Haptic and Virtual Reality Glove Comparison

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ABSTRACT

Virtual reality (VR) and haptic gloves are changing the way individuals can be trained in various tasks, including battlefield and medical procedures. These gloves allow the user to interact with objects in the virtual world and haptics allow for the sense of touch while interacting with these objects. This research compares three different VR glove types (BeBop Forte Data, VRgluv ENTERPRISE, and HaptX DK2 gloves) in terms of usability, functionality, ergonomic benefits or challenges, and general satisfaction level. Interviews of VR glove subject matter experts were conducted based on the integration process required for each type of device. An anonymous survey was administrated to the subjects for feedback based on usability, functionality, ergonomic benefits, and satisfaction level. The research also used small groups of individuals to test a set of gloves to give end-user feedback on the gloves, each group only tested one set of gloves.

Quantitative and qualitative results were analyzed, yielding the mean and standard deviation of interview and survey items. Findings were thoroughly evaluated to produce initial interpretation of these results. All three types of gloves have their own unique design that provides different experiences for the users. Each set of gloves was identified with the concerns and benefits it provides to training specific tasks then compared across the board to help identify the appropriate glove for the appropriate tasks. It is the intent to deliver the results to the Original Equipment Manufacturer to assist in improving their systems and provide potential users with comparative data to support purchasing decisions. The goal of future research is to go back to each of these companies and see their newest changes that they have made since this comparison and determine the new feedback from users. This paper will present the findings of the glove comparison, along with evidence that may be beneficial for selecting haptic solutions for specific trainings.

ABOUT THE AUTHORS

Madison Quinn, MS is the Research Analyst at Engineering & Computer Simulations, Inc. (ECS) supporting all applied research projects in support of military training research. Ms. Quinn is responsible for conducting scientific literature reviews, designing usability study survey instruments, administering surveys, conducting interviews, and supporting data collections through quantitative and qualitative analyses. Most recently, Ms. Quinn supports research on combat medicine training prototypes and assessments and has experience with immersive and innovative technologies used for training such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), haptic gloves, and haptic-based weapons. Ms. Quinn holds a Bachelor of Arts in Psychology from Southern Illinois University and a Master of Science in Industrial / Organizational Psychology from Bellevue University. Ms. Quinn is also working on getting her Ph.D in Industrial Organizational Psychology with an emphasis in Qualitative Research from Grand Canyon University.

Shane Taber is the CTO of ECS and focuses on the development of innovative emerging technologies for use in military training and education. In his time at ECS, Mr. Taber has been instrumentally involved with developing and designing several flagship simulations and technologies, including the Tactical Combat Casualty Care Sim (TC3Sim) and VA Virtual Medical Center (VA-VMC). Throughout his professional career, Mr. Taber has continually advocated and explored the application and utilization of emerging media and technology for learning, education, and training, including Extended Reality (XR), AR, VR, Synthetic Training Environments (STE), and haptics. Mr. Taber has filled various duties and roles including Creative Director, Project Manager, and Development Director, and currently serves

as part of the Senior Leadership Team. Prior to working at ECS, Shane worked in academic research at the Institute for Simulation and Training (IST) developing cutting-edge research projects, simulations, and technologies in the emerging technologies of MR for application within military, science museums, and cognitive behavioral therapy. Mr. Taber holds a Bachelor of Arts degree in Digital Media and Interactive Entertainment form the University of Central Florida, providing a foundation in fine art, video production, game design, digital media, and 3D visualization. He is also a Certified Scrum Product Owner and holds certificates in project management and CMMI.

Justin Welzien is a lead software engineer at ECS and has been in the simulation and training industry for over 15 years. Graduating with Summa Cum Laude honors, he holds a Bachelor of Arts degree in Digital Media from the University of Central Florida. Mr. Welzien spent much of his career as a Digital Artist responsible for forging the high-visual-fidelity asset pipeline, which has produced several award-winning products. His role then transitioned to Technical Artist, where he developed tools to streamline asset integration and improve development productivity. Mr. Welzien then became a Software Engineer, helping shape and architect technical solutions for several programs. Over the past several years, he has spent much of his time leading teams for the TC3Sim programs.

David Fahr is a lead software engineer at ECS. He holds a Bachelor of Science in Game and Simulation Programming from DeVry University and has worked within the simulation space for over 10 years. Mr. Fahr has lead development on numerous training simulators that provides its users with unique experiences using virtual reality, augmented reality, and a mixture of each through multiplayer connectivity. Mr. Fahr has also worked closely with several DoD branches to provide classroom-based training simulators that range from standalone, web, and mobile platforms. Some of the simulators allow tracking of student progress to provide instructors with performance insights which can be leveraged for additional training or feedback opportunities.

Matthew Becchio is a software engineer at ECS. His responsibilities include designing and developing serious games and gameplay features based on client requirements and concepts, maintaining and assuring solid User Experience (UX) throughout the development cycle of the application, and tracking and running gameplay metrics/analytics. Mr. Becchio has received his Bachelor of Arts degree in Digital Media – Game Design at the University of Central Florida. He has been making entertainment and serious games for 6+ years as both a software engineer and game designer. He holds multiple awards for both professional and personal projects. Matt has experiences in building applications across a range of platforms including desktop, mobile, WebGL, and VR. He has also been a sitting committee member for the Serious Games Showcase & Challenge, hosted at I/ITSEC, for 4+ years where he has evaluated and judged a variety of serious games that have used a range of hardware devices including desktop, mobile, WebGL, VR, AR, MR, and custom-built hardware controllers and devices.

Edwin Cardalda is a software engineer at ECS and holds a Bachelor of Science degree from DeVry University in Game & Simulation Programming. He brings over 10+ years of professional experience in software engineering and simulation development. Mr. Cardalda specializes in the production of a wide variety of software products including serious games for medical training, combat training, aviation & aircraft maintenance trainers, virtual reality, and augmented reality. Over the years he has worked on several projects that have earned awards such as the IMSH 2017 Serious Games and Virtual Environments Best in Show award and winner of I/ITSEC's People's Choice Award in 2021 Serious Games Showcase & Challenge.

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INTRODUCTION

The U.S. Army is interested in the use of innovative technologies to instruct and assess on critical tasks such as tactical combat casualty care (TC3) and care under fire (CUF). One such research project involves the creation of a CUF simulation using VR gloves (with haptic features) for Soldier performance assessment. The research and engineering team is in the process of creating a realistic experience that Combat Life Saving (CLS) Soldiers or Combat Medic Specialists (MOS 68W) could face in a real-life conflict. The main goal of this research is to determine whether the addition of innovative technologies could produce more realism, yielding a more valid and reliable assessment of CUF performance. Paramount to this research is the selection of the optimal VR glove in terms of usability, functionality, ergonomic benefits, and satisfaction level. The research and engineering team selected three glove types to investigate: BeBop Forte Data gloves, VRgluv ENTERPRISE gloves, HaptX gloves. The gloves were chosen based on previous discussions from the innovation team. All types of gloves were purchased with the intent to integrate them into a CUF VR simulation. The BeBop Forte gloves, VRgluv ENTERPRISE gloves, and HaptX gloves include haptic sensors, providing the user a sense of touch while interacting with objects in the VR environment.

Figure 1. BeBop Forte Data Glove

The BeBop website (https://bebopsensors.com/) states that, "The Forte Data Gloves take workplace training to the next level by enabling natural hand interaction and providing haptic feedback to help you create the most intuitive and immersive VR training experience for skilled workers." BeBop gloves are the lightest weight gloves of those evaluated, weighing in at only 3.65 oz (each). Features include hand tracking, haptic feedback, and facilitated retrieval of objects in VR environment. The price is estimated at $10,000 per pair (prices are subject to change) and the research team acquired two sets for this project. An example of the glove can be seen in Figure 1.

Figure 2. VRgluv ENTERPRISE Glove

VRgluv ENTERPRISE (https://www.vrgluv.com/enterprise) are gloves that add immersive touch and realistic interactions in the VR experience. VRgluv is directed for training hands-on tasks in VR to increase training effectiveness. They use force feedback of up to 10lbs. The price is estimated at $9,000 per pair (prices are subject to change) and the team purchased one pair for this project.

Figure 3. HaptX DK2 Glove

HaptX DK2 gloves (https://haptx.com/) provide haptic feedback with microfluidic skin according to HaptX, this gives true-contact haptics. The gloves can apply up to 40lbs per hand of force. HaptX prides itself in the ability to use the gloves for training by building real muscle memory in VR. The gloves currently cover the entire hand and forearm. The price is estimated at $80,000 per pair (prices are subject to change) and is currently developing a new set to come out later.

RESEARCH GOALS

The glove comparison study has one primary research goal and one secondary goal. The primary goal is to determine which gloves would provide the optimal experience in a VR simulation in terms of usability, functionality, ergonomic features, and general satisfaction from an engineer perspective and consumer perspective. The secondary goal is to uncover the necessary information about these gloves to evaluate which might be better positioned for future research projects.

RESEARCH QUESTIONS

To support the abovementioned research goals, the following research questions were identified:

- What usability concerns or benefits exist due to the glove's form factor, design, or features?
- What functionality concerns or benefits exist due to the glove's form factor, design, or features?
- What functionality concerns or benefits exist due to the glove's integration into the VR scenario?
- From an ergonomic perspective, what are the potential benefits and challenges when using VR gloves, and are there specific gloves that pose more benefit and/or challenge than others?
- What is the advantage to having haptic feedback when using VR gloves (and with which specific tasks)?
- What is the user's overall level of satisfaction with each of these gloves?

METHODOLOGY

A questionnaire and interview open-ended questions (See Appendix) were created by the research team for each of the haptic gloves. Engineers and consumer participants were asked to complete the questionnaire which included demographic questions to better understand the individuals' backgrounds and experiences with these particular gloves and other virtual reality gloves. Specific engineers were then interviewed following a structured protocol (See Appendix). These engineers had direct experience with integrating glove sets into a VR scenario (that is being developed for the broader research project). The consumer participants were able to try the demo that each glove comes provided with upon purchase. The demos were specifically created by each of the glove companies as a marketing pitch for selling the gloves so that there was no bias demos. After the demo, each participant filled out a usability survey based on their experience with the specific glove they tried.

PARTICIPANTS

We were not required to do any participant recruitment for the engineers, as the study engineers (n=5) are current staff members on the research project. Due to their direct experience with each glove type, all participants provided feedback on the BeBop gloves (n=5), two participants provided feedback on the VRgluv gloves (n=2), and four participants provided feedback on the HaptX gloves (n=4). Engineers working directly with the gloves in the VR simulation were interviewed more in-depth on BeBop and VRgluv had two engineers and HaptX had three engineers. For the consumer participants, they were recruited through interest of trying the virtual reality haptic gloves for further research projects.

ENGINEER RESULTS

BeBop Engineer Survey Data (Quantitative Results)

100% of the participants (n=5) had 10+ years' experience with video games and had at least four years of experience with VR (with 20% having at least 10 years' experience with VR). Participants (n=5) reported either a 9 or 10 (on a 10-point scale) regarding their comfort level with technology overall.

Regarding familiarity with the gloves, only two people had used the gloves 10+ times. On a 4-point agreement scale, comfortability of the BeBop gloves was rated as 2.40 (mean) with a standard deviation (*SD*) of 1.02. Freedom for finger movement was rated as 3.00 (*SD*=0.63). Manageability of the gloves was rated as 2.40 (*SD*=1.02), and intuitiveness of the gloves was rated as 2.80 (*SD*=1.17). Glove fit was rated as 2.25 (*SD*=0.83). The adequate force feedback was rated as 2.20 (*SD*=0.75). Light weight was rated as 3.40 (*SD*=0.80). The gloves' ability to function as

intended regarding integration into a VR simulation was rated as 2.00 (*SD*=1.26). Intent to recommend these gloves for future haptic research was rated as 1.80 (*SD*=0.75). Comparative quantitative results between the gloves are shown in Table 1.

BeBop Engineer Interview Data (Qualitative Results)

The interviews were conducted one-on-one with a series of open-ended questions (See Appendix for protocol).

Concerns identified by participants (n=2) included:

- Requires calibration every time scenario is started
- Difficult time connecting to the system
- Fingers jitter back and forth in VR
- Uncomfortable (hands and fingertips)
- Strap across the back of each of finger is constraining

Benefits identified by participants (n=2) included:

- Gloves have a charge life of four to five hours
- Gloves are not tethered

VRgluv Engineer Survey Data (Quantitative Results)

100% of the participants (n=2) had 10+ years' experience with video games. One individual had 7-10 years' experience with virtual reality and one individual had 3-7 years' experience. Participants (n=2) reported either a 9 or 10 (on a 10-point scale) regarding their comfort level with technology overall.

When regarding familiarity with the gloves, one person had used the gloves more 10 times and the other had used them twice. On a 4-point agreement scale, comfortability of the VRgluv gloves was rated as 3.00 (mean) with a standard deviation (*SD*) of 0.00. Freedom for finger movement was rated as 3.00 (*SD*=0.00). Manageability of the gloves was rated as 3.50 (*SD*=0.50), and intuitiveness of the gloves was rated as 2.50 (*SD*=0.50). Glove fit was rated as 3.50 (*SD*=0.50). The gloves adequate force feedback was rated as 2.50 (*SD*=0.50). Light weight was rated as 2.00 (*SD*=0.00). The gloves' ability to function as intended regarding integration into a VR simulation was rated as 2.50 (*SD*=0.50). Intent to recommend these gloves for future research was rated as 2.00 (*SD*=0.00). Comparative quantitative results between the gloves are shown in Table 1.

VRgluv Engineer Interview Data (Qualitative Results)

The interviews were conducted one-on-one with a series of open-ended question (See Appendix for protocol).

Concerns identified by participants (n=2) included:

- Software development toolkit needs to be improved
- Hold a charge for about two to three hours
- Heavier and blocky gloves
- Gloves make a particular noise that could affect the realism of the environment

Benefits identified by participants (n=2) included:

- Gloves are not tethered
- Provides excellent haptics
- Easy to hold weapon with
- Gloves hold a charge of 2 to 3 hours

HaptX Engineer Survey Data (Quantitative Results)

100% of the participants (n=4) had 10+ years' experience with video games. 50% of participants (n=2) had 7-10 years' experience with virtual reality and the other 50% (n=2) had 3-7 years' experience. All participants reported higher than 8.5 (on a 10-point scale) regarding their comfort level with technology overall.

When regarding familiarity with the gloves, two individuals had used the gloves more than 10 times and the other two had used them 3 to 5 times. On a 4-point agreement scale, comfortability of the HaptX gloves was rated as 3.50 (mean) with a standard deviation (*SD*) of 0.50. Freedom for finger movement was rated as 3.25 (*SD*=0.43). Manageability of the gloves was rated as 3.00 (*SD*=0.00), and intuitiveness of the gloves was rated as 4.00 (*SD*=0.00). Glove fit was rated as 3.50 (*SD*=0.50). The gloves adequate force feedback was rated as 3.25 (*SD*=0.43). Light weight was rated as 2.25 (*SD*=0.43). The gloves' ability to function as intended regarding integration into a VR simulation was rated as 3.25 (*SD*=0.43). Intent to recommend these gloves for future research was rated as 3.75 (*SD*=0.43). Comparative quantitative results between the gloves are shown in Table 1.

HaptX Engineer Interview Data (Qualitative Results)

The interviews were conducted one-on-one with a series of open-ended question (See Appendix for protocol).

Concerns identified by participants (n=3) included:

- Heavier gloves
- Thimbles on the fingers and thumbs cause an issue with grabbing virtual items
- System needs to be restarted periodically to avoid issues with compressive system
- Tethered gloves
- Difficult to use certain weapons due to the magnetic tracking in the gloves

Benefits identified by participants (n=3) included:

- Gloves do not require charging because they are connected to system
- Includes a backpack mode (could be beneficial in a CUF scenario)
- Does not require calibration (just a quick hand scale for display)
- Provides excellent haptic feedback

Table 1. Glove Comparison Engineer Quantitative Data

Rating Statement	BeBop Gloves (n=5) Mean (*SD*)	VRgluv Gloves (n=2) Mean (*SD*)	HaptX Gloves (n=4) Mean (*SD*)
I was comfortable with the gloves on my hands.	2.40 (1.02)	3.00 (0.00)	3.50 (0.50)
My fingers had freedom to move while wearing the gloves.	3.00 (0.63)	3.00 (0.00)	3.25 (0.43)
The gloves were manageable to use	2.40 (1.02)	3.50 (0.50)	3.00 (0.00)
The gloves were intuitive to use.	2.80 (1.17)	2.50 (0.50)	4.00 (0.00)
The gloves fit well.	2.25 (0.83)	3.50 (0.50)	3.50 (0.50)
The gloves had adequate force feedback.	2.20 (0.75)	2.50 (0.50)	3.25 (0.43)
The gloves were light weight.	3.40 (0.80)	2.00 (0.00)	2.25 (0.43)
The Integration of the glove functioned as intended	2.00 (1.26)	2.50 (0.50)	3.25 (0.43)
I would recommend the gloves for future research projects.	1.80 (0.75)	2.00 (0.00)	3.75 (0.43)

CONSUMER RESULTS

Consumer perspective consisted of individuals interested in the haptic gloves and took the opportunity to test out the demo that each glove manufacture created. The consumers were asked some demographic background questions about their experience with video games, virtual reality, and comfortability level with technology.

BeBop Consumer Survey Data (Quantitative Results)

A total of 11 participants were able to try the BeBop gloves. 72.72% of the participants had 10+ years' experience with video games, 9.09% had 7-10 years, and 18.18% had 0-3 years' experience. 18.18% of the participants had 10+ years' experience with virtual reality, 18.18% had 3-7 years' experience, and 63.64% had 0-3 years' experience. All participants except for one had rated their comfort level with technology 8 or higher on a scale of 1 being not at all and 10 being extremely comfortable.

On a 4-point agreement scale, comfortability of the BeBop gloves was rated as 3.36 (mean) with a standard deviation (*SD*) of 0.64. Freedom for finger movement was rated as 3.36 (*SD*=0.77). Manageability of the gloves was rated as 3.27 (*SD*=0.62), and intuitiveness of the gloves was rated as 3.18 (*SD*=0.57). Glove fit was rated as 3.18 (*SD*=0.57). The gloves adequate force feedback was rated as 2.70 (*SD*=1.00). Light weight was rated as 3.73 (*SD*=0.45). The gloves' ability to function as intended regarding integration into a VR simulation was rated as 2.82 (*SD*=0.83). Intent to recommend these gloves for future research was rated as 2.91 (*SD*=0.67). Comparative quantitative results between the gloves are shown in Table 2.

VRgluv Consumer Survey Data (Quantitative Results)

A total of 18 participants were able to try the VRgluv gloves. 88.89% of the participants had 10+ years' experience with video games and 11.11% had 3-7 years' experience. 16.67% of the participants had 10+ years' experience with virtual reality, 5.56% had 7-10 years' experience, 33.33% had 3-7 years' experience, and 44.44% had 0-3 years' experience. All participants had rated their comfort level with technology 6 or higher on a scale of 1 being not at all and 10 being extremely comfortable.

On a 4-point agreement scale, comfortability of the VRgluv gloves was rated as 3.22 (mean) with a standard deviation (*SD*) of 0.71. Freedom for finger movement was rated as 3.28 (*SD*=0.65). Manageability of the gloves was rated as 3.33 (*SD*=0.47), and intuitiveness of the gloves was rated as 3.17 (*SD*=0.69). Glove fit was rated as 3.28 (*SD*=0.56). The gloves adequate force feedback was rated as 2.67 (*SD*=0.82). Light weight was rated as 2.89 (*SD*=0.81). The gloves' ability to function as intended regarding integration into a VR simulation was rated as 3.00 (*SD*=0.47). Intent to recommend these gloves for future research was rated as 2.88 (*SD*=0.68). Comparative quantitative results between the gloves are shown in Table 2.

HaptX Consumer Survey Data (Quantitative Results)

A total of 16 participants were able to try the HaptX gloves. 93.75% of the participants had 10+ years' experience with video games and 6.25% had 7-10 years' experience. 12.50% of the participants had 10+ years' experience with virtual reality, 12.5% had 7-10 years' experience, 31.25% had 3-7 years' experience, and 43.75% had 0-3 years' experience. All participants had rated their comfort level with technology 7 or higher on a scale of 1 being not at all and 10 being extremely comfortable.

On a 4-point agreement scale, comfortability of the HaptX gloves was rated as 3.44 (mean) with a standard deviation (*SD*) of 0.61. Freedom for finger movement was rated as 3.50 (*SD*=0.50). Manageability of the gloves was rated as 3.38 (*SD*=0.60), and intuitiveness of the gloves was rated as 3.81 (*SD*=0.39). Glove fit was rated as 3.50 (*SD*=0.50). The gloves adequate force feedback was rated as 3.56 (*SD*=0.61). Light weight was rated as 2.69 (*SD*=0.85). The gloves' ability to function as intended regarding integration into a VR simulation was rated as 3.56 (*SD*=0.50). Intent to recommend these gloves for future research was rated as 3.69 (*SD*=0.46). Comparative quantitative results between the gloves are shown in Table 2.

Table 2. Glove Comparison Consumer Quantitative Data

Rating Statement	BeBop Gloves (n=11) Mean (*SD*)	VRgluv Gloves (n=18) Mean (*SD*)	HaptX Gloves (n=16) Mean (*SD*)
I was comfortable with the gloves on my hands.	3.36 (0.64)	3.22 (0.71)	3.44 (0.61)
My fingers had freedom to move while wearing the gloves.	3.36 (0.77)	3.28 (0.65)	3.50 (0.50)
The gloves were manageable to use	3.27 (0.62)	3.33 (0.47)	3.38 (0.60)
The gloves were intuitive to use.	3.18 (0.57)	3.17 (0.69)	3.81 (0.39)
The gloves fit well.	3.18 (0.57)	3.28 (0.56)	3.50 (0.50)
The gloves had adequate force feedback.	2.70 (1.00)	2.67 (0.82)	3.56 (0.61)
The gloves were light weight.	3.73 (0.45)	2.89 (0.81)	2.69 (0.85)
The Integration of the glove functioned as intended	2.82 (0.83)	3.00 (0.47)	3.56 (0.50)
I would recommend the gloves for future research projects.	2.91 (0.67)	2.88 (0.68)	3.69 (0.46)

DISCUSSION

As seen in Table 1, there is a variety of pros and cons from an engineering perspective. BeBop gloves are a lighter weight option that the fingers can freely move and not feel constrained. VRgluv does have the ability to feel natural on the hands and are manageable to use. The HaptX gloves do have adequate force feedback and functionality above the others. In Table 2, the consumers found the gloves to be roughly even on some accounts and overall had a higher agreeable rate than the engineers. The consumers believed that HaptX still have the highest rating for adequate force feedback. An interesting notice was the engineers stated in interviews that they felt the BeBop gloves were uncomfortable on the fingertips and strap constraint movement, but the consumers rated them higher than VRgluv on comfortable and freedom to move fingers. The engineers noted that the HaptX gloves were tethered which accounted for the lower ratings of the gloves being light weight which is a concern for certain job/task training scenarios. VRgluv was noted to work well with virtual reality weapons which is noted for potential CUF trainings.

In the answering the question of which gloves serve the best purpose, it is interesting to see the difference between consumer and engineer. Engineers are more exposed to the inner workings of the gloves that many consumer/end users might not ever see. They spend a larger amount of time with the gloves that may have shaped their opinion and they were able to become familiar with the gloves which could cause it to feel natural. This affects the impression given by the gloves to the individuals but is viable data to know based on moving forward with haptic gloves in job/task trainings and research projects. The research showed that overall, consumers will still see the addition of haptics as an agreeable need and the current gloves are still worth exploring.

FUTURE RESEARCH

In the future, our research will look at comparing these gloves once more development or a new prototype is available. Research could also be expanded to examine other VR and haptic gloves, such as, SenseGlove, Dexmo, Ultraleap, Sensorial XR, and TELASUIT GLOVE. The research team also plan to collect data from soldiers and medical students to add to these findings of gloves for CUF and medical training. Furthermore, these gloves could be used in a comparison study looking at training different medical procedures or job task training.

REFERENCES

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APPENDIX

BeBop Questionnaire

Demographic Questions

- How many years of experience do you have with video games?
  - 0-3 3-7 7-10 10+
- How many years of experience do you have with virtual reality?
  - 0-3 3-7 7-10 10+
- Rate on a scale of 1-10 (1 being low and 10 being high), how would you rate your comfort level with technology in general.
  - 1 2 3 4 5 6 7 8 9 10
- Indicate the amount of times you have used Bebop gloves? (If more than 10, you can put 10+)
  - _____
- What other virtual reality gloves have you used and how many times? (If more than 10, you can put 10+)
  - _____

Questionnaire for BeBop

	Strongly Disagree	Disagree	Agree	Strongly Agree
I was comfortable with the BeBop gloves on my hands.				
My fingers had freedom to move while wearing the BeBop gloves.				
The BeBop gloves were manageable to use.				
The BeBop gloves were intuitive to use.				
The BeBop gloves fit well.				
The BeBop gloves had adequate force feedback.				
The BeBop gloves were light weight.				
The integration of the haptic BeBop glove functioned as intended.				
I would recommend Bebop gloves for a future haptics research project.				

Interview Questions for Bebop (Open-Ended)

- Are the BeBop gloves stable and what key technology challenges must be considered when fielding the product?
- How long does the BeBop glove charge last and how long does it take for them to fully charge?
- Are BeBop gloves tethered to the device or free roaming?
- What concerns do you have with BeBop gloves in terms of the physical space provided to work in? Is a larger space required? Or is physical space not a concern?
- How long does it take to calibrate BeBop gloves?
- Is it difficult to hold a weapon with the BeBop gloves? Pull a trigger?
- What type of tracking do the BeBop gloves use?
- How might BeBop gloves differ when used in VR vs AR or MR?
- In comparison to other Haptic gloves, how would describe the level of haptic feedback on the BeBop gloves?
- Do you believe that the cost of the BeBop gloves is worth it? (explain)

VRgluv Questionnaire

Demographic Questions

- How many years of experience do you have with video games?
  - 0-3 3-7 7-10 10+
- How many years of experience do you have with virtual reality?

- 0-3 3-7 7-10 10+

- Rate on a scale of 1-10 (1 being low and 10 being high), how would you rate your comfort level with technology in general.
  - 1 2 3 4 5 6 7 8 9 10
- Indicate the amount of times you have used VRgluv gloves? (If more than 10, you can put 10+)
  - _____
- What other virtual reality gloves have you used and how many times? (If more than 10, you can put 10+)
  - _____

Questionnaire for VRgluv

	Strongly Disagree	Disagree	Agree	Strongly Agree
I was comfortable with the VRgluv gloves on my hands.				
My fingers had freedom to move while wearing the VRgluv gloves.				
The VRgluv gloves were manageable to use.				
The VRgluv gloves were intuitive to use.				
The VRgluv gloves fit well.				
The VRgluv gloves had adequate force feedback.				
The VRgluv gloves were light weight.				
The integration of the haptic VRgluv glove functioned as intended.				
I would recommend VRgluv gloves for a future haptics research project.				

Interview Questions for VRgluv (Open-Ended)

- Are the VRgluv gloves stable, and what key technology challenges must be considered when fielding the product?
- How long does the VRgluv gloves charge last and how long does it take to fully charge them?
- Are the VRgluv gloves tethered to the device or free roaming?
- What concerns do you have with VRgluv gloves in terms of the physical space provided to work in? Is a larger space required? Or is a physical space not a concern?
- How long does it take to calibrate the VRgluv gloves?
- Is it difficult to hold a weapon with the VRgluv gloves?
- What type of tracking do the VRgluv gloves use?
- How might VRgluv gloves differ when used in VR vs AR or MR?
- Do you believe that the cost of the gloves is worth it? (explain)

HaptX Questionnaire

Demographic Questions

- How many years of experience do you have with video games?
  - 0-3 3-7 7-10 10+
- How many years of experience do you have with virtual reality?
  - 0-3 3-7 7-10 10+
- Rate on a scale of 1-10 (1 being low and 10 being high), how would you rate your comfort level with technology in general.
  - 1 2 3 4 5 6 7 8 9 10
- Indicate the amount of times you have used HaptX gloves? (If more than 10, you can put 10+)
  - _____
- What other virtual reality gloves have you used and how many times? (If more than 10, you can put 10+)
  - _____

Questionnaire for HaptX

	Strongly Disagree	Disagree	Agree	Strongly Agree
I was comfortable with the HaptX gloves on my hands.				
My fingers had freedom to move while wearing the HaptX gloves.				
The HaptX gloves were manageable to use.				
The HaptX gloves were intuitive to use.				
The HaptX gloves fit well.				
The HaptX gloves had adequate force feedback.				
The HaptX gloves were light weight.				
The integration of the haptic HaptX glove functioned as intended.				
I would recommend HaptX gloves for a future haptics research project.				

Interview Questions for VRgluv (Open-Ended)

- Are the HaptX gloves stable, and what key technology challenges must be considered when fielding the product?
- How long does the HaptX gloves charge last and how long does it take to fully charge them?
- Are the HaptX gloves tethered to the device or free roaming?
- What concerns do you have with HaptX gloves in terms of the physical space provided to work in? Is a larger space required? Or is a physical space not a concern?
- How long does it take to calibrate the HaptX gloves?
- Is it difficult to hold a weapon with the HaptX gloves?
- What type of tracking do the HaptX gloves use?
- How might HaptX gloves differ when used in VR vs AR or MR?
- Do you believe that the cost of the gloves is worth it? (explain)