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Exploring Indirect Relations between Topics in Augmented Reality to Inform the Design of a Neuroscience Experiment

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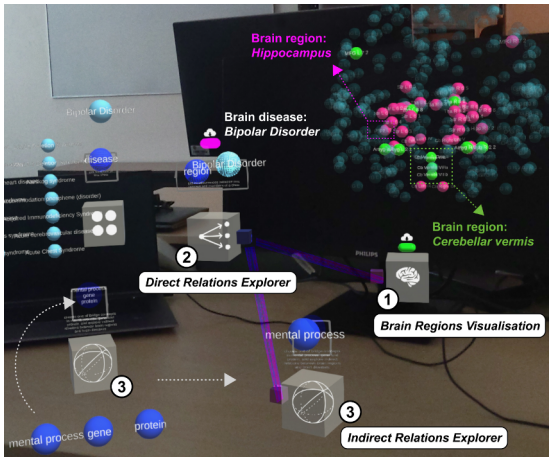

Figure 1: A participant explores direct relations between the brain disease *Bipolar Disorder* (② middle) and all brain regions, such as *Hippocampus* (pink sphere, ① upper right), and selects mental processes as the intermediate topic (③ lower left) to explore the indirect relation between *Bipolar Disorder* (② middle) and the brain region *Cerebellar Vermis Structure* (3 green spheres, ① upper right). Brain regions with no direct or indirect relations are visualised as light blue spheres.

Abstract

Neuroscientists analyse publications to inform experiment design. Exploring direct relations between topics, such as brain diseases and regions, aids this process. Brain diseases may also connect indirectly to regions through topics such as mental processes. We aim to establish whether exploring indirect relations helps design experiments.

Using a user-centred design approach, we interview neuroscientists to establish the usefulness of exploring indirect relations, specify functionality, and design a corresponding visualisation. Nine neuroscientists indicated the visualisation is *suitable* to present the functionality, the functionality is *useful* to explore indirect relations, and exploring indirect relations is *useful* to design experiments.

Index Terms: Topic-based Literature Exploration, User-centred Design, Data Visualisation, Augmented Reality.

1 Introduction

Before conducting an experiment, neuroscientists need to understand the relevant literature to ensure the experiment will make a useful contribution. This process is time-consuming. Topic-based, rather than publication-based, literature exploration allows users to explore large numbers of publications simultaneously, providing an overview of the relations between neuroscience topics, such as brain regions and brain diseases. Direct relations are derived from co-occurrences of two topics in the same sentence in the title or abstract of a publication [4]. For example, the brain disease *Bipolar Disorder* and the brain region *Hippocampus* occur in the title of the publication *Lithium effects on Hippocampus volumes in patients with bipolar disorder*[1]. We use the Knowledge Graphs of Brain Science, which contains topic co-occurrences in titles and abstracts from 414,224 neuroscience publications (2010–2022) in PubMed[2].

Participants from previous studies [3, 4] suggested that exploring less obvious, *indirect* relations could provide more opportunities for designing experiments, as weak evidence indicates a potential connection, though no publication has yet confirmed it. We define an indirect relation between two topics when there is no direct relation between them but each co-occurs with at least one other common topic. For example, there is no direct relation between the brain disease *Bipolar Disorder* and the brain region *Cerebellar Vermis Structure*. There are, however, 9 co-occurrences of *Bipolar Disorder* with *Psychological Inhibition*, and 7 co-occurrences of *Psychological Inhibition* with *Cerebellar Vermis Structure*. We thus conclude that there is an indirect relation between the topics *Bipolar Disorder* and *Cerebellar Vermis Structure*, in this case through the intermediate topic *Psychological Inhibition*. DatAR, a 3D Augmented Reality prototype, provides a visualisation of the relative locations of brain regions affected by the same diseases, Fig. 1.

Our main research question (RQ1) is: *How does exploring indirect relations between topics contribute to designing a useful experiment?* Using a user-centred design approach, we consulted three neuroscientists to establish that exploring indirect relations is a useful user task and identified one functional requirement and two visualisation requirements via interviews with the same three neuroscientists. Based on these functional and visualisation requirements, we designed the *Indirect Relations Explorer*, Fig. 1 ③.

Our second research question (RQ2) is: *To what extent is the visualisation suitable for the specified functionality in presenting indirect relations?* We recruited nine neuroscientists to evaluate the suitability of the visualisation using the DatAR prototype. All participating neuroscientists reported that the visualisation is suitable for presenting indirect relations.

Our third research question (RQ3) is: *To what extent is the implemented functionality useful for exploring indirect relations?* The nine neuroscientists who evaluated RQ2 also assessed the usability of the functionality and indicated that the corresponding functionality is useful for exploring indirect relations.

Our final step is to evaluate the main research question, the usefulness of indirect relations in designing useful experiments (RQ1). The same nine neuroscientists were consulted and confirmed that indirect relations can be useful in identifying an experiment likely to make a useful contribution.

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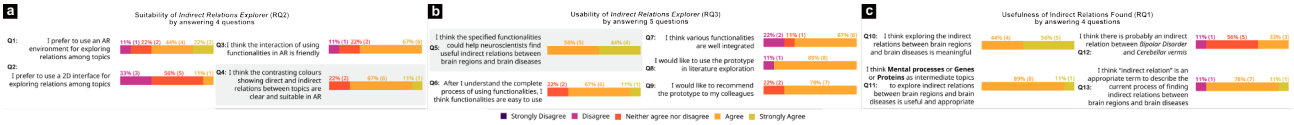

Figure 2: Nine participants' attitudes on (a) the suitability of the indirect relations visualisation (RQ2), (b) the usability of the indirect relations functionality (RQ3), and (c) the usefulness of indirect relations found (RQ1).

The contributions of this work are (i) the useful user task of exploring indirect relations between neuroscience topics; (ii) functionality that enables the user task; and (iii) a visualisation that supports the functionality.

2 Method

We follow a user-centred design approach of problem discovery to design support for an identified user task [1]. We collaborated with three neuroscientists to

- identify the useful user task of exploring indirect relations between topics and determine a representative task for later evaluation: exploring the indirect relation between the brain disease *Bipolar Disorder* and the brain region *Cerebellar Vermis Structure* via mental processes[3], Fig. 1.

- determine the corresponding functionality for the task. ***Selecting intermediate topics:*** Each neuroscientist has a different focus on research topics, such as genes or mental processes. Neuroscientists were interested in manually selecting intermediate topics to explore indirect relations between brain regions and diseases.

- determine suitable visualisations. ***Single visualisation:*** Neuroscientists would prefer to see both direct and indirect relations at the same time. ***Contrasting colours:*** Neuroscientists want to infer different relations between topics by determining the difference between colours. We use contrasting colours to distinguish direct and indirect relations in visualisations, Fig. 1.

We seek to obtain feedback from neuroscientists through evaluations to gain in-depth insights. We use the qualitative method, including Likert scale questionnaires (Fig. 2) and open-ended interviews, to assess users' perceptions of the visualisation (RQ2), functionality (RQ2), and the user task (RQ1).

The evaluation is centered on three metrics: ***Suitability*** evaluates how the designed visualisation supports the presentation of indirect relations within the AR environment (RQ2); ***Usability*** measures how the implemented functionality satisfies human-computer interaction requirements for exploring indirect relations (RQ3); and ***Usefulness*** assesses how exploring indirect relations between topics aids neuroscientists in designing experiments (RQ1).

Because of the proof-of-concept character of our research, we are not focusing on quantitative performance results but rather on qualitative insights into the suitability and usability of our design for neuroscience researchers. Problem discovery studies typically require between 3 and 20 participants, with 5 to 10 being a good baseline [2]. For this study, we recruited 9 participants[4].

3 Results

3.1 Suitability of Indirect Relations Visualisation (RQ2)

Seven participants found the display of direct and indirect relations clear and suitable, Fig. 2 (a), Q4. Two participants recommended using two similar colours for direct and indirect relations. All nine participants suggested improving the readability of overlapping labels on spheres. Potential solutions include matching the label colours with those of the spheres and implementing a filter to display only labels related to direct and indirect relations.

3.2 Usability of Indirect Relations Functionality (RQ3)

All nine participants found the indirect relations functionality useful for exploring indirect relations between topics, Fig. 2 (b), Q5. Six participants agreed with the method of constructing and integrating the *Indirect Relations Explorer* into the DatAR prototype, while two participants found it too complex to understand, for example, relevant widgets always need to be selected and connected. A potential suggestion is to develop a tutorial to guide users in operating the functionalities for exploring indirect relations, which could improve the usefulness of the DatAR prototype for users in their daily literature exploration work.

3.3 Usefulness of Indirect Relations (RQ1)

All nine participants stated that exploring indirect relations between topics is useful for designing experiments, Fig. 2 (c), Q10. Eight participants agreed that "Indirect Relations" is a suitable term to describe relations between topics through a third topic, while one participant suggested that "Secondary Associated Network" is a better term for this, Fig. 2 (c), Q11. Six participants thought that the indirect results found could only provide inspiration for further literature review, rather than evidence to ensure the experiment would make a useful contribution. They thought it was difficult to judge to what extent the indirect relations were useful in ensuring useful contributions. Neuroscientists expressed a desire for more detailed information about indirect relations, such as access to the publications containing the co-occurrences.

4 Conclusions and Future Work

This work contributes to finding and visualising indirect relations between a selected brain disease and all brain regions, and vice versa, supporting neuroscientists in their complex task of designing experiments. We will continue collaborating with neuroscientists to understand how we can provide the provenance of the indirect relations found, for example, by providing the specific intermediate topics, such as a gene, that contribute to the indirect relation and by providing direct access to the publications that are the sources of the two direct relations.

[3] See also the video: https://indirect-relations-video

[4] All nine participants are neuroscience researchers at the University Medical Center Utrecht, experienced in literature exploration but new to AR.

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