CUSTOMIZING THE FEATURES AND GESTURE ELICITATION ON OPEN BRUSH

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Fig. 1. Open brush (Available at https://github.com/icosa-gallery/open-brush/tree/main)

OpenBrush is a free software program that facilitates 3D painting. Several brushes and other tools are available in the open brush to make painting objects easier. The project's objective is to improve the software's usability by developing customized brushes that enable users to draw images more quickly and with fewer gestures. The custom brush gestures are aimed at improving eye-hand coordination and reducing the spatial and perception depth issues while sketching.

CCS Concepts: • **Custom Tools** → Leaf brush; Checkbox brush; Rectangle brush; Paw brush; Flower brush.

Additional Key Words and Phrases: Hand gesture tracking, VR limitations, Sketching tools, Gesture elicitation

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1 INTRODUCTION

The emergence of 3D open brush software technology has revolutionized how we manipulate and interact with the virtual world. Virtual reality, specifically open brush technology, provides users with a feeling of being part of the world they are creating and manipulating, resulting in increased creativity and instant feedback on their choices. Compared to a 2D screen, the 3D open brush technology offers a natural and intuitive way of interacting with the brush using gesture elicitation, which increases accuracy and provides a more desired user experience. Gesture elicitation invokes specific hand movements that trigger a response in the user interface or system, and it has been used successfully in domains such as 3D gaming and medical training for laser surgeries. In addition to the custom brushes, the open brush software offers a range of features, including color merging, new environments, and extra shape features like animals, that provide the user with a vast array of choices when interacting with the software. Our group has implemented several custom brushes, including a new checkbox and rectangle brush, to enhance the user experience. To compare the use of these new shape brushes with the base brush, we conducted an ANOVA test to compare the results of the base brushes with the newly introduced shapes. Aside from the ANOVA test our group conducted a gesture-tracking methodology to compare the patterns and hand movements or elicitation between base brushes and newly created custom brushes. This paper covers the hand gesture tracking methodology, which is a process of capturing and analyzing hand movements to detect and recognize specific gestures, and the limitations of 3D sketching in VR. Although 3D sketching offers unique and immersive ways to sketch, some limitations in precision, limited haptic feedback, software support or compatibility, limited accessibility to VR tools, and limited collaboration in an active 3D environment can exist. To address these limitations, the 3D sketching tools for our project include the tilt brush, a blender of sketching, animation, and modeling environment, which offers users the ability to create three-dimensional brush strokes and use their room as the canvas. Furthermore, our project has improved depth perception in relation to spatial awareness and also improved hand-eye coordination by sketching the images with a good gesture stroke mechanism and custom brush design.

2 RELATED WORK

Human civilization's lifestyle, production structure, and labor relations have all undergone significant changes as a result of the wave of information technology. This wave has also pushed society toward a new social philosophy characterized by three-dimensionality, diversity, and real-time[24]. Virtual reality (VR) enables data visualization in an immersive and engaging manner, and it can be used for creating ways to explore scientific data. [21]. Like smartphones and the Internet, virtual reality (VR) will be a highly disruptive technology[38]. Technology for virtual reality (VR) has undoubtedly changed how we interact with digital information and perceive our surroundings. VR has created new opportunities for entertainment, education, and other industries by submerging users in digital landscapes that mimic real-world experiences[36]. The increasing role of virtual environments in society, especially in the context of the pandemic and evolving metaverse technologies[19]. This work aims at adding more features to the Open Brush software to draw efficiently with fewer gestures. Below is the related work involved in the hand gesture tracking methodology and 3D sketching in VR limitations, 3D sketching tools and gesture elicitation in VR systems.

2.1 Hand gesture tracking methodology

Automated hand gesture recognition is an important technology that plays a crucial role in Human-to-Machine Interfaces (HMIs) and smart living.[26] With the ability to recognize and interpret hand gestures, computers, and other machines can be controlled without the need for traditional input devices like keyboards or mice. Researchers are working on tracking the hand gestures to improve the device's accuracy so that patients with impaired vision are supported by adding additional supportive tools. SketchingWithHands is a 3D sketching tool that uses first-person hand configuration to allow users to develop designs and models [17]. With the advancement of computer technology and hardware devices, human-computer interaction has now become a common element in our way of life. The use of gesture signals in this HCI piqued the curiosity as it is a great way to interact with the computer [2]. The use of hand gestures provides an attractive alternative to cumbersome HCI devices[33]. Gesture recognition has numerous applications: human–computer interaction (HCI), human–robot interaction (HRI), video surveillance, security, sports, and more[25]. By learning and analyzing the 3D motion state of the human hand, a more natural and efficient human-computer interaction environment can be created[14]. The tool tracks the user's hand movements and converts them into 3D sketches using computer vision and motion sensors. It is intended for handheld devices. It makes use of wearable data gloves, the most precise method for capturing hand motion. Optical tracking with RGB or RBGD cameras produces excellent results while tracking a single hand or two separate hands. Due to the sensitivity of optical systems to occlusions and self-occlusions, tracking both hands simultaneously with complex interactions with optical devices is quite difficult [28]. For precise hand tracking, the Hand Painter tool utilized VR gloves [29]. As our study does not primarily focus on hand tracking, we may simply use virtual reality (VR) gloves for tracking. For example, the Pinch glove is a device that includes five sensors, one in each fingertip, that can detect when any two or more digits come into contact and complete a conductive path. The device allows developers to define various actions based on these pinch gestures.To track the motion of each virtual hand within an application, the glove has a back-of-hand mount that can accommodate Polhemus or other sensors, providing a high degree of accuracy and flexibility. In addition, Virtual reality (VR) headsets and devices are a natural fit for creating immersive experiences and environments for users. These devices use advanced technologies such as high-resolution displays, motion sensors, and haptic feedback to create a realistic and interactive virtual environment.

2.2 3D sketching in VR limitations

Virtual reality (VR) can be defined as a computer-generated environment or experience that immerses the user in a simulated or artificial world. This environment is designed to replicate a real or imaginary space and can be experienced using VR headsets or other specialized devices. One of the defining features of virtual reality is its ability to encompass multiple senses, including sight, hearing, and, in some cases, touch. This creates a sense of presence or immersion that allows users to interact with and explore the virtual environment as if it were real. [16] VR can enhance virtual manufacturing by creating immersive and interactive environments for users to explore and interact with the virtual models. With VR, users can visualize and manipulate virtual models in 3D space, allowing them to detect and resolve design issues before they occur in real life [34]. 3D drawing is a good example of VR. The pursuit of meaning through painting is a process of embodiment, a silent dialogue between the self and the state of being. In virtual reality, 3D drawing can be realized.[29] The challenges of 3D drawing in virtual reality can be divided into two phases: the planning phase and the creation phase. Users encounter difficulties with their spatial awareness and depth perception throughout the planning stage. Depth perception issues have been recognized as affecting 3D sketching by Arora et al [4] by performing the experiment with 20 participants. These issues, in particular distance underestimation and differing targeting accuracy between movements in the lateral and depth directions, are well-known issues with stereo displays. While the user must take into account spatial relationships while sketching, they contribute to inaccurate 3D positioning of strokes. Another limitation of the VR system is stereo deficiencies. In a study by Barrera Machuca et al., 30 individuals used an HMD with varied degrees of stereo deficiency to perform a 3D pointing task in both AR and VR worlds. The study examined the participants' subjective experiences together with their accuracy and time to complete the task. The study's conclusions demonstrated that 3D pointing tasks in both AR and VR settings are strongly impacted by stereo defects in HMDs. Participants' accuracy was worse and their completion durations were longer with higher stereo-deficiency HMDs than with lower stereo-deficiency HMDs. Also, the participants claimed that HMDs with greater stereo defects gave them a lower subjective experience. The Open source tilt brushes to some extent handle the depth perception and spatial issues. Users encounter difficulties with eye-hand coordination in the creation phase. The 3D drawing demands greater physical dexterity as well as cognitive and sensorimotor abilities than 2D drawing was concluded after performing the user study with 28 skilled participants. The necessity to regulate more degrees of freedom during movement results in this higher effort [39]. The Visuomotor Coordination is Different for Different Directions in Three-Dimensional Space[35]. Specifically, movements in the vertical direction were slower and more variable than movements in the horizontal direction. Therefore the new brushes developed would aim for horizontal strokes than vertical strokes.

2.3 3D Sketching tools

Consumers and researchers are favoring new interaction technologies such as pen, voice, and vision over the traditional keyboard and mouse-based human-computer interaction.[13]In recent years, sketch-based interactive methods have become widely used in many retrieval systems, where users can input a sketch as a query and retrieve relevant results based on that sketch. Sketch-based 3D model retrieval has become an active research area, with various works being presented in this field. [37] For example, SketchUp 4.0 is the latest version of this popular, reasonably priced 3D sketching tool. In the early stages of 3D design, sketches are used to quickly conceptualize ideas and gain insight into problems and possible solutions[1]. With the advent of more accessible virtual reality (VR) and augmented reality (AR) technologies, sketching has the potential to become an even more powerful and easy-to-use content creation method [5]. The use of sketch-based interactive methods and sketch-based 3D model retrieval has opened up new possibilities for intuitive and user-friendly human-computer interaction, making it easier for non-experts to access and use 3D models. Early systems were involved in a technique called freehand 3D drawing which is just one-to-one mapping of body movements to the strokes for 3D drawing. These freehand 3D drawing has reduced accuracy. Researchers later started developing more complex and accurate sketching tools. Symbiosis Sketch was created to assist users to generate 2D sketches on flat surfaces and then extrude those designs into 3D space [3]. This technique helps users overcome depth perception problems. The earlier works that are discussed here were done on planer surfaces. Google created the tilt brush to address the challenge of depth perception on non-planer surfaces. The portable Tilt device includes a special feature that allows users to share and work together on creations.VRSketchIn is a 3D sketching approach that allows users to sketch 3D objects using a pen and tablet. The researcher conducted the user study using 15 participants. The user study's findings demonstrated that VRSketchIn outperformed conventional VR sketching tools in terms of speed and accuracy [11]. A free-form modeling method for VR settings is described by Schkolne et al [31]. Free-form triangulated surfaces are created in 3D space by hand movements. To collect data about hand orientation and position, cyber gloves are employed. Users can effortlessly shift their viewpoint by moving around their drawing using immersive 3D drawing tools. This quality is crucial because it allows users to build a mental representation of the object they are sketching by viewing a 3D object from various angles. Rock I.et al studied viewpoint shift by conducting research using 32 participants. The participants were asked to compare and visualize how three-dimensional items would appear from various angles. The study evaluated the participants' objective performance on the task, as well as their accuracy and response times. The study's results demonstrated that it is possible for people to mentally rotate items and picture how they would appear from various angles. Participants' ability to swiftly and precisely compare how objects appeared from various angles suggests that they had the mental capacity to move the objects. In addition, the subjects described having seen strong, tangible images in their minds [30]. The openBrush software has implemented the easy shift of viewpoint. By including spray brush tools and certain ready-to-use figures like birds, flowers, and other objects, we plan to improve the template features in the Open Brush software and make sketching simpler. A good set of brushes does a lot. It enables capable artists to create almost any effect imaginable, from the intricate details of flower petals to wispy billowing clouds, to the subtly blended shifting tones of a sunset [22].

2.4 Gesture Elicitation

To improve user experience (UX), gesture elicitation devices have arisen and are the source of numerous studies on multimodal human-computer interaction [12]. The most crucial instruments for interacting with the physical world are human hand motions[32].One of the main advantages of gesture interaction is that it reduces the cognitive load required to operate devices, making them more accessible to a wider range of users. Additionally, gestural interfaces can provide users with a more immersive and engaging experience, especially in virtual reality.In the domains of Human-Machine Interaction (HMI) and Virtual Reality (VR), 3D hand posture estimation can offer fundamental information regarding gestures[10]. The process of finding and creating hand gestures that are natural, effective, and simple to recall for carrying out tasks is known as gesture elicitation. The best gestures for a particular application must be determined by gathering information and user feedback. A gesture elicitation study uses a common technique for asking a sample of end users to suggest gestures for carrying out tasks in a specific context of use, as determined by the users' roles, the platform or device they are using, and the physical setting in which they are working [7].Gesture elicitation is a critical step in designing effective gesture-based systems. The goal of gesture elicitation is to create a set of gestures that are intuitive, easy to remember, and effective for performing a specific task. It involves recognizing the context of use, determining the tasks that need to be performed, and then working with the end user to generate a set of gestures that are natural and comfortable to perform.Gesture elicitation is the process of finding and creating natural, effective, and memorable gestures to accomplish a specific task. Gesture elicitation studies typically employ a common technique of asking end users to suggest gestures to perform a task in a specific context of use, based on the user's perspective, platform, or device being used, and the physical environment in which they are working.Few studies on gestural elicitation have taken additional body parts into account; the majority have concentrated on hand gestures [9].Gesture elicitation study is a different bottom-up strategy from conventional gesture design methodologies for locating and creating 'excellent' gestures for gesture-based systems [40]. Pérez-Medina, for instance, talks about a study on nose-based gestures for IoT tasks that included 12 male and 12 female participants. 912 nose-based movements associated with 19 reference sites were found in the study, and they were grouped into 23 different categories with the possibility of subcategories. The study reached a consensus set of 38 gestures for nose-based interaction after applying several criteria [27].The example of nose-based gestures for IoT tasks is an example of gesture-inspired research that generates a set of gestures based on user input. Today, because this media has access to a more natural interaction experience, mid-air gestures are a common input method [15].A unique type of natural HCI (Human-Computer Interaction) is mid-air interaction. Users engage with digital content on distant displays or remote devices using their entire body, with a particular emphasis on their hands, and gestures, postures, and motions during mid-air interaction [18].Air gestures are becoming more common as an input method. This is because they allow for a more natural and intuitive interaction experience, as users can use their entire body to engage with digital content on a remote display or remote device. In over-the-air interaction, users primarily use their hands and gestures, postures, and motions to navigate digital content.In addition, Gesture elicitation has significant potential in virtual reality (VR) systems, as it can enhance the user's experience by providing a more intuitive and immersive way to interact with digital content. In a VR environment, users can interact with objects and navigate through the virtual space using hand gestures and body movements.With the development of virtual reality (VR) and human-computer interaction technology, how to use natural and efficient interaction methods in virtual environments has become a research hotspot. Gestures are one of the most important means of communication for humans[20].Gestures in VR can be used to manipulate virtual objects, navigate through environments, and perform various other actions. This can enhance the user's sense of immersion and make the experience more intuitive and engaging. In conclusion, gesture elicitation has great potential to enhance user experience and provide a more intuitive and immersive way to interact with digital content in various fields, such as HMI, VR and IoT. Most of the VR systems with the controller use grasping gestures . In order to distinguish between grasp, rotation, movement, and release gestures, the application must implement them separately [23]. The user has a natural object interaction when press and drag are included [6]. For example, it enables pushing an object without having to physically grab it first. When interacting with point-and-click virtual reality systems like the Oculus Quest 2 and the Hololens 2, the pinch gesture has been the most popular way to grab items that are both close to the user and far away. It's likely that when inexperienced people utilize hand-tracked VR for the first time, they will interact naturally based on their real-world experiences. There are numerous ways to pick up items in the real world. People alter their movement and aim toward the item depending on where it is located. In this approach, the gesture is not always the same, just as the click of a controller button is not always indicative of the features of the object or of the context in which grabbing takes place. The connection between these components, which not only results in immersion in VR but also predictability for the user who has developed embodied cognition for grasping items since early childhood, is the most logical and natural interaction. For the gesture elicitation in the open brush we have used the gesture strokes from the GestOnHMD: Enabling Gesture-based Interaction on Low-cost VR Head-Mounted Display paper as it deals with the shapes similar to the brushes which we created [8] .

3 METHODOLOGY

3.1 Design

Our project's objective is to make it simple for users to sketch using custom-packaged patterns and object brushes in open brush software running in virtual reality applications. Our main objective is to use a VR system to sketch designs more quickly and with fewer gestures. We created five unique brushes to test whether it takes less time to sketch the design using the custom brushes than using the standard brushes and to gather user feedback. The five custom brushes created for this study are the checkbox brush, the leaf brush, the rectangle shape brush, the flower brush, and the paw brush. The tube distance UV brush mechanism is used for creating the checkbox brush. This technique produces a texture that resembles tubes. The geometry is drawn in accordance with the controller's range of changing coordinates as it moves across the surface. The paw, rectangle, and flower brushes are created using the genius particle mechanism. The genius particle mechanism rotates the images and the user can select the direction in which they should be sketched. The leaf brush is created using the hull brush mechanism. The leaf brush has more depth perceptive which can be created using the hull brush mechanism. The other brushes just draw the image by computing the change in coordinates between the knot and the controller, but the hull brush mechanism also calculates the changes in the surface frame coordinates to give obtain the depth perceptive. As we studied in the related work the vasomotor coordination is better when the horizontal strokes are used than the vertical strokes therefore custom brushes are designed to use only horizontal strokes than vertical strokes. The depth perception and spatial issue would be minimal in the tube distance uv mechanism, genius particle mechanism, and the hull brush mechanism. The gesture strokes are also recorded for both the standard and the custom brushes.

The gestures are annotated using the user-defined gesture set as a reference which was designed for the GestOnHMD project. Figure 2 is the image of the user-defined gesture set used for VR. Once the gesture annotation of each participant is taken for both the basic and custom brush the agreement rate AR(r) and agreement index A(r) is calculated to find the similarity in the gestures used between participants which is calculated using the formula in Figure 3 and Figure 4.

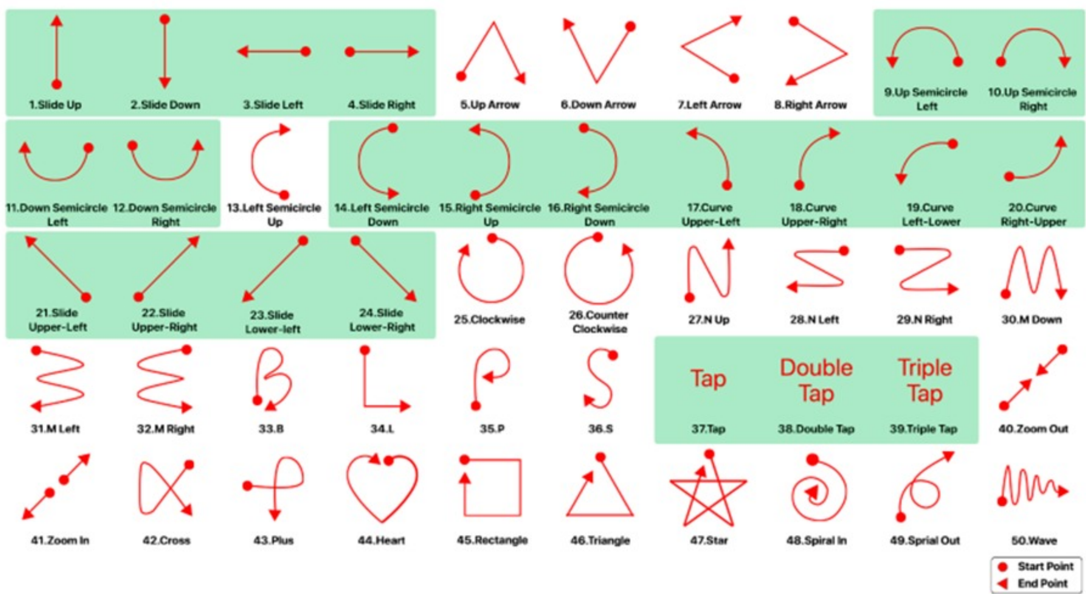

Fig. 2. User-defined gesture set used for VR (Available at https://ieeexplore.ieee.org/document/9382928)

$$A(r) = \sum_{P_i \subseteq P} \left(\frac{|P_i|}{|P|} \right)^2$$

Fig. 3. Agreement index (Available at http://depts.washington.edu/acelab/proj/dollar/agate.html)

$$AR(r) = \sum_{P_i \subseteq P} \frac{\binom{|P_i|}{2}}{\binom{|P|}{2}}$$

Fig. 4. Agreement rate (Available at http://depts.washington.edu/acelab/proj/dollar/agate.html)

3.2 Participants

Participants were 50 people who voluntarily consented to complete this study. We took the study with 30 male participants and 30 female participants and there were between age groups of 19 to 30 years (M=25, SD= 3). Each experiment has 12 participants and 4 groups are formed for each experiment. Male/standing, Female/Standing, Male/Sitting, and Female/Sitting are the four different group combinations.

3.3 Material

In this experiment, we used Unity software to generate the VR environment. The open brush code is integrated with the unity software. Oculus Quest 2 is used as the VR headset and linked to the HP laptop(AMD Ryzen 3 3250U with Radeon Graphics 2.60 GHz, 8.00 GB RAM) for the VR Output Display.

3.4 Usability study

This usability study is common for all the experiments conducted. Participants were asked questions before the experiment and also after the experiment and their responses are noted and analyzed. The participants with prior VR experience are not allowed to participate in the experiment as it would create a learning effect. The same participants were not allowed to participate in more than one experiment as that would also create a learning effect and would lead to wrong results.

The pre-experiment question are as follows:

1. What is your age?
2. Do you have prior experience in using VR devices?
3. Are you an artist?
4. Do you prefer doing the experiment sitting or standing?

The post-experiment questions are as follows:

1. Did you enjoy doing this experiment?
2. Which brush do you prefer for sketching?

4 EXPERIMENTS

4.1 Experiment 1: Sketching using Leaf brush

4.1.1 ***Procedure.*** Participants are asked to poll the pre-experiment survey and their responses are noted. Participants were asked to wear the Oculus Headset and asked to adjust to have clear vision. The participants were given a demo of how to perform the experiment and were asked to sketch each object once before starting the experiment. The marker brush is the standard brush, and the leaf brush is the custom brush used for sketching images. Half of the participants were told to sketch using the custom brush first and the other half of the participants were told to sketch using the standard brush first to prevent the learning effect. Once the participants started the experiment the timer is started, and the gesture is also observed for the participants. The task completion time and the gesture are noted for each participant. The participants are later asked post-experiment questions.

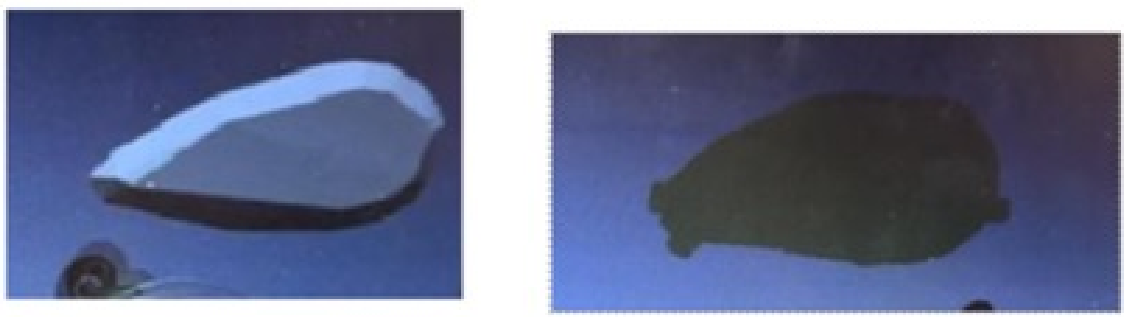

Fig. 5. The leaf images sketched using custom brush vs The leaf image sketched using marker brush

4.1.2 ***Results***

. **1. ANOVA Test Results:** The repeated measure ANOVA test is conducted to analyze the significant differences between the means task completion time between the four groups. The effect of the groups on the task completion time was not statistically significant ($F(3, 8) = 0.737$, ns). The effect of the brush type on the task completion time was statistically significant ($F(1, 8) = 22.338$, $p < .005$). The effect of brush type X groups was not statistically significant ($F(3, 8) = 1.393$, $p > .05$).

2. Gesture Elicitation Results: The agreement index for the standard marker brush and the custom leaf brush are 0.5138 and 0.7222 respectively. The agreement rate for the standard marker brush and the custom leaf brush are 0.469 and 0.7727 respectively. The gesture annotated stokes for marker standard brushes are down semicircle right+up semi circle right and antiClockwise Rotation. The gesture annotated stokes for the leaf custom brush are left semicircle down and right semicircle up.

3. User Survey Results: The 11 out of 12 participants liked the custom brush and 1 out of 12 participants liked the basic brush. From the survey out of 12 participants, 4 participants were artists. All 12 participants liked the experiment.

4. Mean Task Completion Time Results: A graph is plotted using the task completion time mean calculation for the different group combinations shown in Figure 6. The mean completion time of the various combinations is shown in Table 1.

Table 1. Mean Task Completion Time

Group	Mean task completion time (In sec)
\Marker	15.88
\leaf	6.48
\marker and female	17.148
\leaf and female	5.983
\marker and male	14.615
\leaf and male	6.976
\marker and female and standing	22.74
\leaf and female and standing	6.42
\marker and female and sitting	11.553
\leaf and female and sitting	5.567
\marker and male and standing	13.596
\leaf and male and standing	6.16
\marker and male and sitting	15.63
\leaf and male and sitting	7.793

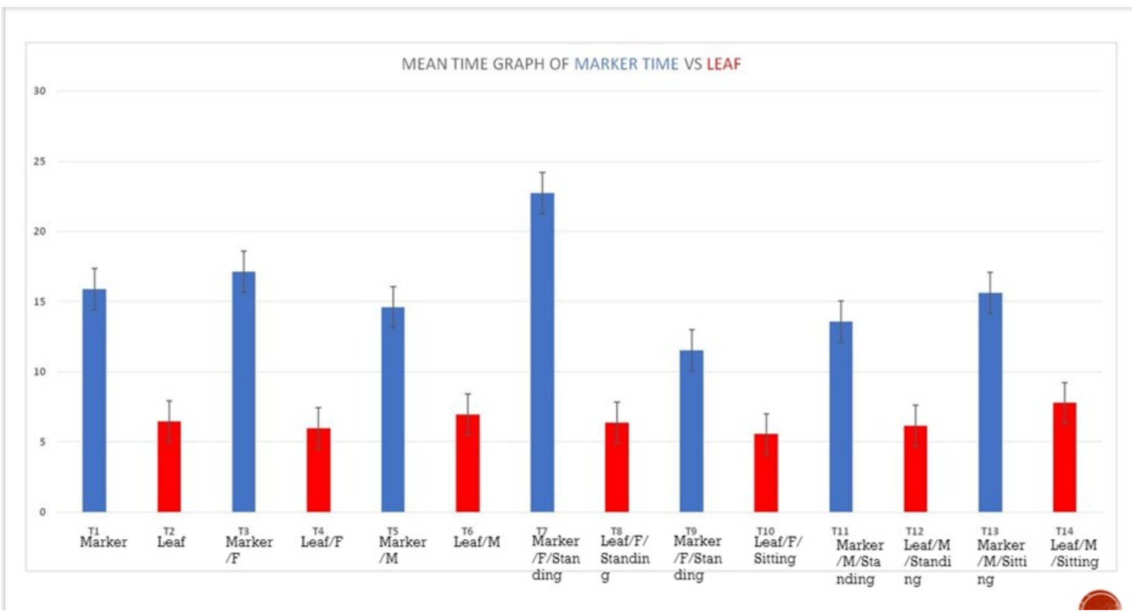

Fig. 6. Mean time graph of marker time vs leaf

4.1.3 *Discussions*.

We can infer that the marker needs more time to sketch the same image than the leaf from the mean task completion time graph. The ANOVA test also indicates that the effect of the brush type on the task completion time was statistically significant. The custom leaf brush has higher similarity readings than the marker standard brush according to the agreement index and agreement rate. We can also conclude from the user poll that 91.66 percent of the participants preferred custom brushes for sketching.

4.2 Experiment 2: Sketching using Rectangle brush

4.2.1 ***Procedure.*** Participants are asked to poll the pre-experiment survey and their responses are noted. Participants were asked to wear the Oculus Headset and asked to adjust to have clear vision. The participants were given a demo of how to perform the experiment and were asked to sketch each object once before starting the experiment. The Duct tape brush is the standard brush, and the rectangle brush is the custom brush used for sketching images. Half of the participants were told to sketch using the custom brush first and the other half of the participants were told to sketch using the standard brush first to prevent the learning effect. Once the participants started the experiment the timer is started, and the gesture is also observed for the participants. The task completion time and the gesture are noted for each participant. The participants are later asked post-experiment questions.

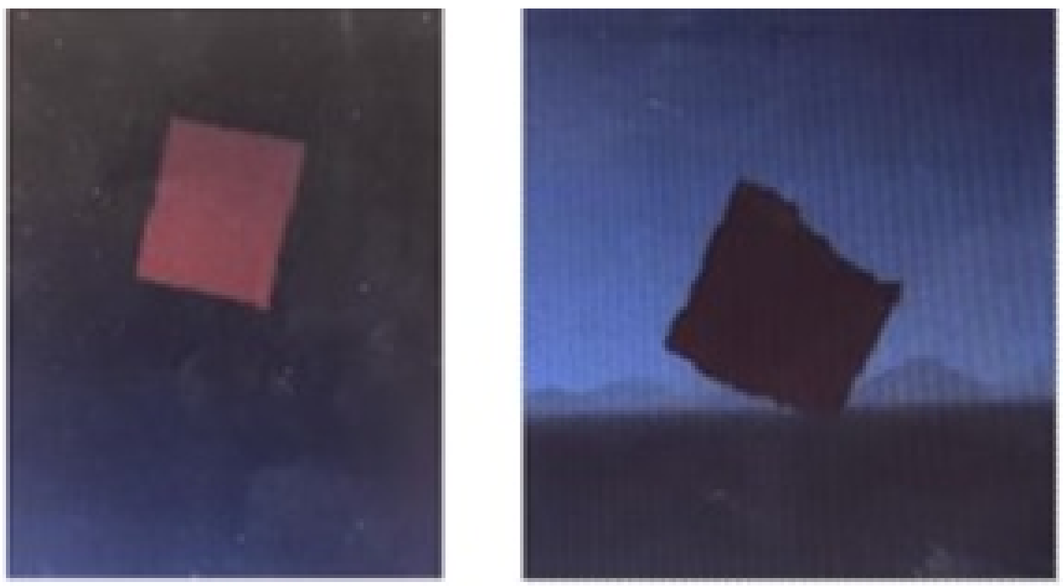

Fig. 7. The rectangle images sketched using custom brush vs The rectangle image sketched using marker brush

4.2.2 ***Results***

. **1. ANOVA Test Results:** The repeated measure ANOVA test is conducted to analyze the significant differences between the means task completion time between the four groups. The effect of the groups on the task completion time was not statistically significant ($F(3, 8) = 0.685$, ns). The effect of the brush type on the task completion time was statistically significant ($F(1, 8) = 9.083$, $p < .05$). The effect of brush type X groups was not statistically significant ($F(3, 8) = 0.444$, ns).

2. Gesture Elicitation Results: The agreement index for the standard duct tape brush and the custom rectangle brush are 0.2777 and 1 respectively. The agreement rate for the standard marker brush and the custom leaf brush are 0.2121 and 1 respectively. The gesture annotated stokes for Duct Tape standard brushes are slide left, slide up, slide down, and slide right. The gesture annotated stokes for the rectangle custom brush is a point stroke.

Table 2. Mean Task Completion Time

Group	Mean task completion time (In sec)
\ducttape	3.4608
\rectangle	2.29
\ducttape and female	3.8
\rectangle and female	2.38
\ducttape and male	3.11
\rectangle and male	2.19
\ducttape and female and standing	3.32
\rectangle and female and standing	2.24
\ducttape and female and sitting	4.29
\rectangle and female and sitting	2.53
\ducttape and male and standing	3.04
\rectangle and male and standing	1.72
\ducttape and male and sitting	3.18
\rectangle and male and sitting	2.66

3. User Survey Results: The 9 out of 12 participants liked the custom brush and 4 out of 12 participants liked the standard brush. From the survey out of 12 participants, 2 participants were artists. All 12 participants liked the experiment.

4. Mean Task Completion Time Results: A graph is plotted using the task completion time mean calculation for the different group combinations shown in Figure 8. The mean completion time of the various combinations is shown in Table 2.

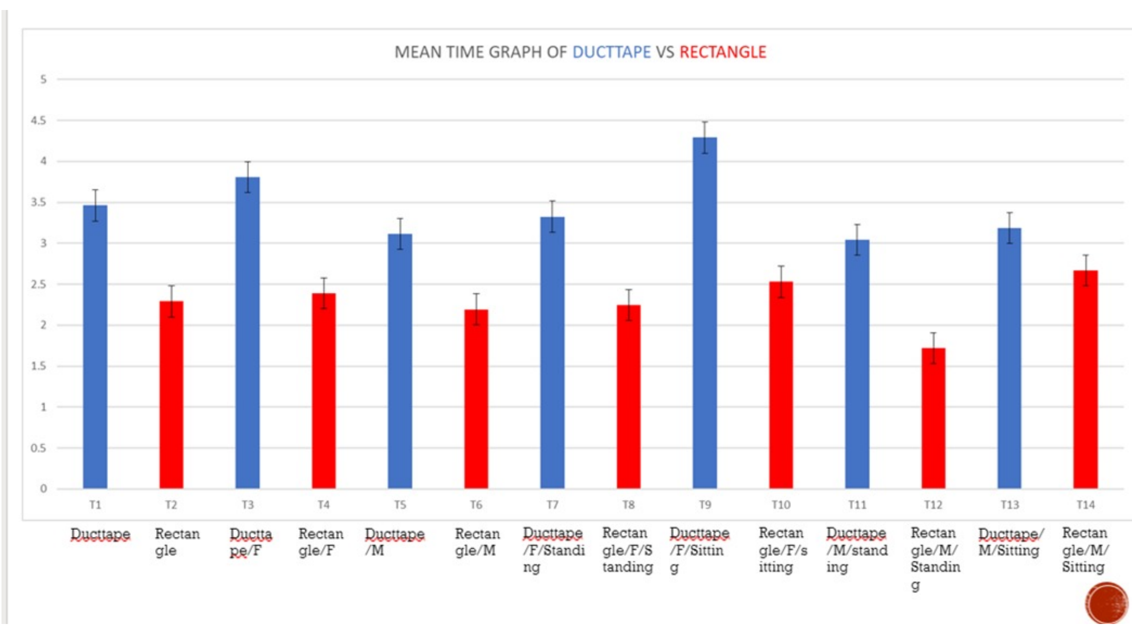

Fig. 8. Mean time graph of marker time vs rectangle

4.2.3 ***Discussions.*** We can infer that the duct tape brush needs more time to sketch the same image than the rectangle from the mean task completion time graph. The ANOVA test also indicates that the effect of the brush type on the task completion time was statistically significant. The custom rectangle brush has higher similarity readings than the marker standard brush according to the agreement index and agreement rate. The rectangular brush's agreement rate and agreement index are both 1, indicating that everyone who participated in the trial used the same gesture annotation to draw the rectangle. We can also conclude from the user poll that 75 percent of the participants preferred custom brushes for sketching.

4.3 Experiment 3: Sketching using Checkbox pattern brush

4.3.1 ***Procedure.*** Participants are asked to poll the pre-experiment survey and their responses are noted. Participants were asked to wear the Oculus Headset and asked to adjust to have clear vision. The participants were given a demo of how to perform the experiment and were asked to sketch each object once before starting the experiment. The marker brush is the standard brush, and the check patterned brush is the custom brush used for sketching images. Half of the participants were told to sketch using the custom brush first and the other half of the participants were told to sketch using the standard brush first to prevent the learning effect. Once the participants started the experiment the timer is started, and the gesture is also observed for the participants. The task completion time and the gesture are noted for each participant. The participants are later asked post-experiment questions.

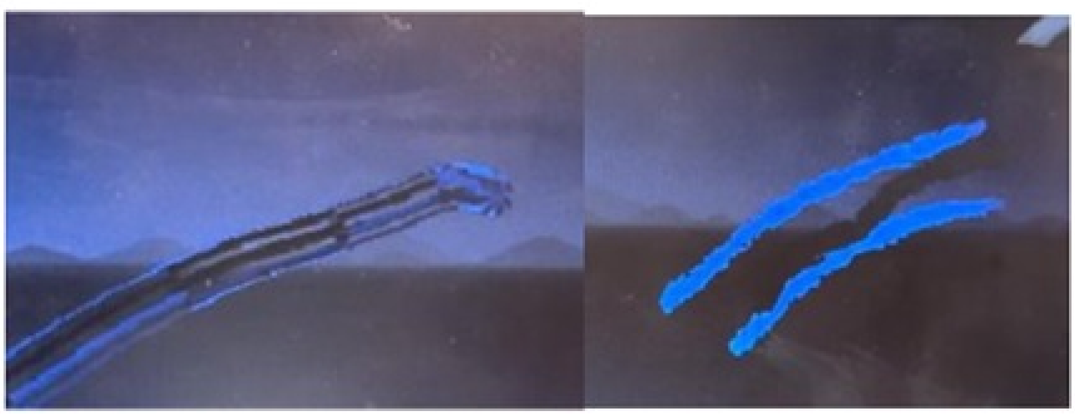

Fig. 9. The checkbox images sketched using custom brush vs The checkbox image sketched using marker brush

4.3.2 ***Results***

. **1. ANOVA Test Results:** The repeated measure ANOVA test is conducted to analyze the significant differences between the means task completion time between the four groups. The effect of the groups on the task completion time was not statistically significant ($F(3, 8) = 0.532$, ns). The effect of the brush type on the task completion time was statistically significant ($F(1, 8) = 46.888$, $p < .0005$). The effect of brush type X groups was not statistically significant ($F(3, 8) = 1.596$, $p > .05$).

Table 3. Mean Task Completion Time

Group	Mean task completion time (In sec)
\pencil	5.702
\checkbox	3.114
\pencil and female	5.82
\checkbox and female	3.28
\pencil and male	5.57
\checkbox and male	2.941
\pencil and female and standing	6.21
\checkbox and female and standing	2.516
\pencil and female and sitting	5.43
\checkbox and female and sitting	4.056
\pencil and male and standing	5.73
\checkbox and male and standing	2.96
\pencil and male and sitting	5.42
\checkbox and male and sitting	2.91

2. Gesture Elicitation Results: The agreement index for the standard pencil brush and the custom checkbox brush are 0.2777 and 0.47222 respectively. The agreement rate for the standard pencil brush and the custom checkbox brush are 0.2121 and 0.4393 respectively. The gesture annotated strokes for pencil standard brushes are slide right+slide right, slide right+slide left, slide left+slide left, slide right+slide right. The gesture annotated strokes for the rectangle custom brush are slide right, and slide left. To create an image that resembles the custom brush, the participants must draw two parallel lines, therefore the gesture annotation for both lines is noted. As a result, we find two reading combinations for each participant.
3. User Survey Results: The 8 out of 12 participants liked the custom checkbox brush and 4 out of 12 participants liked the basic brush. From the survey out of 12 participants, 4 participants were artists. All 12 participants liked the experiment.
4. Mean Task Completion Time Results: A graph is plotted using the task completion time mean calculation for the different group combinations. The mean completion time of the various combinations is shown in Table 3. The mean time graph is plotted for the pencil and the checkbox brush. Figure 10 is a bar graph with the standard error of + or - 1 showing the mean task completion time for all the combinations.

4.3.3 ***Discussions.*** We can infer that the pencil brush needs more time to sketch the same image than the checkbox brush from the mean task completion time graph. The ANOVA test also indicates that the effect of the brush type on the task completion time was statistically significant. The agreement index and agreement rate show higher similarity readings for the custom checkbox brush than the marker standard brush. The gesture elicitation strokes are largely sliding right and slide left with no up and down motion, which is also indicative of how the custom brushes are designed to sketch utilizing horizontal rather than vertical strokes. Thereby enhancing Visuomotor Coordination while sketching. We can also conclude from the user poll that 66.66 percent of the participants preferred custom brushes for sketching.

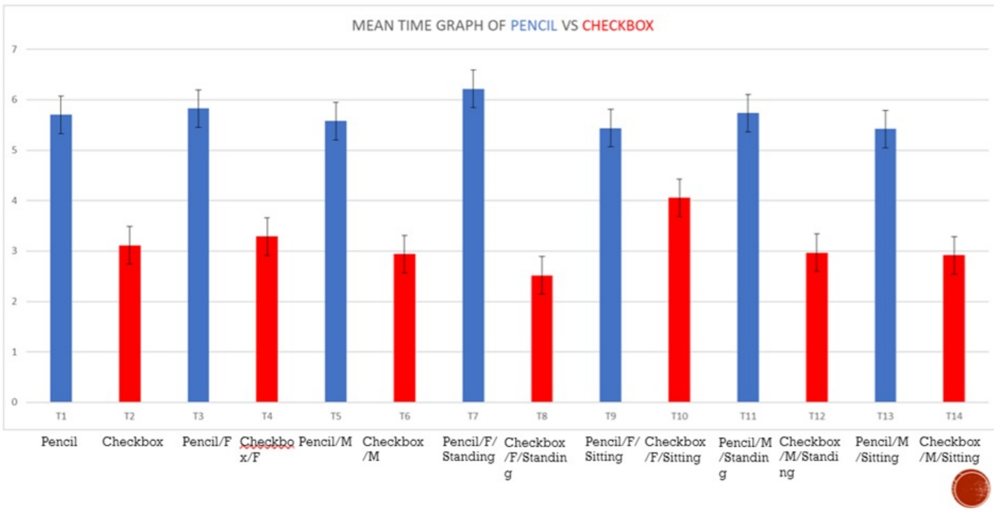

Fig. 10. Mean time graph of marker time vs checkbox

4.4 Experiment 4: Sketching using Flower brush

4.4.1 ***Procedure***. Participants are asked to poll the pre-experiment survey and their responses are noted. Participants were asked to wear the Oculus Headset and asked to adjust to have clear vision. The participants were given a demo of how to perform the experiment and were asked to sketch each object once before starting the experiment. The marker brush is the standard brush, and the flower brush is the custom brush used for sketching images. Half of the participants were told to sketch using the custom brush first and the other half of the participants were told to sketch using the standard brush first to prevent the learning effect. Once the participants started the experiment the timer is started, and the gesture is also observed for the participants. The task completion time and the gesture are noted for each participant. The participants are later asked post-experiment questions.

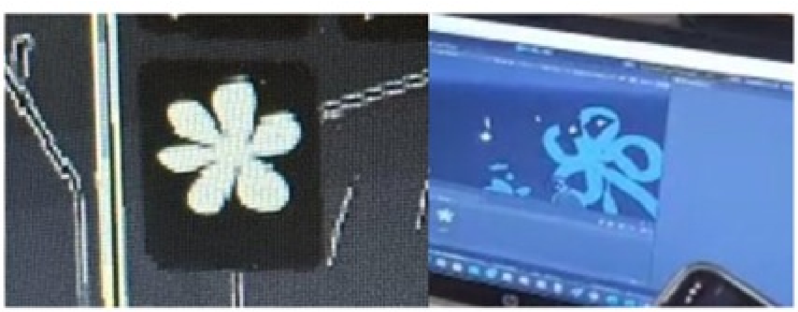

Fig. 11. The flower images sketched using custom brush vs The flower image sketched using marker brush

Table 4. Mean Task completion Time

Group	Mean task completion time (In sec)
\Marker	20.09
\flower	1.79
\marker and female	19.56
\flower and female	1.77
\marker and male	22.26
\flower and male	1.81
\marker and female and standing	18.21
\flower and female and standing	1.3
\marker and female and sitting	20.923
\flower and female and sitting	2.243
\marker and male and standing	16.33
\flower and male and standing	1.16
\marker and male and sitting	24.9
\flower and male and sitting	2.46

4.4.2 *Results*

. **1. ANOVA Test Results:** The repeated measure ANOVA test is conducted to analyze the significant differences between the means task completion time between the four groups. The effect of the groups on the task completion time was not statistically significant ($F(3, 8) = 2.490$, $p > .05$). The effect of the brush type on the task completion time was statistically significant ($F(1, 8) = 151.548$, $p < .0001$). The effect of brush type X groups was not statistically significant ($F(3, 8) = 1.092$, $p > .05$).

2. Gesture Elicitation Results: The agreement index for the standard marker brush and the custom flower brush are 0.5 and 0.319 respectively. The agreement rate for the standard marker brush and the custom flower brush are 0.454 and 0.257 respectively. The gesture annotated stokes for marker standard brushes are Up semicircle left+left semi-circle down+down semicircle right+right semi-circle up+up semicircle left, Up semicircle right+right semicircle down+down semicircle left+left semicircle up+up semicircle right. The gesture annotated strokes for the flower custom brush are slide up, slide down, slide right, slide left. To create an image that resembles the custom brush, the participants must have five semi circles, therefore the gesture annotation for all the semi circles is noted. As a result, we find two reading combinations for each participant.

3. User Survey Results: The 11 out of 12 participants liked the custom flower brush and 1 out of 12 participants liked the basic brush. From the survey out of 12 participants, 4 participants were artists. All 12 participants liked the experiment.

4. Mean Task Completion Time Results: A graph is plotted using the task completion time mean calculation for the different group combinations. The mean completion time of the various combinations is shown in Table 4. Figure 12 is a bar graph with a standard error of + or - 1 showing the mean task completion time for all the combinations.

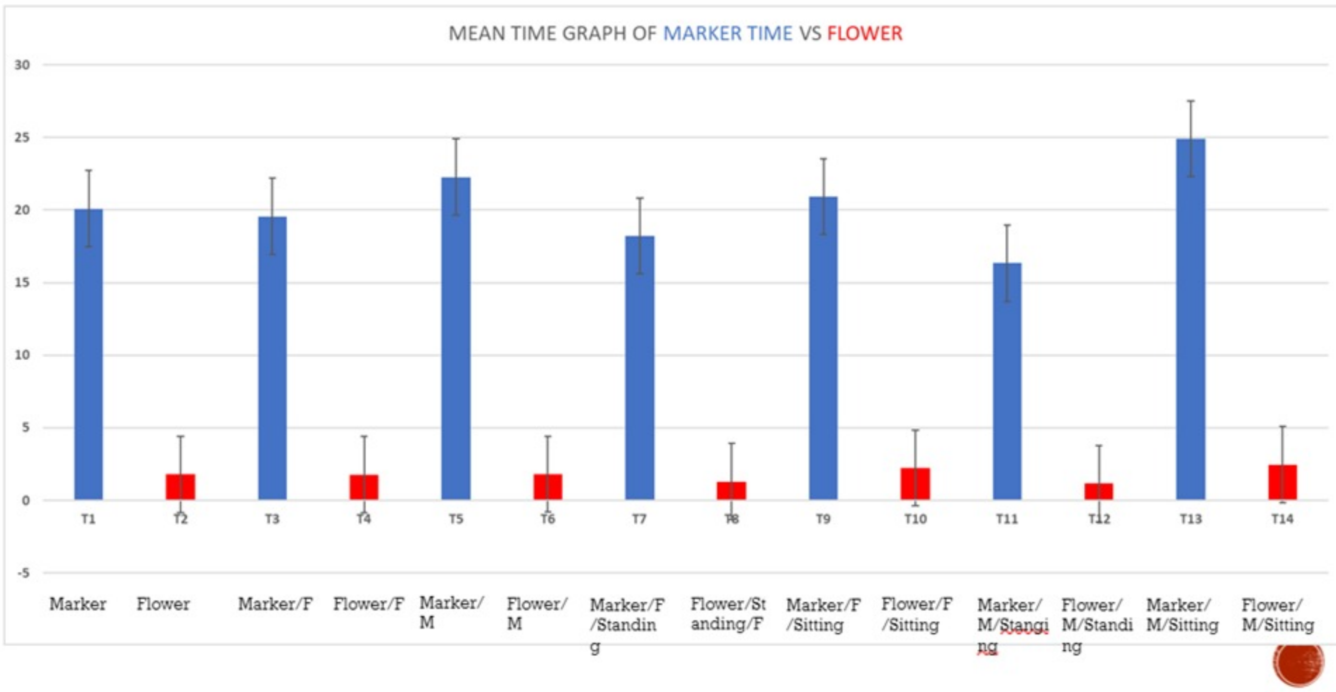

Fig. 12. Mean time graph of marker time vs flower

4.4.3 *Discussions.*

We can infer that the marker brush needs more time to sketch the same image than the flower brush from the mean task completion time graph. The ANOVA test also indicates that the effect of the brush type on the task completion time was statistically significant. The agreement index and agreement rate show higher similarity readings for the custom flower brush than the marker standard brush. The custom brush strokes have improved hand-eye coordination and lessen the spatial and perceptual problems as the strokes are simple gestures compared to the base brush gestures which is evident from the task completion time record and clarity of the image sketched by the user. We can also conclude from the user poll that 91.66 percent of the participants preferred custom brushes for sketching.

4.5 Experiment 5: Sketching using Paw brush

4.5.1 *Procedure.*

Participants are asked to poll the pre-experiment survey and their responses are noted. Participants were asked to wear the Oculus Headset and asked to adjust to have clear vision. The participants were given a demo of how to perform the experiment and were asked to sketch each object once before starting the experiment. The marker brush is the standard brush, and the paw brush is the custom brush used for sketching images. Half of the participants were told to sketch using the custom paw brush first and the other half of the participants were told to sketch using the standard brush first to prevent the learning effect. Once the participants started the experiment the timer is started, and the gesture is also observed for the participants. The task completion time and the gesture are noted for each participant. The participants are later asked post-experiment questions.

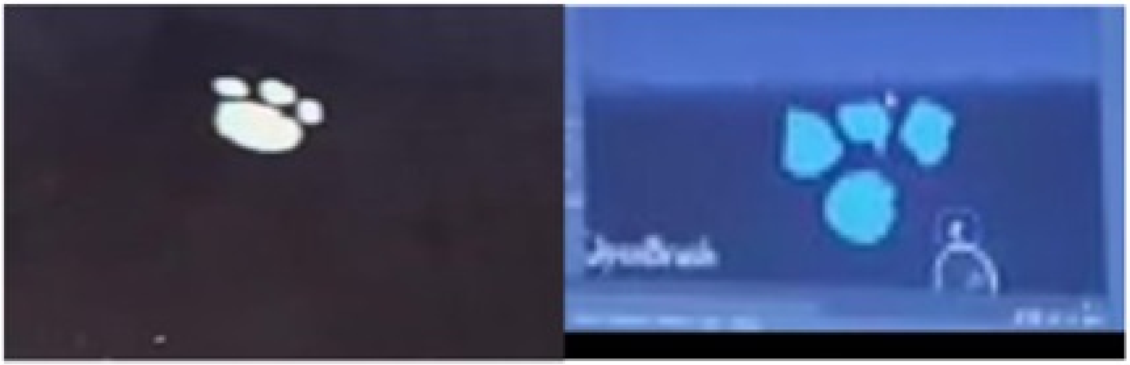

Fig. 13. The paw images sketched using custom brush vs The paw image sketched using marker brush

4.5.2 ***Results***

. **1. ANOVA Test Results:** The repeated measure ANOVA test is conducted to analyze the significant differences between the means task completion time between the four groups. The effect of the groups on the task completion time was not statistically significant ($F(3, 8) = 0.717$, ns). The effect of the brush type on the task completion time was statistically significant ($F(1, 8) = 55.259$, $p < .0001$). The effect of brush type X groups was not statistically significant ($F(3, 8) = 0.762$, ns).
2. Gesture Elicitation Results: The agreement index for the standard marker brush and the custom paw brush are 0.625 and 0.52 respectively. The agreement rate for the standard marker brush and the custom paw brush are 0.59 and 0.287 respectively. The gesture annotated stokes for marker standard brushes are clockwise +clockwise+clockwise+clockwise, counterclockwise +counter clockwise+counter clockwise+counter clockwise. The gesture annotated strokes for the paw custom brush are slide up, slide down, slide right. To create an image that resembles the custom brush, the participants must have three circles, therefore the gesture annotation for all three circles is noted. As a result, we find two reading combinations for each participant.
3. User Survey Results: The 10 out of 12 participants liked the custom paw brush and 2 out of 12 participants liked the basic brush. From the survey out of 12 participants, 3 participants were artists. All 12 participants liked the experiment.
4. Mean Task Completion Time Results: A graph is plotted using the task completion time mean calculation for the different group combinations shown in Figure 14. The mean completion time of the various combinations is shown in Table 5.

4.5.3 ***Discussions.*** We can infer that the marker brush needs more time to sketch the same image than the paw from the mean task completion time graph. The ANOVA test also indicates that the effect of the brush type on the task completion time was statistically significant. The agreement index and agreement rate show higher similarity readings for the custom paw brush than the marker standard brush. The custom brush strokes have improved hand-eye coordination and lessen the spatial and perceptual problems as the strokes are simple gestures compared to the base brush gestures which is evident from the task completion time record and clarity of the image sketched by the user. We can also conclude from the user poll that 83.33 percent of the participants preferred custom brushes for sketching.

Table 5. Mean Task completion Time

Group	Mean task completion time (In sec)
\Marker	13.83
\paw	2.8
\marker and female	15.53
\paw and female	2.96
\marker and male	12.12
\paw and male	2.63
\marker and female and standing	13.53
\paw and female and standing	3.26
\marker and female and sitting	17.54
\paw and female and sitting	2.66
\marker and male and standing	12.76
\paw and male and standing	3.36
\marker and male and sitting	11.48
\paw and male and sitting	1.9

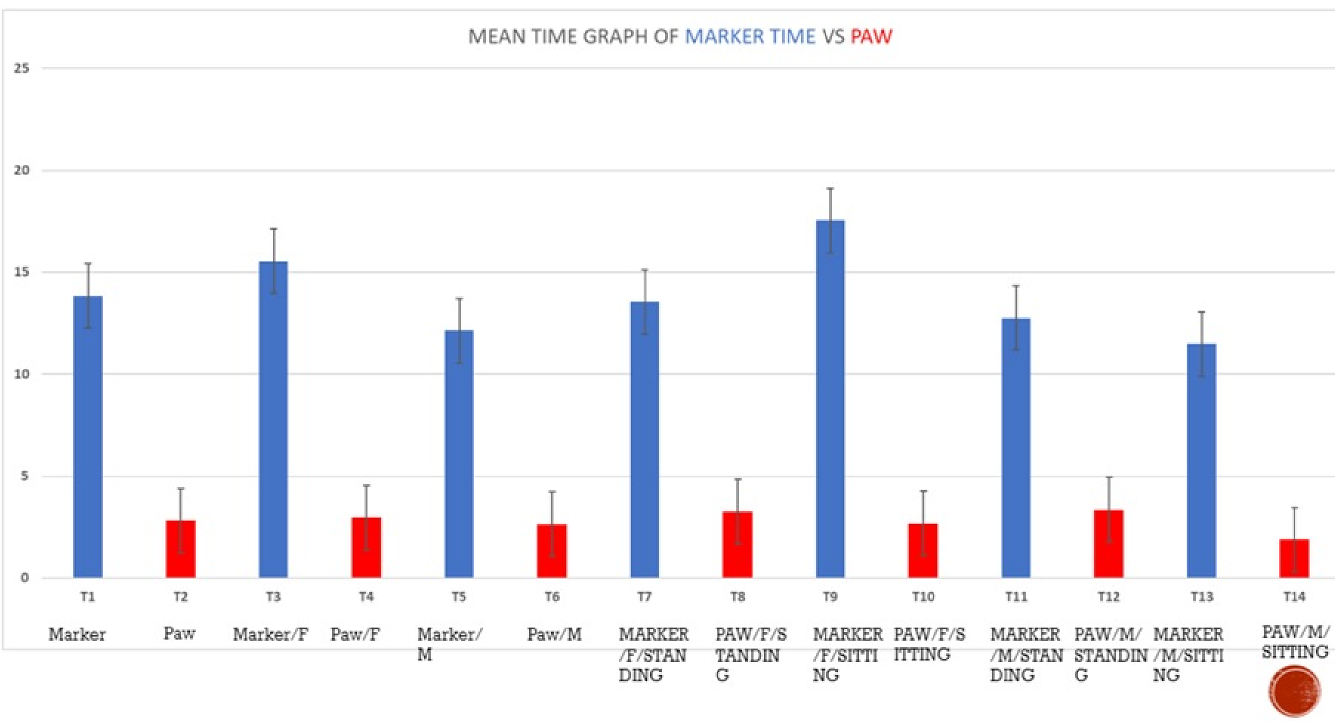

Fig. 14. mean time graph of marker time vs paw

5 CONCLUSION

This study aims to determine whether the use of custom brushes in virtual reality (VR) software can improve the efficacy of sketching designs. In the experiment, five custom brushes were constructed, including the checkbox brush, the leaf brush, the flower brush, the rectangle brush, and the paw brush. There were 60 participants in the study, with an equal number of men and women between the ages of 19 and 30. Participants were instructed to doodle images using both the standard marker brush and the custom brush during the experiment. Each participant's assignment completion time and gestures were recorded. The methodology of the study included a pre-experiment survey to capture demographic information and prior experience with VR devices from participants. The post-experiment survey inquired about the participants' enjoyment of the experiment and their preferable sketching brush. The ANOVA test was used to determine whether there were significant differences between the four groups based on gender and position (sitting or standing) in terms of the mean task completion time. The results demonstrated that the effect of brush type on task completion time was statistically significant, with participants completing the task faster when using custom brushes. According to the results of the gesture elicitation, the agreement index and agreement rate were greater for the standard marker brush than for the custom brushes. The quick and simple strokes used for sketching with custom brushes improve eye-hand coordination and lessen the spatial and perceptual problems that are present with base brushes. The gesture elicitation strokes are largely sliding right and slide left with no up and down motion, which is also indicative of how the custom brushes are designed to sketch utilizing horizontal rather than vertical strokes. Thereby enhancing Visuomotor Coordination while sketching. Images created with custom brushes have a more regular and flawless shape than those created with basic brushes. When compared to the base standard brushes, drawing images with custom brushes takes less time. According to the results of the post-experiment survey, the majority of participants preferred custom brushes over standard brushes, which they found to be more convenient. More custom brushes should be added to the open brush to enhance the open brush user experience and reduce the VR limitations.

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