

# Improved Third-Person Perspective: a solution reducing occlusion of the 3PP?

P. Salamin, D. Thalmann, and F. Vexo  
Virtual Reality Laboratory\* (VRLab) - EPFL

## Abstract

Pre-existing researches [Salamin et al. 2006] showed that Third-Person Perspective (3PP) enhances user navigation in 3D virtual environments by reducing proprio-perception issues. Nevertheless, this approach has shown drawbacks related to occlusions and adaptation time. The perspective proposed in this paper - our Improved Third-Person Perspective (i-3PP) - does allow the user to see through his/her body in order to fix 3PP limitations like occlusions. As gamers prefer using 3PP for moving actions and the First-Person Perspective (1PP) for fine operations, we verify if this behavior is extensible to simulations in augmented and virtual reality. Finally we check if the i-3PP would be preferred to the other perspectives for any action.

**CR Categories:** J.4 [Social and behavioral sciences]: Computer applications—Psychology;

**Keywords:** immersion, proprio-perception, exocentric perspective, distance evaluation, occlusion avoidance

## 1 Introduction

While playing video games, it has been noticed that gamers do not always use the First-Person Perspective (1PP). They usually prefer the Third-Person Perspective (3PP) for the moving actions and the 1PP for fine manipulation with the hands. We assume the 3PP is sometimes preferred in video games because it provides benefits to the user, e.g. a wider Field of View (FoV).

Another main issue in virtual environments (VE), and thus in video games, is the user immersion even if there is no technology lack. It seems to be a psychological problem: the mis-perception of oneself, because the user does not see him-/herself in the environment. We already proven that 3PP is very useful and even more intuitive to perform some actions [Salamin et al. 2006] but it also bring new bias: the occlusion because of the user body. A solution to this problem would be to allow the user to switch from one perspective to the other but what about a user performing fine manipulation while walking? We propose then an “Improved Third-Person Perspective” (i-3PP) mixing both perspectives. Globally, the user see the environment with the original 3PP except for the area of his/her head and shoulders. At this location, the 1PP is provided in continuum of the 3PP as if his/her head was half-transparent. Notice that we performed the experimentations with a video through system in order to easily change the environment from reality to augmented reality or virtual reality in the future.

\*<http://vrlab.epfl.ch/>

In this paper, we first make a state of the art to highlight the current problems of simulations with a HMD in virtual and augmented reality. We propose then some experiments with all the three perspectives cited above to verify their respective benefits. Finally we conclude with the obtained results and possible improvements of our system.

## 2 Related Works

The 3PP appeared in the video games a few years ago. It seems to be preferred in action games while the avatar is running into galleries [Richard Rouse 1999] and provide a more global (wider) view of the environment even if it adds occlusions.

In [Arsenault and Ware 2004], some problems of coordination between hands and eyes are highlighted. Such problems, like distance evaluation, are increased in our case because of using mono-vision (only one camera) with the HMD. But we assume they could be partially compensated by the use of 3PP that increases the FoV and user immersion.

It has been shown in [Popp et al. 2004] that people better evaluate the distance to a target when they must walk to it because they will have to provide an effort to reach it. In our case, we amplify this effort with our system that is not so heavy but a bit cumbersome. Wearing such equipment would then be a way to avoid the underestimation of the distances.

A small resolution combined with a bad image quality can affect the tester judgment [Thompson et al. 2004]. We decided then to use a HMD Sony Glasstron with a resolution of 800 per 600 at 60Hz. It has been shown in [Knapp and Loomis 2004] that the limited field of view of a HMD is not the cause of distance underestimation. We will then see if the user is perturbed and if he/she better estimates the distances with 3PP. Moreover it has been shown in [Messing and Durgin 2005] that this underestimation of the distances is linear and overall valuable for virtual environments. So, even if it is also written in [Willemsen et al. 2004] that people usually underestimate the distances with a HMD, people used to work with this device (like gamers with video games) should be able to compensate for it.

From a psychological point of view, we assume that seeing oneself moving but in another side can be disturbing. As said in [Lok et al. 2003], watching one’s body in the environment (augmented or virtual reality) is important to feel in the simulation. 3PP would reinforce the user immersion because our tester would see him-/herself and not a character controlled with buttons in the HMD.

As the user sees the top of his/her body in the environment through the HMD, a camera following him/her is needed - like in video games. On the technical side, the location of the camera behind the user is a real problem because of collision with the environment (e.g. walls, doors, and ceiling). In action games like EA Hellgate London<sup>1</sup>, the camera must always stay in the environment being able to view the avatar even if the character is backed up against a wall. In this case, they move the camera to the front of the user. Depending on the characteristics of our camera (field of view and focal), the distance between camera and user head should at least around 100 cm to provide a global vision of the scene. Moreover, as the user must be able to see the objects in front of him on the

<sup>1</sup><http://www.hellgatelondon.com/>



**Figure 1:** Left: 1PP view; center: both small and light cameras used during the tests; right: improved 3PP

ground, the camera is higher than the head location. The tester must then be careful with the walls, ceilings and other obstacles.

Finally, the 3PP becomes a hot topic because of technology impact in the society, e.g. psycho-therapists using VR devices. By the way, even artists like Marc Owens seem to have been inspired by our first 3PP prototype <sup>2</sup>.

### 3 Experiments

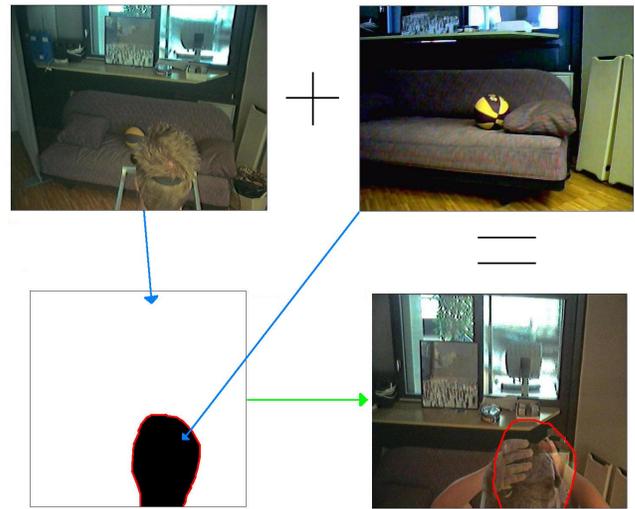
#### 3.1 Hardware Setup

In order to improve the user comfort, we first built a rigid backpack into which we put the equipment. There is then an added 1-meter-long arm on the top of this backpack to carry the camera that will provide the 3PP video stream. We decide to work with a radio color mini-spycam (picture on the top center of the Figure 1) with a wide FoV providing a video flow in PAL format (628 per 482 with a 62° pinhole). It only weights a few grams and can thus be easily fixed on the HMD. Concerning the i-3PP, we add a webcam Trust Wide Angle Live WB-6200p (picture on the bottom center of the Figure 1) providing a video flow of 1280 per 1024 pixels at a frame rate of 30 fps with a view angle 45% bigger than a common webcam (focal length at 50mm).

We treat the PAL signal of the spy-camera mixed with the video flow of the webcam for the i-3PP in our application. The video is then sent to the HMD SONY Glasstron PLM-S700E via the VGA output with a resolution of 800 per 600 at a refresh rate of 60Hz.

Obviously, fields of views of both cameras and the HMD are different. As the last one is smaller than those of the cameras, we do not have to extend the pictures taken by the camera, which would reduce image quality (pixels appearance) and therefore immersion. Moreover, as written before in Section 2, the smallness of the HMD field of view can sometimes distract the user during experiments. Providing to him/her a video flow with a larger angle of view reduces this bias. Notice that the difference between the respective field of views between HMD and cameras is not large enough (only 1.5 times) to disconcert the tester. We can conclude that this mapping should slightly improve the immersion quality of the user in the simulation.

As you can see in the right picture of the Figure 1 we use a rigid backpack because the bars of aluminum fixed to it must not oscillate as the tester moves. We use a swiveling pivot point (picture on the bottom center of the Figure 1) to plug the camera at 80cm behind and 50cm upper the user eye position with an orientation of 7.3 degrees in direction to the bottom from the horizontal. We have a field of view of 60 degrees which means the tester can see



**Figure 2:** Perspectives presentation: 3PP (top left) fills the white part of the mask (bottom left) while 1PP (top right) fills the black one (bottom left) in order to mix them to create the Improved 3PP (bottom right).

his/her shoulders, head and objects in front of him/her at a distance larger or equal to 1.5m corresponding to two footsteps. For the improved third-person perspective, we only add a wide-angle webcam (on the right bottom) in front of the user (maintained with rigid bars around the neck of the user (picture on the bottom center of the Figure 1)). This webcam is located 20 centimeters in front of the tester neck, horizontally centered, and pointing down with an angle of 7.3 degrees with the horizontal in order to get a kind of continuum between both perspectives. Concerning the first-person perspective, we simply plugged the camera on the HMD (picture on the left of the Figure 1) on front of the eyes in the center.

#### 3.2 Software Setup

Our C++ application is based on OpenGL and consists in acquiring video flows from 2 cameras. Once we get these streams, three ways to display them are of interest: 1PP (shown one the top picture of the Figure 2), 3PP (on the left bottom picture of the Figure 2), and i-3PP in which we mix in real time the video streams coming from the front camera with the image taken from the back one. In this last one, we mainly show the picture of the back camera except where the user head occludes the scene. At this specific location, we replace the current streaming by the picture of the front camera (on the right bottom of the Figure 2). The tester who is wearing the HMD has then the illusion to see him-/herself at the 1PP, 3PP, or both perspectives combined.

In order to acquire the video flows from any connected video device that we display in full screen (to send them onto the HMD), we use the DirectShow Video Processing Library (DSVL). The first video stream corresponds to the spy-camera at the first- or third-person perspective while the second one is the webcam in front of the user. Concerning the augmented 3PP, after displaying the mixed video stream buffers as textures with the help of a mask, we must define at the beginning of the simulation. We indeed need to know the exact position of the user body (head and shoulders) which corresponds to the place where we display the second video stream.

For the mask delimitation (see the center bottom picture on the Figure 2) we work with the brightness difference on a snapshot (that

<sup>2</sup><http://www.marcowens.co.uk/products.html>

we can take at every moment at the beginning of the simulation) of the spy-camera. The user must wear dark clothes (e.g. a black shirt) and faces to a light. We get a quite highly-contrasted snapshot where it is easy to differentiate the user body in the picture. We can then create the appropriate mask for the simulation by increasing the contrast until we have a black body on a white background. We display the 3PP camera stream on the white part of the mask and the webcam video flow on the black one. We darken a bit the second video stream in order to show that it only shows what happens in front of the user, but he/she must keep in mind that it is his/her body because it is the main advantage of this perspective: being able to see one's body seems to increase the user immersion.

But as both cameras are very distant each other, their point-of-view is also very different. We setup the textures in our application to create pseudo-continuity between both pictures at the distance of one tight arm for the thin manipulations. Otherwise, every element will be seen as too big if it closer and very reduced them if it is farther (e.g. the ground).

Depending on the perspective, we want to use during the simulation, the user sees either the video flow of the first camera (at the first- or at the third-person perspective) or both video streams (spy-cam and webcam) combined, which means the he/she sees him-/herself during the simulation at the 3PP without the occlusion of his/her own body.

### 3.3 Experiments Presentation

Our simulation is composed of six experiments. We want to check which perspective is preferred. Every test will be performed with the three perspectives: 1PP presented on the left of the Figure 1, original 3PP, and i-3PP presented on the right of the Figure 1 (the non improved one does not need the webcam in front of the tester).

We begin the experiment by providing to the user, for fifteen minutes, the vision of fishes in the sea with soft music to wind him/her down. We want to avoid that external stress lead to addition bias in the simulations. Once done, we start the experiments we can separate into three ordered steps:

1. Adaptation: adaptation time in a room followed by a walk through a corridor.
2. Static: opening a door and putting a dice into a cup
3. Dynamic: playing football and basketball with another person

We chose to perform these steps in this pre-definite order because it also corresponds to the difficulty of each task. Obviously, the tasks in the static and the dynamic steps are permuted from a tester to another one in order to counter-balance and validate our tests. This provides then four study cases because of the permutations of two elements in both steps (static and dynamic).

Concerning the perspectives, we change their order between subjects to get counter-balanced results. We need then a panel of six users to satisfy the previous condition (permutation of the order for three perspectives). Consequently, we need then 24 testers for our experiments.

We first make an accommodation experiment to check how the user accommodates with the current and randomly-chosen perspective. We also measure the time he/she needs to get comfortable with this viewpoint. We think he/she should prefer the third- instead of the first-person perspective because he can see him-/herself in the environment with more hindsight to appreciate the objects around him/her and the distances. He/she should better appreciate the distance because, even if he/she is wearing a HMD, he/she knows the distance between the camera and his/her head and can more easily

evaluate them by size comparison. It should be more immersive and as the camera is behind him/her, the provided image in the HMD seems to have a bigger angle of view. This should be an improvement of comfort despite the HMD small field of view bounds. Once performed, there are five randomly-chosen experiments that we present hereinafter.

In one of the next experiments, the user must walk through a 50-meter-long gallery composed of two 90-degree curves with some obstacles of several sizes on the ground. Note that he/she does not know in advance where the obstacles are. This experiment reveals if the user mainly prefer to perform moving task with the help of the 1PP, 3PP, or both perspectives combined (i-3PPfirst). We check if the user avoids every obstacle and does not hit against the walls. We verify also the time to perform this action and get his/her feeling.

We have two experiments for the interaction with a static environment. In one of them, the user must go and open a door. As written in [Knapp and Loomis 2004], the distances should be badly evaluated with the HMD which would mean a collision with the door or that the user misses the handle because he/she is not yet close to the door. With this experiment we can check which perspective is the most appropriate for the distance evaluation. We also verify if he/she uses the same way to open the door with every perspective.

The other one consists in putting a ball into a cup of coffee. The main aspects we want to highlight during this experiment are the elapsed time, the result, and the way the users deal with to perform the task. This experiment should mainly help us to define which perspective is preferred for fine manipulations.

The last-presented experiments concern the eye-limb coordination of the user in a dynamic environment. For this, we send a ball to the user in two different ways: with the foot (rolling ball) and with the hand (flying ball). As the user cannot easily see close objects with 3PP, these experiments will help us to verify if he/she can easily extrapolate the position of the approaching objects. During these two last experiments we focus on the number of balls the user can touch and catch.

The goal of all these experiments is to evaluate which perspective is preferred in different situations. After the experiments, we also ask the tester for his/her feeling about the immersion quality during the simulation and which perspective he/she globally preferred. We present in the following section the results obtained with these experiments.

### 3.4 Testers

In order to get counter-balanced tests, we make these experiments with 24 male people between 20 and 47 years old. Only 3 of them can be considered as "gamers" and have already worn a HMD.

## 4 Results

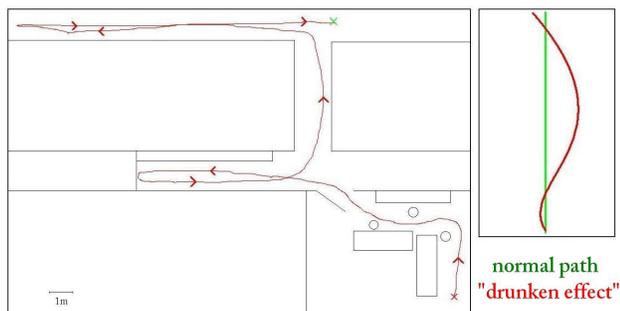
### 4.1 Adaptation experiment

The main goal of this first experiment is to help the tester getting used with the current proposed perspective. Walking in a room without any obstacles and not going too close to the walls should be very easy with every perspective. We make this experiment to test how much time the user needs to feel comfortable with the current perspective and his/her first feeling.

Testers really enjoyed 3PP. After some seconds, they try to go closer to the walls and test when they really reach them. 1PP and i-3PP results are globally similar to the 3PP ones for the adaptation step in an empty and square room.

|                             | 3PP   | 1PP   | i-3PP |
|-----------------------------|-------|-------|-------|
| Average adaptation time [s] | 252.2 | 177.9 | 297.3 |

**Table 1:** Adaptation experiment average results (24 testers)



**Figure 3:** On the left: Schema representing the path to follow to perform the walking experiment; on the right: schema representing the “drunken effect”

This step is globally concluding enough. After less than five minutes (as you can see on the Table 1), every tester seems to be fine with every perspective. We expected it would be more difficult to get used with the 3PPs because it is not a common viewpoint but everyone seems to enjoy it with an adaptation time a bit longer than the other perspectives.

## 4.2 Walking in a gallery

After the tester get used with the perspective, one of the tasks he/she is asked to perform is to go out of a room (path described is represented on the Figure 3) where some desktops oblige the tester to use alternate and longer ways to avoid to stumble against them. The user must then go through an already-open door. Note that because our system is quite invasive (see in pictures on the right of the Figure 1, he/she must bend his/her knees for height reasons while passing through the door border. After this, he/she goes on the left through a small gallery with some rotation to perform. These galleries are less than one and half a meter wide (shown on the left of the Figure 3). With this experiment, we check the time elapsed to perform it and the number of collisions. We can then evaluate the preferred perspective for moving actions.

While testing 3PP, the user must memorize the location of the obstacles on the ground because he/she is not able to look at his/her feet. Notice that the user must get used that he/she needs to turn his/her trunk to glance at the right or the left, because of the system is bound to his/her back. As we made some pre-tests, we were afraid the tester would become ill during this simulation with this viewpoint but there was no matter about that. After some adaptation time to avoid the walls, he/she finely avoids the obstacles. The user can easily walk when he/she does not need to follow a straight line. It is interesting to notice a light “drunken effect” (shown on the right of the Figure 3) on the testers while they are going through the straight galleries, but they do not necessarily feel it. The user needs an average time of three and half a minute to perform this step with 3PP.

When the testers experiment 1PP, they can orientate their head to the right or the left but the main advantage of this perspective is that they can look up and down. It is easier to avoid the small obstacles

|                                | 3PP   | 1PP   | i-3PP |
|--------------------------------|-------|-------|-------|
| # of collisions with obstacles | 3.3   | 2.5   | 2.5   |
| # of collisions with walls     | 0.2   | 3.5   | 0.5   |
| Elapsed time [s]               | 189.9 | 152.8 | 155.6 |

**Table 2:** Walking experiment average results (24 testers)

like dustbins or desktops. There is no difference with 3PP regarding the wall avoidance. While going through the galleries the “drunken effect” was stronger than with 3PP and some testers crashed against the walls. Due to the limited FoV of the camera, there are almost no differences with 3PP to turn while changing of gallery but at the end of the walk, most of the testers feel seasick. This is maybe due to the fact they could not follow a straight way in the galleries during this step, but it is interesting to remark there was not this problem with the previous perspective. The average time needed to perform this task was around two and half a minute.

For the walking experiment, i-3PP provides all the advantages of 3PP. There is almost no “drunken effect” and every obstacle is avoided because the user can see the obstacles in front of him/her. It is more comfortable for him/her because he/she does not have to memorize the obstacle position while they are quite far (around 2 meters).

This experiment showed us that 3PP and i-3PP are preferred while the users need to walk in a gallery even if they seem to need more time to perform the task.

## 4.3 Door opening experiment

In the next experiment, as there is no stereo vision and as the FoV of the HMD is smaller than the human eye one, the testers should then have some problems to evaluate the distance they have to walk until they are able to catch the handle [Willemssen et al. 2004].

We remarked that most of the time the user experiments the 3PP, he/she catches the handle at the first time. Usually he/she sticks up his hands up in the air in the air and can easily evaluate the distance with the door by extrapolation and comparison of the handle and his/he hand size.

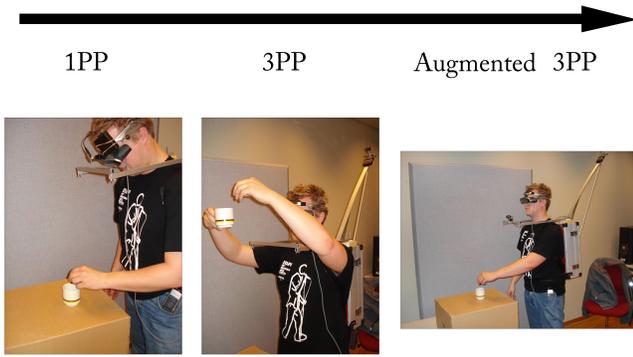
To accomplish this task with the 1PP, the testers usually take a bit more time and often overvalue the distance between them and the door. Obviously, once against the door, they easily take the handle without any effort because they can orientate their head and look at the handle. We think the users could easily take the handle with the third-person perspective because the handle still was in their FoV.

By using i-3PP, the users better evaluate the distance to the door with the global point of view. Moreover, if the handle is not too low, the user can see it through him with the help of the camera in front of him/her. There is then no need of extrapolation to guess the handle location.

Our tester do not need more much time to catch the handle and open the door (a fraction of second at maximum) but they usually seem to overvalue the distance to the door with 1PP. However, if the handle had been lower or out of their field of view, most of the testers confess they would have had to fumble it for a moment with 3PP. We can then affirm that for actions combining walking and hand manipulations, users prefer the i-3PP.

## 4.4 Ball in a cup experiment

For this task, we do not tell them anything about the way they have to use to perform this action because we did not think it would



**Figure 4:** View of the user putting a ball in a cup at every perspective



**Figure 5:** View of the tester receiving and passing a ball to another person with his foot

change from a perspective to another one.

When the users approach of the desktop with 3PP (shown on the right top of the Figure 4), most of them take the cup in a hand and the ball in the other one. There is no depth but a direction problem because the desktop was not high enough to be in the field of view of the user. One of the testers missed the ball and had to fumble on the desktop to find it. After they caught both elements, they all brought them up to make them appear in their FoV to put the ball in the cup.

Every user perfectly performed this step with 1PP (picture on the left top of the Figure 4). Most of them only took the ball in one hand and put it down in the cup with no need to catch the cup. No one seems to meet depth problems due to the “mono vision”.

The results of i-3PP are very close to the 1PP ones except for one tester who took up the cup as if he was still with 3PP.

As we predicted it, there is a problem with target actions and hand manipulations when it happens at low height. In this current case, the objects were not in the field of view for 3PP. Our participants need then more effort and time to perform this task. Notice that while the fine manipulation can be performed between the stomach and the neck height, i-3PP resolves the occlusion problem.

#### 4.5 Football experiment

We present now the interaction with an external people and a mobile environment.

Most of the testers get and stop the ball with their foot while they were working with 3PP but all of them touch the ball. At the first pass, almost no one get it. After this, with the ball placed under their foot, they easily do a pass in the good direction with a well-evaluated distance precision. No unbalance is detected during this

|                      | 3PP | 1PP | i-3PP |
|----------------------|-----|-----|-------|
| # of touched balls   | 9.7 | 2.8 | 9.6   |
| # of caught balls    | 9.3 | 1.3 | 7.7   |
| # of well-sent balls | 9.2 | 5.5 | 7.3   |
| Unbalanced testers   | 1   | 18  | 4     |

**Table 3:** Football experiment average results (24 testers)

|                      | 3PP | 1PP  | i-3PP |
|----------------------|-----|------|-------|
| # of touched balls   | 5.2 | 4.6  | -     |
| # of caught balls    | 3.1 | 4.7  | -     |
| # of well-sent balls | 8.6 | 10.0 | -     |
| Unbalanced testers   | 0   | 0    | -     |

**Table 4:** Basket-ball experiment average results (24 testers)

operation. Most of testers can stop the ball and send it correctly to the other people after three passes.

While using 1PP, almost no tester neither gets nor stops the ball with his/her foot at the first pass. Even for the next passes, few testers could sometimes touch the ball but only one could stop it once. Moreover, as the ball is moving and he/she looks at it, he/she seems to lose his/her marks which makes them feel a strong unbalance feeling. They do not recover easily their stability. Regarding the pass they had to do, there are two approaches: Those who are looking at the ball, and those who are glancing at the other player while making the pass. The firsts do not pass the ball in the good direction (there was an angle deviation of about 15 degrees) and the others miss sometimes the ball. The distance evaluation to perform the pass seemed to be accurate enough.

The results obtained with i-3PP are very close to the 3PP ones. As they can see through their body, they can better appreciate the trajectory that they extrapolate while they are working with the simple third-person perspective. No unbalance is detected and the second time they performed the task, most of them catch the ball and are able to send it once the ball is under their foot.

We can remark that the testers seem to anticipate very finely the ball location while using 3PP (Table 3). It seems obvious that 3PP is preferred for this kind of action. This can be due to the field of view (the bounds) which is more common with the real eye field of view? However, they better perform with 3PP but it is easier for them to prepare the ball with their foot when they use 1PP. The switch is thus really interesting for this kind of actions.

#### 4.6 Basket-ball experiment

This step is quite similar to the previous one. The main difference resides in the way to pass the ball: with the hands instead of the feet.

When we perform this experiment with 3PP, some participants touch the ball with one hand or catch it because the other person sends the ball on them. They try nine other times (ten passes) the experiment and half of them can touch the ball (some catch it). There is no matter to send it back to the other guy, even for the direction or for the distance. No stability problems are encountered during this experiment with this perspective.

The results obtained with 1PP are almost similar to those obtained with 3PP. There was no loss of stability during this experiment in opposition to the football step. It is probably because the testers do not need to move and rotate a lot their head to follow the trajectory and catch the ball. Unfortunately, no one caught the ball but ev-

|                  | 3PP | 1PP | i-3PP |
|------------------|-----|-----|-------|
| Feel comfortable | 18  | 20  | 20    |
| Feel unbalanced  | 6   | 3   | 6     |
| Get sick during  | 3   | 1   | 2     |

**Table 5:** Global summary of the testers answers and feeling

|               | 1PP      | 3PP     | i-3PP    |
|---------------|----------|---------|----------|
| Adaptation    | 3        | 2       | 2        |
| Walking       | 3        | 2       | 2        |
| Door opening  | 1        | 2       | 3        |
| Ball in a cup | 3        | 1       | 2        |
| Football      | 2        | 2       | 2        |
| Basket-ball   | 3        | 3       | 0        |
| TOTAL         | 15 (12*) | 12 (9*) | 11 (11*) |

**Table 6:** Global summary of testers results: 3 points to the best, 1 to the worst, 0 if not done (\* results without the basket experiment)

everyone sent it perfectly to the other person at the first pass. Few of them touch it at the second trial.

The task could unfortunately not be performed with i-3PP because of the trajectory of the ball. Indeed, it would have hit the front camera before the tester should have caught it if we tried the experiment with this perspective. Unfortunately, results of this experiments cannot be significant because only few of testers succeeded this step and because i-3PP is unfortunately not usable.

#### 4.7 Analysis tools and results summary

After these experiments we ask the testers to know exactly how they felt during the experimentations; How hard it was; Why they use this way to perform the action, etc. For most of the questions, they only have to cross a case where appeared numbers from 0 to 10. Number 0 means the worst and 10 the best. Blank lines were also available for comments.

We show the comparison and summary of their feeling (Table 5), their results (Table 6), and their preferences (Table 7). Even if i-3PP is not always the best perspective for the action and has some restrictions (e.g. the basket-ball experiment), it is preferred most of the time. This perspective seems then to be a good alternative to a switch between both other views during the experiments.

## 5 Conclusion

This study confirms our first assumption: The privileged perspective depends on the task to perform. 3PP can be associated with moving actions while 1PP is used for fine manipulations with hands.

|               | 1PP      | 3PP      | i-3PP    |
|---------------|----------|----------|----------|
| Adaptation    | 3        | 3        | 3        |
| Walking       | 1        | 3        | 3        |
| Door opening  | 2        | 1        | 3        |
| Ball in a cup | 3        | 1        | 2        |
| Football      | 1        | 2        | 3        |
| Basket-ball   | 2        | 3        | 0        |
| TOTAL         | 12 (10*) | 13 (10*) | 15 (15*) |

**Table 7:** Global summary of testers perspective preference as Table 6 (\* results without the basket experiment)

The advantages of 1PP and 3PP without their drawbacks are combined in i-3PP. The first results obtained are very promising. Being able to see through one's body is a real improvement to reduce occlusion. The main drawback of this solution resides in its size and the obstruction it generates in front of the tester.

In conclusion, i-3PP is preferred in almost every situation. The combination of two video streams is obviously not natural for the user, but as the added one (1PP) "replaces" less than a quarter of the original video stream and is half-transparent, the user can always see his/her head and is then not too much disturbed. Moreover, the continuum between both videos streams reduces the bias introduced by this blending. Finally, it could be very interesting to improve our system with a mobile 3PP camera following the user head orientation.

## Acknowledgments

This research has been partially supported by the European Coordination Action: FOCUS K3D (<http://www.focusk3d.eu>)

## References

- ARSENAULT, R., AND WARE, C. 2004. The importance of stereo and eye coupled perspective for eye-hand coordination in fish tank vr. *Presence* 13, 5, 549–559.
- KNAPP, J. M., AND LOOMIS, J. M. 2004. Limited field of view of head-mounted displays is not the cause of distance underestimation in virtual environments. *Presence* 13, 5, 572–577.
- LOK, B., NAIK, S., WHITTON, M., AND BROOKS, F. P. 2003. Effects of handling real objects and self-avatar fidelity on cognitive task performance and sense of presence in virtual environments. *Presence: Teleoper. Virtual Environ.* 12, 6, 615–628.
- MESSING, R., AND DURGIN, F. H. 2005. Distance perception and the visual horizon in head-mounted displays. *ACM Trans. Appl. Percept.* 2, 3, 234–250.
- POPP, M. M., PLATZER, E., EICHNER, M., AND SCHADE, M. 2004. Walking with and without walking: perception of distance in large-scale urban areas in reality and in virtual reality. *Presence: Teleoper. Virtual Environ.* 13, 1, 61–76.
- RICHARD ROUSE, I. 1999. What's your perspective? *SIGGRAPH Comput. Graph.* 33, 3, 9–12.
- SALAMIN, P., THALMANN, D., AND VEXO, F. 2006. The benefits of third-person perspective in virtual and augmented reality? In *VRST '06: Proceedings of the ACM symposium on Virtual reality software and technology*, ACM, New York, NY, USA, 27–30.
- THOMPSON, W. B., WILLEMSEN, P., GOOCH, A. A., CREEM-REGEHR, S. H., LOOMIS, J. M., AND BEALL, A. C. 2004. Does the quality of the computer graphics matter when judging distances in visually immersive environments? *Presence* 13, 5, 560–571.
- WILLEMSEN, P., COLTON, M. B., CREEM-REGEHR, S. H., AND THOMPSON, W. B. 2004. The effects of head-mounted display mechanics on distance judgments in virtual environments. In *APGV '04: Proceedings of the 1st Symposium on Applied perception in graphics and visualization*, ACM Press, New York, NY, USA, 35–38.