

Do you Feel like Flying?

A Study of Flying Perception in Virtual Reality for Future Game Development

Soroosh Mashal, Matthias Kranz, and Gerold Hoelzl

Abstract—Being able to fly is still a dream. Till today it is only possible with heavy use of technology. Video games incorporated flying as a fancy way of movement inspired by mythical creatures, gods and fantasies.

In Virtual Reality, with its deep immersion, the avatar control especially for flying is still performed by physical controllers that lack to feel like a natural extension thus hindering the full immersion. To overcome this limitation, this work did an exploratory study on (i) the perception of wings as a natural body extension and the (ii) natural movement performed by humans when flying.

In a Virtual Environment, we studied the extent of the virtual presence and body ownership of wings. Results highlight that placing wings on the shoulders in an angelic form and controlling them by arm movements is the preferred way to extend human capabilities towards flying in non-technologically restricted VR-Games.

Index Terms—Virtual Reality, Flying, Immersion, Wing Perception, Avatar Ownership, Game Design, Interaction.

1 MOTIVATION

From ancient history to today's video games, the extension of the human capabilities to be able to fly is usually envisioned by having a wing based body extension on the back of the human. Whether it is the stories of angels, Valkyries of Odin or the waxed wings of Icarus, humans as a species always had the ambition to expand imagination and limits to conquer the skies. Despite this deep innate expectation, game designers and especially the development of controlling avatars in virtual environments neglected these aspects. The extension of the human body is done by mechanical apparatus like in Birdly [1] that is the de facto standard for immersive flying simulation. The mechanical nature of the system can give you the feeling of gliding, but due to its restricting nature, it can not give you an immersive, natural feeling of flying for avatars in an angelic form. We aim to design a natural, non-restricting interface that puts users in an immersive VR environment and gives them the illusion of flying.

In order to do that, we adapted the user-centered design approach and established a feedback loop to redesign and iterate until we achieved the most natural interaction scheme. This is a challenging but major step that breaks new ground for flying perception in Virtual Reality environments compared to the currently well-established approaches that give you just a gliding perception and do not account clearly for the bouncing effect in the flight.

Such serious games can also mean more to some souls than others. "Feet, what do I need you for when I have wings to fly?": said Frida Kahlo. Flight in Virtual Reality

can give people with mobility problems the chance to experience an escape from reality and confine of their bodies into an immersive environment in which they can be embodied in an avatar with no mobility limitation.

This paper is an exploratory research in the area of perception and immersion of flight that uses an iterative user-centric design approach in all Sections and Experiments. Except for the cases where the results from the iterations are valuable (e.g. haptic studies), only the final experiments and questionnaires are mentioned in the paper. The paper is structured as follows:

In Section 2 we posit the Related Work for immersive VR and flying. Section 3 explores the general perception of flight, wings attachment, wing model and the user's valuation of an immersive VR game with flying functionalities. It uses questionnaires and a multicultural population/sample size to ensure it takes all backgrounds into account. Based on the findings from Section 3, we provide the user with an additional layer focusing on haptic immersion in Section 4. In Section 5 we present the experiments on the output of the Section 4. The first experiment 'Immersion Study' (be referred to 5.2.1) focuses on flight immersion, wing ownership and embodiment. In addition to that, it also validates the user valuation of the system. The second experiment 'Interaction Study' (be referred to 5.2.2) selects a smaller VR expert group from the first experiment and tries to explore the best interaction scheme for other in-game actions along with flight functionalities. In addition to that, it tries to find the causation of the perception found in Section 3.

2 RELATED WORK

Two decades ago Virtual Reality was more of a sci-fi gadget rather than a consumer product, but nowadays, you can see it in various fields ranging from phobia therapy and serious games to the entertainment industry.

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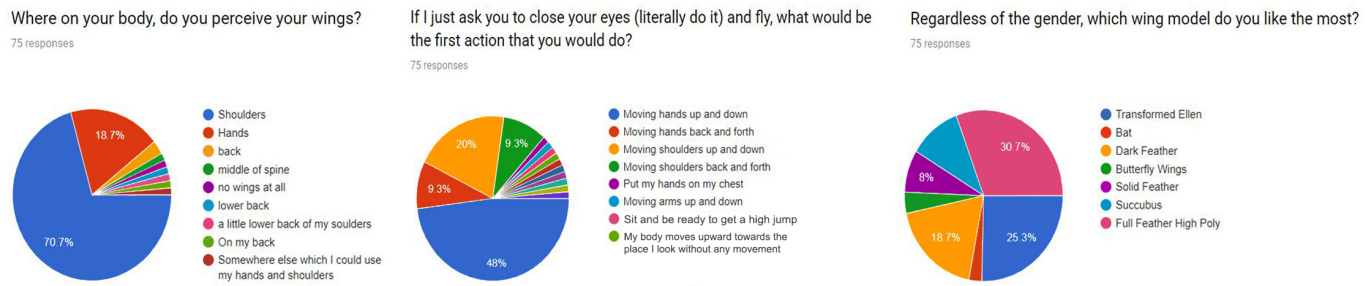


Fig. 1. Wing Location Attachment on the Body (left), Bodily Movement Conductive to Simulating Flight (middle), Favorite Wing Model (right).

The User-centered design approach is an iterative design process in which designers focus on the users and their needs in each phase of the design process. It uses a combination of investigative methods and tools (e.g., surveys and interviews) and generative ones (e.g., brainstorming) to develop an understanding of user needs. The four phases of this process are understanding context of use, specify user requirements, design solutions, evaluate against requirements [2].

2.1 Elaborating Flying on Presence and Immersion

Body transfer illusion is possible and we need the possibility of controlling the avatar to achieve it [3]. In addition, [4] shows that this illusion are highly dependent on synchronous visuo-tactile stimulation. Thus, we used OptiTrack in our experiments.

A vast range of perspectives towards the immersion and interactivity in Virtual Reality is presented in [5]. The article ranks role-playing games as the highest when it comes to interactivity and second when it comes to immersion. Virtual Reality technology should be integrated into games so that it can remain relevant in this fast-paced trend [6]. The design approach and the taken development process is highly dependent on its goals. The user's expectation of the game and environment is the first and most important factor in producing immersion in Virtual Reality and 3D computer games [7]. We also see how user centred design approaches can help us achieve this goal [8].

2.2 Flying and Wings

In [9], OptiTrack and fundamental physics of flying were used to implement a realistic approach towards a natural bouncing movement rather than gliding. Despite immersive flying results, the users did not feel virtual body ownership. A simple reason for that was using a bat as the avatar. Another point which we tried to note and adjust in comparison to this study was to create an immersive environment which would be interactive. Noting the pyramid of presence and immersion [10] [11], we must always make sure that without underlying factors, we may not achieve higher level results. Regardless, the implementation of tools and processes in our study are pretty similar to theirs. However, our prime difference is that we took the user-centered approach [2] to design the system and within those feedback loops and design researches, we tried to ensure that the final product is as usable and acceptable as possible by people.

The work presented in [11] is focusing specifically on the extension of the human body and various effects. They conclude that visuomotor feedback was required in order to establish agency and body ownership of the wings, and visuotactile feedback significantly enhanced body ownership of the wings, and agency according to questionnaire ratings. This study emphasizes the importance of visual and its relevance for agency and body-ownership.

Using the body instead of controllers is more engaging and immersive [12]. In addition, it mentions the positive effect of synchronous flapping audio feedback for immersion.

Thus, due to its iterative refining process, the user-centered design approach was used in the study. In addition, the VR experience was integrated in a game with a adjusted story to ensure relevancy in the future.

3 PERCEPTION RESEARCH

We posit the research process and results of wing and flying perception here. One of the essential parts of each design process is to understand the expectations of users and design in a way that would cover the majority of the population. It is apparent that there is no one-size-fits-all model or perception for anything, however, the majority of the population normally can be covered by findings out the most favorite model.

The research questions were as follows:

- 1) When it comes to an extended winged body (avatar) for humans, where on their body do they perceive their wings? Or do they even imagine flying with wings?
- 2) When asked to fly, what is the natural action that they do? In other words, how do they perceive themselves flying?
- 3) Among the variety of wings presented visually, which one is preferred?
- 4) If there were a product in an amusement park/arcade in which you could experience immersive flying, how much would one pay for it?

3.1 Study Design and Research Results

The sample size for the study included 73 VR enthusiasts who were from Germany, Iran, India, Italy, France, Netherlands, Colombia, Romania, Bosnia and Herzegovina, and Korea. The participants were 50.7% male and 48% female

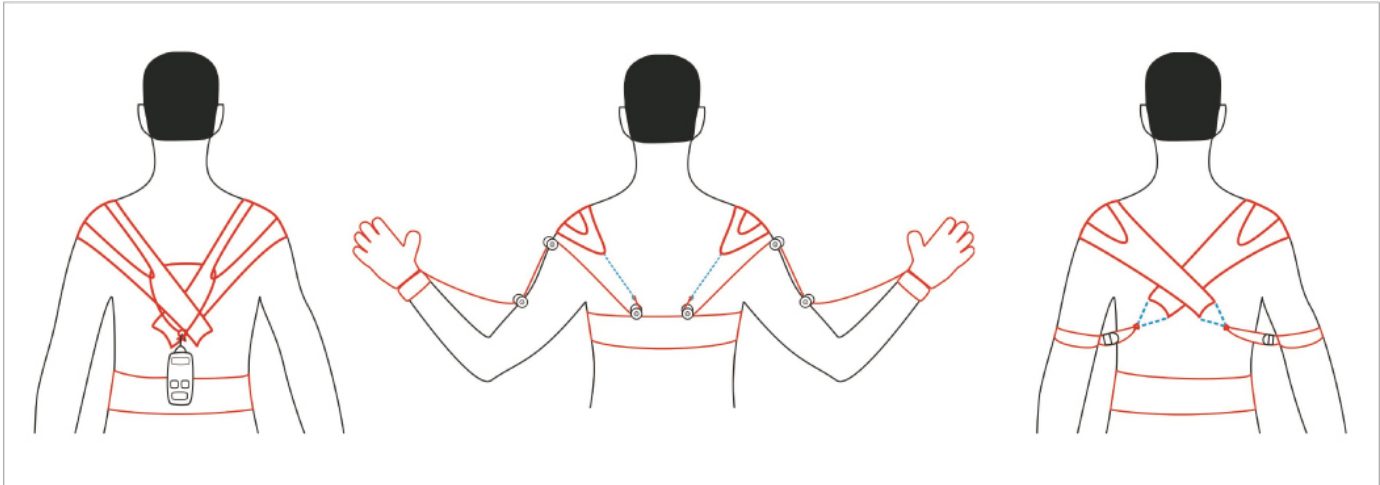


Fig. 2. Force Measurement for Scapular Contraction (left), Initial Concept Design for Prototype (middle), Final Model for Haptic Feedback (right).

(the rest preferred not to say). Thus, we did our best to ensure the representativeness of the population.

As seen in Fig. 1 on the left, we learned that 78.6% of the participants imagine wings to be located on their shoulders and back (in the area between spine until shoulders - butterfly mode), while only 18.7% of the participants expect their wings on their arms (bird mode). The rest 2.6% preferred to fly without wings (superman mode). Thus, we placed the wings on the shoulder for our avatar implementation.

Regarding the movement of flight, as seen in Fig. 1 in the middle, the following results were gathered. The majority of the study participants were moving their hands and arms up and down (48%). In addition to that, 9.3% of the study participants were moving their hands and arms back and forth. The second highest group were the ones who were moving their shoulders up and down who consisted 20% of the study participants. They are followed by 9.3% who move their shoulders back and forth. The rest were single ones who did scapular contraction and protraction or simply wanted to fly like Superman. Thus, we used the arm movement for our VR game as the input for flight.

Considering the wing model (Fig. 1 on the right), the sum of 74.7% of the study participants liked feathery wings. Among them, 44% liked the dark color and 30.7% liked the white color. It was followed by succubus, solid, butterfly, and bat with 10.7%, 8%, 4%, and 2.7% respectively. Thus, we used the dark feather model for our angelic model implementation.

The initial iterative interviews and questions showed that VR arcade users would pay up to 30 euro. Thus, the range of 5-30 euro was used for the final questionnaire. The participants were eager to pay 17.8 euros on average to try such a game in an amusement park or arcade. It should be noted that 28% of the participants were eager to pay the maximum amount. This implicitly shows the extent of their enthusiasm about the VR experiment. The same rule applies to upcoming experiments.

4 HAPTIC STUDIES

As mentioned in [11] using haptic feedback can lead to a higher degree of wing ownership.

The perception results presented in Section 3.1 indicate that the majority of people perceive having wings on the back and shoulder, and the same majority move their arms as the first intuitive action to fly. This contradiction introduced a challenge to provide haptic feedback.

The first part of research was more focused on the biology of avian and flying insects. As the majority of participants perceived wings on their back and shoulders, it made sense to provide the haptic feedback on that point. Looking at human biology, Rhomboids were identified as the most relevant muscles to move wings on the back (if we had any). Thus, scapular contraction and protraction seemed to be the most relevant perceived movement of a pair of wings on the back.

To test the hypotheses, a gadget was designed as seen in Fig. 2 (left) to test the effect of external scapular contraction and protraction on the users. The participants reported 100% owning wings during this experiment. We also found out that the best way to externally make this movement on the user's body is to have an orthogonal push with soft support on the spine (like a palm of a hand). The prototyping was done using a user-centered approach to ensure the highest acceptability by the end users.

The next step was to find the range of required force to do scapular contraction. The table 1 shows the measurements. We also learned that scapular contraction is different between males and females and it is highly dependent on the user's muscles and body type. In our measurements for orthogonal pull with support on the spine, the lowest was 36.16 Newtons for a female and the highest was 46.72 Newtons for a male. Thus, adaptability of the gadget to different forces and sizes is vital from an industrial design perspective. One idea was to use mini actuators which are attached to the skin on the rhomboid to do scapular contraction. In order to do so, the amount of change should have been measured. Table 2 shows the changes in a different setting.

TABLE 1
Scapular Contraction Force Measurement

Subject	Gender	Test Type	Average Force (N)	Info
1	Male	Orthogonal with Hand Support	40.00	180cm height, 63kg
1	Male	Diagonal without hand support	30.00	180cm height, 63kg
2	Male	Orthogonal with Hand Support	46.72	173cm height, 54kg
3	Female	Orthogonal with Hand Support	34.16	175cm height, 78kg

TABLE 2
Scapular Contraction and Protraction Differences

Configuration	Scapular Protraction in pixels	Scapular Contraction in pixels	Difference in percentage
Lying closed arms	486	449	8.2
Lying 45 degree open	466	455	2.4
Lying 90 degree open	445	417	6.7
Lying 135 degree open	451	443	1.8
Lying 180 degree open	451	447	0.9
Standing closed arms	515	461	11.7
Standing 45 degree open	471	438	7.5
Standing 90 degree open	488	447	9.1
Standing 135 degree open	514	479	7.3
Standing 180 degree open	486	449	8.2

The model was tested on three users based on a user-centered approach using tapes attached to the skin and ropes to pull them manually with calculated force. They unanimously mentioned that the approach provides no immersion and feels really bad. Further questioning indicated that they were feeling the tension on the skin surface and the inner muscles were not being stimulated to provide the users with the sense of wing ownership.

The next approach was to use the force from the users' arm movement as an external force for scapular contraction. The model was designed as seen in the Fig. 2 (middle). However, after seven iterations of user feedback including 4-5 users in each iteration, it was ultimately changed to Fig. 2 (right). The gadget was tested in isolation without VR and it appeared to be effective. However, the integration of gadget with the VR was detrimental to the experience. The users indicated the following factors as the most important reason: 1) The gadget could be felt as an auxiliary thing which was taking away our focus, 2) The bands on the shoulder were sliding towards the neck when we were moving arms up. This propelled us to try to provide the haptic feedback on the arms.

The paper wings model focused on providing the haptic on the arms rather than the back. All initial participants (6) accepted the model, thus we used it for the final research as seen in the Fig. 4. Table 3 summarizes the major findings for the final system configuration as shown in Fig. 3.

TABLE 3
Tested Haptic Models Conclusion

Model	Accept	Major Reason
Small Actuator on the Skin	No	Pull was felt on the surface rather than muscle
Bands on the Shoulder	No	Limiting movement, and bands were being dislocated towards the neck during play
Paper Wings with feathers	Yes	Air drag force and feathers aligned with natural movement

5 STUDY EVALUATION

The next step was to test the hypothesis of angelic avatar in a virtual environment with another set of participants who were new to the system.

5.1 Implementation

The implementation was done in Unity using C sharp language. Wing models were created in 3Ds-Max and were imported into Unity. The 3D Game Kit of the Unity Asset store was used to provide the base environment for the game. In addition to that, a story was developed so that the users would have the basics of immersion served. OptiTrack was used to track wing game objects. The movement of those objects was used to trigger fly function and flying animation inside the game. The system configuration and the connections can be seen in Fig. 3.

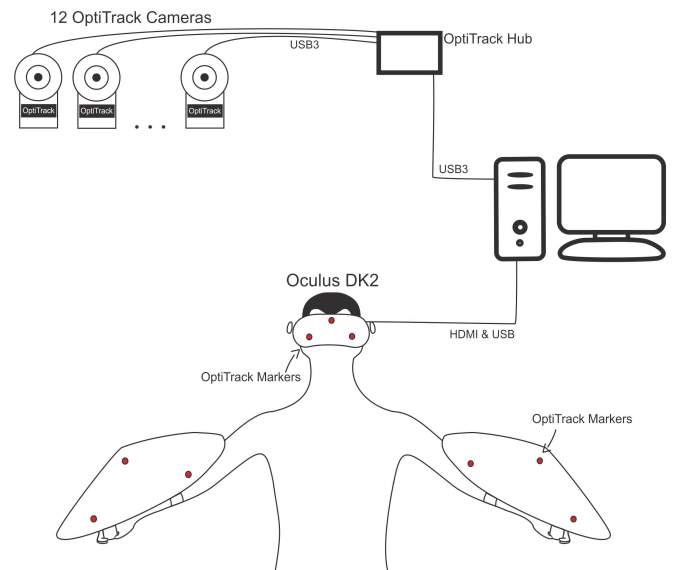


Fig. 3. System Setup with OptiTrack for high precision movement tracking and the Oculus DK2 as VR output device.

The wing animation curves were adjusted to reflect a natural flapping movement rather than a linear movement. The fly function would bounce the character upward and forward. The amount of bouncing was exposed as a public variable to be adjusted, however, during the first experiment, it was fixed so that we make sure it does not interfere with other factors. The orientation of the character is based on the direction of the HMD (Head Mounted Device) which is the direction that the player looks. The value of the slerp

was adjusted to reflect the best user experience with the least chance of cybersickness. The initial iterations before the final experiment showed us that users move side to side and back and forth in the environment. Therefore, we had an area of 6 square meters for them cleared and safe to ensure they have this freedom. In addition, the initial experiments showed the first sign of cybersickness after 15 minutes. Thus, we ensured that the portal inside the game (final goal) can be found in less than 10 minutes to ensure that the experience will not cause any cybersickness. This natural movement The final character in the environment can be seen from a third person perspective in the Fig. 4.

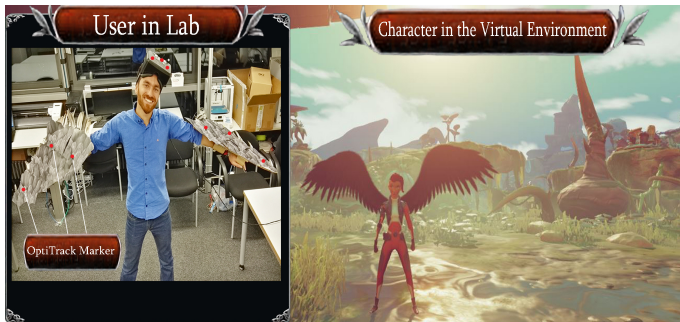


Fig. 4. The Researcher with the Wings in the Lab (left), and the corresponding view with selected Wings attached to the Back of the Avatar inside the Game (right).

As seen in Fig. 3, the system consists of three main parts, namely PC, OptiTrack, and Oculus Kit. Twelve OptiTrack cameras track the markers in the environment. Three markers are required on each object to make a rigid body. The data from the cameras are transmitted to the OptiTrack hub and then to the PC. Motiv software translates the data from OptiTrack cameras into coordinates and objects and sends it as a stream of data to Unity game engine running on the same PC. Unity gets the objects (wings and HMD) coordinates from Motiv and calls functions based on any change to the coordinates. Lastly, Unity sends the output to the monitor and Oculus.

5.2 Experiments

Two experiments were carried out to study the immersion and embodiment with different functionalities. The first one was focused on the immersion aspect, and the second was focused on the interactions in an environment with such flight functionalities.

5.2.1 Immersion Study

We will explain the conducted experiment to assess and evaluate the implemented system which was described in Section 5.1. As mentioned in the Related Work Section 2, there are multiple ways to have an assessment of presence and immersion in Virtual Reality. This study will mainly use questionnaires to assess the presence of the participants.

The experiment was carried out in EISLab at the University of Passau, Germany. The area covered by OptiTrack was almost 10 square meters, however, due to the connecting cable of Oculus, only 6 square meters were used. Since the

participants were using flapping for locomotion, the area was pretty abundant.

To add a layer of haptic feedback, a set of light-weight wings were created using carton and real feathers. The effect of drag force of moving arms while wielding the wings was tested on a group of six before the final experiment. They unanimously noted the effect is positive, thus, it was included in the final experiment.

TABLE 4
Immersion Questions

Question	Source	Factor	Subset
To what extent did you have a sense of being in the virtual environment?	SUS	Presence	
To what extent were there times during the experience when virtual environment became the 'reality' for you, and you almost forgot about the 'real world' of the laboratory in which the whole experience was really taking place?	SUS	Presence	
When you think back about your experience, do you think of the virtual environment more as images that you saw, or more as somewhere that you visited?	SUS	Presence	
During the time of the experience, which was strongest on the whole, your sense of being in the virtual environment, or of being elsewhere?	SUS	Presence	
How natural did your interactions with the environment seem?	Witmer	Control Factor	Natural
How much did the visual aspects of the environment involve you?	Witmer	Sensory Factor	Involvement /Control
How natural was the mechanism which controlled movement through the environment?	Witmer	Control Factor	Natural
Were you able to anticipate what would happen next in response to the actions that you performed?	Witmer	Control Factor	Involvement /Control
How compelling was your sense of moving around inside the virtual environment?	Witmer	Sensory Factor	Involvement /Control
How quickly did you adjust to the virtual environment experience?	Witmer	Control Factor	Involvement /Control
To what extent you felt having wings?	This Study	Ownership	
To what extent you felt embodied as the character inside the game?	This Study	Embodiment	

The users were tested individually. The process started by telling the user the story of the game so that the atmosphere they see in VR and contradiction between moving arms and having wings on the shoulder would have some logical explanation in their mind. The environment contained enemies, poisonous waters which they must avoid, magical platforms which will be activated when stepped on, crystals which would be activated when passed through,

and finally the great portal which they had to find and pass through to finish the game.

The task was to discover the new planet and the ultimate goal was to find the great portal. Depending on the user strategy, it would take 10 minutes on average for a user to discover the planet and find the portal.

Table 4 shows the questionnaire used to assess the immersion. The first Section of the questionnaire consists of 12 questions. The first 4 are taken from *Using Presence Questionnaires in Reality*, the next 6 are taken from *Measuring Presence in Virtual Environments: A Presence Questionnaire*, and the last 2 are inclusive to this study. The questionnaire's reliability is tested using Cronbach's alpha (0.81) that is above an acceptable threshold for exploratory researches (0.7). The next Section of the questionnaire included demographic questions, followed by two questions. First one asking about their experience of VR, and the second one asking their eagerness to try out this system in an amusement park.

In this study, 27 participants were students of the University of Passau aging between 18 to 34 years old. 59.3% of the study participants were male and 40.7% were female which shows a relatively balanced distribution of genders. From nationality perspective, the participants were from the following countries: Germany, France, Spain, Russia, Mexico, Iran. Two third of the participants had experienced Virtual Reality before. Thus, ensuring that the majority had some point of reference beforehand. One third had not experienced Virtual Reality beforehand, however, they stated that they were totally familiar with the technology.

To what extent you felt having wings?

27 responses

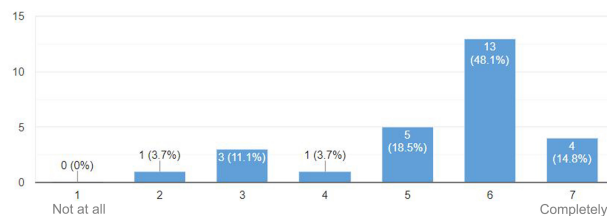


Fig. 5. Perceived Wing Ownership.

To what extent you felt embodied as the character inside the game?

27 responses

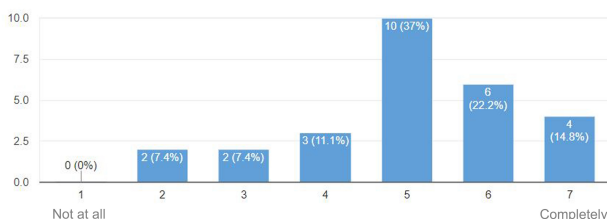


Fig. 6. Avatar Embodiment in the developed Virtual Environment.

The results showed that the arithmetic mean of immersion in the Likert scale was 5.5 out of 7. The Fig. 5 shows the distribution of answers for the wing ownership. The arithmetic mean for this aspect was 5.4 out of 7 in the Likert

scale. Furthermore, the details of avatar embodiment is demonstrated in Fig. 6. The arithmetic mean for this aspect was 5/7 in the Likert scale.

The majority of the study participants (85.2%) indicated that they would pay up to 30 euro (highest in the list) to play such a game in an amusement park or an arcade.

Conclusively, this experiment showed that the action of flapping flight is more natural in comparison to gliding-only and it can increase the user's presence in Virtual Reality games. In addition to that, we found out that when it comes to flying, having adjustable flapping speed can become a positive factor in immersion. Another important lesson was to have gliding in parallel to flying which can be activated based on the user's movement. This is certainly another user-centric factor which must be taken into account. There was no report of cybersickness for this experiment, as we tried to eliminate it by reducing the required time to almost 10 minutes. It is advisable to have future studies in a CAVE environment with safety measures and also add walking to the game to compare the results.

5.2.2 Interaction Study

This experiment focused on answering the following questions considering that the hands are controlling the wing flaps using the expert interviews with the participants:

- 1) What is the natural action to interact with an in-game object?
- 2) What is the natural action to attack while holding a weapon?
- 3) Does the user enjoy adjustable flapping speed or find it overwhelming?
- 4) What factors have contributed to creating the user's perception of wing attachment and natural flying movement?

This experiment used the same environment as explained in the Implementation Section 5.1. The sample size in the study was 7 people from the last study who considered themselves as VR gamers. Based on the user-centered approach, four of them were used for development (iterative stage) and three of them were used for the final experiment phase. The process was as follows:

- Hypothesizing a possible interaction
- Implementing it in Unity
- Having the users try it out
- Interviewing the users to get their feedback
- Decision on improvement or discarding the interaction model

Upon finalization of the user-centered design approach process, 3 different participants were used as test subjects to validate the design. The interviews and observations showed that the users start to feel slight dizziness after 15 minutes and prefer to take a rest after 20 minutes. There was no case of nausea or strong cybersickness. The following results have been identified as the most immersive interaction models when it comes to object interaction:

- 1) **Object interaction:** moving the main hand (usually right) towards the object and having colliders (in Unity Game Engine) to activate on the collision of

the hand and the object boundary. It was the natural interaction to grab an object and it did not interfere with the flapping detection as it was horizontal rather than vertical and only one hand rather than two.

The next object interaction was simply getting close to the object without the need to move the arm to interact (e.g. grab) with the object. It also proved natural in cases where objects needed to be activated.

- 2) **Attack with hand-held weapon (e.g. Sword, staff, polearm):** Using both hands and moving them fast forward was identified as the best model. It must be noted that this is the case when they are having wings, so the results showed that by distinguishing between vertical movement for flight, and horizontal movement for attack/interaction, the user can have the best experience and alignment with the environment.
- 3) **Flapping flight sensitivity:** The users unanimously find the flapping flight sensitivity option useful. However, they wanted to calibrate it in the beginning and have it constant during the game as oppose to changing it during the flight (like rocket power). They mentioned that too many adjustment levers during the game can be detrimental to the experience.

In order to answer the fourth research question in the current experiment, the participants were interviewed to note down all of the factors contributing to the perception of wings/flight in the order that comes to their mind. These interviews showed that the users indicated the followings as the most important factors. The same words used by the participants are mentioned here.

- 1) **Flight perception:** Birds, butterflies, insects, Kite, Plane
- 2) **Wing perception:** Movies, Angels, Statues, Games, Church

Further questioning revealed that people perceive wings on their shoulders because that is the image they have usually seen, and they naturally move their arms because that is the movement of flying birds that are the most common flying noticeable objects around them.

6 SUMMARY AND DISCUSSION

Accounting for the general perception of the population is the first stage of a user-centered design approach. In this stage, we divided the perception into two main aspects: wing perception and default flight movement.

The first is related to the avatar design and the agent embodiment, and the second defines the configuration and input of the system and the game. The research result indicated that 89.4% perceive the wings located on their shoulder and their back. This means the angelic avatars should be the choice when it comes to game design and development for characters with wings.

Furthermore, the results indicated that 57.3% of people move their arms as the default instinctive action to fly regardless of their cultural background. This fact opened up a hard design challenge.

The next step of immersion was to provide haptic feedback. The result was that 100% of participants, six for the initial experiments, agreed that hard-paper wings with feathers are the most suitable model. The last experiment on the angelic avatar and flapping flight performed with 27 participants provided the following results. The arithmetic mean for presence, avatar embodiment, and wing ownership were 5.5, 5.0, and 5.4 out of 7 on the Likert scale respectively. In this study, we used the Likert scale to measure the extent of the participants' presence rather than interviews with yes/no questions or similar questionnaires.

In addition to that, the results of the expert interview with the participants who have tried both Birdly and Valkyrie personally showed that avatar embodiment and flapping flight are the key advantages.

The next step was to design an interaction scenario in which the users can find it natural to move their wings and change objects and perform attacks to kill enemies. The game story was used to inform players and teach them these interactions. In our example scenario, the avatar was a character enhanced with robotic wings and the following interactions were the ones which the wings were programmed to respond to.

- 1) Flight: Flapping - Movement of hands up and down with calibration of sensitivity by the players.
- 2) Interaction with objects: Moving one of the hands towards the object while having the other one stationary. For example, opening a door, or picking up an item.
- 3) Attack: Moving both hands forward. Ideally, the speed of attack (e.g. the sword swing) should match the velocity of the movement.

Through our iterative process, we found the optimal game-play period was 10 minutes to prevent the effects of cybersickness and none of the 27 participants in the first experiment experienced it. However, in the second experiment in which there was no time limit and ultimate winning goal, the participants started to feel a little dizzy after 15 minutes and preferred to take a break after 20 minutes.

The participants also indicated the following factors which have contributed to the formation of their perception of a wing extension on the human body: depictions of angels in movies, churches, statues and paintings (art), and games.

The adjustable flapping speed also proved to be a positive factor in immersion. The results showed that all participants who had the adjustment option felt more immersed, expressed more control over their avatar and could fly longer without getting tired.

To measure how much the participants value the experience and additionally to show that they are VR enthusiasts, two separate studies were carried out. On the first study the participants were eager to pay 17.8 euro as an average on a price range from 5 to 30 euro. This number was before trying out the system (expected value).

On the second study, they were presented with a 30 euro price tag after their experience and 85.2% of them were willing to pay that amount (actual value).

Discussing limitations and lessons learned in this study for future work, we now see the absence of any force feed-

back channel from the VR world to the user as a drawback. In other words, when the wings of the user in the virtual environment were hitting an object or were exposed to a force e.g., the player would fall from a cliff or change the medium from air to water, there was no channel to provide this feedback to the user in the real environment. Although no study participant commented on that issue, it opens up a research line for future studies to use e.g. VR haptic feedback vests and study its effect on immersion based on forces generated in the VR world that the virtual avatar is exposed to, projected back into the physical world on the real user/gamer.

We see a second limiting factor in the interaction experiment in Section 5.2.2 in the navigation studies, respectively how users navigate in the VR world. Currently, the movement was solely done using flying, however, adding walking to such interactions should be studied. Moreover, in our setting, the user was flying towards the direction he was looking at, respectively his head was pointing to. Although this was the best setting we found through our iterations, in games and scenarios where you have to fight multiple enemies, this might not be the best case anymore. A possible future study can explore further on the relation between the complexity of the environment (e.g. number of enemies and elements in each moment) and navigation in the environment.

7 CONCLUSION

Do you feel like flying? The hypothesis and driving force of the paper can now be answered with yes. We revised the traditional design approach of systems that promise you to make you feel like flying. We put the user in the center throughout the whole design and implementation process and came up with a system solution that does not restrict the user movement thus keeping the unbound flexibility and felt weightlessness that is expected while flying. We investigated in the movement and force perception a user anticipates and recognizes while flying in a virtual environment. Combining the results in multiple conducted user studies we showed that users felt more naturally in flying than in today's available off the shelf systems. Throughout the development we saw the clear need of heavy user involvement and experimenting to deal with the decoupling of the VR-Environment and its processing by the human brain, and the physically perceived forces. Understanding this complex relationship, we were able to design and implement a system that gives the users a unique and natural feeling of flying and also dealing with negative effects like cybersickness. We clearly showed with our results, that less complex systems can be built by combining (i) specifically, spatially restricted generated physical forces in combination with (ii) the human cognitive matching process in VR-Environments to fully immerse users into the VR-World.

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