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| **Participant 1** | |
| [Baseline] |  |
| [Human Horizontal] |  |
| [Robot Horizontal] |  |
| [Human Vertical] |  |
| AR Arm helpful? Why? | Yes. It helps to project the interaction of my arm with objects. |
| Vertical better than horizontal virtual arm? Why? | Human arm in robot orientation felt better because I can feel moving my arm in that direction |
| Virtual human or robot arm was more helpful? | The human arm was better |
| Exploratory Task |  |
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| **Participant 2** | |
| [Human Horizontal] | I use hologram when the robot didn’t follow my movement, to see the position |
| [Human Vertical] | The robot feels lighter than the first task and it’s following me better |
| [Baseline] | I am feel more familiar with the robot |
| [Robot Horizontal] | I didn’t used the hologram because I am already familiar with the robot and it’s easier to do it without the hologram |
| AR Arm helpful? Why? | Yes, because it can give me a preview of which way the Robot will move |
| Vertical better than horizontal virtual arm? Why? | It’s better with my own arm |
| Virtual human or robot arm was more helpful? | Virtual human arm |
| Exploratory Task |  |
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| **Participant 3** | |
| [Human Vertical] |  |
| [Robot Horizontal] |  |
| [Human Horizontal] |  |
| [Baseline] |  |
| AR Arm helpful? Why? | [corrected] There was the rendering of the task, so I only looked at that. I did not use the holograms at all. |
| Vertical better than horizontal virtual arm? Why? |  |
| Virtual human or robot arm was more helpful? |  |
| Exploratory Task | This is hard, because I thought I was moving one way, but actually it was moving in a different direction, and it’s (the crayon) not close to the whiteboard. |
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| **Participant 4** | |
| [Robot Horizontal] |  |
| [Baseline] |  |
| [Human Vertical] |  |
| [Human Horizontal] |  |
| AR Arm helpful? Why? | None of the holograms were really helpful |
| Vertical better than horizontal virtual arm? Why? | The vertical arm would be the most helpful as it’s in the same orientation as the robot, but I was not using it. |
| Virtual human or robot arm was more helpful? | No |
| Exploratory Task | [P4]: In the pointing task, I just need to move my finger around. That's kind of easier. But in this task, I have to also pinch my fingers. And I have to figure out whether this pinch is working or not.  [exp]: Okay. What about the depth?  [P4]: Yeah, the problem is that I don't know how far I am from the whiteboard, sometimes I can move my finger around, but it doesn't do anything.  [exp]: Okay. I think we should include that line, right?  [P4]: Like in the end, if I push my fingers too far, it might just go through the (task plane).  [exp]: And remember in the pointing test, there was a line telling you how close you, and maybe that will help.  [P4]: Yeah, yeah, true. |
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| **Participant 5** | |
| [Baseline] | Very difficult to do since the robot arm is not going the same direction as my arm |
| [Human Horizontal] | The hologram helps for tracking the movement, making the task easier |
| [Human Vertical] | The hologram shows me clearly the movement of the robot arm, so I don’t need to figure out the direction. It makes the tasks becomes very easy. |
| [Robot Horizontal] | The robot arm hologram isn’t that useful. I didn’t even need to see it to complete the task. The hand hologram in the 2nd session is more useful |
| AR Arm helpful? Why? | It’s very helpful especially the vertical human arm. Since it follows the direction of the robot, I don’t need to think of the direction my arm goes to control the robot arm. |
| Vertical better than horizontal virtual arm? Why? | It was a lot more helpful with the virtual arm in the same orientation as the robot, because I don’t need to think about the right direction of my arm movement. The vertical human arm makes me feel like I’m really controlling my own arm. In my opinion, the horizontal robot and no hologram is both not helpful |
| Virtual human or robot arm was more helpful? | Virtual human arm. |
| Exploratory Study | [exp]: So with these two last task, the drawing and the grabbing objects, do you think they were easier or more difficult compared to the pointing task.  [P5]: For the grabbing one? The grabbing one is easier than the pointing, but the marker 1 is harder than the pointing.  [exp]: And you can you tell why?  [P5]: Because like for the marker, I cannot see how far is it, like there is no red line or anything, if I remember. So like, I don't know like if the marker already touch the whiteboard or not. And, and because like, I think there is a little bit delay when the marker touch the whiteboard. So like, I don't know, like if it's already been, you know, draw or not. Yeah, but like for the grabbing one, because like it change color.So like I already know the exact, okay, it's already been grabbing.  [exp]: Okay, I think you also notice that when you are drawing something on a surface, you have a feeling of you're touching something. In this case, you're drawing on the air, so there is a lack of haptic feedback.  [P5]: Maybe like if there is, you know, like a sound of the robot arm hitting the arm or it will be.  [exp]: So what the strategies do you use when you were pointing, like to move your arm? What kind of thinking what you doing?  [P5]: So like, I only saw how the robot move. Like I don't remember it, but like when I move here and then I go, then I memorize it. Oh, so like if I go here, the robot will move there.  [exp]: Okay. What about the holograms? Were they helpful?  [P5]: For me, the most helpful one is the third.  [exp]: Okay. Yeah, the vertical are different.  [P5]: Because sometimes I move my arm too much, the second one like will tell me like your arm is like this, you know, because show me the picture.  [P5]: Yeah, but like, I do feel like if the robot arm is not going at this physical arm, like it's not helpful at all. It’s already hard for me to figure out my own hand. But like when the hologram changes into the robot arm, it's making me harder. |
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| **Participant 6** | |
| [Baseline] |  |
| [Human Horizontal] |  |
| [Human Vertical] |  |
| [Robot Horizontal] |  |
| AR Arm helpful? Why? | I didn’t use it at all. I was looking directly at the real robot arm. |
| Vertical better than horizontal virtual arm? Why? | No |
| Virtual human or robot arm was more helpful? | I was not using the holograms |
| Exploratory Study | These tasks are much harder than the pointing task. The hardest part about the drawing task is that I didn’t know when I was close enough to the whiteboard. Force feedback would help because I can’t really see the distance. |
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| **Participant 7** | |
| [Baseline] | It requires a small practice to get use to robot arm. |
| [Human Vertical] |  |
| [Robot Horizontal] |  |
| [Human Horizontal] |  |
| AR Arm helpful? Why? | Yeah, the arms were helpful for me to control the robot arm. I was able to control the robot arm. |
| Vertical better than horizontal virtual arm? Why? | I think it was more helpful when the orientation of the virtual arm was in the horizontal direction. |
| Virtual human or robot arm was more helpful? | I think the virtual robot arm was quite helpful. The human arm was not helpful. I was able to exactly monitor the movement of my arms, so the virtual arm was quite convenient to check. |
| Exploratory Study | [exp]: Compared to the previous target selection task, were the grasping or this drawing task easier? Harder?  [P7]: Yeah, it was a bit harder than the previous one. Maybe it's because I had more practice on selecting the targets. So for that task, I didn't have much exercise. Maybe if I have to, I if I have a practice, you know, I am sure that it will also be easier one. But yeah, yeah, the previous one was quite easier because I had a lot of practice, a lot of repetition.  [exp]: More repetition. That's why interesting. And then I guess with the grasping or the drawing, did you find the depth difficult?  [P7]: Yeah, yeah, it was a bit difficult compared to the previous classes.  [exp]: What kind of information like would you think like if shown would.  [P7]: Yeah, I think the when I was trying to grasp the object, yeah, I was able to see only one line. Okay, but I think there should be two lines for the two fingers. So that deflection when you move it. Yeah, so there should be two lines. And when the two lines hit the parameter of the object, yeah, so you just close it at that graph. So it would be quite helpful because when I was trying to move it, there was only one line. So I wasn't able to, you know, quickly know that whether it my hands and touch the parameter, the outer surface of surface object or not. So I think in my opinion, there should be two lines of pointing these two fingers. And when you move it, so when you see both the lines are touching the outer parameter of the object. Yeah, you just close it and press it. So I think it will work in right? That could be one amendment in my opinion. That was the only thing I was, you know, it was very difficult for me to find out whether I had touched the parameter or.  [P7]: Think two lines when you have only one line, you don't know whether you have, yeah, fingers have touched the upper surface. So if you have two lines going in and you see, okay, these two lines are hitting the outer parameter of the okay display. Yeah, so that would work, I think. Okay, same for the writing as well when you're trying something. So there should be a line that should follow your one finger, only one finger, right? Okay. Because usually when you're trying to write, you don't feel the other finger. Yeah, so just it should be like all the other places should be closed. And if your lefty handy, right handed, yeah. So then just use it like this and it should be quite convenient. So it was a bit more difficult to, you know, perfectly right. Yeah, I wasn't able to write perfectly, to be honest. So it, there should be a line and when you do like this, it should start writing. So there should be some indication like now it's starting to write. Yeah, it was there was no indication like now it's starting to write or not.  [exp]: Yeah, that’s great. And then just in general, the pre going back to the previous task, or like just in general, did you develop some kind of control strategy?  [P7]: When I was doing in the beginning. So I will not be using my mind properly like that. Okay, just moving hands and like this. Yeah, so when I realize that when you move for actually you need to understand the orientation of your arm. Yeah, for instance, when I was moving left, so it was moving down. Exactly. Yeah, so you should actually clearly know about this thing when you are good at knowing that when you move left, yeah, the robot arm will move down. So when you are clear about this, it will be very fast of that. So in the beginning, I was not, to be honest, sure. So I was just learning like this. But in the later stages when I got to know that, when you both, yeah, the hand will move down. So actually the user should, you know, carefully know about the movement of your arm and the movement of the robot arm. Yeah, so when you are clear about this benefit, it becomes cohesive. |
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| **Participant 8** | |
| [Baseline] |  |
| [Robot Horizontal] |  |
| [Human Horizontal] |  |
| [Human Vertical] |  |
| AR Arm helpful? Why? | Yeah, I feel like I could see the arm and in some, in my periphery of view. |
| Vertical better than horizontal virtual arm? Why? | So yeah, because it is in the orientation of the robot arm was like, okay, it was more simple to understand |
| Virtual human or robot arm was more helpful? | The human arm, I think the orientation and it's a little bit the drawing or the arm is like more, the schematics is less complicate or is easy for me to understand. Compare it to the complete arm, the robotic arm with all that articulation. I don't know how to move it, but I know how move to move my arm. |
| Exploratory Study | I think this task requires a lot of more precision movements. I think with a little bit more practice, I could grab a little more precise movements. Also I think the of depth is difficulty.  Because it helps a little bit more because you can see the virtual arm and you can have it on your peripheral view, right? Like see how the arm, the virtual arm is moving. Yeah, so you can correct the movement of your arm. So it will, for example, if I want to move it to the right, so, or a little bit come back to my body so I can. And just the movement of my arm is like seeing your own arm movement.  I think maybe you can like try to find a way that, yeah, put the Hologram on the real robot arm to help a little bit more. |
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| **Participant 9** | |
| [Baseline] |  |
| [Robot Horizontal] |  |
| [Human Vertical] | Confusing holograms |
| [Human Horizontal] |  |
| AR Arm helpful? Why? | No they were not aligned with my arm and increased my difficulty |
| Vertical better than horizontal virtual arm? Why? | Yes but the help is limited . I preferred just looking at the robot |
| Virtual human or robot arm was more helpful? | No it was equally worse |
| Exploratory Study | Oh, the drawing is difficulty, but the grabbing is easy.  In the drawing task, I don’t know when I’m touching the plane. |
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| **Participant 10** | |
| [Human Horizontal] | The distance between the object and my arm is harder to measure with eyes compared with the up, down, left and right directions. |
| [Baseline] | Always drawing circles seems helpful to assist me to control the robot army to click the red dot. |
| [Human Vertical] | The first click is always the difficult part, because the distance should be adjusted. After that, things become easier. |
| [Robot Horizontal] | Sometimes there are misjudgements about the distance but I can adjust it quickly. |
| AR Arm helpful? Why? | No, they are not sync, and the fingers of the AR arms can not show the real distance with red dots. |
| Vertical better than horizontal virtual arm? Why? | With my own arm was more helpful. I am familiar with my own arm. Observing its movements make me react and adjust the robot arm faster. |
| Virtual human or robot arm was more helpful? | Both of them are not helpful. The reasons are the same with two questions above. |
| Exploratory Study | The drawing task is the most difficult, and the grabbing one is the second most difficulty.  It’s like maybe the same way as pointing to the dots, but the drawing task is much more difficult than the other ones. Because when you click something, you only need to contact with the plane only once or twice, but when you draw you need to find the right plane and continuously contact with it many times.  I think since this is my first experience of this, I can maybe find the right plane once or twice, but it’s difficult to find the right plane all the time.  I used to be a painter, I drew a lot of pictures and sketch on the board. This is so different without feeling the board, it’s just like drawing on the air.  Most of the time I use my arm to compare with the robot arm to grab something or click the dots. |
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| **Participant 11** | |
| [Human Horizontal] |  |
| [Baseline] |  |
| [Robot Horizontal] | With the virtual robot arm it feels weird to look at it while performing the task so I just look at the real robot arm instead. |
| [Human Vertical] | With the virtual human arm in the orientation of the robot arm I think it less confuses me |
| AR Arm helpful? Why? | No, I think it is because when I perform the task, I am looking at the disk of targets. I preferred to focus on the robot during the task. |
| Vertical better than horizontal virtual arm? Why? | No |
| Virtual human or robot arm was more helpful? | Human |
| Exploratory Study | These last two tasks are more difficult than the pointing task, because you have to make sure that it’s on the same plane.  I feel like the grabbing is kind of lagging.  Yeah, the pointing line was helpful to select things.  With the drawing task, I was not sure if I was close enough, but actually I went to far. |
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| **Participant 12** | |
| [Human Horizontal] | Physically demanding |
| [Human Vertical] | Getting more used to control the robot |
| [Robot Horizontal] | Na |
| [Baseline] |  |
| AR Arm helpful? Why? | The first one, a little bit, but most of the time I was focusing on the dots. I was sometimes using the virtual arms to check. |
| Vertical better than horizontal virtual arm? Why? | When I see the virtual arm in the vertical direction, I feel more secure. |
| Virtual human or robot arm was more helpful? | The human arm is better. I just feel like it’s better. |
| Exploratory Study | For the first few tasks, you just have to approach one point, and grabbing is similar. But the drawing is completely different, and the direction is a bit confusing.  The grabbing one is hard to determine when to start to grab, because from my perspective I see my hand is already interfering with the object, but when I close my hand it’s not grabbed. So maybe there can be some indication, for example when it’s ready to grab, it can change color. |
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| **Participant 13** | |
| [Human Horizontal] |  |
| [Robot Horizontal] |  |
| [Baseline] |  |
| [Human Vertical] | I fell more confident to do the task, also feel the task more easier |
| AR Arm helpful? Why? | Not that much, I think using the rule of movement is much easier |
| Vertical better than horizontal virtual arm? Why? | Own arm is better because it is easier to understand the movement |
| Virtual human or robot arm was more helpful? | Not that much, but being helpful to some extent |
| Exploratory Study |  |
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| **Participant 14** | |
| [Human Horizontal] |  |
| [Robot Horizontal] |  |
| [Human Vertical] | More easier due to sync |
| [Baseline] |  |
| AR Arm helpful? Why? | Not much because I learnt to sync with constant practice |
| Vertical better than horizontal virtual arm? Why? | Virtual arm in same orientation was better |
| Virtual human or robot arm was more helpful? | Virtual human arm was better |
| Exploratory Study |  |
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| **Participant 15** | |
| [Human Vertical] |  |
| [Baseline] |  |
| [Human Horizontal] |  |
| [Robot Horizontal] | Hologram helps me to find the distance |
| AR Arm helpful? Why? | Yes, helping to find the distance |
| Vertical better than horizontal virtual arm? Why? | Same with my own arm |
| Virtual human or robot arm was more helpful? | Human arm |
| Exploratory Study |  |
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| **Participant 16** | |
| [Human Vertical] |  |
| [Baseline] |  |
| [Robot Horizontal] |  |
| [Human Horizontal] |  |
| AR Arm helpful? Why? | Not much because I was more focused on the target |
| Vertical better than horizontal virtual arm? Why? | It was more helpful than the others, however it still confuse me when trying to achieve the target. |
| Virtual human or robot arm was more helpful? | I think the virtual human arm was not very helpful for me, but it could have been better maybe if the position of the virtual arm was closer to the robot arm |
| Exploratory Study | Yeah, the last two tasks were a bit more difficult, because it requires to close the fingers, and requires maintaining the position in the same plane, but it was very interesting as well to try new things.  Cuz I wanted to draw continuously, but maybe I was getting off the plane, and yeah so it’s hard to stay in the same plane, so the drawing was more difficult.  So to move the robot, actually I rotated it in my head in my mind. So I imagine myself like horizontal, and it was easier that way. |
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| **Participant 17** | |
| [Human Vertical] | When I move my arm too fast the robot arm is in sync. The hologram helped my a lot to perform the task, even thought I was not seeing the hologram directly because I was focused on the red dot. |
| [Human Horizontal] | This version of the hologram didn’t help. It was more difficult to control it. I could complete the task only because the first task had the rotated hologram arm |
| [Baseline] | At this point I learned the position of the circles and I was able to perform the task faster. It was better to have no hologram to distract me |
| [Robot Horizontal] | The hologram didn’t help me to complete the task. I was a bit tired and I just used the strategy of following the path clockwise. |
| AR Arm helpful? Why? | Yes Only when the human arm was rotated |
| Vertical better than horizontal virtual arm? Why? | Yes the rotated arm helped me to have a reference of my own arm over the machine |
| Virtual human or robot arm was more helpful? | I prefer the human arm |
| Exploratory Study |  |
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| **Participant 18** | |
| [Human Vertical] |  |
| [Human Horizontal] |  |
| [Robot Horizontal] | The hologram doesn’t hinder my attention. I totally focused on the task and robot hand. |
| [Baseline] |  |
| AR Arm helpful? Why? | I didn’t use AR arms during study |
| Vertical better than horizontal virtual arm? Why? | Yes I think so but I just focus on the robot gripper, task circles, and my hand movement |
| Virtual human or robot arm was more helpful? | Yes |
| Exploratory Study |  |
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| **Participant 19** | |
| [Human Vertical] | Very cool. Seems like in a science fiction movie. The movement is a bit counter intuitive, but all good after getting used to it. |
| [Robot Horizontal] | As getting more used to the movement, the task gets easier. |
| [Human Horizontal] | Originally I thought the flipped movement logic might cause me hard to control the robot. But it turns out I can quickly get used to it. The holograms are good for visualising my arm, but they are not that useful when I have get used to the movement. |
| [Baseline] | It is a bit uncomfortable after wearing Hololens 2 for a period. |
| AR Arm helpful? Why? | Somewhat helpful. As I get used to the movements, they could probably be ignored. |
| Vertical better than horizontal virtual arm? Why? | With my own arm. Because it feels more natural. |
| Virtual human or robot arm was more helpful? | Virtual human arm. Feels more natural. Also I can directly see the real robot arm. |
| Exploratory Study |  |
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| **Participant 20** | |
| [Robot Horizontal] |  |
| [Baseline] |  |
| [Human Horizontal] |  |
| [Human Vertical] |  |
| AR Arm helpful? Why? | Yes. Because I can see my arm motions and my motion direction. |
| Vertical better than horizontal virtual arm? Why? | Yes. It shows my arm motion clearly. |
| Virtual human or robot arm was more helpful? | Virtual human arm |
| Exploratory Study | The last two tasks were more difficult, the grabbing is easier than drawing. Because drawing it’s difficult to make like a continuous motion and handle the direction at the same time.  When I draw, it’s really sensitive to the motion, so when I want to make a line, it’s like sometimes it’s like not touching the plane, because it’s really sensitive.  When moving the robot, I just think about the rotation and rotate it in my head. |
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| **Participant 21** | |
| [Robot Horizontal] | The hologram did not really align with the movement of the real robot arm in terms of the angle |
| [Human Vertical] | I am getting more experienced from practicing and previous tasks, also the hand hologram helps me to track and confirm the movement of my hand and arm, where both factors contribute to quicker completion of the tasks |
| [Baseline] | For this part I can only rely on and refer to the physical arm during the task, as during the previous two parts I mainly relied on the movement of physical robot arms instead of the virtual arm or hand, and I am also getting more proficient and used to it, so I completed this task with much ease. |
| [Human Horizontal] | I almost completely relied on the movement of the physical robot arm rather than the virtual human arm next to it because I think I have mastered the task in terms of all crucial techniques |
| AR Arm helpful? Why? | Sort of, but as I was quite fast getting used to it so I gradually reduced the frequency I referred to the AR arms |
| Vertical better than horizontal virtual arm? Why? | With the physical robot, because with such I can manually calibrate it with my mind, if it goes in the same orientation with my own arm, then it cannot provide much extra information |
| Virtual human or robot arm was more helpful? | A virtual human one for sure, because the virtual robot arm is just a simulation copy of the real robot arm and doesnâ€™t provide much reference |
| Exploratory Study |  |
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| **Participant 22** | |
| [Robot Horizontal] | We can add a virtual plane in front of the virtual robot arm |
| [Human Horizontal] | Better than the last one, the virtual robot arm. But it is not a main factor for completing the task. |
| [Baseline] | I think the virtual robot arm is kind of meaningless. |
| [Human Vertical] | It gives participants confidence to do the experiments, successfully control the robot arm in reality. |
| AR Arm helpful? Why? | Yes, it gives human confidence to control the robot. |
| Vertical better than horizontal virtual arm? Why? | With my own arm since it was my own arm |
| Virtual human or robot arm was more helpful? | Virtual human arm |
| Exploratory Study |  |
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| **Participant 23** | |
| [Robot Horizontal] |  |
| [Human Horizontal] |  |
| [Human Vertical] |  |
| [Baseline] |  |
| AR Arm helpful? Why? | I think not the first one, but the second and third, especially the third, is the most helpful. I think the first one is the same as the real robot arm, so it doesn’t provide me any information. |
| Vertical better than horizontal virtual arm? Why? | So I’m performing the task, I’m imagining the whole targets rotated 90 degrees, so it’s better for me to use the rotated arm to choose the targets, because it’s in the same orientation as the robot arm. |
| Virtual human or robot arm was more helpful? | Human robot, as I can see my arm performing something on the side. |
| Exploratory Study | Yeah, I think the two tasks are more difficulty. For the first one it’s 3d, and I have to grip it. For the drawing task, it’s hard to keep the hand in the same distance from the plane, so it’s quite difficult. Yeah why is the line missing for this task?  For controlling the arm for the pointing task, I just imagine the targets rotated and then use the virtual hand to reach the rotated targets, and because it’s round so I just need to turn it. |
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| **Participant 24** | |
| [Robot Horizontal] | Sometimes it does not move as expected. Sometimes I canâ€™t see the target (hand is blocking) |
| [Human Vertical] | Hand helps with orientation |
| [Human Horizontal] | Better than the last with the hand in natural position. That was confusing. I have gotten used to this by now. |
| [Baseline] |  |
| AR Arm helpful? Why? | Only the one that is vertical representation of the arm. |
| Vertical better than horizontal virtual arm? Why? | With the robot, just need to know how the arm reacts. I can see my own arm so that’s duplicated if horizontal. |
| Virtual human or robot arm was more helpful? | Human arm |
| Exploratory Study |  |