Relationship between Respiratory Data Factors and BOLD signals in MRI

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BACKGROUND

We already know that the End-Tidal O2 (ETO2) and End-Tidal CO2 (ETCO2) with the Blood-oxygen-level dependent (BOLD) MRI sequences. End-Tidal is the partial pressure of gas at the end of the breathing cycle, or when a person breathes out. In this case, oxygen (O2) and carbon dioxide (CO2), respectively.
Additionally, it is more feasible and easier for a computer to do the daunting task of completing a regression than simply doing it by hand, since there are already lots of factors that goes into determining the coefficients. More importantly, if there are new discoveries that may hint at a correlation, a well-written program can easily take those new pieces of data and create new conclusions with little to no hassle.
Using this relationship, we can potentially visualize any abnormalities in the data, like mismatches in the real BOLD and predicted BOLD, and see what they mean to find out any health complications that patients may have before it happens.

HYPOTHESIS

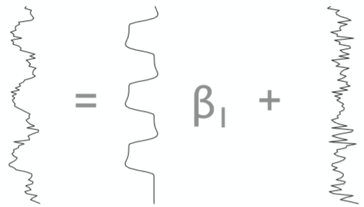
EXPECTED OUTCOME

Since we already know that ETO2 and ETCO2 are, by themselves, correlated to BOLD MRI scans, it is possible that respiratory rate could be a factor impacting the BOLD.

METHODS

Study participants: Data range from middle aged people (SH) and older people (particularly in Whittier) (WH). There are 22 SH patients and 19 WH patients considered.

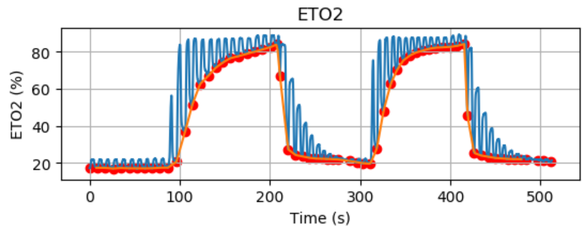
Linear Regression: Linear Regression is the idea that when each signal is amplified by some single value, or the coefficient, it equals another data. The formula is as follows: **Data = A x B + unexplained variability**, where **A** is a n x m matrix of the "m" amount of signals at "n" time, **B** is a m x 1 of "m" number of single coefficients for each signal, and **unexplained variability** is any residual data that could not be accounted for, especially since the final regressed line is not going to perfectly match the original BOLD data signal.



Single Variable Regression Example
Source: "ICA" Course – fsl.fmrib.ox.ac.uk

Programming: The minimum peaks for ETO2 and the maximum peaks for ETCO2 are determined. The peak distances from each gas then becomes the respiratory rate for each gas. Along with other data determined, these data points are interpolated to the same number of data points as the BOLD, up to 480 seconds (8 minutes) of data points. Then, the data is regressed to the BOLD signal to create a predicted signal, which becomes the BOLD model. Phase shifts are also determined based on the whitespace distance between the actual and predicted BOLD signal, then shifted and re-regressed accordingly.

RESULTS



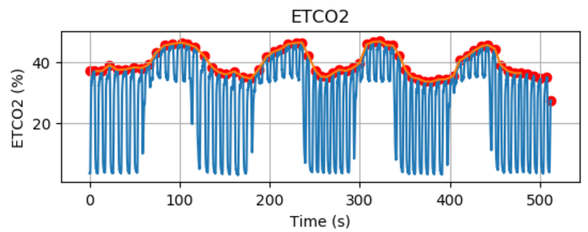
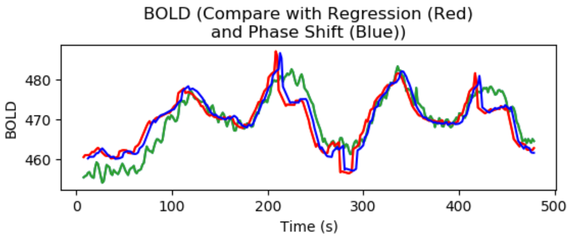
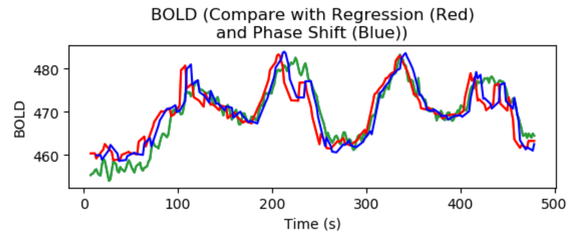


Chart of the End-Tidal Gas with Peaks Trendline



BOLD Model regressed additionally with O2 Respiratory Rate overlay with Real BOLD



BOLD Model regressed additionally with CO2 Respiratory Rate overlay with Real BOLD

		Count	Percentage
SH	Improved	19	86%
	Worsened	3	14%
WH	Improved	14	74%
	Worsened	5	26%

Result of Adding O2 Respiratory Rate as Regression Factor

		Count	Percentage
SH	Improved	16	73%
	Worsened	6	27%
WH	Improved	13	68%
	Worsened	6	32%

Result of Adding CO2 Respiratory Rate as Regression Factor

CONCLUSIONS

Regressing ETO2, ETCO2, and either the respiratory rate of O2 or CO2 results in better linear correlation for the most part. Some patients barely changed or had worse correlation. It is hard to determine that O2 is the best overall additional factor due to the small group considered for each niche.
Using both CO2 and O2, together, is not always best, since overfitting is possible.

ACKNOWLEDGEMENTS

Borzage, M. (2019). Personal Communication.
Chang C, Glover GH. Relationship between respiration, end-tidal CO2, and BOLD signals in resting-state fMRI. Neuroimage. 2009;47(4):1381–1393. doi:10.1016/j.neuroimage.2009.04.048.
John, R. E. (2003, August 01). End-Tidal Carbon Dioxide Monitoring.
Lecture Slides & Practical Data (2018 Course). (n.d.). Lecture, Boston.