The Visual Appearance of User's Avatar Can Influence the Manipulation of Both Real Devices and Virtual Objects

Abdelmajid Kadri[1]
P&I Lab.
University of Angers/ENSAM

Anatole Lécuyer[2]
BUNRAKU Project
INRIA/IRISA

Jean-Marie Burkhardt[3]
EIFFEL Project
University of Paris 5/INRIA

Simon Richir[4]
P&I Lab.
ENSAM

ABSTRACT

This paper describes two experiments conducted to study the influence of visual appearance of user's avatar (or 3D cursor) on the manipulation of both interaction devices and virtual objects in 3D Virtual Environments (VE). In both experiments, participants were asked to pick up a virtual cube and place it at a random location in a VE.

The first experiment showed that the visual appearance of a 3D cursor could influence the participants in the way they manipulated the real interaction device. The participants changed the orientation of their hand as function of the orientation suggested visually by the shape of the 3D cursor.

The second experiment showed that one visual property of the avatar (i.e., the presence or absence of a directional cue) could influence the way participants picked up the cube in the VE. When using avatars or 3D cursors with a strong directional cue (e.g., arrows pointing to the left or right), participants generally picked up the cube by a specific side (e.g., right or left side). When using 3D cursors with no main directional cue, participants picked up the virtual cube more frequently by its front or top side.

Taken together our results suggest that some visual aspects (such as directional cues) of avatars or 3D cursors chosen to display the user in the VE could partially determine his/her behaviour during manipulation tasks. Such an influence could be used to prevent wrong uses or to favour optimal uses of manipulation interfaces such as haptic devices in virtual environments.

CR Categories: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – Artificial, augmented, and virtual realities; H.5.2 [Information Interfaces and Presentation]: User Interfaces – Input devices and strategies, Interaction styles, User-centered design; H.1.2 [Information Systems]: User/Machine Systems – Human factors.

Keywords: 3D cursor, avatar, visual appearance, directional cue, orientation, manipulation

1 INTRODUCTION

Numerous devices and interaction techniques have been designed during the past decade to define efficient ways of selecting and manipulating objects in Virtual Environments (VE) [1]. One of the most famous techniques is the "virtual hand" developed by Robinett and Holloway [2] that makes an analogy with our natural way of picking up objects in reality. A 3D cursor which looks like a hand is used to match the motions of the user's real hand and to select and manipulate straightforwardly the objects in Virtual Reality (VR).

Today, the avatars or 3D cursors used to display the user during manipulation tasks in VE can look very different. Indeed, the visual shape of the user's avatar can either be a tool (e.g., screwdriver, hammer), the whole or a subpart of the body (eye, hand, finger) or even any other object with or without a semantic content (arrow, star, sphere). We do not know today the potential effect of the visual appearance of these avatars on the behaviour of the users, during virtual manipulation tasks. Thus, in this paper, we focus our investigation on the two following questions:

- Does the visual appearance of the avatar or 3D cursor used to display the user in the virtual environment have an effect on his/her way of manipulating the interaction device?
- Does the visual appearance of the avatar have an effect on his/her behaviour when manipulating virtual objects?

We have conducted two experiments to investigate these two issues. We focused our experiments on the effect of one basic property of the visual aspect of the user's avatar: the presence or absence of a directional cue. The task of the participants was to pick up a virtual cube and place it at random locations in a VE. In the first experiment, we studied the influence of the avatar's directional cue on the way participants manipulated the real interaction device. We used 3D cursors with different orientation cues and we studied their influence on the orientation of the users' hand when manipulating the interaction device. In the second experiment, the participants were exposed to six possible 3D cursors with different visual directional cues. We looked at the influence of this directional cue on the way participants picked up the cube. In particular, we studied how the directional cue of the 3D cursor could change the picking location, i.e., the side by which the cube was selected.

The remainder of this paper is organized as follows: a literature review is presented in section 2 concerning the observed influence of avatars in virtual environments. The two experiments and their results are then described in section 3. The paper ends with a general discussion in section 4 and a conclusion in section 5.

2 RELATED WORK

Virtual reality applications use avatars with different appearances to represent the user in the simulated environment. The appearance of the avatar may have different functions and different audiences and, consequently, convey information of different natures. Most of the studies on avatars in VR were focused on Collaborative Virtual Environments (CVE). In CVE, avatars have generally the appearance of the whole human body or subpart of the body such as the head or hand [2]. Due to the collaborative context, most VR studies focused on social and communication issues.

In videogames, the user can control precisely the visual appearance of his/her human avatar by choosing its age, size, weight, shape of the body and face (nose, eyes, hair and mouth), etc [3]. Yee [3] observed that gamers were emotionally linked with their avatar. Each gamer finds the visual appearance of

[1]e-mail: abdelmajid.kadri@univ-angers.fr
[2]e-mail: anatole.lecuyer@irisa.fr
[3]e-mail: jean-marie.burkhardt@inria.fr
[4]e-mail: simon.richir@angers.ensam.fr

his/her avatar very important, since it determines largely the way they are perceived by the other gamers [3].

According to Benford et al. [4], one of the main interests of avatars used in CVE is to know, in a blow of eye, if we are alone or not, and to identify the other present persons via their avatars. Benford et al. stated that an avatar could supply a lot of information such as: identity, location, capacity, activity, availability, attention, or presence; exactly like the human body does in real life.

In many CVE, like in NetICE of Leung and Chen [5], every participant is represented by a human-looking avatar with a realistic face. "Human-like" avatars are generally used to "humanize" the communication between the users of the CVE [6, 7]. Several studies underlined that to humanize the communication, the human-like avatars must have realistic face and realistic expressions [8-10]. For instance, Koda [11] showed that an avatar with a realistic face was more appreciated than without. Casanueva and Blake [12, 13] studied the influence of the movements (body gestures and facial expressions) and level of realism of an avatar on the social presence. They noticed that the more the avatars were realistic and performed movements, the more the feeling of social presence increased. They also observed that the social presence was more influenced by the movements of the avatar than by its level of realism.

In several recent studies it was shown how human-like avatars could convey feelings [14, 15]. Prada et al. [16] studied the influence of the avatars in a game. They found that the participants were highly receptive to the feelings expressed by the avatars. They noticed that this receptivity was stronger for young participants. Prendinger et al. [17] showed that an emphatic behaviour of the avatar could reduce the stress of participants during a game. Furthermore, they observed that participants perceived the game as less difficult when the avatar had a friendly behaviour. In the study of Slater et al. [18], the participants had to make a speech in virtual reality in front of a group of avatars. These avatars could express interest or indifference. They found that participants perceived clearly the level of interest of the avatars. Furthermore, the more the avatars expressed interest, the more the level of anxiety of the participants decreased.

In the field of e-business, Lee and Chung [19] evaluated the influence of human avatars on the behaviour of on-line customers. They found that the use of avatars in commercial websites could give more satisfaction to the customers and increased their intention to purchase. Furthermore, on-line customers perceived products as being of a better quality in presence of an avatar.

The visual appearance of avatars used in VE can also be non-anthropomorphic and unrealistic. Mortensen et al. [20] observed that unrealistic avatars could still convey important information in VE. In their study, two distant participants had to collaborate inside a CVE to carry an object through a maze. Although the participants were represented by unrealistic avatars, they could manage the task and handle very difficult passages inside the maze. Furthermore, the researchers found that each participant could still perceive the feelings of the second person.

However, what about the use of avatars in non-CVE contexts? In this case, the objective of using avatars is not to support communication of personal or social cues to other participants. The information of avatar is conveyed for the user himself (as opposed to other users) and is of different nature. Such avatars are self-oriented and task-related. They provide information about user's position, possible actions, etc.

Appearance of avatars or 3D cursors used in the field of 3D interaction techniques for the selection and manipulation of objects in VE can be either anthropomorphic [2] or not [21]. Virtual hands [2] are very popular representations that were used in several interaction techniques like in the Go-Go [22] or HOMER technique [23], for selecting distant objects. More simple shapes like cones or spheres, have also been used many times to display the position of the user when reaching and manipulating virtual objects, for instance within the Bubble Technique [24]. In the Haptic Hybrid Rotation technique [25], the avatar used in the VE looks identical to the extremity of the real haptic device manipulated by the user.

Previous works on handed manipulation of real and/or virtual objects investigated internal and external determinants of hand movements (e.g., grasping [26], object manipulation and transportation [27]), together with perceptual and motor dependencies, sometimes within a collaborative perspective (e.g., [28]). They studied the role of characteristics of object's properties (i.e., size, orientation or distance) on movement planning and control. Object size was shown to affect grasp aperture, whereas object orientation was found to affect both transportation and orientation [27].

Object manipulation within 3D interaction techniques in Virtual Environments differs on several dimensions from handed manipulation of objects in the real world [29]. A specific dimension is the presence of an avatar or 3D cursor as an intermediate representation between the target object and the user's hand in the course of manipulation tasks. To the authors' best knowledge, the potential influence of the properties of such 3D cursors representing the user within 3D VE has not been studied in the case of selection and manipulation tasks. However, in the field of 2D Graphical User Interface (GUI), Phillips et al. [30] evaluated the impact of 2D cursor's visual orientation on mouse positioning movements for desktop displays. They found that the visual directional cues provided by a mouse cursor could induce performance differences. Po et al. [31] extended the results of Phillips et al. They evaluated four visual 2D cursor orientations and one orientation-neutral 2D cursor in a circular menu selection task. They found that cursors visually oriented toward the lower-right corner of a display yielded the poorest performance overall. The orientation-neutral cursors were associated with the best performance. Po et al. found also that 2D cursors aligned with the direction of movement led to better performances.

3 Experiments

We have conducted two experiments to study the influence of the visual appearance of the user's avatar on the user's behaviour when manipulating the interaction device and selecting virtual objects. The two experiments were focused on one basic property of the avatar's visual appearance: the presence (or absence) of a directional cue. The first experiment studied the influence of the visual orientation of the avatar on the way participants manipulated a real interaction device. The second experiment studied the influence of the visual directional cue of avatars on the way participants picked up a virtual object.

3.1 Experiment 1: Influence of the visual orientation of the user's avatar on the manipulation of the real interaction device

In this experiment, we studied the effect of the avatar's visual orientation on the user's strategy regarding the manipulation of the real device. The participants had to perform a pick-and-place task. We used two different virtual-hand 3D cursors, with different visual orientations. Unknown to the participants, we recorded the angular orientation of the extremity of the device, to determine if the directional cue of the 3D cursor had an influence on the way the participants manipulated the device.

3.1.1 Participants

Sixteen participants aged from 22 to 32 (mean=23.7, sd=2.5) took part in this experiment. There were 8 women and 8 men. All of them were right-handed and naïve to the purpose of the present experiment.

3.1.2 Experimental Apparatus

We used a haptic device (PHANToM Omni of Sensable Technologies [32]) in passive mode (i.e., without any force feedback) to track the orientation and position of the user's hand precisely (Figure 1). We removed the stylus of the PHANToM and the participants could directly insert the last phalanx of their index inside the extremity of the interaction device. The participants could then manipulate the extremity of the interaction device using their dominant hand.

Figure 1: Experimental Apparatus

The virtual scene (see Figure 3) was made of a chessboard, a pink cube, a green platform and one 3D cursor (avatar of the user). The visual feedback was displayed on a 19" computer screen in monoscopic conditions, with a frame rate of 85Hz (see Figure 1).

When manipulating the PHANToM device, the participants could move accordingly the virtual avatar. However, the orientation of the avatar was kept constant, as the rotations of the device and of the user's hand were not applied to the 3D cursor.

3.1.3 Procedure

The participants were seated in front of the screen, with the PHANToM device being placed in front of them (see Figure 1). The participants could use their non-dominant hand for the keyboard.

At the beginning of each trial, the participants were explicitly told by which side they had to pick up the cube. For this aim, a panel was displayed visually on the computer screen until the participant pressed one key of the keyboard. This panel indicated the picking side using both a textual explanation and a graphical representation (see Figure 2). The participants were asked to select and pick up the cube by the centre of the indicated side.

Then, the virtual cube was automatically positioned on a virtual platform located at the top of the screen (see Figure 3). Every trial consisted in two phases: one phase for the selection of the cube and one phase for the displacement of the cube:

- Selection: The participants had first to press one start key on the keyboard. Then, the avatar automatically appeared at its initial position, i.e. at the bottom of the screen (see Figure 3). The participants had to grasp the extremity of the PHANToM and remove it from its neutral position. Then the user had to pick up the virtual cube located on the upper platform. To do so, they had to put the semi-transparent spherical envelope of the avatar (see Figure 4) in contact with the cube and press the space bar.
- Displacement: Once the cube was selected, the final position where the cube was to be released was randomly selected and indicated to the participants by a change in colour on the chessboard (see Figure 3). The participants had to move the virtual cube to its final position. The motion (positions) of the participants was directly applied to both the avatar and the cube (apart from the rotation) via the PHANToM device. To release the cube, the participants had to release the space bar. When the participants estimated that the cube was well positioned, they could end the trial by pressing one key of the keyboard. The avatar disappeared and the participants had to replace the PHANToM at its neutral position, i.e. to clutch it on its base. The next trial was then launched by pressing one key of the keyboard.

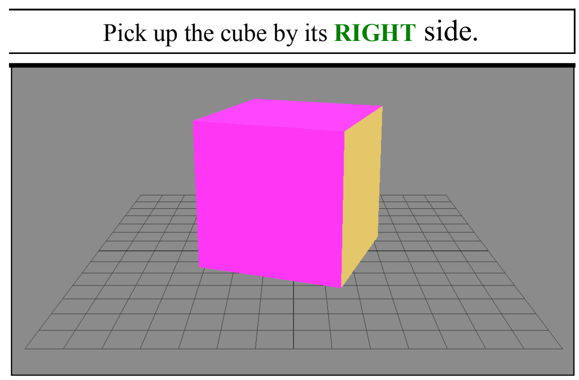

Figure 2: Panel indicating the required picking side (colored in yellow)

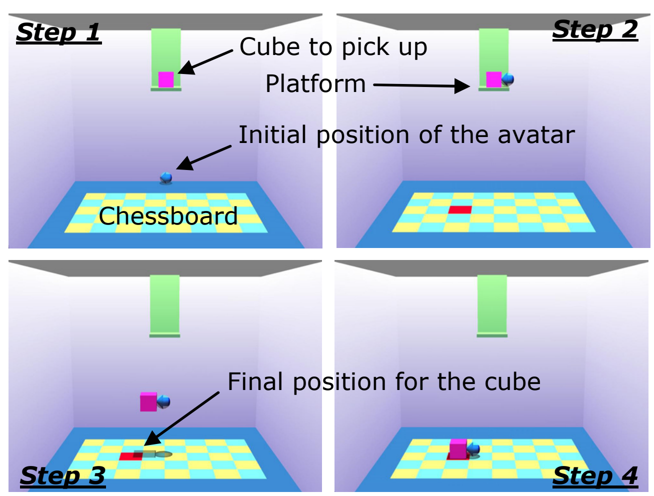

Figure 3: Virtual scene and task procedure

3.1.4 Conditions

We used two avatars of the user's right hand (see Figure 4): one virtual hand with the index finger pointing to the left (rX=0°;

rY=90°; rZ=0°), and one virtual hand with the index finger pointing to the front (rX=0°; rY=15°; rZ=0°). Thus, these two avatars differed only by their orientation around the Y-axis (DrY=+75°).

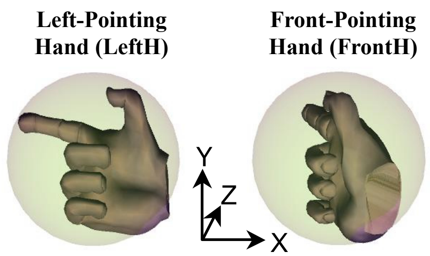

Figure 4: Avatars used in Experiment 1

The participants were divided into 2 groups of 8 persons. We used a between-subjects experimental plan, as each group used only one avatar (left-pointing hand or front-pointing hand) during the entire experiment.

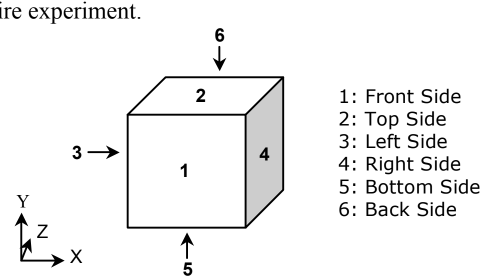

Figure 5: Sides of the virtual cube

We used three possible sides to pick up the cube: the front side, the top side and the right side (see Figure 5). The 3 cube sides appeared successively and randomly within each block of three trials. The participants had to achieve 15 blocks in total. Thus, each participant of each group had to perform 45 trials made of (1 avatar condition) * (3 cube sides for picking) * (15 trials). At the beginning of the experiment the participant had a learning phase of 3 trials. The experiment lasted about 40 minutes, including the learning phase and breaks.

3.1.5 Collected data

Two data were recorded for each trial: (1) the time (in seconds) between the beginning of the trial and the successful picking of the cube, and (2) the orientation (in degrees) of the extremity of the PHANToM on the three axes (X, Y and Z) when the participant picked up the cube. The initial orientation of the PHANToM, when inserted in its base, was constant and equal to: rX=-24°; rY=0°; and rZ=0°.

3.1.6 Results

We first ran an Analysis of Variance (ANOVA) on the time spent to pick up the cube. Globally, the results showed that participants were 8,6% faster to pick up the cube by the Front side (t=7813ms, sd=6905ms) than by the Right side (t=8550ms, sd=7325) and 10,7% faster than by the Top side (t=8750ms, sd=8105). We also noticed that the time to pick up the cube was 3.5% shorter with the left-pointing hand (t=8221ms, sd=7840), than with the front-pointing hand (t=8521ms, sd=7071). However, no significant effect was found for both the Avatar condition (F(1,14)=0.73, n.s.) and the Side of the cube to select (F(2,28)=1.223, n.s.). We observed a significant main effect of the Trial condition (F(14,196)=39.101, p<.0001) that suggests a typical learning effect, as the time necessary to pick up the cube decreased with the number of trials. No two or higher order interactions were found significant.

Then, the mean orientations of the PHANToM's extremity when the cube was picked up are illustrated successively for the three directions of space (X, Y, Z), as function of the two avatars (LeftH and FrontH) on Figures 6, 7 and 8. The highest angular difference of orientation between the two avatars when manipulating the PHANToM device concerned the Y-axis (see Figure 7): +23,75°.

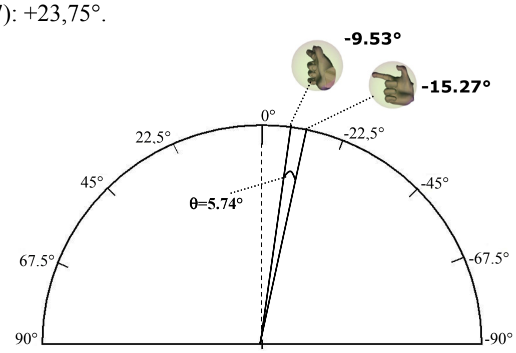

Figure 6: Orientation of the PHANToM's extremity on the X axis when picking up the virtual cube as function of the two possible avatars

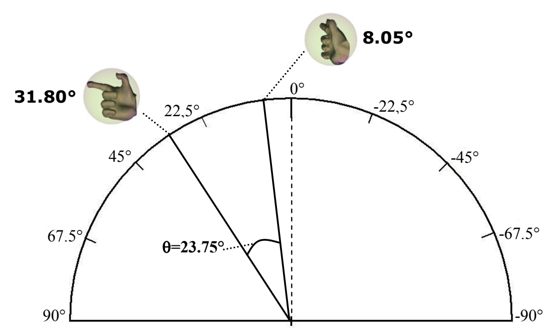

Figure 7: Orientation of the PHANToM's extremity on the Y axis when picking up the virtual cube as function of the two possible avatars

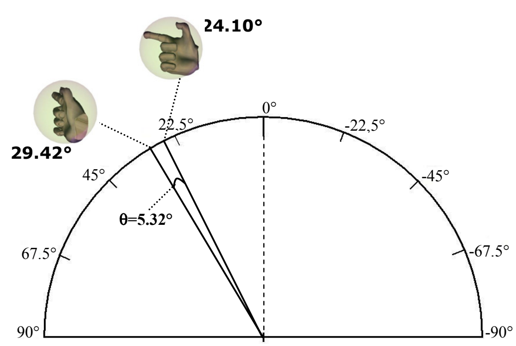

Figure 8: Orientation of the PHANToM's extremity on the Z axis when picking up the virtual cube as function of the two possible avatars

We performed a Multivariable Analysis of Variance (MANOVA) on the Orientation of the PHANToM on the three axes (X, Y and Z). The between-participants factor was the Avatar condition. The results showed a significant main effect of the avatar on the orientation of the PHANToM's extremity (Lambda Wilks=0.378; F(3,716)=391.909, p<0.0001). Subsequent analyses showed that this effect was found significant for the three directional components (X-axis: mLeftH=-15.27°, sd=13°; mFrontH=-9.53°, sd=9°; $F(1,718)=46.15$, $p<.0001$; Y-axis: mLeftH=31.80°, sd=14°; mFrontH=8.05°, sd=9°; $F(1,718)=724.82$, $p<.0001$; Z-axis: mLeftH=24.10°, sd=28°; mFrontH=29.42°, sd=37°; $F(1,718)=4.074$, $p<.0304$).

Table 1: Average orientation of the PHANToM's extremity on the three axes, according to both Avatars and target Sides

Avatar	Axis X		
	Front Side	**Top Side**	**Right Side**
Left-Pointing hand	-15.68°	-14.00°	-16.12°
Front-Pointing hand	-9.63°	-9.02°	-9.93°
	Axis Y		
	Front Side	**Top Side**	**Right Side**
Left-Pointing hand	28.42°	28.88°	**38.10°**
Front-Pointing hand	7.45°	9.20°	7.50°
	Axis Z		
	Front Side	**Top Side**	**Right Side**
Left-Pointing hand	24.37°	25.08°	22.85°
Front-Pointing hand	29.98°	31.44°	26.85°

In a second step, we made an ANOVA on each indicator. We found a significant effect of Trial on the X-axis ($F(14,196)=5.759$, $p<.0001$). It corresponded to a decrease in absolute value of orientation for X-axis with practice. We observed a significant main effect for the Avatar condition only on the Y-axis Orientation ($F(1,14)=19.401$, $p<.0006$). There was also a significant main effect of the Side specified as a target for the picking of the virtual cube ($F(2,28)=6.902$, $p<.0037$). The ANOVA showed a significant two-way interaction between Avatar and Side ($F(2,28)=11.206$, $p<.0003$) (see Table 1). More especially, the combination of the left-pointing hand with the right side of the cube improved strongly the angular value of the orientation of the PHANToM on the Y-axis (see Table 1). No other effects than those reported above were found significant.

3.1.7 Discussion

The three different target sides of the virtual cube were located at three different positions. The participants had probably to rotate their wrist slightly differently to reach these three sides. This could explain the significant effect found for the target side on the orientation of the PHANToM's extremity.

The two hand-like avatars used had the same graphical shape but they had different orientation on the Y-axis concerning their main directional cue, i.e., the pointing direction of their index finger. This difference of orientation induced a strong difference of orientation of the extremity of the PHANToM device on the Y-axis. It could reach a high angular value of more than +30° when the side to reach was the right one (38.10° with LeftH vs. 7.50° with FrontH). This latter case could correspond to the most "favourable" side for a right-handed person.

Thus, it seems that the participants rotated more their hand and their finger around the Y axis, when provided with the avatar with the higher Y-angle value. This result suggests that the participants tended to align their finger with the virtual finger. In other words, they had a tendency to mimic the gesture of their avatar.

3.1.8 Conclusion

The results of this first experiment showed an influence of the avatar on the user's manipulation of the real interaction device. The participants changed the orientation of the extremity of the device depending on the orientation suggested visually by the avatar.

3.2 Experiment 2: Influence of the visual directional cue of the user's avatar on the selection of a virtual object.

This second experiment was conducted to study the potential influence of the visual directional cue of the user's avatar on the strategy of selection of a virtual object. For this aim, participants were asked again to pick up a virtual cube and to position it on a chessboard. In this experiment, the participants could select the cube by the side they wanted. They were exposed to six different avatars (arrows, hands, etc). Unknown to the participants, we systematically recorded the side by which they picked up the cube. Thus, we could study if the directional cue of the avatars had an influence on the side chosen by the participants to pick up the virtual cube.

3.2.1 Participants

Twelve new participants aged from 21 to 39 (mean=24.9, sd=6.1) took part in this experiment. There were 8 women and 4 men. All of them were right handed. They were naïve to the purpose of the experiment.

3.2.2 Experimental Apparatus

The same experimental apparatus and experimental procedure were used as in Experiment 1. However, in this experiment, at the beginning of each trial, the participants were not explicitly specified by which side they had to pick up the cube. The participants could thus select and pick up the cube by side they wanted.

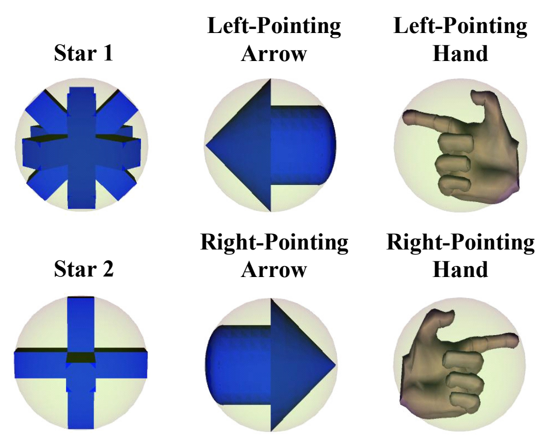

Figure 9: Avatars used in Experiment 2

3.2.3 Conditions

We used six different avatars, as displayed on Figure 9. These six avatars were: two arrows, two stars, and two virtual hands. The hands and arrows both provided a directional cue as they pointed to the left or right. Again, a surrounding 3D semi-transparent sphere was used to provide the same contact area with the virtual cube (see Figure 9).

Every participant had to perform 66 trials consisting in 11 blocks of 6 trials. In each block, the participant was exposed successively to the 6 possible avatars, which appeared in a random order. At the beginning of the experiment, every participant had a learning phase, which enclosed 6 trials: the 6 different avatars in random order. The experiment lasted about 40 minutes, including the learning phase and breaks.

3.2.4 Collected data

For every trial, we collected the side by which the participant picked up the cube: front, back, bottom, top, left, right (see Figure 5).

3.2.5 Results

The average percentages of selection for each side of the virtual cube are provided in Table 2 as function of the six avatars. Globally, the participants preferred to pick up the cube by its front side (34% of the trials for all participants, whatever the experimental condition). Then, the participants chose the right side (29%), the top side (17%), the left side (16%) and the back side (3%). The bottom side was very difficult to reach, since the cube was posed on the platform. Thus, this condition was scarcely chosen and it is not reported in Table 2.

Table 2: Choices of the participants concerning the side to pick-up the virtual cube as a function of the six avatars (% values indicated in bold and underlined when positive RD[1] >.20)

Avatar	Front Side	Top Side	Left Side	Right Side	Back Side
Star 1	***48.61%***	***21.53%***	3.47%	22.22%	***4.17%***
Star 2	***40.97%***	***22.22%***	5.56%	24.31%	***6.94%***
Left-Pointing arrow	22.22%	15.28%	0.00%	***62.50%***	0.00%
Right-Pointing arrow	33.33%	15.97%	***46.53%***	0.69%	3.47%
Left-Pointing hand	22.92%	13.19%	0.00%	***63.19%***	0.69%
Right-Pointing hand	34.72%	15.97%	***42.36%***	2.78%	***4.17%***

There was an intermediate relationship between the type of avatar and the selection strategy for picking up the cube (V^2 Cramer=.11). To further analyse this association, we computed the associated Relative Deviations[1] (RD). The results (also displayed in Table 2) showed the following trends. When provided with the two star avatars (Star1 and Star2), the participants favoured more strongly the front, top and back sides. The front side remained the most chosen area in both star conditions. In the case of the other avatars, we found a clear effect of the right vs. left directional cue on the side chosen for picking the cube. The arrow and the hand pointing to the left were more associated with the right side of the cube. Conversely, the arrow and the hand pointing to the right were preferentially associated with the left side of the cube. A positive attraction was also observed between the right-pointing hand and the back side. The statistical test confirmed the effect of the avatar condition on the selected side of the cube (Khi2=373.975, DoF=20, $p<.0001$).

[1] The Relative Deviations (RD) measure the association between two nominal variables. They are computed on the basis of a comparison between observed and expected frequencies (i.e. those that would have been obtained, if there was no association between the two variables). There is an "attraction" when the RD is positive and a "repulsion" when it is negative. By convention, we only report positive RD that are >.20.

3.2.6 Discussion

A predominance of the front side was globally noticed. This is probably due to the fact that the front side was the most visible and the easiest to access.

The star-like avatars were found highly correlated with the front side. Then, when the participants used the arrow and the hand avatars pointing to the left, they tended to pick up the cube by its right side. When provided with the arrow and hand pointing to the right, they favoured the left side of the cube. Taken together, these results suggest first that if the avatar gave a directional cue, the user tended to pick up the virtual object by "pointing" the avatar toward the centre of the virtual object. Second, when no main directional cue was suggested by the avatar the participants tended to use the front of the target as the selection area.

Interestingly, the influence of the directional cue was observed in similar proportions for the arrows and for the hands. This suggests that the anthropomorphic appearance of the virtual hands did not increase the effect of the directional cue. This result seems to weaken the hypothesis of a potential analogical transfer or procedural transfer with the hand-like avatar as compared to the arrow shapes. However, the percentage of left side choices was found slightly superior (+10%) for the right-pointing arrow than for the right-pointing hand. This could be due to the fact that all participants were right-handed and, thus, they might have been less influenced by an avatar corresponding to a left hand.

Last, the strategy of selecting the front side still remained highly chosen (~33%) in the case of the right-pointing avatars. This could be explained by the fact that all participants were right-handed and they all manipulated the device with their right hand. Thus, it was more difficult for them to rotate their wrist and point to the right, and it was thus less "natural" for them to reach and pick up the cube by its left side.

3.2.7 Conclusion

This second experiment showed a strong influence of the visual appearance of the avatar on the participants' strategy of selecting a virtual object. The visual directional cue associated with each avatar influenced the way participants picked up the virtual cube. Indeed, the participants picked up the virtual cube by different sides when the directional cue of the 3D cursor was changed. Star-like cursors (with no main directional cue) led the participants to pick up the cube by its front or top. The directional cue of the virtual hands and virtual arrows made the participants pick up the virtual cube by its right or left sides.

4 GENERAL DISCUSSION

Our results showed that a visual property of the avatar chosen to display the user in a virtual environment could influence the behaviour of the participants during a manipulation task. The directional cue suggested visually by the avatar modified both the way participants grasped the extremity of the interaction device and the way they picked up a virtual object.

In the first experiment, we found that the directional cue of the avatar made the participants rotate their interaction device. They tended to align the device (and their finger) with the orientation of the virtual hand displayed visually. In the second experiment, we found that participants picked up a virtual cube by different sides when the directional cue of the 3D cursor was changed. If the avatar contained a directional cue, the user tended to pick up an object by "pointing" toward the object's centre.

As compared to the previous studies of Philips et al. [30] and Po et al. [31] which were achieved in 2D desktop environments, we did not focus on users' performance but on users' behaviour.

We found that the users naturally adapted their picking strategy to the directional cue suggested by the 3D cursor. They tended to pick up the virtual object by “pointing” toward its centre. This result seems consistent with the previous findings of Po et al. [31] who showed that performance decreased when the directional cue of a 2D cursor was contradictory with the direction of motion. Besides, Po et al. [31] showed that drops in performance due to the directional cue of 2D cursors differed as function of the interaction device used. Here we found a direct influence of the avatar’s directional cue on the physical manipulation of the interaction device.

In the future, we should see more and more VR applications available on the market which will all require 3D cursors and avatars of the user. The results of the present study could inspire the designers of such 3D virtual environments. Indeed, considering the results of the second experiment, it becomes possible to design virtual cursors that induce specific behaviour and strategies of manipulation of objects in virtual environments. Besides, if uncontrolled, the visual appearance of the avatar and more especially its main visual directional cue could generate unwanted motions and unwanted uses of the input device.

It could become interesting to design avatars that change automatically their visual properties as function of the manipulation context. It is already the case in some desktop applications with 2D cursors that change, for instance, when passing over a web link. Similarly, we could adapt the directional cue of the avatar according to the manipulation task to perform or to the properties of the virtual object to select.

One other interesting application of our results concerns the manipulation of haptic devices. Haptic interfaces have generally a limited workspace that can be inconvenient for the manipulation of virtual objects. More especially, the rotational range of haptic devices can be very small and the user may reach rapidly the mechanical stops of the device when rotating his/her hand. Specific 3D interaction techniques have been developed to cope with this problem [25]. Considering the results of the first experiment of this paper, it could be possible to restrain the orientation of the haptic device by using the visual orientation of the user’s avatar. However, future work is necessary to investigate this possibility.

5 Conclusion

We have studied the influence of the directional cue of the avatar used to display the user in the virtual environment during a selection and manipulation task. The results of a first experiment showed that the visual orientation of the avatar influenced the way participants manipulated the real interaction device. The participants changed the orientation of their hand as function of the orientation suggested visually by the shape of the 3D cursor. The second experiment showed that the directional cue of an avatar could change the way participants selected and picked up a virtual cube. The visual directional cue of arrows or virtual hands could make the participants pick up the virtual cube by its right or left sides. Other cursors (with no main directional cue) led the participants to pick up the cube by its front or top.

Our results suggest that the choice of the graphical display of the user’s avatar or 3D cursor is very important in virtual manipulation tasks. Indeed, the visual directional cue of an avatar can partially determine the manipulation strategy in the VE. It could support or impair the user when he/she manipulates virtual objects and interaction devices. Such effect could be used to favour optimal uses of manipulation interfaces in virtual environments, such as with haptic devices with limited rotational workspace.

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