Artistic Affordance in Virtual Reality Painting

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ABSTRACT

The emergence of Virtual Reality (VR) programs has enabled painting activity to be done in a virtual world, offering a unique art medium with significantly different material properties than physical art mediums. This materiality difference potentially produces a perception of affordance, a theory coined by Gibson about how an environment offers action possibilities. We conducted experiments to explore our own artmaking experience in an immersive virtual environment using a VR painting program. We used a heuristic qualitative approach consisting of initial engagement, immersion, incubation, illumination, explication, and creative synthesis. We found that the affordance of VR painting is mainly generated from virtual brushes. The painting simulation in VR has also generated a sense of agency, namely the artist's sense of control when creating art in the virtual environment. The study proposes a new concept of artistic affordance in VR, which refers to everything in a virtual environment that affects the creative process and artistic expression during VR artmaking. The comprehension of artistic affordances helps communicate VR's functionality and usability to creative and artistic means and can increase users' satisfaction and engagement in artmaking practice. The study suggests that haptic feedback is needed with the relatively high learning curve of VR painting and that developers, researchers, and artists should collaborate to design a richer user interface to further establish VR as an artistic medium.

Keywords: *agency, artistic affordance, virtual painting, virtual reality.*

ABSTRAK

Kemunculan Virtual Reality (VR) memungkinkan kegiatan melukis dilakukan di dunia maya, menawarkan media seni yang unik dengan sifat yang sangat berbeda dengan media seni konvensional. Perbedaan materialitas ini berpotensi menghasilkan alternatif media baru, sebuah teori yang dikemukakan oleh Gibson tentang bagaimana suatu lingkungan/sistem menawarkan alternatif berkreasi yang baru. Pada penelitian ini dilakukan eksperimen untuk mengeksplorasi pengalaman pembuatan karya seni dalam ranah virtual menggunakan *software* VR-Pain. Kami menggunakan pendekatan kualitatif heuristik yang terdiri atas keterlibatan awal, pencelupan, inkubasi, iluminasi, penjelasan, dan sintesis kreatif. Pada proses penelitian, ditemukan bahwa kemungkinan berkreasi dengan VR-Pain dihasilkan dari kuas virtual. Simulasi lukisan dalam VR juga melahirkan *sense of agency*, yaitu rasa kontrol seniman saat menciptakan karya seni pada lingkup virtual. Studi ini mengusulkan konsep baru keterjangkauan artistik dalam VR, yang mengacu pada segala sesuatu di lingkungan virtual yang memengaruhi proses kreatif dan ekspresi artistik selama pembuatan seni VR. Pemahaman terhadap kemampuan artistik membantu mengomunikasikan fungsionalitas dan kegunaan VR ke sarana kreatif dan artistik serta dapat meningkatkan kepuasan dan keterlibatan pengguna dalam praktik pembuatan seni. Studi ini menunjukkan bahwa diperlukan kolaborasi antara umpan balik diperlukan pengembang, peneliti, dan seniman untuk merancang antarmuka pengguna atau pilihan tools dalam sistem VR yang lebih kaya sehingga akan menjadikan VR sebagai media artistik yang lebih baik.

Kata Kunci: alternatif-media-baru, lukis, rasa-kontrol, seni, *virtual-reality*.

INTRODUCTION

Virtual reality (VR) has become an increasingly popular tool and creative medium in fine art and design in recent years. The rise of technology and online communication platforms in VR like the *Metaverse* has transformed the way we appreciate art. Rather than being limited to physical spaces, we can now appreciate art digitally from anywhere in the world. For instance, museums around the world have jumped at the chance to use virtual reality (VR) to produce dynamic displays, immersive tours, and stunning visual storytelling. VR in museums is transforming how we interact with historical and artistic works (e.g. see Sylaiou, et. al, 2023; Murwonugroho, et. al, 2023). VR technology can even be utilized to preserve and promote cultural heritage, including traditional performing arts like dance and music (e.g. see Rustiyanti, et. al, 2020; Reshma et al, 2023). The availability of VR devices, in the form of Head Mounted Displays (HMD), that are more compact, practical, and affordable for the general public means that VR devices are no longer exclusive and limited. The revival of VR has contributed to the creation and development of new artistic expressions, mainly digital media-based works of art.

Artmaking practice, especially painting, can now be done in virtual space which utilizes HMD devices and VR programs such as *Tilt Brush, OpenBrush, Painting VR,* and *Gravity Sketch*. As a new art medium, the VR program differs from physical art media in terms of materiality, space, and time. VR painting programs enable an immersive art creation process in which users and viewers

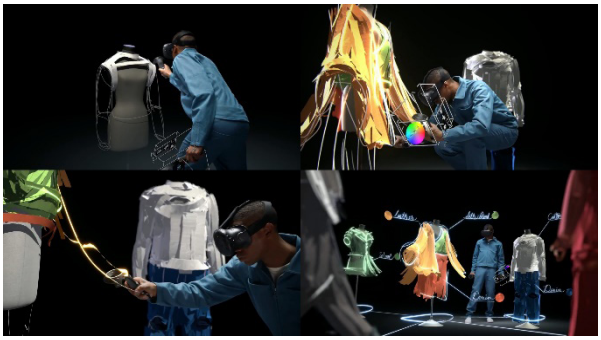

Figure 1. Painting process in virtual reality using VR program
(source: https://www.youtube.com/watch?v=TckqNdrdbgk, August 2023)

can freely move within and outside the work being created, and users can apply painting techniques that are not possible using physical media in the real world.

When artists create works of art using conventional physical 2D-based mediums, they adapt and utilize the material properties of the media in various techniques to create 3D visual illusions from 2D planes. However, the "canvas" in VR painting programs is not limited to a solid flat surface. VR painting canvas is a room-scale virtual environment in which 3D images are created directly in the air, using the simulation and reproduction of various visual elements such as lines, shapes, colors, and paint effects from various brush types.

We believe that how artists adapt to the materiality of VR is influenced by affordance. Affordance is a concept coined by Gibson (1979) about the possibility of certain behaviors caused by the environment, in this case, the virtual environment and its characteristics. The handheld controller that accompanies a VR program that mimics the motion of painting is also closely related to the user's sense of control over the virtual environment,

otherwise known as agency (Mayer, 2014). Rethinking the notion of materiality in VR as an art medium presents an opportunity to consider the relationship between artists and their work, where VR technology, as the latest medium of creative expression, produces new aesthetic meanings that break the threshold between the physical and the virtual. The authors see the possibility of a theoretical gap regarding the concepts of affordance and agency in creating works of art using VR programs.

Based on these phenomena, a study of the artmaking process using VR is essential to discover how a work of art is formed in virtual space and how digital objects in VR painting programs affect the behavior and creative process of artists, especially those who have never used VR as an art medium when they are adapting to this VR technology. The central questions then formulated for this study: How do virtual 3D elements (objects materiality, virtual space) become affordances that affect the behavior of artists during the creative process? Also, what virtual environment features play a role in generating agency perception in the VR painting program.

In this paper, we draw on Gibson's affordance theory, which comes from the psychology of ecological perception, to explore artmaking practice in a VR environment. Gibson's affordance theory is highly applicable to the study of VR experiences due to its foundational principles that focus on the relationship between the environment and the observer. This theory, which emphasizes the opportunities for action that objects or environments provide to an individual, offers a robust framework for understanding how users interact with and perceive virtual environments.

We utilize *OpenBrush* as the main VR painting program for this study. The scope of this study is not only focusing on the characteristics of the virtual environment but also the simulation of painting tools, in this case, virtual brushes. A hypothesis is proposed that VR as an art medium can influence the creative artistic behavior of users, specifically artists, and thus can be considered a new form of affordance that explains the phenomenon of perception in the practice of painting in a virtual environment.

BACKGROUND

The term "affordance" was first coined by James G. Gibson, an ecological psychologist, in his article *The Theory of Affordances* in 1977. This concept was developed by Gibson out of his interest in understanding visual perception, later specified as an ecological approach to perception. He defined affordance as everything the environment provides and stimulates for an individual (Gibson, 1979). In this context, the environment is the surface that separates the substances in the individual's space. Gibson argues that information about environmental affordance can be obtained visually, such as the composition and layout of a surface. An example of affordance is if an object has a flat, broad, and hard surface, it has affordance because we can walk, stand, or run on it. Affordances can differ for everyone, which could lead to different behaviors.

Since it was first coined by Gibson, the concept of affordance has evolved. Norman (1988) developed the concept of affordance in the context of Human-Computer Interaction (HCI) and focused on the relationship between tangible objects and their users. He believed that affordance is obtained by deducing a user's prior knowledge and experience of possible actions (Norman, 1988). This differs from Gibson's concept of affordance, which does not depend on experience, knowledge, culture, or the actor's ability to perceive.

Tucker and Ellis (1998; 2001) also introduced the concept of micro affordance, which based on the idea that affordance comes not only from the characteristics offered by the environment but also from motor attributes (the act of grasping, wrist orientation, and left and right-hand strength to the fingers) present in the visual representation of objects (tools) Tucker & Ellis, 1998; Tucker & Ellis, 2001). Another concept of affordance coined by Humpreys (2001) is paired object affordance which is when one object is "active" while the other object is "passive". This relates to how affordances emerge when actors use new tools. Actors will use visual features from tools and objects, as well as semantic systems that provide contextual and associative knowledge about them. By analyzing a tool's sensory information, specialized knowledge can be obtained to understand its conventional use.

It has been observed that the concept of affordance has shifted towards the inclusion of tools as a part of the environment. The latest concept of affordance primarily revolves around the idea of enabling actions with specific body parts like hands. This concept can be applied to various scenarios, such as using known tools, unknown tools, new tools, or even non-tool actions when artists use various simulated painting features in VR painting programs.

From a broad perspective, the impact of VR technology on human behavior can also be explained using Actor-Network Theory (ANT). ANT is a theoretical framework that highlights the influence of both human and non-human entities in creating social and technological networks (Latour, 1993). The theories of affordance and ANT both focus on the dynamics of interactions. According to ANT, a VR system can be viewed as a network of different entities, such as hardware components (HMD, controllers, and sensors), software algorithms, virtual objects, and human users. Each of these entities contributes towards shaping the possibilities within the virtual environment.

The concept of affordance introduced by Gibson has been widely adopted and adapted across various fields, including design, human-computer interaction (HCI), and information science. However, as the concept has been applied to new domains and technologies, particularly digital and artistic interactive media, several issues have arisen that suggest the need for a reevaluation or a new conceptualization of affordance. (Oliver, 2005; Burlamaqui & Dong, 2015).

METHOD

We conducted an artmaking experiment using a heuristic qualitative research approach to explore the authors' authentic

and personal experiences using a VR painting program. The authors acted as participants in this experiment. The authors' educational background is from graduate school in art and design. However, we have no prior experience in using VR in artmaking practice.

We use the heuristic approach of Moustakas (1990) to examine our experience in an organized and systematic manner, in which observations focus internally, such as how the researcher responds and feels towards external situations, instead of observing interactions outside the researcher. Moustakas emphasizes that researchers who use this approach investigate, analyze, and reflect on the researcher's personal experiences to find new meanings and understandings. The heuristic method developed by Moustakas is particularly well-suited for exploring the concept of affordability in VR due to its emphasis on personal experience, self-reflection, and discovery. This method allows researchers to delve deeply into the subjective experiences of individuals, which is crucial when investigating a multifaceted concept like affordability in the context of VR. Moustakas' heuristic approach also fits this research because it aligns with the authors as the artist who has never used VR as a creative medium. This method's research process is expected to produce "a self-transformation that almost always has social and transpersonal implications" (Moustakas, 1990).

Moustakas' heuristic method consists of six stages: initial engagement, immersion, incubation, illumination, explication, and creative synthesis. The following are the stages of this research using the Moustakas heuristic approach:

Initial engagement

We started by using HMD devices and handheld controllers while familiarizing ourselves with the basic technicalities of VR devices. We then opened the OpenBrush VR program, trying all its menus and features, and identified all the virtual brushes intuitively, spontaneously, and expressively without targeting specific final shapes.

Immersion

During this stage, we delve deeper into the VR painting program by engaging in the artmaking process. To ensure an authentic experience, we utilize all the available tools and facilities within the *OpenBrush* VR application to create a series of artworks. Our approach to crafting these pieces is guided by an active imagination, while still maintaining a sense of control. To capture our thoughts, feelings, imaginations, and insights gained throughout the creative process, we keep a journal.

Incubation

During this stage, we took a break from painting activities for a few days. We reviewed and contemplated the results of visual brush strokes on the artwork without judging or criticizing. We also identified similar familiar artistic experiences based on our artistic knowledge and took notes on new materialities we encountered when adapting to new technology and painting programs in VR.

Illumination

We explore the data's findings during this illumination process and evaluate the artmaking process. We note insights and observations about the patterns and themes that emerge regarding each tool in the VR program.

Explication

In this phase, virtual brushes are categorized within the VR program by their affordance, agency, and material characteristics to address research inquiries. The outcomes are then presented through visual aids such as tables and figures, providing a clear classification of the findings.

Creative synthesis

During the conclusive stage of our experiment, we put into practice the information we gathered on the material properties of virtual brushes. To ensure the accuracy and reliability of our findings, we conducted multiple repetitions of the artmaking process to observe the effects of these properties on the final outcome. Through this iterative process, we were able to confirm our initial results and gain a deeper understanding of how virtual environment and virtual brushes can be used in the creation of virtual artwork.

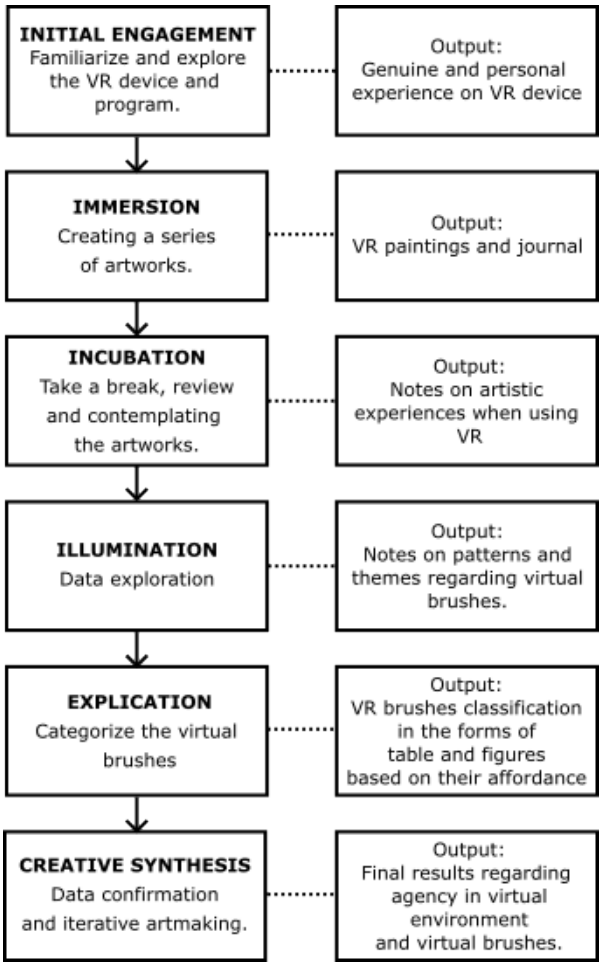

Figure 2. Flow diagram of the heuristic approach used in this research.
(Source: authors documentation).

FINDINGS

As the authors are artists mainly working with physical and/or digital 2D and 3D non-immersive media, we used to rely on our position and movements on the support of hard surfaces such as tables or other objects while making artwork. The first thing we noticed when we enter the virtual space is the non-human abilities in virtual space that are mainly caused by its immersiveness and how the visual elements float in the air, free of physical laws. The sense of control we felt from the painting tools simulation generates agency, even when the whole body actively moves to the rhythm of the brush strokes. The scale and teleport feature affords us various viewpoints of the artwork. This feature does not exist in the physical world. We believe that the scale feature enhances the workflow and, thus, the creative process. We believe that these features confirm the concept of

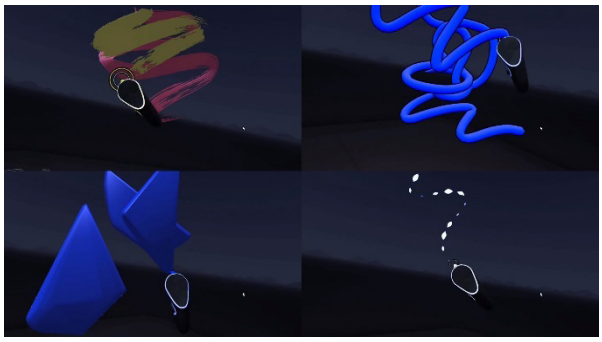

Figure 3. Flat brush (upper left); Tube brush; (upper right); Hull brush (lower left); Particle brush (lower right).
(Source: authors documentation).

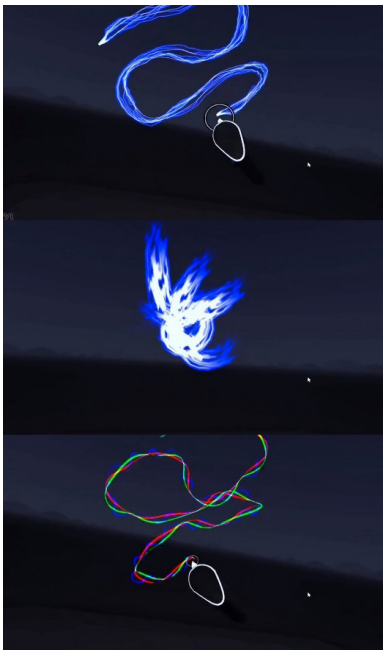

Figure 4. Sample of animated brush.
(Source: authors documentation).

affordance from Tucker and Ellis's micro affordance theory. We also can immediately recognize the placement of the "palette" and "brush" interface on the left and right-hand positions, which is aligned with Humphrey's paired object affordance theory.

Overall, there are 109 virtual brushes in the *OpenBrush* program. 63 brushes can be accessed on the standard menu, and 46 brushes can only be accessed on the advanced/ experimental menu. Based on the visual appearance, virtual brushes in the *OpenBrush* program can be divided into (1) *Flat* or ribbon-shaped brushes, (2) *Tube* or cylinder or other shapes with thickness, (3) *Hull* or short, thick, and sharp brushes, and (4) *Particle* or brush stroke that produces multiple small objects that follow the path of the stroke. Some types of brushes have an animation effect in which brush strokes have automatic movement to their shape or texture.

We categorized the virtual brushes based on their impact on affordance into four levels: High, Medium, Low, and Very Low. The High affordance category means that the materiality of the virtual brush offers high opportunities for action and freedom for us to create shapes and forms. Consecutively, the strokes produced from virtual brushes in the Medium to Very Low affordance categories tend to be stiffer, thereby limiting artistic creativity. We argue that this is due to the materiality of the virtual brush, which only allows the creation of specific rigid shapes. For instance, a flat brush generates straight strokes that tend to be stiff. This type of brush is relatively tricky to use to create dynamic plastic shapes. Thus, the action possibilities on the flat virtual brush are low. This brush materiality affects the overall user agency. However, flat brush strokes can be applied to give the illusion of plasticity if used small and stroked in large quantities to create a sense of dimension. Furthermore, several types of brushes that have animation or particle motion (Figure 4), significantly limit the creative process. The visual aesthetic of these brushes is only suitable for specific

Table 1 Artistic affordance level of virtual brushes in VR painting program

areas and actions.

No.	Brush Name	Type	Animation	Affordance Level
1	Faceted Tube	Tube	-	High
2	Icing	Tube	-	High
3	Lofted	Tube	-	High
4	Petal	Tube	-	High
5	Spikes	Tube	-	High
6	Toon	Tube	-	High
7	Tube Toon Inverted	Tube	-	High
8	Wire	Tube	-	High
9	Bubble Wand	Tube	-	High
10	Guts	Tube	-	High
11	Keijiro Tube	Tube	-	High
12	Muscle	Tube	-	High
13	Mylar Tube	Tube	-	High
14	Rain	Tube	-	High
15	Sparks	Tube	-	High
16	Tapered Wire	Tube	-	High
17	Tube (Highlighter)	Tube	-	High
18	Tube (Flat)	Tube	-	High
19	Tube (Marker)	Tube	-	High
20	Coarse Bristles	Spray	-	High
21	Dot Marker	Spray	-	High
22	Leaves	Spray	-	High
23	Splatter	Spray	-	High
24	Leaves2	Spray	-	Medium
25	Tapered Marker	Flat	-	Medium
26	Thick Paint	Flat	-	Medium
27	Velvet Ink	Flat	-	Medium
28	Wet Paint	Flat	-	Medium
29	Charcoal	Flat	-	Medium
30	Feather	Flat	-	Medium
31	Fire2	Flat	-	Medium
32	Oil Paint (Geometry)	Flat	-	Medium

No.	Brush Name	Type	Animation	Affordance Level
33	Wet Paint (Geometry)	Flat	-	Medium
34	Chromatic Wave	Tube	√	Low
35	Disco	Tube	√	Low
36	Light Wire	Tube	√	Low
37	Neon Pulse	Tube	√	Low
38	Wire (Lit)	Tube	-	Low
39	Lofted (Hue Shift)	Tube	-	Low
40	Bubbles	Particle	√	Low
41	Embers	Particle	√	Low
42	Smoke	Particle	√	Low
43	Snow	Particle	√	Low
44	Stars	Particle	√	Low
45	Rising Bubbles	Particle	√	Low
46	Diamond	Hull	-	Low
47	Matte Hull	Hull	-	Low
48	Shiny Hull	Hull	-	Low
49	Unlit Hull	Hull	-	Low
50	Smooth Hull	Hull	-	Low
51	Cel Vinyl	Flat	-	Low
52	Pinched Flat	Flat	-	Low
53	Pinched Marker	Flat	-	Low
54	Duct Tape	Flat	-	Low
55	Felt	Flat	-	Low
56	Flat	Flat	-	Low
57	Highlighter	Flat	-	Low
58	Ink	Flat	-	Low
59	Light	Flat	-	Low
60	Marker	Flat	-	Low
61	Oil Paint	Flat	-	Low
62	Paper	Flat	-	Low
63	Soft Highlighter	Flat	-	Low
64	Taffy	Flat	-	Low
65	Tapered Flat	Flat	-	Low
66	Tapered Highlighter	Flat	-	Low

No.	Brush Name	Type	Animation	Affordance Level
67	Digital	Flat	-	Low
68	Double Flat	Flat	-	Low
69	Drafting	Flat	-	Low
70	Dry Brush	Flat	-	Low
71	Duct Tape (Geometry)	Flat	-	Low
72	Fairy	Flat	-	Low
73	Flat Geometry	Flat	-	Low
74	Gouache	Flat	-	Low
75	Ink (Geometry)	Flat	-	Low
76	Lacewing	Flat	-	Low
77	Leaky Pen	Flat	-	Low
78	Marbled Rainbow	Flat	-	Low
79	Marker (Geometry)	Flat	-	Low
80	Paper (Geometry)	Flat	-	Low
81	Race	Flat	-	Low
82	Single Sided	Flat	-	Low
83	Space	Flat	-	Low
84	TaperedHueShift	Flat	-	Low
85	TaperedMarkerGeo	Flat	-	Low
86	Watercolor Paper	Flat	-	Low
87	Watercolor Paper (Geometry)	Flat	-	Low
88	Wind	Flat	-	Low
89	Dance Floor	Particle	√	Low
90	Dots	Particle	-	Low
91	Hyper Grid	Flat	-	Low
92	3D Printing Brush	Tube	-	Low
93	Wireframe	Flat	-	Low
94	Diffuse	Flat	-	Low
95	Square Flat	Flat	-	Low
96	Geom/Thick (Duct Tape)	Flat	-	Low
97	Comet	Tube	√	Low
98	Waveform Tube	Tube	√	Low
99	Fire	Flat	√	Low
100	Electricity	Flat	√	Very Low

No.	Brush Name	Type	Animation	Affordance Level
101	Hypercolor	Flat	√	Very Low
102	Plasma	Flat	√	Very Low
103	Rainbow	Flat	√	Very Low
104	Streamers	Flat	√	Very Low
105	Waveform	Flat	√	Very Low
106	Waveform FFT	Flat	√	Very Low
107	Dr. Wigglez	Flat	√	Very Low
108	Concave Hull	Hull	-	Very Low
109	Waveform Particles	Particles	√	Very Low

A detailed description of the materiality and artistic affordance properties of the *OpenBrush* virtual brushes can be seen in Table 1.

The authors' ability to recognize virtual brushes' artistic qualities aligned with Norman's affordance theory. By leveraging our prior knowledge and experience in art creation, we were able to identify the potential for specific creative actions in the virtual environment. For example, the tube brush is used to aesthetically represent an object's texture. However, hull brushes can only be used to give the impression of objects with volume if they are arranged overlappingly. This confirms that the virtual brushes can serve as an agency to creative action. As Lindstrand (2021) explains, affordances enable actions by allowing agents to perceive, interpret, and make distinctions based on the object's properties and the agent's capabilities and interests in the situation. The contextual nature of human-nonhuman interactions in artistic affordance aligns with ANT, which also emphasizes how actors use their influence and how these contexts can change over time.

The act of making this distinction during artmaking in a VR environment depends on the nature of the object (virtual brush and their visual elements) that can be seen, and the ability and interest of the authors as agents in the situation. Following the unique character of the relationship between an actor and his environment, we perceive it differently as an artist and thus recognize the different properties of the VR environment as a possible resource for artmaking. Some samples of our artworks in Figure 5 show that our early perception of brush characteristics guided us to make specific shapes and forms, consequently affecting our creative process.

Based on these findings, we proposed a new concept of affordance: virtual artistic affordance. By expanding the scope, we believe a new concept might encompass emergent affordances (unforeseen uses) or how affordances change based on artistic and creative context. Gibson's original definition focused on the environment's potential for action relative to an organism. This does not fully capture the complexities of interaction in

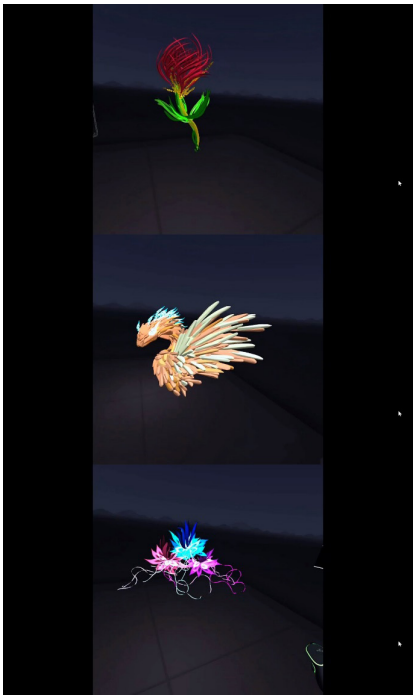

Figure 5. Sample of our artworks created using VR program.
(Source: authors documentation).

the artistic and creative world. We also would like to address the duality, that is, the tension between perceiving affordances inherent to objects (Norman's view) and the relational nature of affordances (Gibson's view), which is a point of ongoing debate. A new concept could bridge this gap by acknowledging the design and the user's role in shaping affordances. Lastly, the rise of complex technologies like AI and virtual reality necessitates a more nuanced understanding of affordances. A new concept might consider how affordances are layered across physical and digital environments or how machines influence them.

We define artistic affordance in VR as everything in a virtual environment that affects the creative process and artistic expressions during VR artmaking. The concept of artistic affordance in virtual space is generated from the following key points:

- Mid-air painting technique where the artist could paint directly in the air and create visual elements that appear to be floating.
- Simulation of painting tools in the form of various types of virtual brushes and strokes.
- Digital commands such as undo, mirror, scale, and teleport.

The new concept of artistic affordances is significant because it communicates VR's functionality and usability to creative and artistic means. Artistic affordance comprehension will helps identify users' cognitive load and frustration, increasing their satisfaction and engagement in artmaking practice. We also suggest that virtual brushes will generate a high learning curve for first-time and non-artist users; not only does painting in the air using VR require an adaptation process, but users who are used to working on flat and solid surfaces need haptic feedback as a movement guide. A number of studies (Wiese et.al, 2010; Arora et.al, 2017; Arora & Singh, 2021) show that the absence of specific feedback causes the strokes produced in VR environments to have a low level of accuracy. The presence of haptic feedback will provide guidance when working in a virtual space. This finding is vital for developing and improving VR painting programs in the future.

DISCUSSIONS

The results show that affordance in VR is not only caused by the characteristics of virtual space that is free from real-world

laws of physics; affordance is also caused by simulations of painting tools, in this case, virtual brushes. Virtual brushes in the OpenBrush VR painting program have different affordance ranges, which means some allow for more creative actions than others. Brushes that simulate real-world paint tend to have high affordance and strong agency, while brushes with unique digital characteristics have a low affordance level and weak agency. Affordance is influenced by several factors, including material properties, animated motion in brush stroke texture, and dynamic particle movement in some brushes.

The study's findings validate Gibson's affordance theory that the VR environment influences artist's behavior. Aligned with Norman's affordance theory, the authors were able to identify the artistic features of virtual brushes. Drawing on our existing knowledge and experience in art creation, we recognized the potential for specific creative actions in the virtual environment. Furthermore, the way we used the brush and palette in the VR program is strongly connected to the theories of Tucker and Ellis on micro affordance and Humphreys' paired object affordance. We also offer a theoretical contribution concerning the affordance phenomenon, specifically the artistic affordance in the virtual environment. We argue that the artistic affordance supports the ANT concept where non-human actors are seen as having agency and the capacity to influence outcomes.

The findings described in this study have some limitations. Due to the relatively high number and diverse virtual brushes available in the VR program, it was not feasible to thoroughly test each brush in detail for the purposes of this study. It is recommended to conduct a more thorough and extensive analysis of all the features included in the VR program, considering an appropriate and optimal duration of time. Furthermore, the study of artistic creative processes using new media is always related to the adaptability and flexibility factors that may vary from user to user. The differences in perceptions between novice VR users and users who actively use VR, and the differences between artists and non-artists user should be studied through further research. This study used a heuristic approach, which was carried out only by the authors as participants. The interpretation of the results tends to be biased and subjective based on the understanding and knowledge capacity of the authors. Future research should also explore different methods for generating more interpretable explanations.

The practical implications of this research for visual artists interested in exploring VR as a creative medium is that they should familiarize themselves with the characteristics of the material, the interface, and its effect on the creative process and artistic expressions. The relatively high learning curve and its effect on user comfort during the creative process should also be considered, so it is suggested that visual or haptic feedback is added. Therefore, developers, researchers, and artists should collaborate to design a richer user interface to further establish VR as an artistic medium.

CONCLUSIONS

Affordance is a unique relational manifestation of agents and virtual environments. The artists's perception of the actions that affordance can generate is influenced by the nature of the virtual space, which provides specific agency actions and ultimately produces artistic affordance. Artistic affordance refers to the potential of a tool or environment to inspire and enable artistic and creative expression. In the context of a VR painting program, artistic affordance is related to the virtual environment's materiality, which offers a variety of artistic actions. The materiality of the virtual environment in a VR painting program plays a significant role in providing artistic affordance to the user. Opportunities for action facilitated by artistic affordance in VR painting programs are generated by simulations of painting tools, specifically virtual brushes, which provide various levels of agency to users who use them to create art.

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