

# Designing a Topic-Based Literature Exploration Tool in AR — An exploratory study for neuroscience

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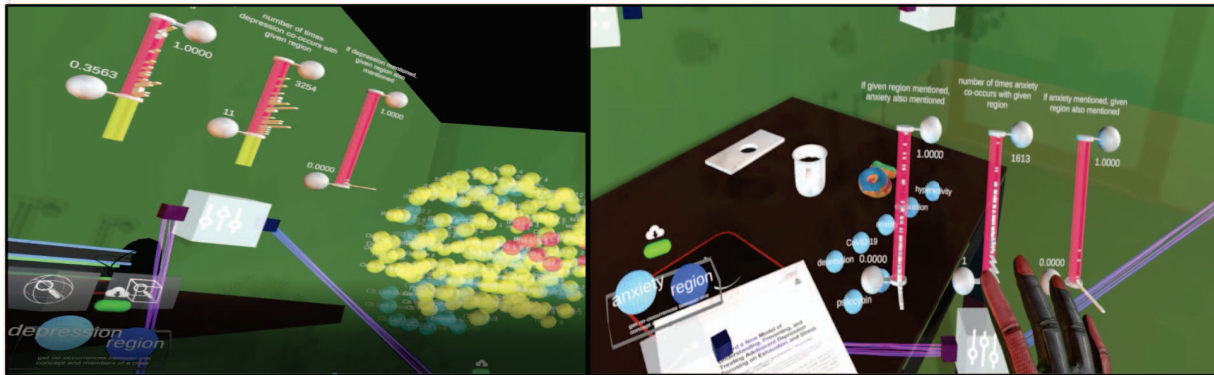


Figure 1: Exploring neuroscience literature to find brain regions corresponding to a specific disease. A user investigates brain regions co-occurring with *Depression*, left, and adjusts the filters for co-occurrences of brain regions with *Anxiety*, right.

## ABSTRACT

The large and increasing amount of scientific literature makes it difficult for researchers to analyse and understand relations between topics even in their specific sub-field. Neuroscience researchers are interested in relations between, for example, anatomical regions of the brain and the diseases that affect them. To explore relations in the extensive body of literature, using the topics themselves rather than individual articles, can provide a higher-level approach. We have created a prototype interactive AR environment to learn more about how topic-based literature browsing might aid researchers in analysing and understanding relations between topics. Given the three-dimensional nature of the brain, we postulate that visualizing neuroscience topics in Augmented Reality would support the exploration of relations between them and thus improve and extend existing literature exploration workflows. We follow a user-centered approach to identify visualization and interaction design requirements. Using an existing analysis of tens of thousands of neuroscience papers, we designed an interactive AR environment to support researchers in finding relations between brain regions and brain diseases that integrates with existing literature review practices. We carried out two qualitative evaluations to verify our design, first with eight neuroscience students as domain experts and then with seven experienced researchers as literature exploration experts. Our analysis of participants' feedback shows that visualizing topics and their relations in the immersive AR environment is clear, understandable and helpful for topic-based literature exploration, specifically, between brain regions and brain diseases. Our AR literature exploration tool has the potential to be used by neuroscientists in their routine literature reviews.

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## 1 INTRODUCTION

Literature exploration is a fundamental task in any research endeavor. While searching for individual papers is the traditional approach to exploring literature, one of its key drawbacks is the difficulty to explore complex relations among topics<sup>1</sup>. We postulate that much effort can be saved, however, by allowing researchers to explore literature via topics. This would enable researchers to analyze relations between topics across papers: e.g., which pairs of topics co-occur frequently in papers [23]? Our goal is to investigate to what extent topic-based, rather than article-based, exploration allows researchers to more efficiently select and find relations among topics from large amounts of literature [10]. To investigate this, we construct a prototype interactive AR environment containing an analysis of literature from the neuroscience domain<sup>2</sup>. One of a neuroscientist's research goals is to identify high-potential relations that could form the basis for a future experiment. Assessing which experiment should be run next requires an understanding of which relations are regarded as established in the literature and which are novel or unproven<sup>1</sup>.

In our neuroscience use case, our aim is to support researchers by providing a 3D exploration environment to find and visualize relations between topics in an easy and understandable way. This allows us to visualize relations directly with sub-regions of a 3D virtual brain and for exploring structures in 3D. The use of spatial layouts of information in virtual and augmented reality has been proven to assist recollection and simple visual exploration [12]. However, there have been few attempts to investigate how spatial cognition aided by immersive technologies could help literature exploration [22]. Our overall research questions are: **RQ1: Which neuroscientists' literature exploration tasks are appropriate for support in an IA AR environment?** and **RQ2: to what extent is the functionality we provide in the tool useful for the tasks validated by RQ1?**

<sup>1</sup>Personal communication with Cunqing Huangfu, a neuroscientist.

<sup>2</sup>We use the Linked Brain Data (LBD) repository as an example of a topic-based analysis of neuroscience literature: <http://www.linked-brain-data.org/>

We follow a user-centered design approach by involving neuroscience and literature exploration experts at early stages in the design. We validated the main task which we support in our prototype by neuroscientists who participated in the first study. Considering these experts' opinions, we improved our preliminary user scenario and asked literature exploration experts to evaluate comprehensibility of the analysis process, prototype environment and cognitive task limitation in the second study. Because of the COVID-19 outbreak we were unable to invite evaluation participants to use our AR environment but simulated it in VR ("Evaluation" section, 6) for the second study. We contribute design requirements and recommendations for the development of immersive analytics tools to support neuroscientists in performing topic-based literature exploration.

## 2 RELATED WORK

**Exploring Biomedical Literature:** Neuroscientists are interested in understanding relations between brain-related topics to find fruitful areas for experimental studies. Literature exploration supports the discovery of hidden and unknown relations by (semi-)automated analysis using machine-learning techniques. Exploring literature can be used by all of scientific areas not only biomedical domains [6, 19]. Biomedical work using this method varies from identifying new connections between genes and illnesses, relations between different diseases, predicting drug reactions and discovering new research areas [2]. To find out relations between brain-related topics and group similar topics in our work, Latent Dirichlet Allocation (LDA) method is applied on the abstract and title of neuroscience literature and presents semantically similar brain diseases.

**Linked Data Visualization:** The Linked Brain Data (LBD) publication repository we use is an Resource Description Framework (RDF) repository of extracted, linked and organized neuroscience publications. The repository has access to title and abstract of publications from online neuroscience resources such as PubMed. Visualizing Linked Data (LD) can help users without technical skills to understand the meaning of content [17]. Several tools offer interactive operations for presenting LD graphs generated from data files or SPARQL endpoints. They present topics as graph nodes and support zooming into/out of the graph along with filtering and editing nodes and edges [3, 15]. For example, Tarsier [21] presents LD sources as interactive 3D graph visualizations. The authors highlight the role of a 3D visualization to understand and analyze this type of data. Providing an intuitive visualization of extracted topics from LBD is crucial to reduce the need of technical skills for neuroscientists.

**Immersive Visualizations of Brain-related Topics:** Immersive visualizations have already been used to support neuroscientists in tasks other than literature exploration. For instance, in presenting the brain connectome, Connectome Visualization Utility, Brain Net Viewer and Connectome Viewer Toolkit use 3D node-link diagrams to support neuroscientists in observing relations between connected nodes [14]. For complex abstract 3D structures that need to be analyzed, 3D-stereoscopic visualization improves the spatial understanding of cells [18]. Also, it is easier to establish relations between brain structures, functions and connectivity in IA [16]. The NeuroCave application uses immersive analytics to support neuroscientists in exploring complex characteristics in network-theoretic approaches [11]. Using a VR headset helps brain researchers to interact with connectomes and cluster brain regions into different groups. It shows that users appreciate using VR environments for presenting 3D data – brain regions – more than a desktop environment. Epilepsy Pre-Evaluation Space tool (EPES) connects MRI and iEEG data by labeling, coloring and animation in a VR environment. The authors show that employing VR for presurgical epilepsy evaluation can help integrate iEEG and MRI data and visualize seizure propagation [1]. Our tool is different from previous work by supporting users in exploring brain-related topics from the literature and their interrelations, and presenting them in an immersive environment.

## 3 DESIGN REQUIREMENTS

A neuroscience researcher<sup>1</sup> provided our initial user scenario (relation-finding) and helped us determine a real neuroscientist's task: to find diseases related to a brain region (e.g., Amygdala<sup>3</sup>). Our design requirements are based on functional requirements that came from neuroscientists' and data discovery experts' opinions and were identified during the tool implementation.

**DR1: Co-occurrences – Present a wide range of co-occurrences of brain diseases with a brain region.** The number of co-occurrences of a topic pair indicates the number of times that a topic, such as a specific brain disease, appears in the same sentence as another topic, such as a brain region. Based on a neuroscientist<sup>1</sup> opinion, diseases that co-occur with a brain region in the literature a few times, or even zero times, can be useful, since they may indicate new research areas for investigation. However, diseases with a high number of co-occurrences are also important, because they verify other researchers' findings. A neuroscientist should be able to explore a wide range of co-occurrences to form an understanding of the relations among the topics in the literature.

**DR2: Neighboring Diseases – Identify unexplored brain diseases that may affect a brain region.** This requirement came from a neuroscientist<sup>1</sup> who hypothesized that brain diseases that are semantically similar may affect similar brain regions [9]. Brain diseases unrelated to a brain region but they are close to the related one are "Neighboring diseases" and can be promising areas for investigation. Our colleagues in Brain-inspired Intelligence group applied the LDA topic model method and t-distributed Stochastic Neighbor Embedding (t-SNE) algorithm in the abstract and title of neuroscientific publication, yielding 3D locations of around 300 diseases. Distance between diseases gives an indication of their semantic similarity. Figure 2 shows a 3D Topic model visualization of diseases. We have to provide an environment to support neuroscientists to identify neighboring diseases.



Figure 2: 3D topic model visualization of around 300 diseases. Depression and Anxiety are located close to each other in the LBD topic model which may suggest that they might affect similar regions.

**DR3: Select Topic – Select one or more topics in the topic model and brain visualization.** Users need to be able to select a single topic, such as brain region or brain disease for further investigation, and to select (at least) two diseases in the topic model, to allow a comparison of co-occurrences of each disease with brain regions (e.g. see [4]).

**DR4: Identify Related Topics –** Users need to be able to identify the 1-n relations between topics. Users need to be able to select a brain region/disease and request all related diseases/regions.

<sup>3</sup>We select the Amygdala as an example since it has relations with about 107 diseases, which is neither very many nor very few.

**DR5: Identify Sources – Provide access to the source literature.** This requirement was derived from a brainstorming session with three data discovery experts and three AR/VR developers. During the process of creating the LBD repository, there was relatively little language analysis on the relation between two topics found in a single sentence. A single instance of co-occurrence is counted when two topics are present in the same sentence and there are no negative words such as “no” or “not” in the sentence. There is no other validation of the meaning of the sentence. For example, “The relation between region A and disease B has been questioned.” is a sentence in the dataset that provides evidence of a relation between region A and disease B. This leads to the requirement that users should be able to access the sentences in the original document, represented by the co-occurrences corresponding to a query, to allow them to assess the positive or negative contribution to the relation.

## 4 DESIGN RATIONALE

**Visualizing Numbers of Co-occurrences:** A visualization of the numbers of co-occurrences between a topic pair needs to be able to deal with both high and low numbers of co-occurrences (DR1, 3). One option would be to indicate the number of co-occurrences by different sphere sizes, where each sphere is a disease/region. For example, as proportional to the number of co-occurrences, to indicate established knowledge, or inversely proportional, to indicate the importance of unexplored research areas. Gauging sizes visually is difficult, however, especially for topics with similar numbers of co-occurrences. Also, differing sphere sizes can lead the user to misinterpret the distance between two spheres that is used to indicate similarity in the topic model and relative positioning of brain regions. We instead use the same size and shape for different numbers of co-occurrences and include a filter that allows users to select the desired range. Rather than being confronted with a tool that hides (potentially) unrelated results, users should be supported in highlighting parts of the result to retain context. For this, we select different colors of same-sized spheres to indicate each result category: Topics within the filter range (red sphere), Topics related to the query but outside the filter range (yellow sphere), and Topics unrelated to the query (turquoise sphere).

**Visualizing Neighboring Diseases:** To detect neighboring diseases (DR2, 3) based on their positions in the topic model, we consider two alternatives. The first is to use clustering methods to find close diseases. Each clustering method, however, has its own shortcomings and, to avoid misleading results, they need to be validated by a domain expert [7]. An alternative is to present diseases based on their 3D positions in the topic model and allow users to visually identify groups of diseases. This position-based exploration depends on users correctly interpreting the relative positions of brain diseases. To visualize the topic model, we can present this on a 2D screen, or in an immersive environment. Given the high cost of a neuroscience experiment, it is vital that the visualization supports users as much as possible in finding neighboring diseases, so a clear representation of the distances among them is crucial. We propose a 3D immersive environment since users should be able to see more information from an unlimited virtual 3D display than from a limited 2D display [8].

**Interacting with Topics:** The two requirements, Select Topic (DR3, 3) and Identify Related Topics (DR4, 3) determine how the user should be able to interact in the environment. We consider a simple grabbing action for selecting topics since it is a natural and common action for users, particularly in immersive environments. We provide a duplication feature for all of our widgets, analysis tools in the immersive environment, and topic spheres to support users in parallel investigations of multiple queries and result comparison. To satisfy DR4, the exploration tool supports different relation-finding queries so that users do not need to know technical query languages.

**Identify Sources:** Our tool identifies correlations between topics

and does not imply that there is a causal relation – it is the neuroscientist who creates an understanding by exploring the source literature. The co-occurrence analysis of the source literature is made available in the LBD repository. To provide access to the publications corresponding to the result of a query, we need to create a connection between our environment and PubMed (DR5, 3). The user is then able to see the source papers and the sentences that contributed to the co-occurrence analysis. This part of the exploration environment shows sentences and papers based on the selected topics. Our goal is to allow the user to determine the reason for the relation provided in LBD, so the sentences displayed correspond only to one disease and one region.

## 5 IMPLEMENTATION

### 5.1 Visualization

We used a number of widgets that are designed for different purposes [20]. Widgets are analysis tools that perform actions such as querying, data manipulation, visualization, or data export. Most of the widgets need user input that should be placed in the widget’s receptacles. Receptacles are for placing category or topic inputs. **Category** refers to the head of a class and **topic** refers to the component of that class (e.g., Disease is a category/class and Depression is one of the topics of that category). The tool generates the visualization of widgets when the user grabs them. All of the widgets are presented in Figure 3.

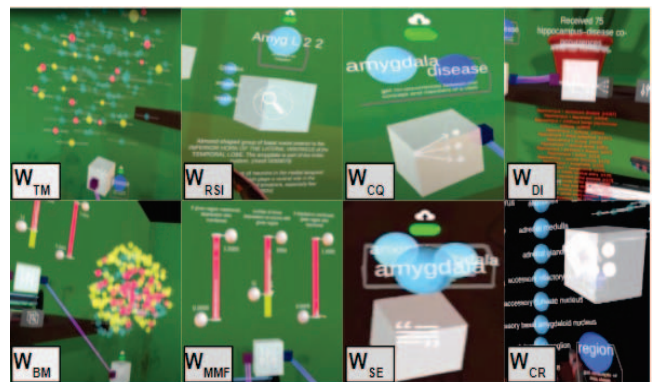


Figure 3: Visualization of the widgets and their icons. Topic Model of brain diseases ( $W_{TM}$ ), Resource Sphere Inspector Widget ( $W_{RSI}$ ), Co-occurrence Querier Widget ( $W_{CO}$ ), Dataflow Inspector Widget ( $W_{DI}$ ), 3D Brain Model Widget ( $W_{BM}$ ), Min-Max Filter Widget ( $W_{MMF}$ ), Sentences Extractor Widget ( $W_{SE}$ ), Class Retriever widget ( $W_{CR}$ ).

### 5.2 Technical features

The AR visualization was built with Unity3D (v2019.3.9f1). We use MetaSDK(v2.7.0.38) to work with the Meta 2 HMD. The VR version is built on SteamVR (v2.5; SDK v1.8.19). The web-based companion application was developed in Angular (v8.2.14). Our code is in principle open source so please get in touch if you are interested in accessing the code.

## 6 EVALUATION

We ran two studies with the goal to allow participants to explore the functionalities of the tool. The tool was further developed after the first study. Since the main task (relation-finding) was the same in both studies, we consider that the precise changes made are irrelevant and thus do not describe them here.

The COVID-19 outbreak meant that we were unable to invite participants into the lab for our second study. We adapted the implementation to VR that simulated an AR environment, Figure 4,

allowing us to find participants who would be able to evaluate the prototype using their own equipment. Because we were unable to find neuroscientists with at-home access to a VR/AR device, we invited participants with literature exploration experience to our study. We measure our evaluation goals through interviews. Answering questions did not require a neuroscience background because: (1) the literature exploration aspect of the tool is relevant to all researchers, (2) we provided an explanation of neuroscience literature case study used in the prototype to participants before carrying out the task.

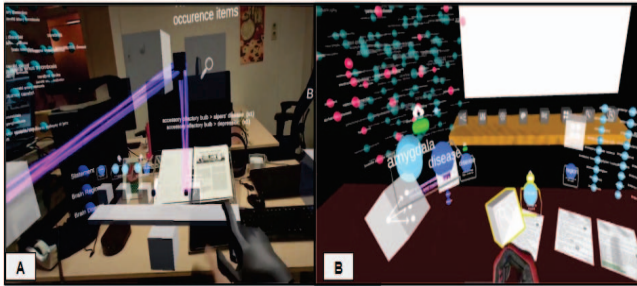


Figure 4: The prototype tool in AR (A). Participants can use virtual widgets to carry out the relation-finding task. Simulated tool in VR based on the researcher’s usual workplace (B).

Based on the user-centered design approach, we were eager to collect opinions that enable us full and rich descriptions rather than make statistical inferences. To answer our research questions and evaluate all important features in our design, we grouped our evaluation goals into five categories; meaningfulness, explainability, visualization, navigation, and performance [5]. The interview questions of both studies were designed based on the guiding scenario for information visualization evaluation [13].

**Literature Topics:** The topics derived from the literature analysis were gathered from neuroscience publications from online resources such as PubMed and are stored as the LBD knowledge graph. LBD contains a set of topics identified and classified within the publication’s title and sentences of the abstract. Brain diseases, brain regions, cognitive functions, and neurons are some of the topics in LBD. For these studies, we investigate how participants are able to explore relations between brain regions and diseases.

### 6.1 Evaluation with Neuroscientists (AR)

**Evaluation goals:** In this study, our aim was to find answers to our first research question (RQ1) by examining the following items:

- **Meaningfulness:** To assess to what extent participants understand the concept behind the tool.
- **Meaningfulness:** To obtain suggestions from participants for custom modifications or additions and novel uses for the tool.
- **Meaningfulness:** To obtain suggestions from participants for improvement in the next iterations.

**Participants:** Eight senior bachelor students in the field of neuroscience participated (P1-P8). They had an understanding of neuroscience literature and were able to evaluate the prototype with respect to their own neuroscience research goals. The session was in-person and they used a Meta 2 headset.

**Procedure and tasks:** Each session started with an explanation about the Linked Brain Data analysis of neuroscience literature and the relation-finding barriers for the neuroscientists continued by an introduction to the tool (15 min). Participants then performed the tasks (20 min) and were interviewed (30 min). The test sessions lasted about an hour. Participants were asked to explore the relation between the Amygdala and associated brain diseases. After this session, we improved our preliminary user scenario based on the information that we gathered from these neuroscientists. For exam-

ple, we added the ability that participants can run a reverse scenario, asking for related brain regions when a disease is selected.

- **Task1: Relation between the Amygdala and Brain Diseases:** The participant was asked to describe their understanding of the Topic Model and if this was incorrect the researcher explained it again. The participant was then asked to use the Topic Model to find the diseases related to the Amygdala.

- **Task2: Relation between the region and Brain Diseases:** The researcher reset the environment. The participant was asked to investigate again without any guidance. They had to select their desired brain region and do the same steps to find related diseases.

### 6.2 Evaluation with Literature Exploration Experts (VR)

**Evaluation goals:** Our goal was to answer the second research question (RQ2) by examining the following items.

- **Explainability:** To identify the salient points of our tool that participants found (positive and negative).
- **Explainability:** To identify whether the participant can explain the analysis process of the tool (comprehensibility of analysis process).
- **Performance:** To see which barriers may prevent participants from following task steps.
- **Navigation:** To look at the influence of representing information in an immersive 3D space.
- **Visualization:** To evaluate the readability of the 3D visualization. Since some parts of the presented data are in 3D, we evaluate whether an immersive space can improve presenting the data from different perspectives.

**Participants:** Seven participants with experience in reviewing literature, but not neuroscience literature (P9-P15), took part using their own steam-VR compatible headset. They had an understanding of the literature exploration task and were able to reflect on their experience, their understanding of the prototype’s functionality, and their observations on the visualization.

**Procedure and tasks:** Each session started by asking participants to read a document introducing the study (8 min). We provided them with seven short videos of the tool environment<sup>4</sup> and a sample of user scenarios (13 min). They ran the tool and carried out four tasks (30 min) and then interviewed (20 min). The whole session took approximately one hour. In this session, participants were asked to consider themselves neuroscience researchers and initiate new research about Amygdala and related diseases by doing four tasks.

- **Task1: Relation between Amygdala and Brain Diseases:** The participant was asked to use the Topic Model to find the diseases related to the Amygdala. The participant was then asked to use filter to find related diseases with more than 400 number of occurrences.

- **Task2: Relation between a related disease and Amygdala:** The participant was asked to look at sentences that indicate the relation between one of the related diseases from the previous task and Amygdala. They had to read the sentences and check the negative ones on the browser.

- **Task3: Relation between a disease and Brain Regions:** The participant was asked to grab an unrelated disease that was semantically close to the related one in the Topic model and find related brain regions in the 3D brain visualization.

- **Task4: Finding additional information about the regions:** The participant was asked to select at least one related brain region from the previous task and generate descriptions and closed topics by Resource Sphere Inspector Widget.

## 7 RESULTS

We investigated all five evaluation categories (Section 6) in both studies. Since meaningfulness is relevant only for participants with neuroscience knowledge, we analysed the results for this category only for the January 2020 study. The results of the other four categories provided by literature exploration experts are valid since

<sup>4</sup><https://edu.nl/c8ukg>

useful, critical, feedback relies on a smooth interaction experience, which was better in the VR version than the AR version. A VR version could better reflect what the AR version could be in the future (given sufficient development, as it is a less-developed technology).

## 7.1 Neuroscientists using the initial AR Prototype

**Meaningfulness:** To satisfy our mentioned evaluation goals on meaningfulness and back to our first research question (Section 1), we tried to understand the neuroscientists' methods for finding relation between topics and make sure that they understand the idea behind the prototype.

More than half of the neuroscience participants perceived the prototyped tool as valuable for exploring literature based on topics. Participants expressed that they did not have appropriate tools to find relations between brain regions and diseases. All participants mentioned that if they want to explore the relations between two topics, they go to PubMed or other online resources and search the keywords. As they stated, it is hard and time-consuming work: they have to read at least the abstract of each paper to explore whether the two selected topics are related. Furthermore, if they could not find any direct evidence, they have to check indirect relations by considering the third topic.

The task to find little-explored relations in academic literature was meaningful to all participants. Our approach to complete the relation-finding task was deemed worthwhile by seven participants (P1-P4, P6-P8). Five participants (P1-P3, P6-P7) said that the environment was visual and informative and could be an option for literature exploration, especially before an in-depth review.

In terms of functionality, we received some suggestions to improve the tool. The ability to search, delete and read the virtual objects or return to the previous step was mentioned by P5. Also, they found the idea of accessing the source sentences and papers interesting (P1,P5,P6), "*It's just a supportive tool; you need to check yourself, be critical of what is shown*" (P7).

## 7.2 Literature Exploration Experts using VR Prototype

**Explainability:** The prototype encouraged participants to have a purpose for the task and try to think like a neuroscientist. "*Although I am not a neuroscientist, I want to make sense of the task.*", P9. Almost all of our participants agreed that we chose an effective and intuitive way of visualizing data operations. In particular, The 3D representations of the topic model and 3D brain were found to be intuitive. P9, who has data analysis experience, indicated the depth of analysis as a clear part of the analysis process in the tool. For example, the ability of the prototype to present source sentences and papers when browsing the relation between two topics was helpful. To improve this part, P15 suggested adding the ability to check why two diseases are close to each other in the topic model.

**Performance:** Participants stated that they wished to have more help during running tasks. They perceived this as a barrier to task completion. They had difficulties with the similarity of the widget icons (resource sphere inspector widget and dataflow inspector widget) which impeded selecting the correct widget. Grabbing small objects with large virtual hands was another impediment that participants mentioned. In terms of functionality to improve performance, some participants (P11, P14) suggested a manual that can help participants when they need to know widgets' functionalities. Storing the participants' findings is another function that boosts participants' performance. For example, a spreadsheet that shows the participants' actions and results are displayed (P13).

**Navigation:** The domain experts perceived the immersive technology as valuable. They reported that the 360° environment facilitated more space for literature exploration. Having floating topic spheres in the immersive environment and navigating among them was found to be convenient. Although some visualizations, such as presenting the result text of one of the widgets in red, misled participants

about the correctness of their actions, others were perceived as very helpful. The green icon when the widget received the results of a query and the purple rope when two widgets were connected in the right way supported participants in taking the correct actions. The results showed that working with the tool was not difficult, but for the first time, participants needed instruction. Almost all participants indicated that the 3D VR prototype is more enjoyable than working with a 2D screen.

To improve the interaction functionality, participants suggested having the ability to collaborate with their peers during working with the tool (P9).

**Visualization:** Participants found the topic model and brain region visualizations useful (P10, P11, P12). Visualizing the topic model in an immersive environment allowed participants to distinguish neighboring diseases by only moving their heads in/out of the model. They (P13) agreed the immersion helped them concentrate on the subject matter. On the other hand, based on many comments (P9,P11,P12,P15), the names of spheres in these two 3D plots overlap with each other, so the readability of names was challenging. The favorite features participants mentioned were the **3D visualizations of the topic model and brain region** (P10-12), **exploring sentences and the 360° data analysis environment**. Participants were able to run all sorts of queries quickly. They also liked the color filter that could help them to highlight the results by changing the topic spheres' color, rather than removing them from the display. Some of the visualization improvements suggested by P9-P12:

- Using different colors for the diseases and region spheres. This can help them to recognize disease and region spheres when they have been moved in the environment after several grabbing actions.
- Considering another visualization for the list of regions' names.
- Adding a search function to find a region name can be beneficial.
- Informing participants whether they chose their desired spheres.

## 8 DISCUSSION

**Exploration Environment:** Neuroscientist participants stated that they would be prepared to use the tool in their daily practice if the interactions improve significantly. Considering the capabilities that immersive analytics (IA) provides for participants, such as the intuitive presentation of 3D graphs and a 360° workspace, we do not intend to move to the limited 2D/2.5D environment on screen. While an IA environment is uncommon for exploring literature, exploring existing relations and finding new ones is intuitive and understandable for participants. Three of our neuroscientist participants expressed the wish to include relation findings in their own 2D workplace; indicating that the environment needs improvement but the rationale behind the approach shows promise.

**Topic Sphere Visualization:** To indicate to participants which topics have been filtered out from the query on the basis of co-occurrences, we used red to indicate topics still within the filtered query and yellow for those outside the filter boundaries. Using bright (e.g., yellow) and warm (e.g., red) colors in the same visualization can lead to incorrect visual assessment of the depth perception and hence the distance between topics. To improve the visualization, we have to rethink the color of the topic spheres if we want participants to perceive their correct position.

In addition, long topic names are challenging to read and currently overlap with the longer topic names (majority of names). We need to adapt the topic sphere layout algorithm to take the length of the topic name into account. A zoom feature would also be useful.

**Selecting Brain Region:** For now, there is no direct connection between brain visualization and the topic model. When a participant wants to find relation between a brain region and brain diseases, they need to use the "Co-Occurrence Querier" widget. We intend to improve the implementation so that participants can select a region in the 3D brain and see highlighted diseases in the topic model.

## 9 CONCLUSIONS AND FUTURE WORK

We designed an augmented reality tool that presents an interactive overview of the relations between brain diseases and brain regions. The goal of our design is to support neuroscientists to explore the literature to identify the most suitable experiments to carry out. Through the use of our prototype tool, expert neuroscientists should be able to form an understanding through the exploration of the tool's representations of topics in the literature. To answer our second research question (Section 1) and based on feedback from neuroscientists on the initial AR prototype, the tool has the potential for use as part of a serious research endeavor.

Our tool design could be extended to explore relations between other brain-related topics such as genes, neurons, and proteins. Our work can be generalized to other research domains, but some of the visualizations, such as the disease topic model or visualization of the brain, should be redesigned based on the related topics.

A logical progression of our research is to make a comparison of the prototype's functionality implemented in a 2D desktop environment and 3D AR. Before a fair comparison can be made, we need to resolve all problems with the AR tool's usability, requiring the development of, for example, higher resolution and a larger field of view. Meanwhile, the goal of our prototype is to understand complex topic-based literature exploration tasks that could be supported in the future and, at the same time, to understand the readiness of professionals to incorporate AR technology into their work.

Our results are the first step at the beginning of a longer process to provide the optimal environment for topic-based literature exploration. They have shown that AR is a suitable solution for this scenario and provide a good basis for the continuing effort to design and develop such a tool.

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