Neural Spatial Alignment During Shared Intentionality Experiments

Kyle Bledsoe, Ridgeway High School, Memphis, TN, Dr. Mark H. Myers, and Dr. Robert Kozma,
Department of Mathematics, University of Memphis,

MEMPHIS CRESH
(COLLEGE RESEARCH EXPERIENCE FOR STUDENTS FROM HIGH SCHOOL)
WWW.MEMPHIS.EDU/CRESH

CLION
Center for Large-Scale Integrated Optimization & Networks

FedEx. INSTITUTE OF TECHNOLOGY UNIVERSITY OF MEMPHIS

Background

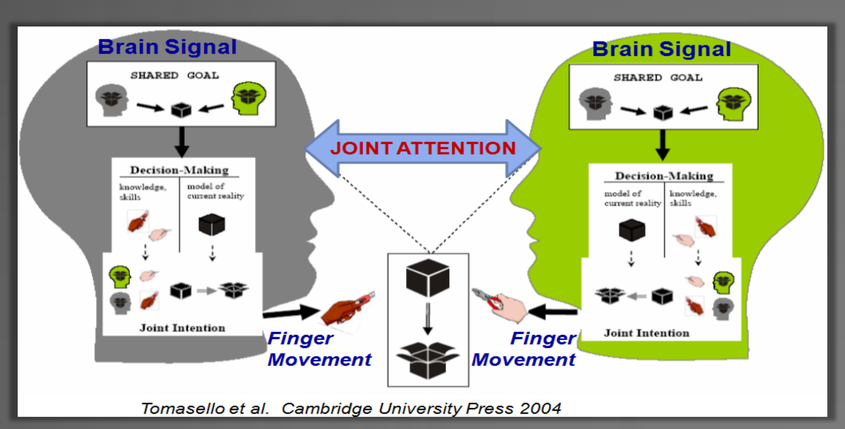
Abstract

- Studies in EEG analysis from human subjects have demonstrated that perceptual information can be captured while subjects were engaged in task oriented activities.
- Phase alignment occurs when individuals are engaged in cognitive activities. Phase alignment has been observed between two individuals engaged in joint activities.
- Our results suggest that the scalp EEG can yield information about the timing of episodically synchronized brain activity in higher cognitive function, so as to support mechanisms of brain–computer interfacing.

Shared Intention

We intend to J iff

1. (a)I intend to we *J* and (b) You intend that we *J*
2. I intended that "we *J*" in accordance with and because of 1a, and *meshing subplans* of 1a and 1b; You intend that "we *J*" in accordance with and because of 1(a), 1(b), and *meshing subplans* of 1(a) and 1(b)
3. Step 1 and step 2 are common knowledge between us.



Tomasello et al. Cambridge University Press 2004

Joint Attention and Social Coordination

- In terms of inter personal coordination we consider human actions in social context. Synchrony coordination dynamics is adopted from bimanual rhythmic coordination - dynamical process, the HKB model (Haken, Kelso, & Bunz, 1985).
- Thus far there is some experimental evidence that supports the idea that the sequence formation of frames begins with the abrupt resetting of phase values on every channel, followed by re-synchronization and spatial pattern stabilization within the frame.

Fast Fourier Transformations

The Fast Fourier Transform was applied to the filtered signal in order to obtain the real and imaginary parts of the signal. Phase angles, in radians, for each element of complex array Z were calculated using the formulae:

$$arctan\left(\frac{imag(z)}{real(z)}\right)$$

where z is a complex array. The angles lie between $\pm\pi$. The phase between two channels was unwrapped across all channels to make it a "continuous" function.

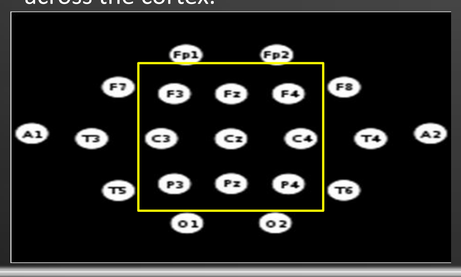
Procedure

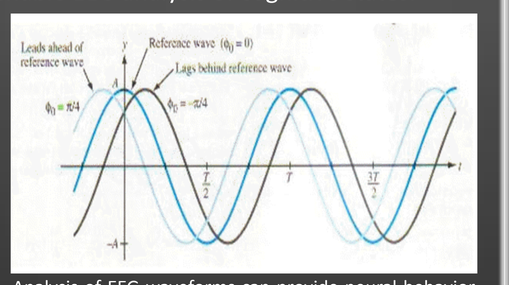
Fig. 1. Evoked-related potentials (ERP) were captured via an EEG cap using nine electrodes. Additional sensors were utilized to capture finger movement via a bend sensor. Grounding and negative connections were facilitated via ear lobe connections. Positive, negative and grounding connections were inserted into an impedance sensor which connected to the Flex/Pro-comp Infinity™ amplifier. EEG data capture was accomplished through BioInfinity™ where data was exported in order to enable EEG analysis of cognitive states.

Continuous records were taken, with the times of various sorts of visual stimuli via a protocol consisting of the following:

1) 1-40s: Rest period
2) 40-50s: Eyes open+ finger movement
3) 50-60s: Rest period
4) 60-70s: Eyes wandering+ finger movement
5) 70-80s: Rest period
6) 80-90s: Eyes closed + finger movement
7) 90-100s: Rest period

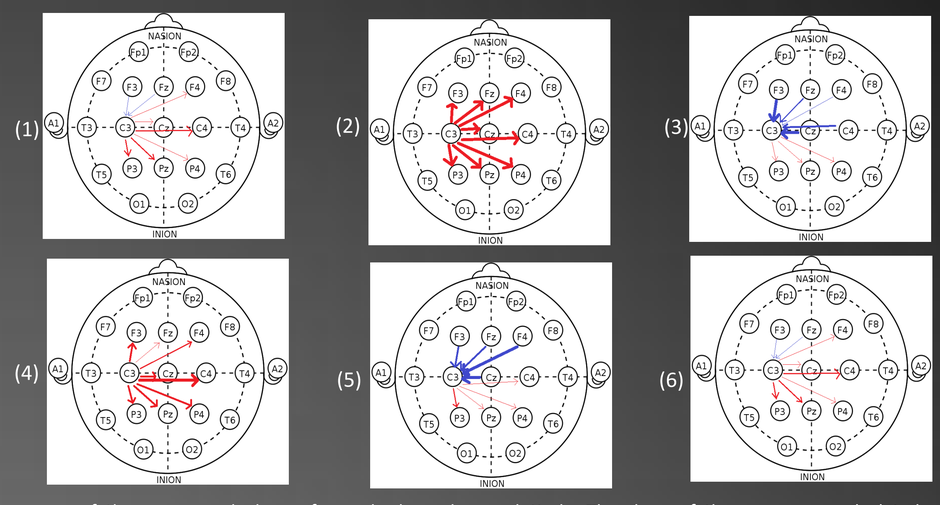
The 10-20 EEG system is utilized in this experiment. We utilized the three by three matrix outlined in the yellow box to illustrate phase movement across the cortex.





Analysis of EEG waveforms can provide neural behavior as it relates to stimulation, i.e. phase leads/lags. As an example, the wave with $\Phi_0 = \pi/4$ is said to lead the wave with $\Phi_0 = 0$ by a phase lead of $\pi/4$; similarly the wave with $\Phi_0 = -\pi/4$ is said to lag the wave with $\Phi_0 = 0$ by a phase lead of $\pi/4$.

Results



The mean of the unwrapped phases for each channel was plotted. The slope of the mean was calculated per reference channel. The slope values were plotted on a two-dimensional display of the 10-20 EEG system in order to determine phase directionality in reference to each channel. Directionality is determined by the slope of the mean of the unwrapped phases, whereas the sign of the slope indicates whether the phases lag or lead from the reference electrode. The thickness of the arrow is determined by the magnitude of the slope (i.e. small magnitudes are given by thin arrows, whereas large magnitudes are signified by thick arrows). The diagram above shows phase directionality for the protocol described previously except the last rest state. See 'Procedure' for protocol time sequence.

A_G	1	2	3	4	5	6	7
2) 1	LG	LG					
3) 1	LG						
5) 1	LG	LG					
A_B	1	2	3	4	5	6	7
1) 1			LG				
3) 1						LG/LD	
4) 1	LG						
6) 1	LG						
8) 1					LG/LD		
K_L	1	2	3	4	5	6	7
5) 1	LG						
10) 1			LD/LG	LD/LG			
C_D	1	2	3	4	5	6	7
1) 1	LG/LD						
2) 1	LG				LG		
3) 1	LG/LD						LG/LD
4) 1	LG	LG			LG		
6) 1	LG						
8) 1	LG						
9) 1	LG						
10) 1	LG			LG			
E_F	1	2	3	4	5	6	7
1) 1				LG/LD			
5) 1	LG						
7) 1	LG		LG				
8) 1	LG						
9) 1	LG						
11) 1				LG			
G_H	1	2	3	4	5	6	7
7) 1		LG					
8) 1		LG					
9) 1	LG				LG		
10) 1		LG			LG		
I_D	1	2	3	4	5	6	7
1) 1	LG						
4) 1	LG	LG					
10) 1	LG				LG		
F_J	1	2	3	4	5	6	7
1) 1	LG		LG	LG			
2) 1	LG						
4) 1		LG					
6) 1	LG						
7) 1							LG/LD
9) 1						LG	

Results

Results of quantitative EEG measurement of the phase of the unwrapped channels have shown synchronized activity occurring more often during (2) Eyes open+ finger movement (40-50s) while both participants were engaged in similar behavior. The most phase lags/phase leads occurred during the initial 40 seconds of the experiment. For each set of participants, ten recordings were performed. It has been observed that there is more instances of phase lags vs. phase leads. Eight out of eight recordings demonstrated phase synchronization between participants.

References

[1] Pockett S, Bold G E J, Freeman W J .EEG synchrony during aperceptual-cognitive task: Wide spread phase synchrony at all frequencies. Clinical Neurophysiology 2009;120(4):695–708.

[2] Poolman P, Frank R M, Luu P, Pederson S M, Tucker D M. A single-trial analytic frame-work for EEG analysis and its application to target detection and classification. NeuroImage 2008;42(2):787–98.

[3] Freeman W J, Holmes MD, West G A, Vanhatalo S. Dynamics of human neocortex that optimizes its stability and flexibility. International Journal of IntelligentSystems 2006a;21(9):881–901.

[4] Freeman W J, Holmes M D, West G A, Vanhatalo S. Fine spatiotemporal structure of phase in human intracranial EEG. Clinical Neurophysiology 2006b;117(6):1228–43.

IRB protocol : 2220, University of Memphis

Acknowledgments

Dr. Firouzeh Sabri – University of Memphis, Physics. CRESH Director
Natavia Mitchell – Harding Academy, Memphis, TN, CRESH researcher
Akshay Padmanabha – Houston High School, Memphis, TN, assistant researcher
Charlotte Augusta Joure – University of Memphis, assistant researcher
Aaron Canales– Ridgeway High School, Memphis, TN, CRESH researcher alumni
Carley Johnston– St. Benedict at Auburndale High School, Memphis, TN, CRESH researcher alumni