Using EEG to Investigate the Visual Properties of Images

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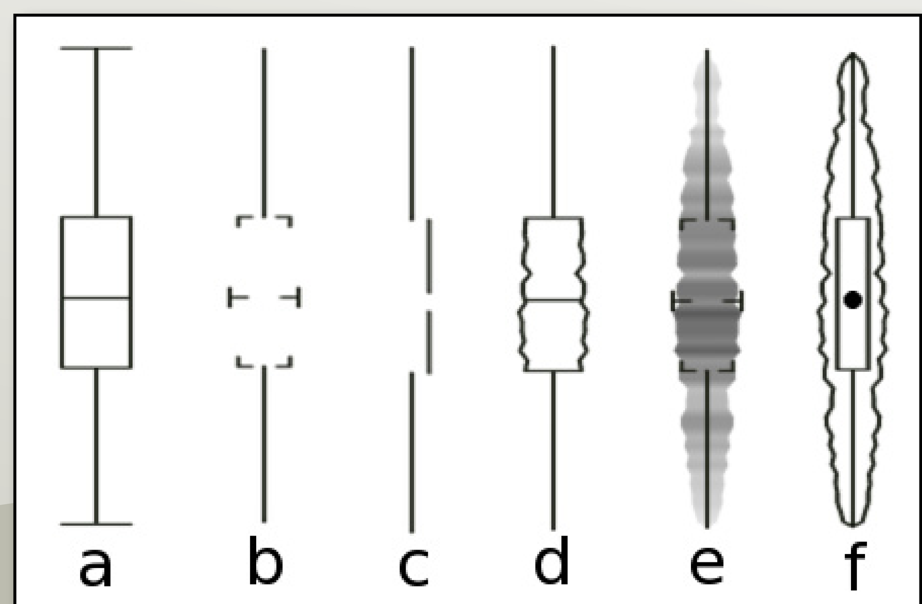
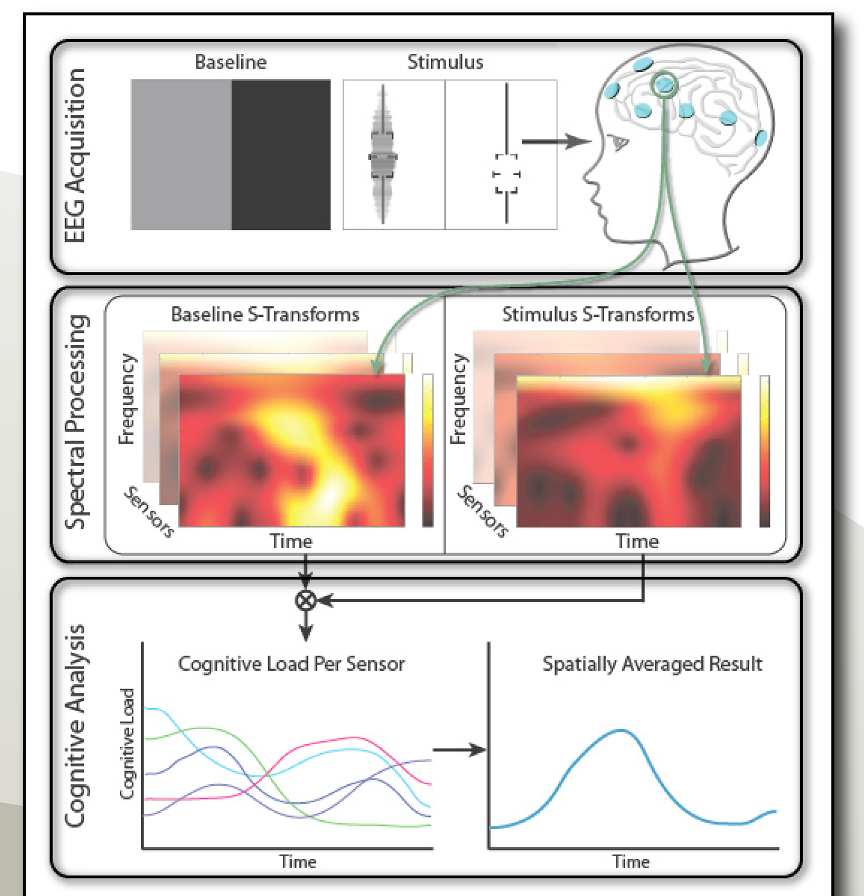
Description

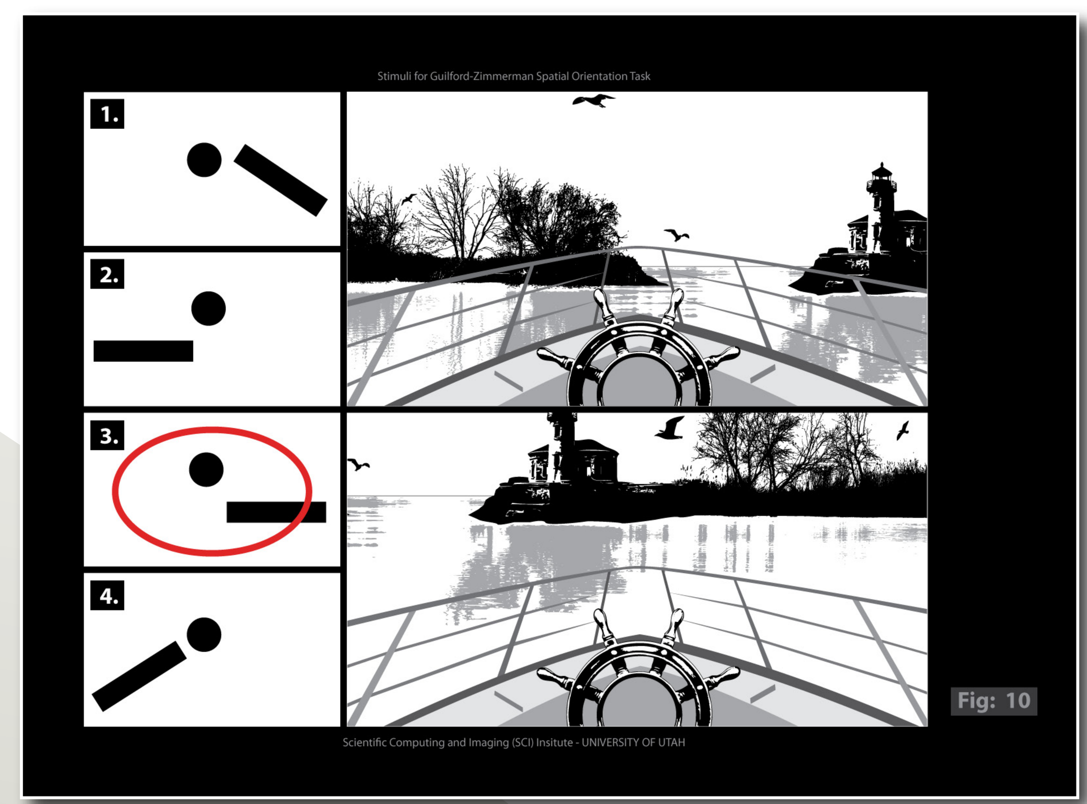
Effectively evaluating visualization techniques and their properties is a difficult task often assessed through feedback from user studies and expert evaluations. We present an alternative approach to visualization evaluation in which brain activity is passively recorded using electroencephalography (EEG). These measurements are used to compare different visualization techniques in terms of the burden they place on a viewer's cognitive resources. In this work, EEG signals and response times are recorded while users interpret different representations of data distributions. This information is processed to provide insight into the cognitive load imposed on the viewer. This work describes the design of the user studies performed, the extraction of cognitive load measures from EEG data, the visualization of raw EEG data and their derived products as well as how those measures are used to quantitatively evaluate the effectiveness of visualizations.



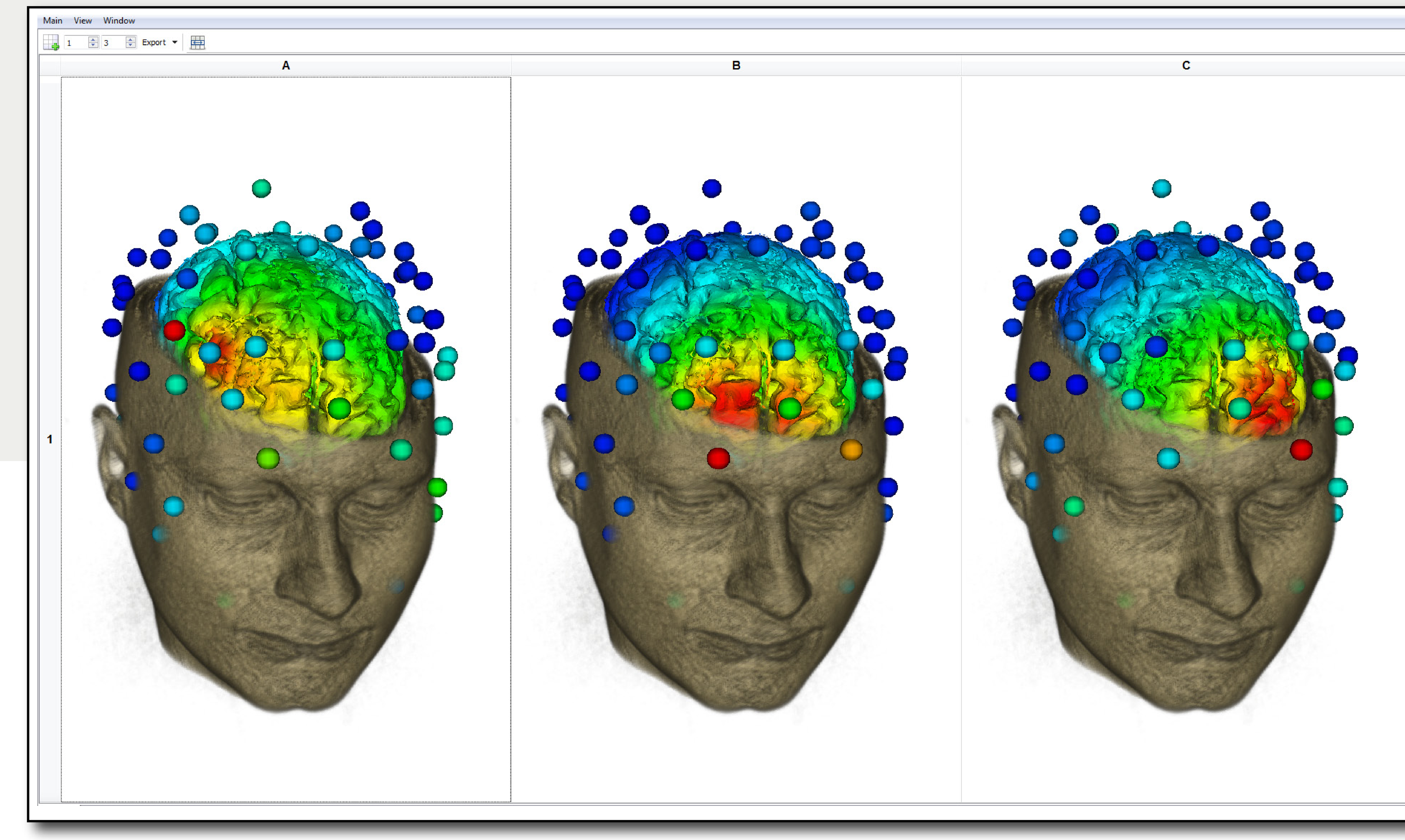
We have completed a study investigating the cognitive differences associated with visualization of distribution data as box plots (Anderson et al). To explore this, EEG data was collected as participants determined which of two displayed datasets had the highest variance. Each pair of distributions were represented by one of the above box plots. Additionally, because the distribution data were generated with well-known parameters, a difficulty score was calculated for each test. The calculation of difficulty based on the properties of the data, rather than the representation of it, allowed a correlation to be made between the difficulty of the task, the visual representation of data, and the cognitive properties determined during analysis.



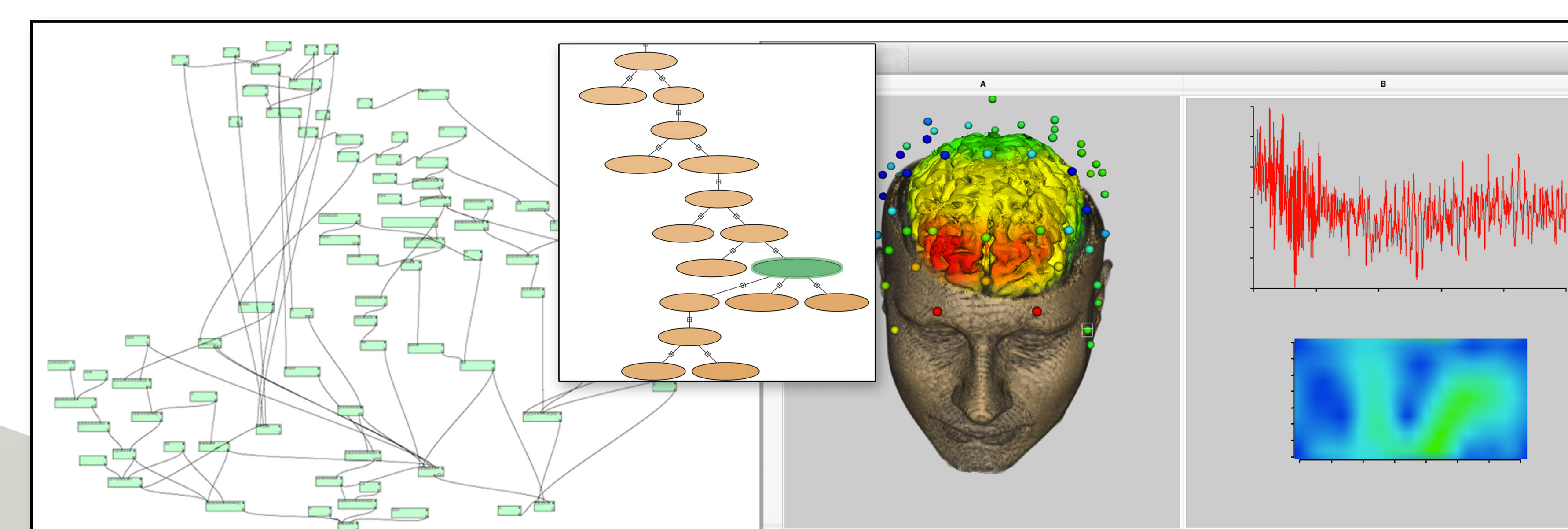
EEG data for our study of box plot visualization is processed to extract cognitive measures used in analysis. Here, each trial is processed separately. After data acquisition (top), each EEG signal is processed using the S-Transform (Stockwell) to generate a time-frequency plane (middle). These planes are then reduced to represent the change in power seen in small frequency bands and spatially weighted to generate a single curve to determine the power change during the test (bottom). This curve is then compared against baseline values to determine cognitive measures associated with the specific task.



A study is underway to examine the cognitive properties of determining spatial orientation in virtual environments. This is a validation of the Guilford-Zimmerman Orientation Survey performed in 1948 (Guilford et al). In this experiment, users were presented with images such as this and were asked to determine which of the smaller images represented the correct change in orientation. Although this test has been validated numerous times, we seek to ask a slightly different question during analysis - "Does the size of computer screen users use make this type of task more or less difficult?"



Visualizing the EEG data collected during experiments can be done in several ways. Here, the sensors of an EEG network are represented along with the MRI of a given participant. By associating a property of each EEG signal with its sensor location, data can be interpolated onto the brain surface given by the MRI. Here, we see alpha band (8-12 Hz) power being displayed across all sensors and the cortical surface at three different times. In this way, the progression of specific brain activity can be seen as it evolves during an experiment.



Visualizing and analyzing EEG data is a complex task requiring many parameters to be tuned, and many methods tested. The VisTrails environment (http://www.vistrails.org) is used to not only provide a visual environment to process and visualize these data (left,right), but it also maintains detailed provenance of the process used to generate any given result (middle). This aspect of VisTrails makes it invaluable in experimental analysis.

References

- The Guilford-Zimmerman Aptitude Survey. Guilford, J. P.; Zimmerman, Wayne S. Journal of Applied Psychology, Vol 32(1), Feb 1948, 24-34
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