR. In the trajectory mode, the object starts moving with a constant speed when a finger is released from the touch surface after drawing a trajectory. A user can start drawing a trajectory by touching anywhere on the surface. This mode also allows a simultaneous movement of multiple dynamic objects. For example, a user selects a car in the virtual scene, draws a trajectory for it and it starts moving in the scene. While the first car is moving, a user can select another car and specify a second trajectory and let the car move. One object is, however, restricted to a single trajectory. If users want to change an existing trajectory, they have to draw another trajectory for a selected object and the previous trajectory will be deleted. The trajectory is visually depicted in the scene and disappears when a dynamic object finishes the trajectory. Given that the trajectory is connected to the world, it moves together with it in the scene control mode.

Figure 2: Study setup: a child is wearing VR glasses as an instantaneous output for the input provided by tangibles and a tablet. New virtual objects are created by placing tangibles on the tablet surface and can be modified via touch input.

3.2 System Implementation

The current implementation consists of three tangible objects and can be further extended to a higher number. Each tangible object is placed on the 3D-printed platform (H = 11 cm), which contains a 3D-printed model on the top and a VR tracker on the bottom to

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[2] https://www.nintendo.com/amiibo/

[3] https://www.lego.com/en-us/dimensions

[4] https://www.google.com/maps

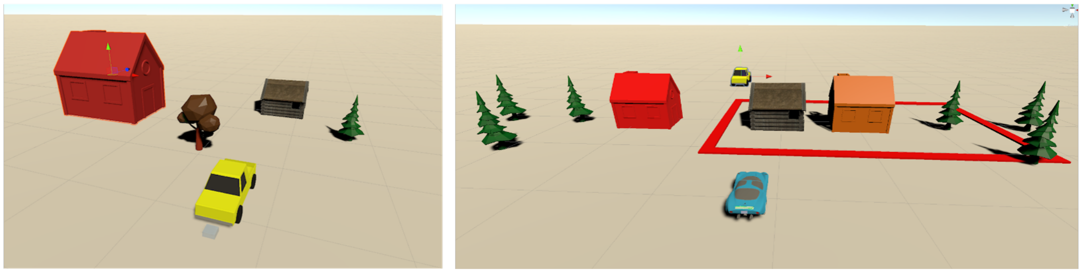

Figure 3: Overview of two tasks: a static setting (left) and a dynamic setting, where the cars had to follow provided trajectories (right).

enable visibility of the objects in VR (Figure 1 left). VRtangibles includes three generic tangible objects: (1) a tree (H = 7 cm), (2) a house (H = 6 cm), and (3) a car (H = 3 cm). As for the VR headset, we used HTC Vive with tracking 1.0 via two HTC base stations. The VR environment is implemented using Unity SDK (2019.4.1f1) and SteamVR assets. For the tablet, we used Samsung Galaxy Note Pro (SM-P900) with a 12.2-inch display, a resolution of 2560 x 1600 pixels, and Android 5.0.2. The data communication between the tablet and the Unity environment was enabled via Wi-Fi. Similarly to tangible objects, the tablet was tracked using a VR tracker, placed on top of the tablet (Figure 1 right). The virtual surface of the tablet was mapped to the VR tracker and was aligned with its physical surface. Similarly, the bottom of the 3D platform with tangible objects was aligned with its virtual surface. The intersection of virtual surfaces between tangible objects and tablets created a point, where a virtual object is created.

4 EVALUATION

We evaluated VRtangibles in the lab experiment and compared it to the state-of-the-art tool called CoSpaces Edu for kid-friendly 3D creation and coding [5], which employs keyboard and mouse interaction on the desktop and a drag-and-drop interaction concept. To this end, we recruited six children (3 male and 3 female) aged between seven and twelve (M = 9.5, SD = 1.9). One 12-years old child had previous experience with VR by trying out a demo in a shopping mall. Another 8-years old child had no previous experience with touch input devices due to parental restrictions. The rest of the children had no previous experience with VR, but use smartphones and tablets on an everyday basis.

The evaluation of the system consists of two parts: (1) creation of virtual scenes based on the provided descriptions using VRtangbiles and CoSpaces, and (2) free play with VRtangibles. The order of conditions with VRtangibles and CoSpaces in the experiment was counterbalanced.

We began with a brief introduction of the VRtangibles and CoSpaces to help children explore and familiarize themselves with both systems. This was followed by two tasks (Figure 3) and an unstructured free play part. For the first task (static setting), children had to create a virtual scene with two houses, two trees, and one car. For the second task (dynamic setting), children had to create a virtual scene with three houses placed in the middle, two forests (with three trees each) to the left and right sides from the houses, and two cars in the front and behind the houses. After placing the cars, children had to assign driving trajectories to the cars to bring them to movement. Children had to adjust the sizes and colors, and spatially arrange the objects comparable to the placement on the picture. Given the limitation of CoSpaces to create dynamic virtual objects and VR space, with CoSpaces children performed only the task in the static setting and could see the result of their work only after the scene was created. In the case of VRtangibles, the pictures with the tasks were placed in the virtual environment to avoid switching between the virtual and real-world, while with CoSpaces the task was printed on a piece of paper and placed in front of children.

After children finished both tasks, they freely explored VRTangibles to express their ideas. The study concluded with a brief semi-structured interview to help children showcase their creations and gather overall impressions. Additionally, we measured the task completion time for all the tasks, the number of times children switched between different tangibles and the task load (excluding the free play) by verbally asking them about each metric of the NASA TLX scale using language children can understand.

5 RESULTS

5.1 CoSpaces

On average children spent 255 s (SD = 88) solving the task with CoSpaces and reported an average score of 20.3 for the task load. Four children have successfully solved the task and two had minor difficulties in changing the color and scaling an object, because it was complicated (P2, F, 8 years old) and not intuitive (P1, M, 10 years old). As one child mentioned, *"It was easy to place a car and a house, but I forgot how to change a color."* [P1, M, 10 years old]. Additionally, two children (P2 and P5) reported problems with using a mouse, because it was new to them and they lacked experience.

5.2 VRtangibles: Static setting

Solving the first task with a static setting using VRtangibles took on average 698 s (SD = 169). The task load was higher than with CoSpaces (49.7) and led to changing a type of tangibles on average 9 times. Only one participant [P2, F, 8 years old] did not finish the task, because she unintentionally removed all the objects from the scene. The rest of the children successfully solved the task and had minor deviations in the mistakes they made, e.g., changing

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[5] https://cospaces.io/edu/

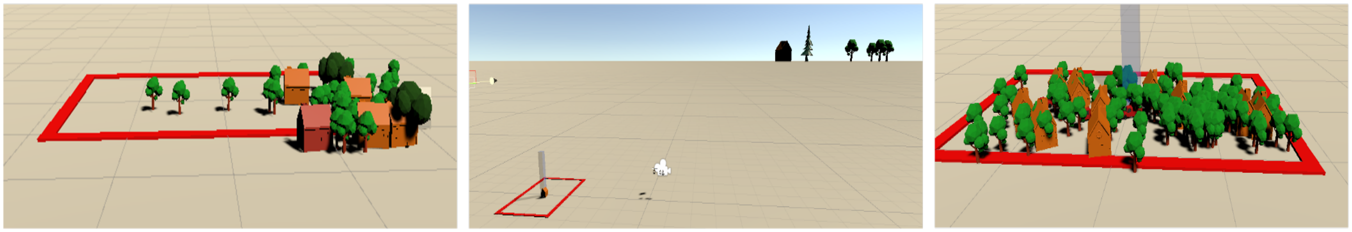

Figure 4: Free play examples: two children created their cities with parks and houses (left), two children scaled trees to their real size (middle), and two children who difficulties placed many objects by continuously “stamping” trees and houses (right).

the color or type of an object, and hitting the soft buttons on the tablet. All children, however, reported that they had fun interacting with VRtangibles. For example, P1 [M, 10 years old] mentioned: *“It was so much fun. Better than an actual school.”.* Children mentioned that they experienced higher immersiveness in the virtual world with VRtangibles compared to CoSpaces. As P4 [F, 12 years old] commented: *“It is very cool to see it before my eyes as if I were in this [virtual] world”.*

5.3 VRtangibles: Dynamic setting

The task in a dynamic setting was solved on average in 543 s (SD = 151). Participants reported an average task load comparable to the previous task (50.1) and changed a type of tangible on average 9 times. The same two participants (P2 and P5) who did not finish the task in the static setting had difficulties with this task and the experimenter terminated the task when no further improvements were observed. Four participants (P2, P4-P6) reported difficulties with moving and recognizing which object is currently selected. Additionally, P2 (F, 8 years old) mentioned that hair was restricting her view in the VR glasses and the VR glasses were too heavy, while P3 (F, 11 years old) forgot to make the last changes in the scene to solve the task completely. In the end, one child [P4, F, 12 years old] mentioned that she enjoyed being in the virtual world: *“I enjoyed being in the world and moving it. [It is] almost like looking from outside a window.”.*

5.4 Free play

The average duration for the free play was 257 s (SD = 108) and led to changing a type of tangible on average 5 times. All children enjoyed this task a lot and mentioned that it was fun. *“Nice task! It was cool to explore new stuff.”* [P5, M, 7 years old]. Although all children found interaction with mouse and keyboard easier, the free play part has demonstrated that all six children enjoyed it the most, found it more fun than CoSpaces, and felt freer to build whatever they wanted compared to the predefined tasks. Two children built new worlds, which looked like villages and cities, two other children scaled the objects to the real world sizes, and the remaining two who had most difficulties with the previous tasks used tangibles to stamp on the tablet as many objects as possible. The overview of examples from the free play is shown in Figure 4. Five (out of six) children found tangibles objects helpful in creating virtual objects because they *“feel natural”* [P1, P6] and *“grasping physical objects feels real”* [P4].

6 DISCUSSION & FUTURE WORK

We have shown that a combination of a VR headset with tangibles and touch input can successfully engage children in VR world and turn them into active creators of virtual scenes. Although children were on average quicker in creating virtual objects with mouse and keyboard, showed lower task completion times and task load index, all of them mentioned that they had more fun interacting with VRtangibles. We assume that this observation can be explained by a higher comfort interacting in the real world compared to a new virtual world, which might require a field evaluation with a longer familiarization period for children. All of our participants were new to virtual reality and some of them were feeling fatigued after wearing a VR headset for a long time. However, older children (e.g., P4, 12 years old) enjoyed a permanent presence in VR due to possible immersiveness and novelty. Only two children had difficulties understanding the interaction concepts, while the rest of the participants have successfully solved the tasks in both static and dynamic settings. Additionally, we found that children tend to switch more between tangible objects when they solve a predefined task and less when they play around and are free in their creative decisions. In this case, children might have felt less restricted in the free play and focused more on the virtual properties of the scene rather than adding new objects.

We see our work as a basis for familiarization with the VR environment and an approach to include non-tech savvy users in the active creation of virtual scenes. Admittedly, the current implementation of VRtangibles is restricted to three tangible objects, which can be further extended to a larger number of smaller objects. Dynamic interaction is limited to the creation of trajectories and can be further extended to jumping and flying. We aim to further extend the idea of the proposed system by integrating tracking of children’s hands using off-the-shelf VR gloves, e.g., Sensoryx VR gloves [6], and enable the creation of virtual models by scanning children’s own toys to facilitate personalized interaction. The question we ask ourselves is whether children still need additional physical proxies to create virtual scenes or operating directly with virtual objects will suffice. In our future work, we aim to evaluate the system with groups of children to study the suitability of the approach for collaborative learning [34] and communication over distance [40].

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[6] https://www.sensoryx.com/

7 CONCLUSION

We presented a design, implementation, and a preliminary evaluation of a system aimed at lowering the barrier of entry to primary school children's in creating VR scenes. Our results suggest that children gained an understanding of the basics of creating virtual in a playful way and showed a high level of engagement during free play. Given the rise of VR technologies and the complexity created by devices, our "ready to use" approach focuses on exposing VR concepts in an age-appropriate modern way and without requiring computer programming knowledge.

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