Data Analytics for Immersive Environments

Investigating the Impact of Therapeutic Interventions on Autistic Traits Using the Autism Spectrum Quotient (AQ)

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Learning Outcomes

To practice the following:

- Formulation of an experiment hypothesis.
- Application of appropriate statistical tests.
- Descriptive and inferential analysis of data.
- Generation of descriptive statistics.
- Report generation in R Markdown and R Notebook.
- Use of R language and R Studio.

Introduction: A Spectrum of Neurodiversity

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by a wide range of social, communication, and behavioral differences. Rather than a singular disorder, autism is understood as a spectrum, meaning that its characteristics manifest differently from person to person, with varying degrees of severity and presentation. This

diversity reflects the concept of neurodiversity, acknowledging that the autistic brain is simply wired differently, not deficient.

Key Diagnostic Domains

The diagnostic criteria for autism, as outlined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), are centered on two core domains:

- Persistent deficits in social communication and social interaction: This includes challenges with reciprocal conversation, nonverbal communication (such as interpreting facial expressions and body language), and developing and maintaining relationships.

- Restricted, repetitive patterns of behavior, interests, or activities: This can involve repetitive motor movements, a strong insistence on sameness and routines, highly focused or intense interests, and unusual reactions to sensory input.

The Importance of Multi-Dimensional Assessment

Given the multi-dimensional nature of autism, assessing its characteristics requires tools that go beyond a single score. Scales such as the Autism Spectrum Quotient (AQ) are designed to capture this complexity by measuring autistic traits across multiple subscales. This allows for a more nuanced understanding of an individual's unique profile of strengths and challenges, which is crucial for developing personalized and effective therapeutic interventions.

While traditional therapeutic approaches have long been the foundation for supporting individuals with autism, they often come with significant limitations. Behavioral and developmental therapies, such as Applied Behavior Analysis (ABA), are evidence-based and widely used. However, their structured and intensive nature can be resource-intensive, and their past emphasis on "normalizing" behavior has drawn criticism from the neurodiversity movement. Similarly, pharmacotherapy is used not for the core symptoms but to manage co-occurring conditions like anxiety or irritability, and it can introduce undesirable side effects that impact treatment adherence. As a result, there's a growing need for innovative, complementary, and more person-centered interventions that leverage technology and alternative methods to improve the quality of life for autistic individuals.

Virtual Reality (VR) therapy has emerged as a promising tool for individuals on the autism spectrum, offering immersive experiences that can facilitate skill development in a safe, controlled environment. By creating simulated real-world scenarios, VR provides a space where individuals can practice social interactions, manage sensory sensitivities, and confront challenges like navigating public spaces without real-world pressure. This project aims to evaluate the efficacy of VR-based interventions in the treatment of autism, focusing on their potential to improve social competence, enhance communication strategies, and foster a sense of independence and confidence among participants.
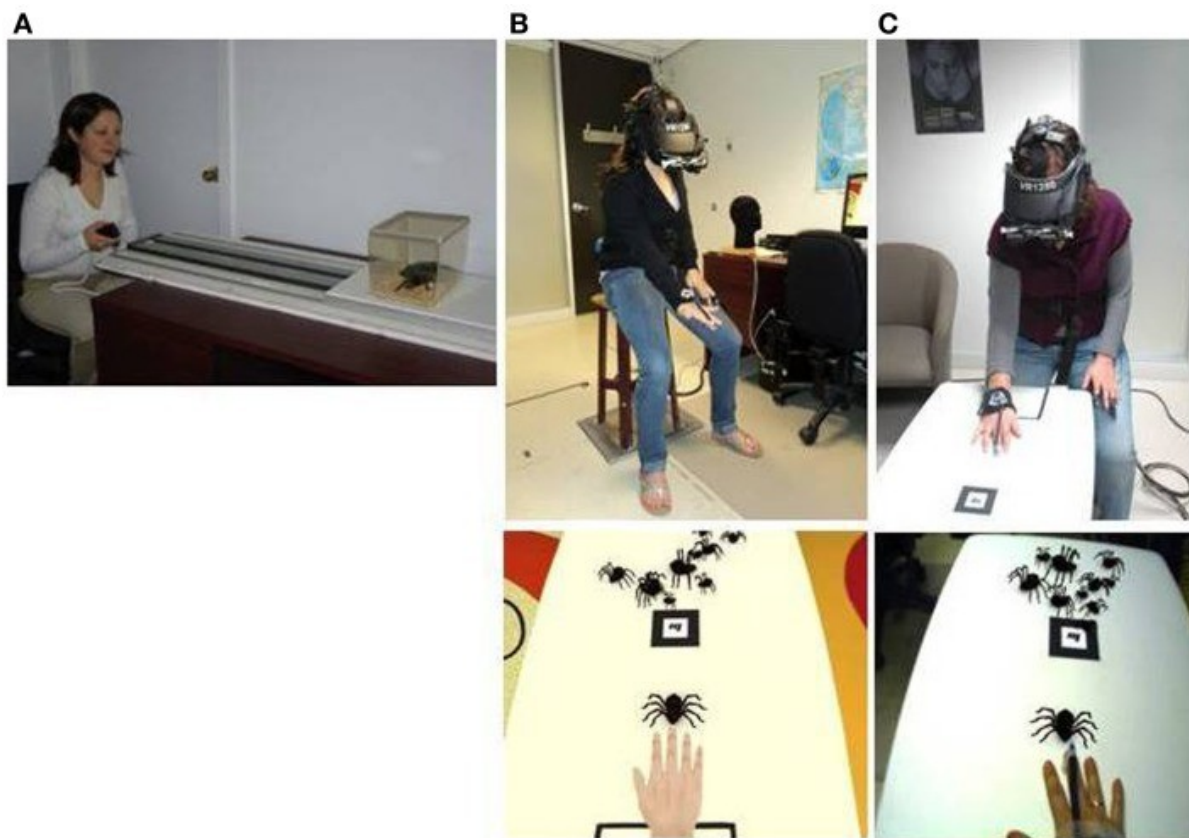
Different Types of CBT Methods

Under the umbrella of Cognitive Behavioral Therapy (CBT), several non-pharmacological approaches are commonly used to support individuals on the autism spectrum. These methods focus on helping individuals manage and reframe challenges related to social interactions, emotional regulation, and repetitive behaviors. Here are some of the well-known non-pharmacological approaches within the CBT framework:

- **Social Skills Training:** This is a structured approach that teaches specific social behaviors and communication skills. It often uses role-playing, video modeling, and group activities to help individuals understand social cues, initiate conversations, and build relationships.

- **Emotional Regulation Training:** This helps individuals identify and understand their emotions, particularly those that can lead to meltdowns or anxiety. Techniques include using visual aids, social stories, and mindfulness exercises to develop coping strategies and self-regulation.

- **Exposure Therapy:** While often associated with anxiety disorders, exposure therapy can be adapted to help autistic individuals gradually confront situations or stimuli that cause them sensory distress or anxiety. This is done in a controlled and supportive environment to reduce sensitivity and increase tolerance.

- **Mindfulness-Based Interventions:** These approaches teach individuals to focus on the present moment and observe their thoughts and feelings without judgment. They can be particularly effective in helping with stress reduction and managing sensory overload.

- **Parent and Caregiver Training:** This is a crucial component that equips parents and caregivers with the tools to support the individual's learning and generalize skills learned in therapy to different settings, such as home and school.

There are several methods for assessing autistic traits, including structured interviews and self-report questionnaires. In this experiment, the severity of autistic traits was assessed using self-report mechanisms. The **Autism Spectrum Quotient (AQ)** was employed, which has the following characteristics:

- **Self-Report Mechanism:** The AQ is a 50-item questionnaire designed to be completed by the individual being assessed.

- **Dimensional Approach:** It provides a dimensional score, meaning it measures the degree of autistic traits rather than simply providing a "yes/no" diagnosis.

- **Five Subscales:** The questionnaire assesses traits across five key domains: social skills, communication, imagination, attention to detail, and attention switching. This allows for a nuanced understanding of an individual's unique profile of strengths and challenges.

- **Scoring:** A higher score on the AQ indicates a greater number of autistic traits. The score can be used to track changes over time and to compare the effectiveness of different interventions.

Scoring and Interpretation of the Autism Spectrum Quotient (AQ)

The Autism Spectrum Quotient (AQ) is a 50-item self-report questionnaire with a total score ranging from 0 to 50.1 A higher score indicates a greater number of autistic traits.2 The original scoring system gives one point for each answer that aligns with an autistic trait, regardless of the strength of agreement ("slightly agree" or "definitely agree").3

While it is a screening tool and not a diagnostic instrument, a total score of 26 or higher is often used as a threshold to suggest the presence of clinically significant autistic traits. Research indicates that the majority of individuals with an official autism diagnosis score 32 or above. In contrast, the average score for neurotypical males is around 17, and for neurotypical females, it is about 15.6 It is also important to note that, on average, males tend to score slightly higher than females in the general population.

Research Objective

The primary objective is to determine if a structured intervention program using either traditional CBT or VR-based therapy can lead to a significant change in **Autism Spectrum Quotient (AQ)** scores over a 12-week period. The study will also compare the outcomes of both intervention groups against a control group to identify which, if either, therapy modality is more effective.

Methodology

Participants will be randomly assigned to one of three groups:

1. **CBT Group:** Participants will receive weekly sessions focused on emotional regulation, social skills, and managing anxiety.

2. **VR Therapy Group:** Participants will engage in VR simulations designed to practice social interactions in a safe, controlled environment.

3. **Control Group:** Participants will not receive either intervention during the study period.

All participants will complete the **50-item Autism Spectrum Quotient (AQ)** at the beginning of the study (pre-treatment) and at the end of the 12-week period (post-treatment). The change in scores will be analyzed using statistical tests, such as paired t-tests and ANOVA, to compare the effectiveness of the interventions.

Experiment Details

Data from a study are presented that investigated the effect of VR exposure therapy, conducted in a virtual reality environment, on patients undergoing treatment for autism.

The study consisted of 300 patients (M=150, F=150) in total, divided into the groups listed below. The participants were randomly sampled from the clinic client list and randomly assigned to one of three groups below:

- CBT Group (M=53, F=47)
- Experimental (VR-based therapy) (M=48, F=52)
- Control (no CBT, no VR) (M=59, F=41)

All patients were adults in the age range of 12 - 40 years. Information on the exact age of participants was not recorded. Gender information was recorded. All groups were of equal size. The three groups underwent 12 weeks of treatment for 50 minutes per week with a therapist. During that time the patients either underwent traditional CBT, used the VR app, or none of

these. AQ measurements for all groups were measured using the self-report mechanism outlined above. Measurements were taken at the start and end of the study.

Requirements

The data gathered will be made available to each student via Moodle. Each group will receive a different subset of the results from the study participants. As part of this assignment, you are required to perform statistical analysis on these data. This will involve the completion of the following steps:

1. Determine whether the data provided are appropriate for the test(s) available and whether any data cleaning is required.
2. Formulate **three** hypothesis tests to be used to compare the effectiveness of the approaches used during the experiment.
3. Determine if the data meet the assumptions required by any statistical test.
4. Provide descriptive statistics (graphs and tables) for any assumptions made.
5. Analyze the data to provide the hypothesis testing conclusion.
6. Determine the 95% confidence interval for the population mean of a **single** group.

Lab Report Structure

These steps will result in the generation of a single R Notebook file containing the R source code. This R Notebook file must be configured to generate an HTML document **(1200 words excluding plots or tables with a minimum of 5 plots/tables allowed)**.

The R Notebook **must** have the following structure:

1. Title (including participant full names)
2. Table of Contents
3. Abstract **(2.5 marks)**
   - Aim and rationale
   - Participants and setting
   - Experiment design
   - Results gathering
   - Findings/implications
4. Introduction **(15 marks)**
   - Topic and context
   - ~~Theoretical framework~~
   - ~~Summary of previous work~~
   - Rationale
   - Hypothesis
5. Method **(20 marks)**
   - Participants
   - Design
   - Materials

- Procedure
6. Results **(40 marks)**
   - Descriptive statistics
   - Inferential statistics
   - Statistical tests
   - Magnitude and direction of results
7. Discussion **(10 marks)**
   - Outline findings and relation to the hypothesis
   - ~~Compare results to background work reported earlier~~
   - Limitations (if confounding variables are clearly identified by your group)
8. References **(2.5 marks)**

Structure, Presentation & Quality

Your R Notebook source code should output **both the code and any data/plot/table** to the rendered HTML document.

A total of **2.5 marks** will be awarded for the clear commenting of any (non-trivial) line of R code and a clear description of any novel processing and/or user-defined functions.

Next, **2.5 marks** will be awarded if all included graphs/tables are formatted to maximize readability (i.e. main heading, labs, tick spacing and frequency, plot character, and caption).

You will be awarded a maximum of **5 marks** based on the clarity, coherence, and quality of your written expression. This corresponds to a report that is clear in its expression, logical in its presentation of the steps followed, and free from grammatical and typographic errors.

Only a single R Notebook file should be submitted. Submission of multiple R Notebook files will result in the grading of only the first (alphabetically listed) R Notebook file.

Version Control Requirements

You must use a recognized online code repository (e.g., GitHub) and make regular well-named commits to your private repository. A link to your code repo must be included in a README as part of the final submission and you must add your lecturer as a developer to the repository. The repository must be named *2024_DAIE_ICA_StudentInitials1.*

Your grade for this component will depend directly upon the **regularity** of your commits. A development project of this size should consist of a minimum of **5+ distinct commit messages** spread over the lifetime of the development. Committing all your code in one commit, before the deadline, will be interpreted negatively.

Any submission made which does not include a repository link will not be graded.

Submission Requirements
1. A **README** file containing a link to your R source code repository. Ensure that **no** changes are made to the repository following the submission deadline. You should

create a separate fork for this submission and leave it unchanged after the deadline. Ask your lecturer for details on fork creation.

2. The assignment must be entirely the work of each student. Students are **not** permitted to share any pseudocode or source code from their solution with any other group in the class.

3. Students may **not** distribute the source code of their solution to any other student, in any format (i.e., electronic, verbal, or hardcopy transmission).

4. Plagiarised assignments will receive a mark of **zero**. This also applies to the individual/group allowing their work to be plagiarised. Any plagiarism will be reported to the Head of Department and a report will be added to your permanent academic record.

5. Late assignments will **only** be accepted if accompanied by the appropriate medical note. This documentation must be received within 10 working days of the project deadline. The Institute standard penalties for late submission will apply.

6. Each student **must** complete and **sign** a single assignment cover sheet. Please submit the signed cover sheet before 5 pm on the Friday of the week of the deadline.

7. Online individual video interviews for this project will be scheduled in the **first week** following the deadline. You will need both audio and video in this interview so please ensure that you have both setups beforehand and adequate connection speed to support the video session (i.e., download/upload speeds >= 1.2Mbps). The interview will not take place in the absence of video and audio from your side of the connection.

8. Failure to attend the **interview** will result in a 0% grade. Both students in a group will be required to answer **several questions** on your submission to demonstrate understanding of the submitted project. Your **individual grade** for this component will be contingent on your **knowledge** of the work you submit.

References

1. Baus, Oliver & Bouchard, Stéphane. (2014). Moving from Virtual Reality Exposure-Based Therapy to Augmented Reality Exposure-Based Therapy: A Review. Frontiers in human neuroscience. 8. 112. 10.3389/fnhum.2014.00112. (Accessed: 3 October 2023)

2. Karami, B., Koushki, R., Arabgol, F., Rahmani, M., & Vahabie, A. H. (2021). Effectiveness of virtual/augmented reality–based therapeutic interventions on individuals with autism spectrum disorder: a comprehensive meta-analysis. *Frontiers in Psychiatry, 12,* 665326.

3. Ip, H. H., Wong, S. W., Chan, D. F., Byrne, J., Li, C., Yuan, V. S., ... & Wong, J. Y. (2018). Enhance emotional and social adaptation skills for children with autism spectrum disorder: A virtual reality enabled approach. *Computers & Education, 117,* 1-15.

4. Maples-Keller, J. L., Bunnell, B. E., Kim, S. J., & Rothbaum, B. O. (2017). The Use of Virtual Reality Technology in the Treatment of Anxiety and Other Psychiatry Disorders. *Harvard Review of Psychiatry, 25*(3), 103-113. (Accessed: 4 October 2023)

5. Lindner, P., Miloff, A., Hamilton, W., Reuterskiöld, L., Andersson, G., Powers, M. B., & Carlbring, P. (2017). Creating state of the art, next-generation Virtual Reality exposure therapies for anxiety disorders using consumer hardware platforms: design

considerations and future directions. *Cognitive Behaviour Therapy, 46*(5), 404-420. (Accessed: 5 October 2023)

6. Didehbani, N., Allen, T., Kandalaft, M., Krawczyk, D., & Chapman, S. (2016). Virtual reality social cognition training for children with high functioning autism. Computers in human behavior, 62, 703-711.

7. Dixon, D. R., Miyake, C. J., Nohelty, K., Novack, M. N., & Granpeesheh, D. (2020). Evaluation of an immersive virtual reality safety training used to teach pedestrian skills to children with autism spectrum disorder. *Behavior Analysis in Practice, 13*(3), 631-640.

8. Freeman, D. et al. (2017) Virtual reality in the assessment, understanding, and treatment of mental health disorders: Psychological medicine, Cambridge Core (Accessed: 6 October 2023)

Additional Resources

The resources below are provided as a mixture of **optional background reading**, technical reference, and useful tools.

- DkIT - Writing in the sciences…: Lab Reports
- Writing Up Research - Discovering Statistics
- Recommended Text - OpenIntro Statistics Videos & Slides
- How to Test for Normality in R
- 7 Types of Statistical Analysis: Definition and Explanation
- PTSD Symptom Scale-Interview Version
- YouTube - Riffomonas Project - R Language Tutorials
- Mendeley - Manage and share research papers
- Microsoft OneNote - Note taking and web page snipping
- R Markdown Cookbook
- R Markdown Cheatsheet
- Understanding YAML headers
- R Markdown Themes
- Harvard referencing quick guide: Citing and referencing material

Formal Harvard referencing guidelines have **not** been strictly followed in this document.