MRSight: Visualizing Insights for Magnetic Resonance Spectroscopy

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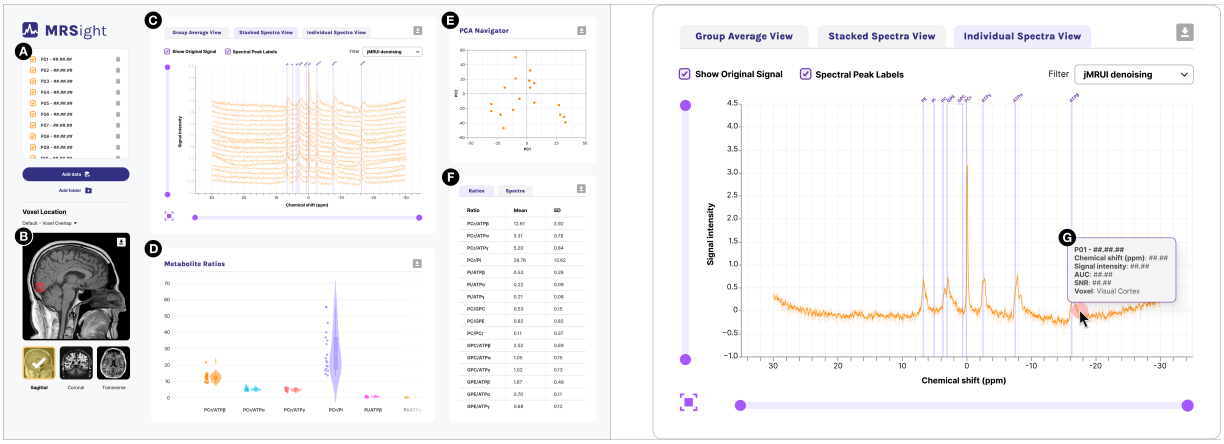

Figure 1: Conceptual overview of the MRSight dashboard with A) MRS data input, B) voxel localization with anatomical context, C) spectral output graphs at different levels of granularity (grouped average, stacked spectra, and individual spectra), D) violin plot showing distribution of metabolite ratios, E) principal component analysis (PCA) plot showing data clusters and outliers, and F) data table with spectra and metabolite ratio values. Users can hover over individual spectra to view details on demand (G).

Abstract

For the Bio+MedVis Redesign Challenge at IEEE VIS 2025, we propose a dashboard visualization design that enables neuroscientists and clinicians to explore, analyze, and communicate phosphorus magnetic resonance spectroscopy (^{31}P-MRS) data. Despite the importance of ^{31}P-MRS data visualization for the early detection of neurological conditions, current visualization practices make it challenging to identify and interpret relationships found in such data, particularly across different time points and patients. It is equally challenging for MRS researchers and their stakeholders to learn to interpret spectral data. We address these challenges by leveraging visualization types that are familiar and routinely used in MRS research, organizing and tiering them in an interactive dashboard according to task priority. Additional figures and a video walkthrough of our design are available at osf.io/b8vmr.

Index Terms: Visualization, magnetic resonance spectroscopy.

1 Introduction

Magnetic resonance spectroscopy (MRS) is an increasingly popular *in vivo* non-invasive technique for studying the composition of biochemical compounds e.g., metabolites in the human brain. By detecting subtle changes in metabolite concentrations in brain tissue regions, MRS allows clinicians to diagnose and monitor neurological abnormalities unidentifiable through standard medical imaging methods [9]. Phosphorus (^{31}P) MRS in particular is used for evaluating energy metabolism and oxidative stress within cells, which are indicators for various neurological conditions such as Alzheimer's or Parkinson's disease [9]. Visualization of MRS data, rudimentarily as a single spectral output graph, is clinically relevant for identifying metabolite concentrations corresponding to peaks in the graph. The validity and robustness of MRS analysis are dependent on voxel localization and spectral quality, knowledge of which are also predominantly communicated through visualizations [8].

Despite the importance of MRS data visualization for clinical insight and quality assurance, standard practices, i.e., single spectral graph or table of metabolite concentrations, make it challenging to identify and interpret relationships found in such data, especially across different time points and patients. Prior visualization research has explored alternate visualization idioms and methods, though these are focused on displaying a subset of metabolites at a time, e.g., Feng et al. [3] use scale driven data spheres to display metabolites within a voxel while Marino and Kaufman [5] focus on a single metabolite ratio for one individual at a single time point. Tools for ^{31}P-MRS visualization in particular remain an unexplored area, with the visualization community primarily focused on hydrogen (^{1}H) MRS with different applications [6], e.g., novel encodings for comparison of all ^{1}H spectral metabolite ratios [4].

To address these challenges, we propose an interactive dashboard visualization design (Fig. 1) that organizes and tiers ^{31}P-MRS visualizations according to the task priorities of MRS researchers as described in Sec. 2. Rather than develop novel idioms or encodings that add to the steep learning curve of MRS data interpretation, we leverage visualizations that are familiar and routinely used by MRS researchers to explore, analyze, and communicate spectroscopy data to stakeholders such as clinicians.

2 Proposed Redesign

We derive an initial set of user tasks as well as a preliminary mockup of the dashboard informed by the challenge description and MRS visualization literature. The tasks and design features were further prioritized through consultation with a MRS researcher.

Task Prioritization—Framed using visualization task typology [2], the typical task flow for MRS data analysis [4] begins with data discovery (T1) where voxel location, spectral output graphs and quality of data acquisition are reviewed, followed by data selec-

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tion and filtering (T2) where spectral voxels of interest are divided into groups and data production (T3) where metabolite ratios are calculated using the spectral output. These ratios are compared and summarized between different groups (T4) e.g., treatment/control.

Through discussions with a MRS researcher, we determined the communication of results across different groups (T4) took priority over the examination of spectra individually or within-group (T1-3). In particular, MRS researchers need to clearly convey overall findings—implications of metabolite ratio values for the diagnosis and grading of neurological disease—to stakeholders who may not have knowledge of MRS techniques. Visualizations should then connect abstract MRS data to concrete anatomical information e.g., showing the brain region which the scan originates from to provide real-world context for stakeholders. However, individual spectral graphs still serve as a means of quality assurance and visually communicate data acquisition and processing errors e.g., by graph curvature or by signal-to-noise ratio. These error checks require a user to view spectral peaks on individual spectra, examine side peaks, and apply denoising techniques. Since outliers detected at the group-level (metabolite ratio values) may not always be indicative of errors, it is necessary for researchers to be able to revisit individual graphs alone or within a group for further investigation. Per Truong and Duncan [8], visualizing voxel localization also acts as a means of quality assurance.

Dashboard Organization—We follow a grouped dashboard layout [1] that organizes visualizations into semantically meaningful columns and aligns them left to right according to the MRS analysis workflow. The leftmost column lists the original input data (Fig. 1A) and their voxel localization (Fig. 1B); here, the user can create folders to group data e.g., by treatment to allow for comparisons between groups in the other graphs (Supp. Fig. 4). The middle column displays the clinically relevant visualizations used to identify metabolite concentrations across individual and grouped data and is thus allocated the most screen space in the dashboard. Specifically, three spectral graph views (Fig. 1C)—group average, stacked spectra, and individual spectra—allow users to compare spectral peaks and assess data acquisition quality across different groups at various levels of granularity, while the violin plots showing distribution of different metabolite ratios (Fig. 1D) provides quick interpretation of the spectral peaks. Lastly, the rightmost column provides additional information about the visualizations in the middle column, specifically a PCA plot (Fig. 1E) to aid users in identifying data clusters and outliers as well as a table (Fig. 1F) to accessibly retrieve numerical values from visualizations in the middle column. Each panel can be downloaded as a figure for dissemination e.g., in a manuscript or a presentation to stakeholders.

Visualization Idioms and Interaction—Informed by dashboard design tradeoffs [1], we balance the visual information shown within the limited screen space and its cognitive cost by 1) using visualization idioms routinely used by MRS researchers and repeating them across levels of data granularity and 2) displaying only one level of granularity at a given time. Through literature and consultation with the domain expert, we determined spectral graphs (along with its grouped and stacked variants) and box plots (and its variants) showing distribution of metabolite ratios were common idioms in MRS studies and adequately fulfilled the task requirements described above. Following Shneiderman's visual information-seeking mantra [7], we use interactivity to transition between different levels of granularity according to task priority. Users are first presented with *overview* visualizations that provide group-level information about the data e.g., group average view of spectral graphs, distribution of metabolites in the violin plot, clusters in the PCA plot (Supp. Fig. 1). Users can then *zoom* into the data, selecting a tab to view individual spectra alone or stacked for comparison as well as using sliders to zoom into spectral peaks e.g., to identify side peaks (Supp. Fig. 2). Once in the individual spectra view, data points associated with this specific spectra become visually salient across other visualizations, i.e., views are linked. Users can do a similar visual *filtering* in the stacked spectra view by hovering over an individual spectra (Supp. Fig. 3). Lastly, users can view *details on demand* by hovering over data points of individual spectra to see a tooltip box of specific values (Fig. 1G), e.g., chemical shift of spectral peak.

3 Discussion and Next Steps

Our preliminary result (Fig. 1) is an interactive dashboard design that addresses challenges associated with identifying and interpreting relationships in MRS data within and across different groups, organized and tiered according to task priority.

The main limitation of our work is the use of mock data, rather than the challenge dataset, in our conceptual mock-up of the dashboard. While the spectral graphs were generated using the challenge dataset in Vega-Altair, all other visualizations use mock data and are solely representative of our concept—voxel location images are open source (see figure credits), metabolite ratios are calculated from amplitudes of spectral peaks rather than best practices of area-under-the-curve, and the PCA plot uses mock values not drawn from the challenge dataset. A second limitation is the lack of an evaluation that assesses whether our dashboard visualization fulfills the task requirements of target users, MRS researchers. Future work should focus on creating and evaluating a functional dashboard prototype that draws fully from a MRS dataset.

Figure Credits

Fig. 1 is created by the authors using brain scans from Reigh LeBlanc (CC BY NC 2.0), Nathanial Luceus (CC BY 2.0), and Wikimedia user Asnaebsa (CC BY SA 4.0). We make Fig. 1 along with additional figures and a video walkthrough of MRSight available on OSF at `osf.io/b8vmr`, released under CC BY 4.0.

Acknowledgments

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