Title

Noise Perception in Immersive Virtual Reality Enables Faster Stroke Diagnosis Time with Holoportation-Integrated Remote Evaluation

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Noise Perception in Immersive Virtual Reality Enables Faster Stroke Diagnosis Time with Holoportation-Integrated Remote Evaluation

A thesis submitted in partial satisfaction of the
requirements for the degree
Master of Science

in

Computer Science and Engineering

by

Zhuoqun Xu

Committee in charge:

Professor Nadir Weibel, Chair
Professor Henrik I. Christensen
Professor Jürgen P. Schulze

2021

The thesis of Zhuoqun Xu is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

University of California San Diego

2021

DEDICATION

For past turbulent years, to everyone who love me and whom I love,

I couldn’t have done it without your help.

Thank you to support me along the way!

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Chapter 3, in full, is one part of the scripts and original materials that has been used in the pilot study. My co-authors Hong-An Nguyen and Dr. Vishwajith Ramesh, together we built entire work-through of user case and scenario study. The thesis author was the primary investigator and author of this paper.

My research mentor from the medical field, Brett C. Meyer, MD. Department of Neurosciences, supports much insightful comment of user study and development.

ABSTRACT OF THE THESIS

Noise Perception in Immersive Virtual Reality Enables Faster Stroke Diagnosis Time with Holoportation-Integrated Remote Evaluation

by

Zhuoqun Xu

Master of Science in Computer Science and Engineering

University of California San Diego, 2021

Professor Nadir Weibel, Chair

Until now, most telemedicines were typically based on synchronous audiovisual communication, which limited the ability of medical experts to work with patients efficiently and effectively in physical tasks, such as stroke diagnosis. HoloSTRokE, or Holoportation-integrated Stroke Team Remote Evaluation, is the project designed primarily as an observational study of enhanced video techniques layered onto an already existing telemedicine for the acute stroke evaluation pathway. Patients will be provided the opportunity to have their image projected via Holoportation (like a hologram) to the consulting provider, and vice versa. This research introduces noise level optimization for holoportation to minimize the uncanny or strangely familiar feelings of eeriness

and revulsion in observers as patients. Hence, the setup time and the fidelity of the reprojected avatar resembling actual human beings are significantly reduced compared to previous research, which requires enormous effort in streaming high fidelity point cloud segmentation throughout the specific-configured network. The research expands the delivery of care for patients who are possibly experiencing a stroke with less mental demanding and higher success rate of diagnosis procedure.

Chapter 1

Introduction

The primary purpose of HoloSTRokE (Holoportation-integrated Stroke Team Remote Evaluation) is to assess the benefit of adding "Mixed Reality" techniques to the standard telemedicine evaluation workflow already in place between University of California San Diego (UCSD) Hub and El Centro Regional Medical Center (ECRMC) Spoke. This Mixed Reality will take the form of standard telemedicine audio and video connectivity with the addition of the application of Holoportation technology.

Holoportation takes advantage of cameras located at both the spoke and hub site, and a Mixed Reality visor that allows the user to see their true environment they are in, but also blends the visual environment from the distant site into their field of vision so they (or their surrogate) can feel the provider (and vice versa) are more immersed in their evaluation moments of care.

HoloSTRokE is a non-randomized, prospective, outcome un-blinded, hub-and-spoke, trial evaluating whether telemedicine consultations (in combination with Holoportation technique) can result in improved patient/ provider satisfaction, patient/ provider feeling of benefit, patient/ provider feeling of immersion. Utilization of Microsoft, Inc. HoloLens 1 or HoloLens 2 and Holoportation camera hardware and software (Microsoft Azure Sensor) and a customized encoder and decoder will allow this pilot experience to be undertaken.

Prior telemedicine trials have shown that some stroke treatments can increase the use of telemedicine [1]. A trial by Meyer et. al. assessing telemedicine decision-making efficacy has also shown, for the first time, efficacy for acute stroke related medical decision making with a low number needed to assess and high sensitivity, specificity and likelihood ratio.[2 3] The rationale for the proposed project centers on assessing enhanced video techniques, within the course of standard telemedicine evaluations for stroke, specifically for their effect on patient/provider perception of usefulness and satisfaction.

Telemedicine is being used more frequently than in the past.[4 5 6] Understanding whether telemedicine in concert with enhanced techniques to allow patients and providers to feel more immersed in the patient care experience (holoportation), will result in improved perception of care and even improved outcomes, would greatly improve our understanding of how to best implement telemedicine technologies into acute stroke care.

However, due to the nature of current immersive technology, the mixed reality visor will inevitably block the sight of view of both direction from doctor and the patients, where it can cause misinformation during the telemedicine visit and delay the actual diagnosis result. Thus there is a need to reconstruct the face with the head-mounted sensors, including eye tracking and facial tracking [26]. While many technologies and research try to reduce the uncanny effect by improving the fidelity and stability of live reconstruction [36], we reverse such procedure and introduce the manipulated noise into the rendering system. We hypothesize that telemedicine consultation in the holoportation with limited noise perception is effective for both patients and providers regarding qualitative outcomes of patient/provider satisfaction, patient/provider perception of immersion, and patient/provider perception of benefit.

Figure 1.1: 3D Reconstruction Avatar from Dr. Brett C. Meyer, MD

Figure 1.2: 3D Reconstruction Avatar with adding noise

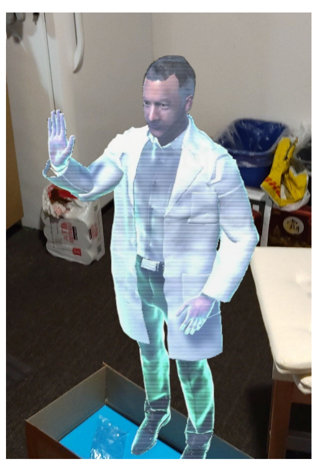


Figure 1.3: 3D Reconstruction Avatar with noise in Mixed Reality

Chapter 2

Background

2.1 Stroke Therapeutics

To date, recombinant tissue plasminogen activator (rt-PA) remains the only approved medical therapy for acute ischemic stroke.[7] If administered within 3 hours of symptom onset, this therapy is associated with a 30% greater likelihood of minimal or no disability at 3 months, with benefit sustained at 1 year as compared to placebo.[7 8] Data supports the possibility that this window could be extended to 4.5 hours, but the FDA has not approved use to any extended time window at this time.[9 10] However, rt-PA is utilized in less than 5% of acute stroke cases,[11 12] while stroke remains the 5th leading cause of death and the leading cause of disability in the United States.[13] rt-PA can be associated with hemorrhagic transformation, especially in the setting of deviations from the accepted NINDS protocol and guidelines.[7 11 12] In direct contrast, there is a significant risk of non-treatment, since one-third of patients excluded from treatment due to symptoms considered too mild or improving either die or are disabled at hospital discharge,[11 14] underscoring the inherent complexity of treatment assessments.

2.2 Telemedicine Efficacy

Telemedicine could potentially improve stroke care in rural settings, facilitate remote specialty consultations, increase numbers of treatments, enhance stroke education, and increase enrollment in stroke clinical trials.[4] Issues regarding reliability and decision- making efficacy have been addressed.[2] Approximately one-third of the U.S. population lives in rural areas.[15] Both rural and medically underserved urban areas may not have access to acute stroke expertise, and may therefore have therapies withheld or even incorrectly administered. Telemedicine solutions have been proposed to meet the needs of these health care shortage areas.[15 16] Research on reliability of the NIH Stroke Scale (NIHSS) has demonstrated viability and feasibility of remote assessment of stroke deficits.[17] Newer technologies have enabled web-based techniques [18 19] and site-independent, 2-way audio and video NIHSS assessments.[2 20 21] A retrospective assessment showed an increase in rt-PA treatments in the telemedicine group (23.8%) vs. the telephone group (3.8%) without treatment complications.[1] Recent deployments have enabled hundreds of patients to receive acute stroke consultations.[22 23] Large- scale, non-randomized reports from the and ARTEMIS and TEMPiS group have shown good long- term outcomes when combining telemedicine and stroke unit care.[24 25]

2.3 Telemedicine Evolution and Plateau

Telemedicine technologies technically began with the invention of the telephone and fax machine and their application in medical care. Clinicians have discussed cases over the phone and faxed medical records to each other for many years. A giant leap in technology occurred once the Internet enabled large amounts of data transmission quickly over the internet. The advent of wireless Internet allowed for site independent telemedicine, freeing up the provider to enable more rapid access to care.[21] Finally, numerous advancements in compression algorithms have enabled data compression and enhanced resolution over the years. Currently, it is reasonable to expect high definition video resolution and near 30 frames per second seamless video during a two way audio-video telemedicine consultation. Unfortunately, there has been a plateau in telemedicine advancements. Although ideas such as smartphone use for telemedicine have been posited, the screen size usually limits the utility of this technique. GoogleGlass techniques potentially have enabled providers to "see through the eyes" of an acute care responder. Three dimensional video capture and haptic technology to enhance the provider's understanding of the medical examination have not met with early successes. In all, these techniques still just result in the clinician looking at the patient "through a tube" and do nothing to enhance the qualitative experience of the patient or provider during the consultation. Telemedicine technology, other than resolution and framerate) has not substantively changed in the past 15 years. With holoportation, there is a potential that patients and providers can feel more immersed in the experience instead of just viewing the scenario "through a tube".

2.4 HoloLens and Holoportation

Microsoft HoloLens is a mixed reality visor developed by Microsoft in 2016. HoloLens 2, as the successor to the previous generation, is a head-mounted display with an adjustable, cushioned inner headband visor. This standalone device contains depth and motion sensors, multiple cameras and environment sense processors. Images are projected on lenses that are equipped with a light rendering engine and waveguide combiners allowing the user to see the virtual objects anchored in the space while keeping the spatial awareness of nearby. Binaural-directed audio speakers are included and do not obstruct external sounds, allowing the user to hear virtual sounds, along with the physical environment.

This technology is already being used for both non-medical and clinical applications unrelated to clinical trials. For medical purposes, HoloLens enables an real-time collaboration and telementorship of urgent remote surgery with enriched environment date [24] Also, CAE

VimedixAR is an ultrasound training simulator integrated with HoloLens that allows healthcare providers to interact with 3D holograms of internal human structures to improve their understanding of anatomy.[27] In April 2017, a team of surgeons in Spain, used the Mixed Reality tool to operate on a patient with a malignant muscular tumor, using the HoloSurg headset to visualize MRI and radiography information during the surgery.[28] Holoportation, a new type of 3D capture technology, allows high-quality 3D models of people to be reconstructed, compressed and transmitted anywhere in the world in real time. When combined with mixed reality displays such as Hololens, this technology allows users to see, hear, and interact with remote participants in 3D as if they are actually present in the same physical space. Communicating and interacting with remote users becomes as natural as face-to-face communication.[29]

2.5 Importance and Rationale for Specific Aims

With the exponential increase in the amount of telemedicine in daily practice, there remains a widening gap in the literature regarding a.) Determining qualitative perception of how integrated the patient and provider are in their care model and b.) Continuing to assess telemedicine outcomes for stroke patients. It is clear that stroke telemedicine experts can reliably and appropriately assess and make treatment decisions for stroke patients in the acute setting. However, the qualitative reality of telemedicine has been the same for many years. Without the ability to immerse yourself in the care of a patient, there is concern that medical care has been defaulted to cold, uncaring, observational, disconnected episodes instead of truly interactive and immersive involvement. As such that the telemedicine becomes more pervasive in medical care, it is of critical importance to find better ways to emote with, communicate with, and interface with patients, healthcare surrogates, and healthcare providers. While the Holoportation can be applied onto the telemedicine, the situation when the doctors and the patients both wearing the headset leads to some confusion on the communication and interaction.

Figure 2.1: Missing eye component can cause confusion for communication

Although stroke specialists can be trained to identify the patient status with certain amount of learning, patients can only have limited knowledge and short amount of time to understand the doctor instruction through the tunnel. There remains a need for new approaches to extending the ability of telemedicine specialists to present themself naturally and treat more acute stroke patients with holoportation. This design focuses on qualitative outcomes related to patient/ provider feelings of satisfaction, patient/ provider feelings of effectiveness, patient/ provider perception of immersion, and patient/ provider perception of benefit. These qualitative factors are integral to advancing the utilization of telemedicine in the field of stroke and in telemedicine overall. It is also of significant importance to assess continued quantitative outcome measures of reliability and patient benefit as well. The worst possible telemedicine future would be one in which telemedicine is indiscriminately used in a cold, uncaring, observational, and disconnected manner, without ensuring that patient and provider qualitative outcomes of perceived benefit are not taken into consideration.

2.6 STRokE-Telemedicine

The UCSD Stroke Center has been performing acute telestroke evaluations since 2001. Originally, these consults were performed as part of the NIH funded STRokE DOC clinical trial.

Results were positive and are listed above. Unrelated to telemedicine research, and directly for standard patient care, the UCSD Stroke Center has provided acute telestroke consultation services to 5 remote hospitals (ED and Inpatient setting) since 2013. One of these 5 sites is ECRMC which will be the location of patients for this study as well. To date, we have provided acute consultations to > 2,000 acute stroke code patients via standard contract with these centers. These processes are the same processes that will be followed for the standard telestroke component of the presented clinical study.

The procedure is current standard of care for these hospitals for obtaining acute stroke evaluations, and is unrelated to any clinical research study.

Chapter 3

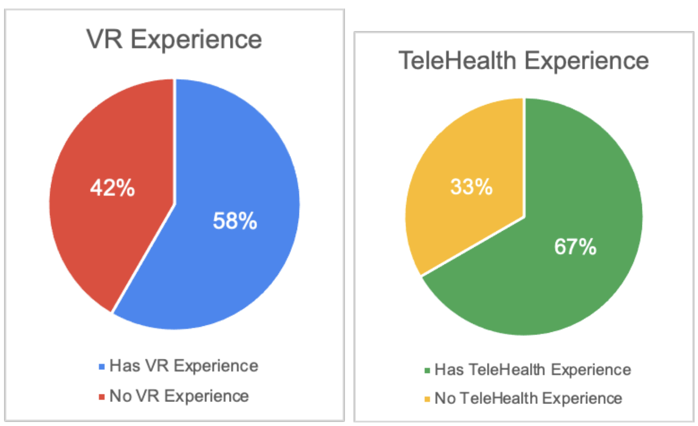
Design and Method

3.1 General Design and Resources

The overall goals are to assess enhanced telemedicine visualization techniques (through noise holoportation techniques) in order to improve quality of care, satisfaction, perception of immersion, perception of benefit, and patient outcomes. We seek to perform a non-randomized, controlled trial focusing on predominantly qualitative outcomes related to telemedicine consultations. There is a critical need for the HoloSTRokE trial because telemedicine technologies are being implemented exponentially across the U.S., while the quality of telemedicine has been the same for many years. Without the ability to immerse yourself in the care of a patient, there is concern that medical care has been defaulted to cold, uncaring, observational, disconnected episodes instead of truly interactive and immersive involvement. As telemedicine becomes more pervasive in medical care, it is of critical importance to find better ways to emote with, communicate with, and interface with patients, healthcare surrogates, and healthcare providers. The overarching purpose of telemedicine is to afford more patients the access to quality care that perhaps they would not otherwise have access to without telemedicine. However, telemedicine is now even being deployed in areas where availability of bedside expertise might be possible, just not but deploying telemedicine may be easier. This reality may result in patients feeling even less immersed in their own patient care moment than before the advent of telemedicine. Access to care is important, but the access to excellent quality care is just important. HoloSTRokE is designed to enhance qualitative aspects of telestroke care.

3.2 Experimental Procedures

There are a total of 12 participants enrolled into the experiment of this user study trial assessing immersive satisfaction, task successful rate and negative impact. For the background information shown in Fig 3.1, 7 participants have VR experience, 5 do not has it and 8 participants have telemedicine experience, the other 4 do not.



(a) (b)

Figure 3.1: Participant Background

This portion of the study is a run in assessment of 12 students as patients to enable optimization of workflow and modification of survey questions if needed. During experiment, 3 different avatar will be showing in different order for each user (Fig 3.2):

1. **Cartoon Avatar:** the most unrealistic avatar that is generated
2. **Realistic Avatar with 0% Noise:** the avatar that modeled and textured based actual doctor without introducing noise

3. **Realistic Avatar with x% Noise:** the realistic avatar that been introduced noise rendering system

(a) (b) (c)

(d) (e) (f)

Figure 3.2: Different avatars for testing

3.2.1 Roles

- Facilitator: This person will give the user instructions for tasks and surveys and take additional notes.

- Tech: This person will change the avatars throughout the study using the order on the spreadsheet
- Actor: This person will voice the various avatars using a script.

3.2.2 Pre-Task Questions

1. The goal of this study is to evaluate and compare the use of mixed reality in telemedicine visits using Holoportation, a mixed reality system.
2. Before we get started, have you ever had a telehealth visit?
3. If yes, approximately when? How many / how often?
4. What are your thoughts on telehealth?
5. Do you have any experience with virtual reality or augmented reality?
6. If yes, what experience?

3.2.3 Between-section Survey

1. How mentally demanding was the task?

   Not Mentally Demanding (1-5) Very Mentally Demanding
2. How physically demanding was the task?

   Not Physically Demanding (1-5) Very Physically Demanding
3. How hurried or rushed was the pace of the task?

   Not Rushed (1-5) Very Rushed
4. How successful were you in accomplishing what you were asked to do?

   Not Successful (1-5) Very Successful

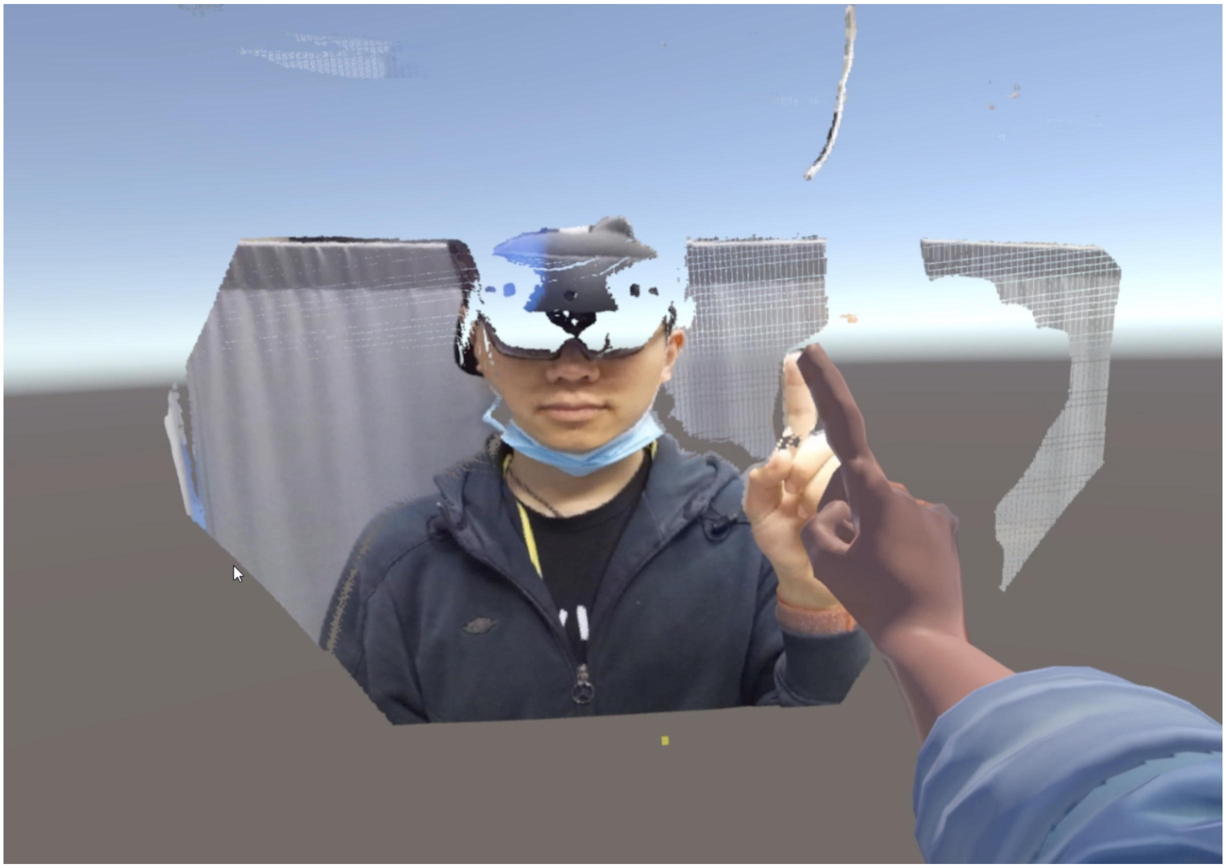


Figure 3.3: Doctor seeing the Patients

5. How hard did you have to work to accomplish your level of performance?

   Not Hard (1-5) Very Hard

6. How insecure, discouraged, irritated, stressed, or annoyed were you?

   None (1-5) Very

7. How comfortable did you feel during the telemedicine portion of this evaluation?

   Not Comfortable (1-5) Very Comfortable

8. How much were you able to feel the caring nature of your telemedicine care provider?

   Not Caring (1-5) Very Caring

9. How immersed did you feel that both you and your care provider were in the evaluation?

Not Immersed (1-5) Very Immersed

10. How beneficial do you feel the additional immersion technique was for your care?

    Not Beneficial (1-5) Very Beneficial

3.2.4 Post-Task Questions

1. Please rank the three visits in order in which you felt most comfortable to least comfortable. Each visit should have a different response.

2. Please rank the three visits in order from most immersive to least immersive. Each visit should have a different response.

3. On a scale of 1-5, how much did you enjoy this augmented reality way of providing your care?

3.2.5 User Testing

Tech: Use the order on the spreadsheet for participants attending random experiments. Change avatars while the user is doing a survey.

Facilitator: In this study, you are a patient who is experiencing possible symptoms of a stroke and consulting a doctor in a telemedicine visit. You will be wearing a headset that will allow you to see your doctor virtually. Similarly, your doctor will wear a headset and see a visual of you. You will interact with your doctor three different times and perform a series of exercises each time. After each series of exercises, you will be asked to complete a brief survey. You will also be asked to complete a final survey at the end. Do you have any questions before we begin?

Actor: Avatar 1 - Cartoon

- Hi, how are you doing today?

- My name is Dr. Meyer. I am a physician located at this hospital but I'm also located remotely. Your local doctor has contacted me and asked me to evaluate you for the possibility of you having a stroke. What your doctor tells me is that you started having symptoms of weakness on one side of your body. I'm going to ask you to do a few things.
- Can you first show me your teeth?
- Next, please hold your arms out in front of you with your palms facing the ceiling. Okay now put your arms down.
- Lastly, follow my finger using your finger to touch it.
- I've just looked at your x-rays and both your CT scan and MRI scan look normal. I don't see any evidence of stroke on the scans, so I don't think we need to do any further evaluation at this time. Thank you for allowing me the opportunity to examine you.

Facilitator: This concludes the first visit. I will now ask you to do a survey regarding this visit only.

Mini survey

Actor: Avatar 2 - Realistic with 0% Noise

- Hi, how are you doing today?
- My name is Dr. Meyer. I am a physician located at this hospital but I'm also located remotely. Your local doctor has contacted me and asked me to evaluate you for the possibility of you having a stroke. What your doctor tells me is that you started having symptoms of weakness on one side of your body. I'm going to ask you to do a few things.
- First, can you squeeze your eyes shut?
- Now, can you repeat after me?

- -Thanks
- -Huckleberry
- -Baseball player
- Lastly, follow my finger using your finger to touch it.
- I've just looked at your x-rays and both your CT scan and MRI scan look normal. I don't see any evidence of stroke on the scans, so I don't think we need to do any further evaluation at this time. Thank you for allowing me the opportunity to examine you.

Facilitator: This concludes the second visit. I will now ask you to do a survey regarding this visit only.

Mini survey

Actor: Avatar 3 - Realistic with X% Noise

- Hi, how are you doing today?
- My name is Dr. Meyer. I am a physician located at this hospital but I'm also located remotely. Your local doctor has contacted me and asked me to evaluate you for the possibility of you having a stroke. What your doctor tells me is that you started having symptoms of weakness on one side of your body. I'm going to ask you to do a few things.
- First, can you raise your eyebrows?
- Next, can you look at my finger and look all the way to the left. Now, look all the way to the right.
- Lastly, follow my finger using your finger to touch it.

- I've just looked at your x-rays and both your CT scan and MRI scan look normal. I don't see any evidence of stroke on the scans, so I don't think we need to do any further evaluation at this time. Thank you for allowing me the opportunity to examine you.

Facilitator: This concludes the last visit. I will now ask you to do a survey regarding this visit only.

Mini survey

End of Experiment

Facilitator: I will now ask you to do a survey regarding all three visits.

Final survey

Chapter 3, in full, is one part of the scripts and original materials that has been used in the pilot study. My co-authors Hong-An Nguyen and Dr. Vishwajith Ramesh, together we built entire work-through of user case and scenario study. The thesis author was the primary investigator and author of this paper.

Chapter 4

Results

An enhanced telemedicine consultation with noise resulted in the participant feeling more successful in doing the task they got assigned, more than 58% or 7 out 12 of the participants gave the rate of most success (first row of Fig 4.1). A large portion of neutral answer has provided toward the survey question about the caring nature of the experiment (fourth row of Fig 4.1). We believe it is due to the inexperience on telemedicine since most of our participants are in young age. In third row of Fig 4.1 about the survey of the immersive level, more than 66% or 8 out 12 of participants think it is more immersive. Also, more than 58% or or 7 out 12 of the participants indicated that they could understand the diagnosis instruction from the realistic avatar with noise.

Compared to participants who have had telehealth or telemedicine experience, 3 out of 4 participants (Fig 4.2) who had no telehealth experience felt most comfortable interacting with the avatar with noise. We also discovered that, in negative questions, the participants generally have an average score on each question. But once again, the realistic avatar with some noise had less negative comments compared to the one without noise. In Fig 4.3 we notice that the avatar with noise gets the highest immersion level. (Note that: We are assessing all these potential qualitative and quantitative outcomes in this study.)

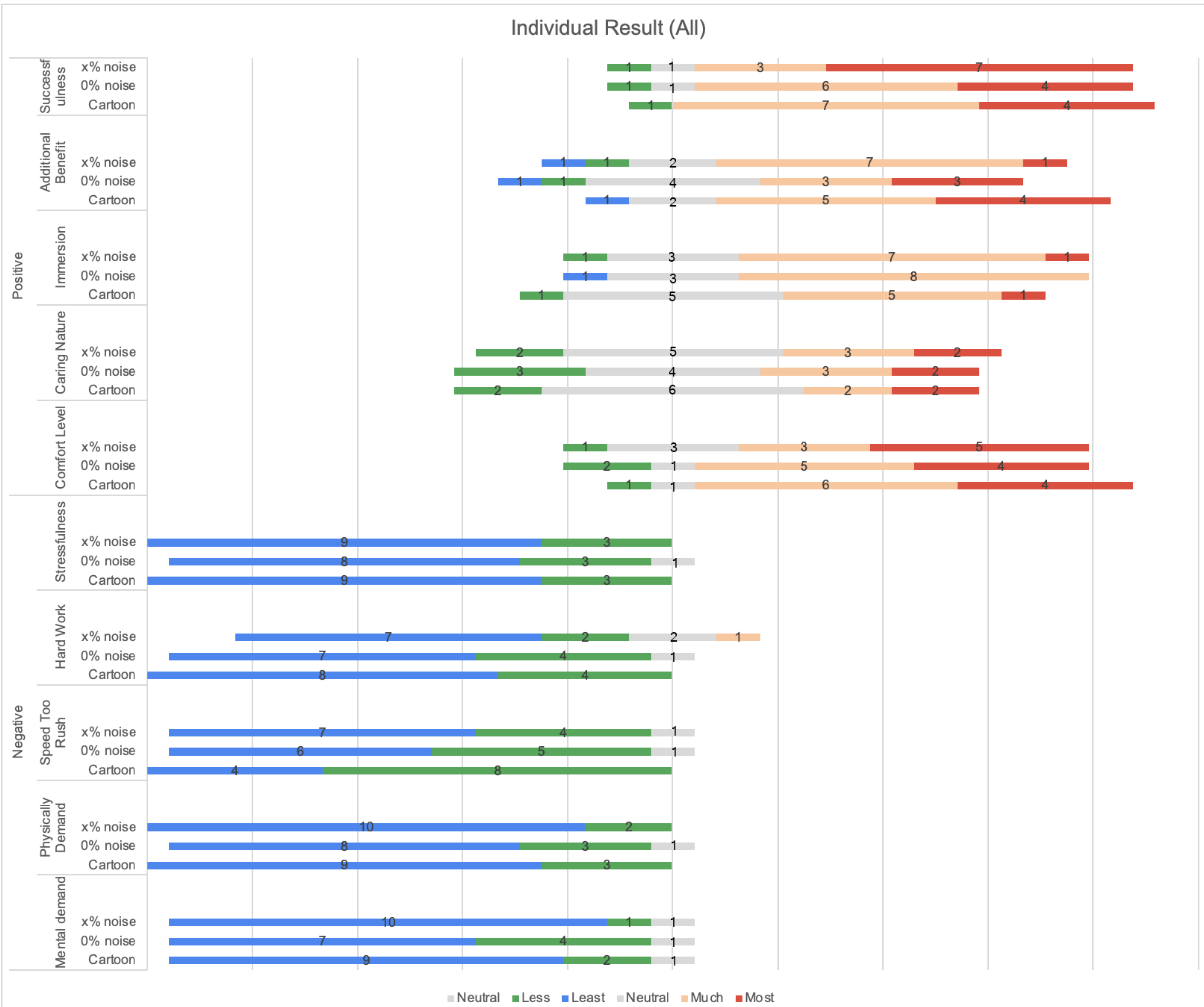


Figure 4.1: Individual survey results from participants

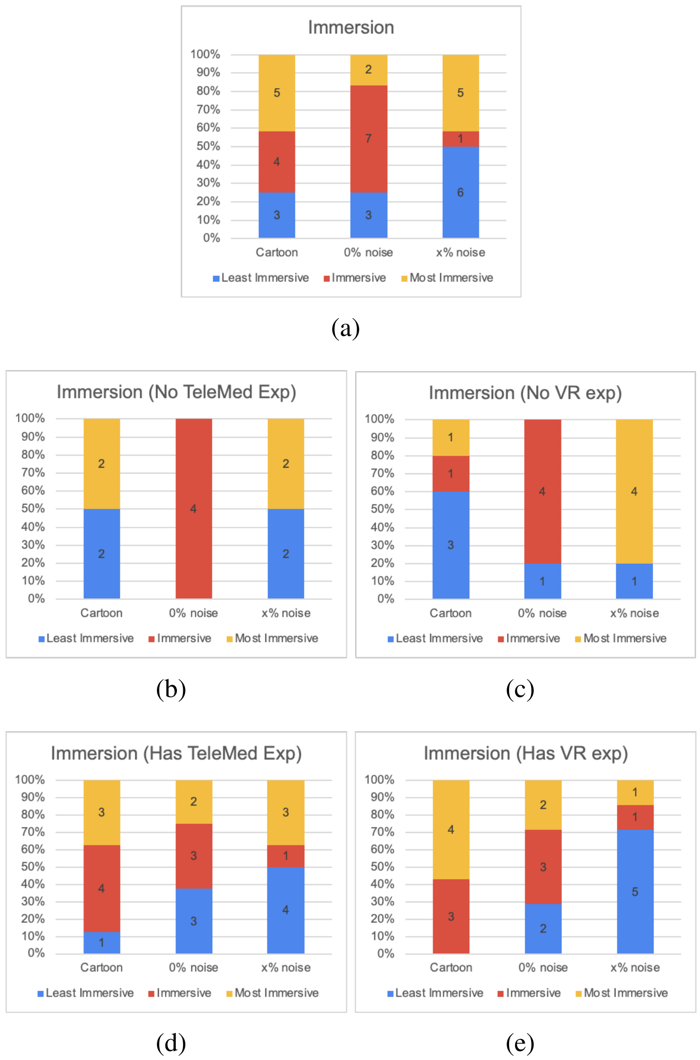
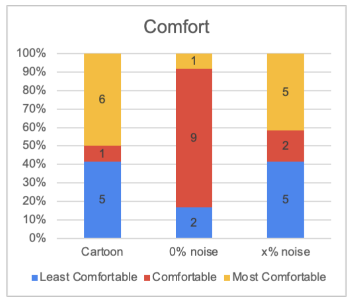
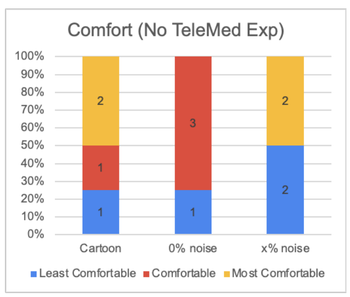


Figure 4.2: Participant sense of immersion with different avatars



(a)



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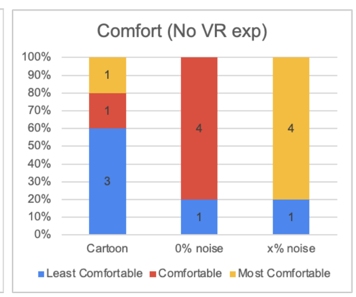

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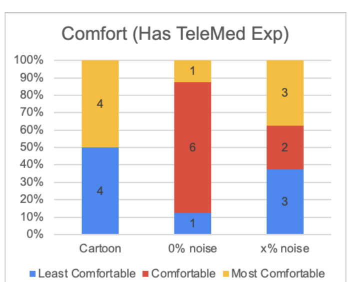

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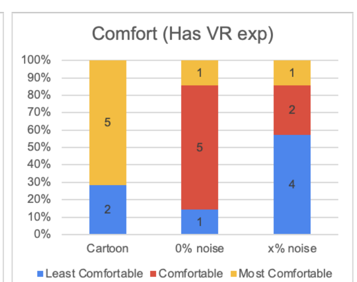

(e)

Figure 4.3: Participant comfort with different avatars

Chapter 5

Discussion

From Fig 4.2 and Fig 4.3, since different participants are seeing random orders of avatars to account for learning, we can see the result is quite diverse in the total sum for both survey on immersion and comfort level. But when applying the condition of previous VR experience in Fig 4.2(c), we found that the participant with previous VR experience most prefer the cartoon character, same result can be found from Fig 4.3(c). In contrast of Fig 4.2(e) and Fig 4.3(e), the realistic avatar with noise is the favorite among participants without any VR experience. Note that both comfort level and immersion have the same patterns. We hypothesize that the participants with VR experience may already be familiar with cartoon avatars (which are quite commonly used) and therefore prefer Avatar 1, whereas participants without prior experience prefer the more realistic looking character. At the same time, the noise reduces the eerie feelings (uncanny effect) towards the realistic avatar (Fig 4.2(a) and Fig 4.2(b)).

Another note is about the condition of Telemedicine or Telehealth experience - most of our participants are younger group around 20s, lack of experience leads the divergent result. We believe further study on the actual stroke patients will produce significant results that show higher trend of preference with above conditions, since most stroke patient will be lack of virtual reality experience and have more telemedicine experience.

5.0.1 Study Limitations

Telemedicine consultations are reliable and have been shown to result in a high degree of accurate decision making for clinical treatment decisions. As such, the telemedicine consultations themselves are unlikely to increase risk for the patients. However, these risks are wholly and completely unrelated to this HoloSTRokE study, as 100% of participant included in this pilot study are young health student that has minimum risk of health-related issue.

The 3 potential risks associated with this study include 1) potential discomfort from putting on the HoloLens visor, 2) potential violations of HIPAA privacy, and 3) potential loss of confidentiality through data collection.

- **Discomfort:** The telemedicine consent or clinical examination will be stopped at any time, upon patient request. All measures will be taken to ensure that the participants are comfortable, and no standard of care treatments will be delayed in any way during any of these assessments. If there is any discomfort when wearing the HoloLens visor, the patient can remove the visor and see the consulting provider via standard video camera (standard telemedicine) or even via alternative solution of tablet/ iPad at bedside which can mimic the perception of the patient and provider being in the same room.

- **Privacy:** For all telemedicine evaluations, there is a concern for potential loss of privacy for patients. As is part of our standard telestroke practices, and unrelated to this clinical study, the patients that are evaluated in our standard UCSD-ECRMC telestroke partnership are located in a designated room in the ED with all reasonable efforts made to provide as private a venue as possible to discuss their medical conditions. There is no additional difference as inherent in this HoloSTRokE study. Similarly, as is part of our standard telestroke practices, and unrelated to this clinical study, the patients that are evaluated in our standard UCSD-ECRMC telestroke partnership have their audio and video images transmitted from point to point via the Internet using an encrypted and HIPAA compliant telemedicine video conferencing technology. The telemedicine systems use data encryption and are HIPAA compliant. The enhanced video signal collected and transmitted also, and therefore, satisfies this encryption requirement.

- **Confidentiality:** Confidentiality will be maintained for all participants for further research. The Redcap database will be used to collect patient data except from this pilot study. This database will be encrypted. Users will be given a password and access only to the projects in which they will be directly involved. All data storage procedures will be HIPAA compliant. No Personal Health Information (PHI) will be collected in the redcap project "HoloSTRokE". Study identifiers only will be designated.

5.0.2 Future Work

Our upcoming plan is to work with Fellow and Faculty from Hillcrest and Jacobs Medical Center in collaboration with UCSD Stroke Center and start to implement into the actual study of stroke patients. We will both perform an NIHSS exam (guided by the fellow using standard telemedicine and scored by the fellow using standard telemedicine and by the faculty using holoportation technique) and record their element scores. We will statistically compare the two results. In this way, without affecting clinical care, and without delaying any medical decision-making, we will compare the Kappa reliability of the NIHSS done via holoportation to the NIHSS done via standard telemedicine.

One key difference to note is that the stroke patients from the actual medical environment are mostly sick and older compared to the student participants in this study. So the comfort level and the immersion may be varied from the results from the young participant.

Chapter 6

Conclusion

Stroke is the leading cause of disability and the 5th leading cause of death in the United States. There may be no benefit to the individual patients from participation in this protocol, and this will be stated. However, our research indicates introducing hologram telementoring with noise rendering has potential to increase the overall performance of stroke disease diagnosis procedure. Patients' sensory systems can identify the doctor's intention while the doctor can adapt the patients' emotion at a reasonable rate which also supports multi-session diagnosis without overwhelming the 2D data interface.

In addition, we showed that applying the realistic avatar with intentional noise can increase immersiveness and comfort level of mixed reality interaction among the participants without virtual reality experience. Moreover, the participants feel more successful to complete the tasks in mixed environment that instructed by humanoid avatar with noise rendering. The results show that the elaborated noise bridges the gap of the uncanny valley effect toward the avatars that imperfectly resemble actual human beings. It redirects user's attention toward the artifacts and alleviates the eerie feelings by distracting user from strangely familiar resemblances. We believe introducing the noise rendering techniques helps the target users with minimum VR experience, especially the stroke patients, to resemble the cognitive process toward the humanoid objects with previous experience and assumption of the display technology.

Chapter 7

Supplementary Materials

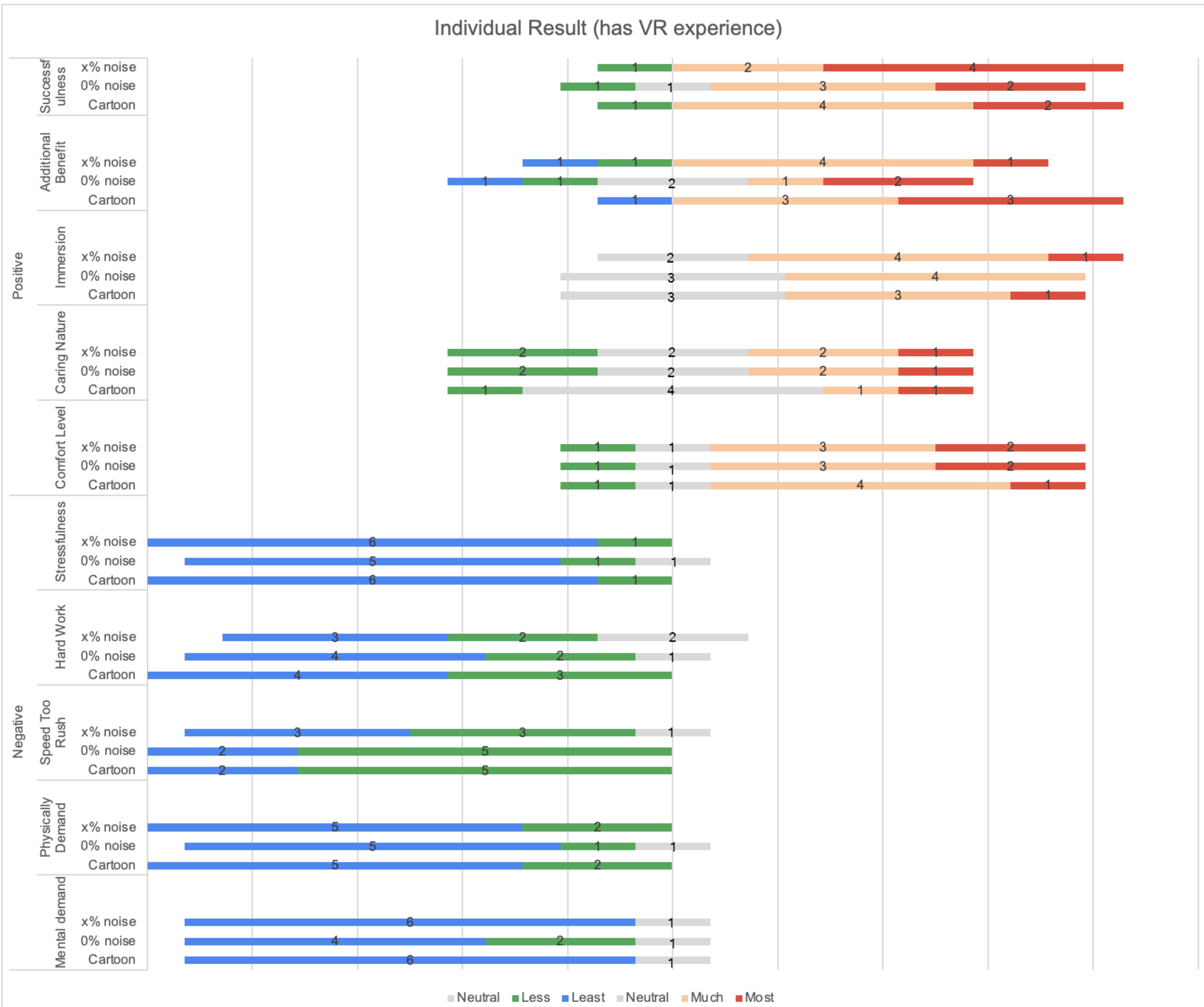

Figure 7.1: Individual survey results from participants with prior VR experience

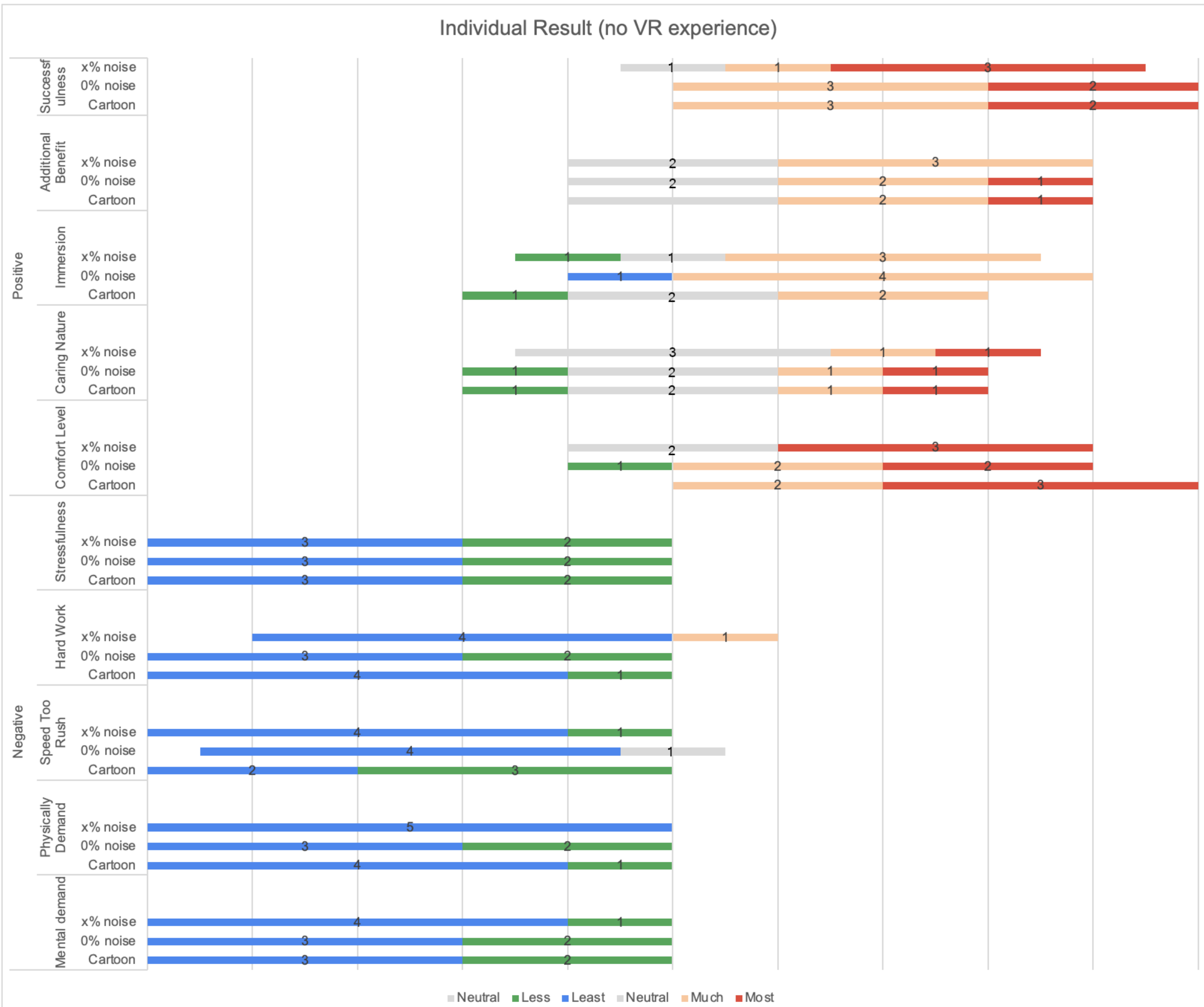

Figure 7.2: Individual survey results from participants without prior VR experience

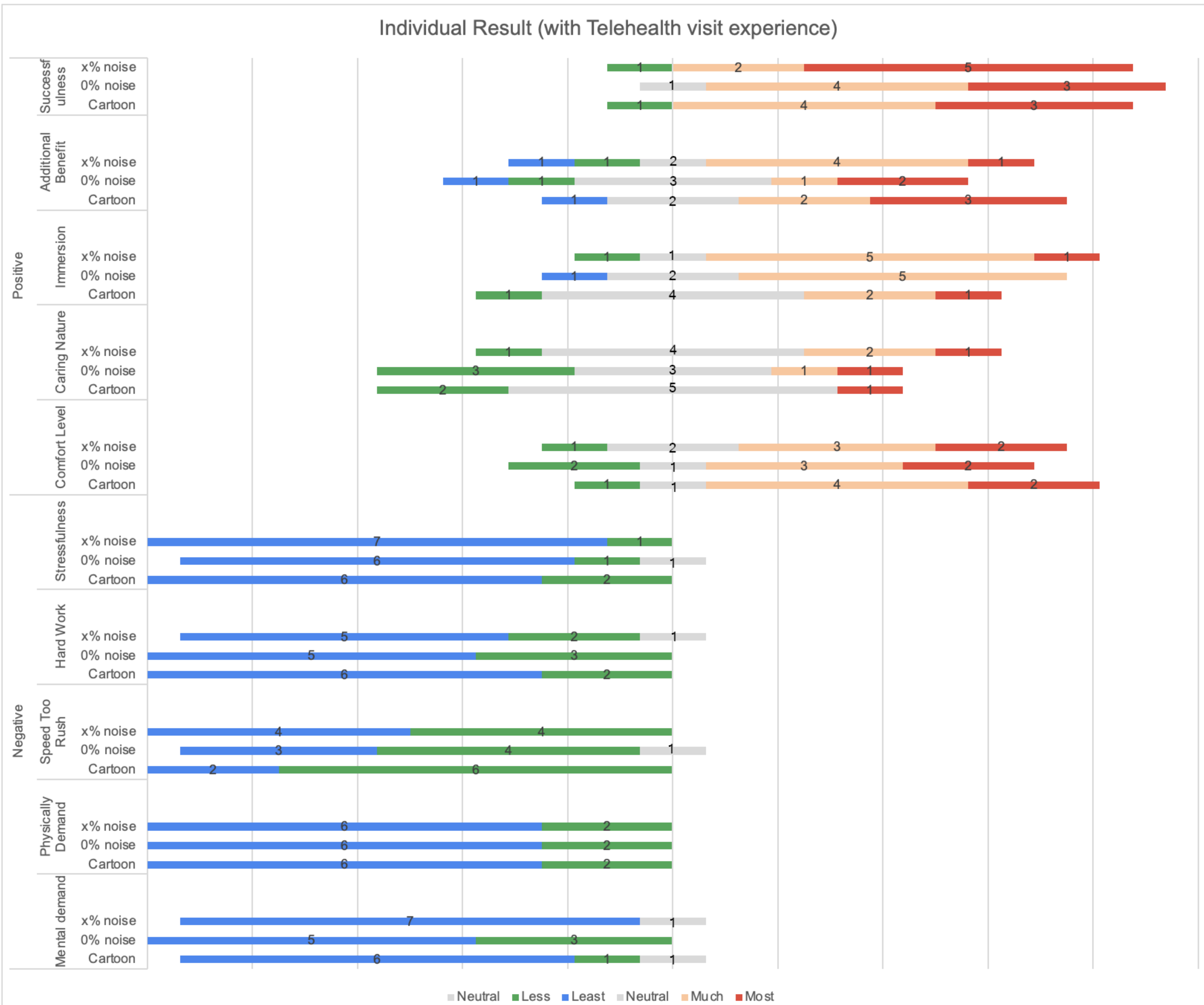

Figure 7.3: Individual survey results from participants with prior telemedicine experience

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