

# DatAR: Comparing Relationships between Brain Regions and Diseases: An Immersive AR Tool for Neuroscientists

Ghazaleh Tanhaei  
Department of Information and  
Computing Sciences, Utrecht  
University  
Utrecht, The Netherlands  
g.tanhaei@uu.nl

Lynda Hardman  
Department of Information and  
Computing Sciences, Utrecht  
University and CWI  
Utrecht, Amsterdam, The Netherlands  
lynda.hardman@cwi.nl

Wolfgang Hürst  
Department of Information and  
Computing Sciences, Utrecht  
University  
Utrecht, The Netherlands  
huerst@uu.nl

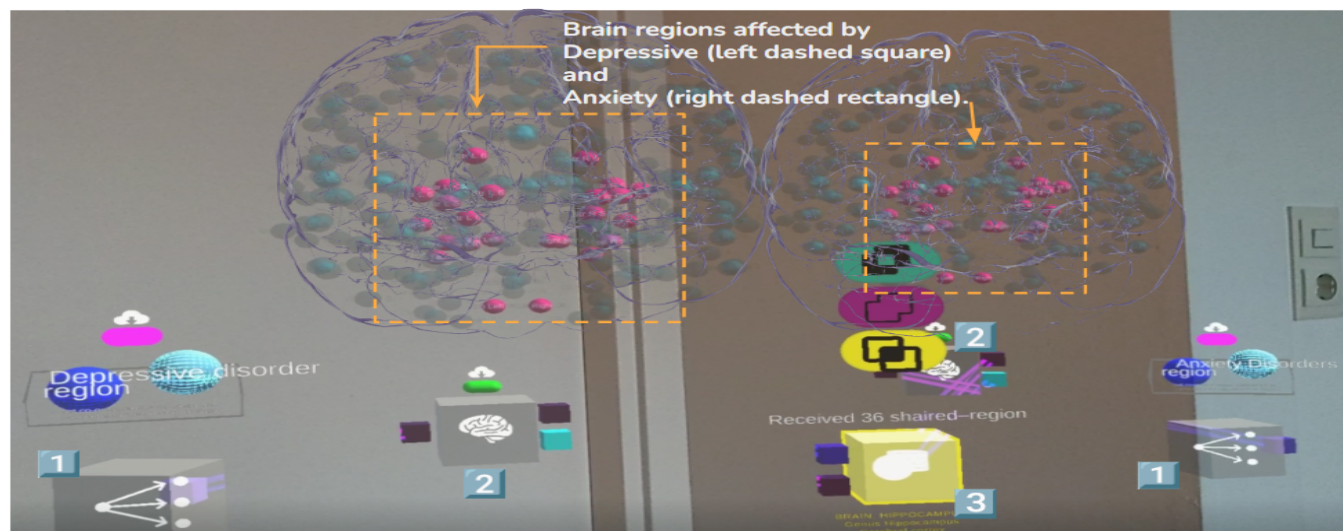


Figure 1: Asking for commonly affected regions by both *Depressive* and *Anxiety* extracted from literature; icon 1, through using Comparison Functionality; icon 3. Brain visualizations; icon 2, highlights the related regions in pink spheres.

## ABSTRACT

Different brain diseases are associated with distinct patterns of affected brain regions. Neuroscientists aim to understand the variability of these patterns across different brain diseases. We used a user-centered design approach to develop support for neuroscientists in exploring and comparing which regions are affected by which diseases based on neuroscience literature. Our study involved six neuroscientists and nine visualization experts who evaluated the usability and explainability of our visualization tool for comparing disease patterns in brain regions. Our results show that our tool can help neuroscientists explore and visualize relationships between brain regions and diseases, and compare patterns of affected regions in an immersive AR environment.

## CCS CONCEPTS

• **Human-centered computing** → **Visualization systems and tools**; **Immersive Analytics**; **Interactive systems and tools**; **Augmented Reality**.

## KEYWORDS

neuroscience literature search, exploratory search, information visualization and visual analytics, measures of user experience and performance, augmented reality, virtual reality

## ACM Reference Format:

Ghazaleh Tanhaei, Lynda Hardman, and Wolfgang Hürst. 2023. DatAR: Comparing Relationships between Brain Regions and Diseases: An Immersive AR Tool for Neuroscientists. In *ACM International Conference on Interactive Media Experiences (IMX '23)*, June 12–15, 2023, Nantes, France. ACM, New York, NY, USA, 3 pages. <https://doi.org/10.1145/3573381.3597222>

## 1 INTRODUCTION

Understanding the relationship between brain regions and brain diseases is crucial for advancing neuroscientists' knowledge of brain disorders and developing effective treatments. However, this task can be challenging due to the sheer volume of literature available on the subject. We present a tool that supports neuroscientists in exploring and comparing which brain regions are affected by

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).  
IMX '23, June 12–15, 2023, Nantes, France  
© 2023 Copyright held by the owner/author(s).  
ACM ISBN 979-8-4007-0028-6/23/06.  
<https://doi.org/10.1145/3573381.3597222>

which diseases based on an analysis of neuroscience literature. Our research question is: **How can we facilitate the exploration, visualization, and comparison of brain region-disease relationships in a usable and explainable manner?**

To address this question, we employed a user-centered design approach, which involved confirming the usefulness of the task, identifying representative tasks, and designing, implementing, and evaluating suitable functionality in an augmented reality (AR) environment. Our tool underwent a study involving six neuroscientists and nine visualization experts, who provided feedback that was used to improve the tool. This version supports multiple types of comparisons between affected brain regions.

Our contribution is a tool that allows neuroscientists to efficiently explore and compare brain region-disease relationships, with the potential to advance our understanding of brain diseases. The tool can be used as a basis for further research in the field of neuroscience and Immersive Analytics (IA) to explore the potential of IA in the analysis of large collections of scientific papers.

## 2 RELATED WORK

The exploration of relationships between topics is crucial for understanding existing knowledge and discovering new insights [10]. In the context of brain research, analyzing the caption of brain images in the literature is one method to find the relationship between brain diseases and the structure of the brain [3, 8]. However, this approach has limitations in visualizing the 3D structure of the brain, which is essential in perceiving relationships among parts of the brain. To address this issue, researchers propose using AR to visualize the 3D brain in a 3D environment, which can help experts understand how a 3D model is arranged spatially [7].

Recent advances in data visualization and analysis have enabled neuroscientists to explore complex relationships between brain regions and diseases. Machine learning algorithms are used to identify patterns and relationships in large datasets. For example, authors used a deep learning approach to predict the connections between brain regions and symptoms of Alzheimer's disease, achieving high accuracy in their predictions [5]. Similarly, the machine learning algorithm helps to identify brain regions that are most affected by *multiple sclerosis*, providing insights into the underlying pathology of the disease [9].

Another approach is the use of multi-modal data integration, which allows researchers to combine data from multiple sources (such as genetics, imaging, and clinical data) to gain a more comprehensive understanding of brain region-disease relationships. For example, a multi-modal approach is used to map the relationships between brain regions and various psychiatric disorders, finding that different disorders are associated with distinct patterns of brain activation [2]. Also, multi-modal data integration can be used to identify brain regions that are most affected by Parkinson's disease, revealing new insights into the disease's underlying pathology [1].

Immersive Analytics (IA) allows researchers to interact with complex data in an intuitive and engaging way. The NeuroCave tool is an example of an immersive visualization specifically made to assist neuroscientists in exploring brain regions' connections [6]. This web-based VR tool enables brain researchers to engage with connectomes and organize distinct brain regions. Studies have

demonstrated that users prefer VR environments in presenting 3D data, such as brain regions, to 2D screen-based environments. Therefore, the use of AR or VR technology can provide an intuitive and engaging way of visualizing the 3D brain structure and help researchers gain new insights into the relationships between brain diseases and regions [4, 7].

## 3 DESCRIPTION OF TASK AND SCENARIO

Our aim is to see how two or more diseases are related to similar brain regions. We follow a user-centered design approach as follows: Step 1, confirm the usefulness of the task: We talked to a neuroscientist where we discussed the idea of finding common regions of the brain that are affected by at least two diseases. This expert believed that this information could help in finding new insights about the relationship between diseases and the brain, as well as finding new ways to treat diseases. Step 2, identify representative tasks: The neuroscientist suggested two diseases (*Depressive* and *Anxiety*) on which to base our representative tasks. *Depressive* and *Anxiety* very often appear in the same publications since they affect similar brain regions. Based on the neuroscience database PubMed, the number of regions related to *Depressive* is very different from the number of regions related to *Anxiety*. To understand where this difference lies, we specify and implement a "Comparison Task". This allows users to compare the related regions of Depression and Anxiety to find similarities and differences in affected regions.

In the demo, users see two visualizations of all brain regions, where one shows all those affected by Depressive (fig. 2, right brain) and the other those affected by Anxiety (fig. 2, left brain). Participants can explore which brain regions, and in which area of the brain (e.g. front, middle, or back), are related to the selected diseases. In addition to the visual comparison, the "Comparison Widget" allows participants to filter the results and draw conclusions. This widget supports researchers to change highlighted regions in two brain models to see;

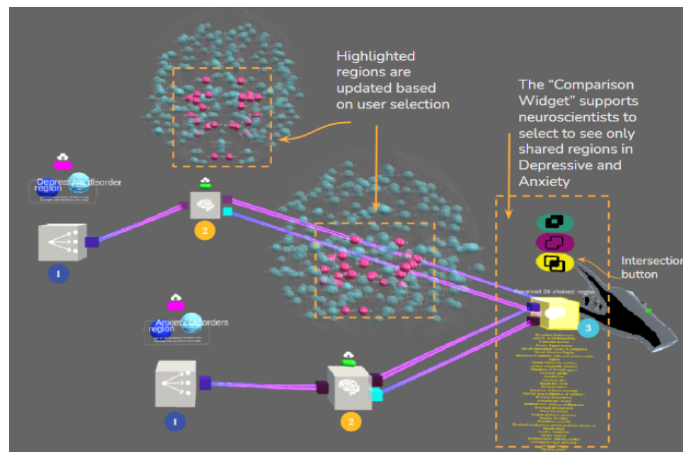
- **Intersection Function;** Only shared regions in both Depressive and Anxiety.
- **Union Function;** All of the regions which are related to Depressive and/or Anxiety.
- **Difference Function;** Related regions to Depressive and not to Anxiety, OR Related regions to Anxiety and not to Depressive.

## 4 IMPLEMENTATION

Data for this study was provided by the Knowledge Graphs of Brain Science (KGBS) available from Triply<sup>1</sup>, which consists of co-occurrences of brain-related topics such as brain regions, diseases, genes, proteins and cognitive functions that occur in abstracts and titles of publications. The publications analyzed for this study were collected from neuroscience publications in PubMed. Positions of brain regions in the 3D Brain Model are extracted from the Scalable Brain Atlas database (SBA)<sup>2</sup>. The visualization tool used in this study, DatAR, was developed and constructed using Unity3D

<sup>1</sup>Knowledge Graphs of Brain Science in Triply <https://krr.triply.cc/BrainScienceKG/-/queries/Brain-Region-Brain-Disease/1>

<sup>2</sup><https://scalablebrainatlas.incf.org/services/regioncenters.php>



**Figure 2: First Person View showing a user interacting with the “Comparison Widget” (yellow menu item above the yellow cube). Item 3 works as the Boolean operation of “intersection”.**

(v2020.3.15f2) with the MRTK package (v2.7.0)<sup>3</sup> and was deployed on a HoloLens 2 head-mounted display.

## 5 DISCUSSION AND CONCLUSION

In conclusion, based on 15 participants’ opinions, our tool has proven to be usable and explainable for neuroscientists in relation-finding and comparison tasks. Results show that participants found it easier to use the widget rather than rely on visual observations. The “Intersection button” was the most useful, while the “Union button” was deemed useless by participants, although one neuroscience participant suggested it could still be useful for certain research. The usefulness of the text providing brain region names varied among participants, with some finding it useful and others not practical. It was suggested that the list of affected regions be sortable and categorizable based on regions to better support neuroscientists’ needs.

Future developments should consider the direction of relationships and differentiate between positive and negative relationships. The direction of relationships means that whether malfunction in the brain region causes a disease or an existing disease causes damage to brain regions. Also, we have not processed the positive or negative meaning of the sentences which indicate relationships between brain regions and diseases. We need to provide more precise visualizations of brain regions to support neuroscientists in understanding which region(s) of the brain are affected by one or more diseases.

Our work provides a novel way of exploring relations between neuroscience topics using AR. This can be extended to other use cases where 3D visualization of 2D data benefits from an immersive environment. Overall, we have demonstrated the potential of immersive AR tools in assisting neuroscientists in exploring and comparing relationships between brain regions and diseases.

<sup>3</sup>The code is available on request.

## ACKNOWLEDGMENTS

We thank Daniel Simões Lopes; Assistant Professor of Computer Science and Engineering at Técnico Lisboa for his helpful comments. We are grateful to our colleagues in the DatAR and HCDA (CWI) groups for their feedback.

## REFERENCES

- [1] Xia an Bi, Xi Hu, Yiming Xie, and Hao Wu. 2021. A novel CERNNE approach for predicting Parkinson’s Disease-associated genes and brain regions based on multimodal imaging genetics data. *Medical Image Analysis* 67 (2021), 101830. <https://doi.org/10.1016/j.media.2020.101830>
- [2] Urs Braun, Axel Schaefer, Richard F. Betzel, Heike Tost, Andreas Meyer-Lindenberg, and Danielle S. Bassett. 2018. From Maps to Multi-dimensional Network Mechanisms of Mental Disorders. *Neuron* 97, 1 (2018), 14–31. <https://doi.org/10.1016/j.neuron.2017.11.007>
- [3] Madeleine Goodkind, Simon B. Eickhoff, Desmond J. Oathes, Ying Jiang, Andrew Chang, Laura B. Jones-Hagata, Brissa N. Ortega, Yevgeniya V. Zaiko, Erika L. Roach, Mayuresh S. Korgaonkar, Stuart M. Grieve, Isaac Galatzer-Levy, Peter T. Fox, and Amit Etkin. 2015. Identification of a Common Neurobiological Substrate for Mental Illness. *JAMA Psychiatry* 72, 4 (04 2015), 305–315. <https://doi.org/10.1001/jamapsychiatry.2014.2206> arXiv:<https://jamanetwork.com/journals/jamapsychiatry/articlepdf/2108651/yoi140096.pdf>
- [4] Marc Janeras, Joan Roca, Josep A. Gill, Oriol Pedraza, Gerald Magnusson, M. Amparo Núñez-Andrés, and Kathryn Franklin. 2022. Using Mixed Reality for the Visualization and Dissemination of Complex 3D Models in Geosciences—Application to the Montserrat Massif (Spain). *Geosciences* 12, 10 (Oct 2022), 370. <https://doi.org/10.3390/geosciences12100370>
- [5] Taeho Jo, Kwangsik Nho, and Andrew J. Saykin. 2019. Deep Learning in Alzheimer’s Disease: Diagnostic Classification and Prognostic Prediction Using Neuroimaging Data. *Frontiers in Aging Neuroscience* 11 (2019). <https://doi.org/10.3389/fnagi.2019.00220>
- [6] Johnson J. G. Keiriz, Liang Zhan, Olusola Ajilore, Alex D. Leow, and Angus G. Forbes. 2018. NeuroCave: A web-based immersive visualization platform for exploring connectome datasets. *Network Neuroscience* 2, 3 (Aug. 2018), 344–361. [https://doi.org/10.1162/netn\\_a\\_00044](https://doi.org/10.1162/netn_a_00044)
- [7] Daniel Paes, Eduardo Arantes, and Javier Irizarry. 2017. Immersive environment for improving the understanding of architectural 3D models: Comparing user spatial perception between immersive and traditional virtual reality systems. *Automation in Construction* 84 (2017), 292–303. <https://doi.org/10.1016/j.autcon.2017.09.016>
- [8] RA Poldrack, JA Mumford, T Schonberg, D Kalar, B Barman, and T Yarkoni. 2012. Discovering Relations Between Mind, Brain, and Mental Disorders Using Topic Mapping. *PLoS Comput Biol* 10, 8 (2012). <https://doi.org/10.1371/journal.pcbi.1002707>
- [9] Ruggiero Seccia, Silvia Romano, Marco Salvetti, Andrea Crisanti, Laura Palagi, and Francesca Grassi. 2021. Machine Learning Use for Prognostic Purposes in Multiple Sclerosis. *Life* 11, 2 (2021). <https://doi.org/10.3390/life11020122>
- [10] Austin R. Ward and Rob Capra. 2020. *Immersive Search: Using Virtual Reality to Examine How a Third Dimension Impacts the Searching Process*. Association for Computing Machinery, New York, NY, USA, 1621–1624. <https://doi.org/10.1145/3397271.3401303>