Examining Neuronal Function during the Completion of Established Graphical Tasks

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Introduction

Recent focus on research into visual cultures (Heywood and Sandywell 2012, Elkins 2008) has highlighted the need to develop contemporary graphical competencies. This research focused on what Fish (1990) describes as 'the visualizing instinct', an area of study that has become more pertinent given the increased impact of the visual on post-modern society (Mirzoeff 1999). Graphicacy which is described as the ability to acquire and communicate meaning from visual forms (Seery et al. 2012) is seen as a requisite skill for all similar to numeracy and literacy. Graphical education in Ireland aims to develop these visual skills however research by Delahunty et al. (2012a) has highlighted possible incongruity between the methods employed to solve applied graphical problems and the aims of graphical education.

This research highlighted worrying approaches taken by students in solving prescribed graphical problems. Students were tasked with applying previously learned graphical knowledge, based on tangential circles, to an alternative applied problem. Visual protocol analysis was implemented in the study and analysis of results revealed that the approach observed tended to reflect a mathematical, sequential and even a formulaic approach. These findings suggested a rehearsed rote strategy as opposed to a visuospatial understanding of the prescribed problem. This becomes a significant issue when compared to the overall intent and philosophy of graphical education in Ireland, which aims to develop creative, visual approaches to solving abstract problems.

The paper sets out to explore the applicability of a research tool, supported by literature from the field of cognitive neuroscience, in order to provide a more extensive analysis of underlying graphical cognition as part of future work. The purpose of this paper is to present a ‘proof of concept’ for implementing an investigative research tool typically utilized within cognitive neuroscience.

Research Tool

The method that is viewed as most applicable to educational research is the electroencephalogram (EEG) approach due to its non-invasive nature (Wilson and Fisher 1995, Neill 2006). EEG captures evidence of electrical currents produced by the cerebral cortex through a number of different electrodes located on the scalp (Rowan and Tolunsky 2003, Ward 2010). Electroencephalography (EEG) is a medical tool used to serve a number of diagnostic functions, one of which is to detect epilepsy and other neurological disorders (Rowan and Tolunsky 2003). As well as established applications in medicine, EEG technology is increasingly being applied to cognitive studies such as the assessment of problem solving behavior and creative thinking (Molle et al. 1999). For the purpose of clarity, this analysis of literature will focus on two aspects of cognition within graphical education, spatial cognition and visualization.

Spatial Cognition

There has been a significant amount of research conducted on cortical activation that occurs during spatial cognition, using EEG technology, and particularly during mental rotation (Gill et al. 1998, Rescher and Rapplesberger 1999, Osaka 1984). Many of the research studies which focus on spatial cognition in this area look for the reduction in power of alpha waves, activity between 8 and 13 Hz, which generally indicates increased cognitive activity in a specific area (Nunez 1995). Gill et al. (1998) conducted a study, using an eight channel (electrode placement) format, to determine the dominant areas of activity during a mental rotation task. Their findings indicated a significant decrease in alpha activity in the right frontal lobe and left parietal region during the mental rotation process. Osaka (1984) conducted a larger study using EEG technology to examine neuronal function during arithmetic and visuospatial tasks. This study involved placing electrodes according to the international 10-20 system, which is now standard practice in EEG research, for electrode placement (See figure 1). Findings from this study indicated increased activity in frontal regions in left and right hemispheres for arithmetic and visuospatial tasks respectively (Osaka 1984).

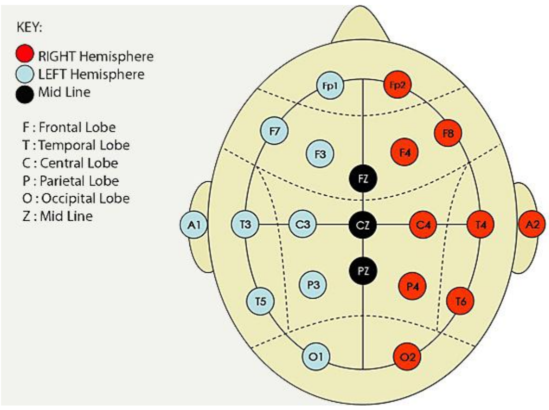

Figure 1: International 10-20 System for Electrode Placement

Previous EEG studies have generally established increased activity in the right parietal area of the cerebral cortex for visuospatial tasks and in particular mental rotations (Rescher and Rapplesberger 1999, Roberts and Bell 2003).

Visualization

Previous research has shown that the building of visual-mental images shares many of the same neural mechanisms underlying visual perception of the physical world (Humphreys and Bruce 1989, Kosslyn 1973). A research study conducted by Marks and Isaac (1995) implemented EEG technology based on 10-20 system placement of electrodes (fig 1) to record neuronal activity while participants built visual mental images from verbal descriptions. Their findings were based on analysis of activity from four quadrants of the cerebral cortex (left and right posterior and anterior sites) and highlighted significant changes in alpha power at the left posterior site during visualization. This aligns with research by Farah (1984) who also found increased activity in the left hemisphere during visualization tasks.

Discussion

There is significant evidence available in the cognitive neuroscience literature (Molle et al. 1999, Nunez 1995, Rescher and Rapplesberger 1999) to highlight the applicability of this particular research tool to analyze underlying cognitive processes. There are multiple perspectives within the, neuropsychological literature, regarding functional localization in the brain, as many areas of neurons are involved in specific tasks such as the components of language comprehension. Graphical cognition comprises of a wide variety of components which include among others; visualization and spatial reasoning (Delahunty et al. 2012b) . Although it is not possible to specify an area of the cerebral cortex involved in all of graphical cognition certain aspects can be localized such as mentally rotating an object (Neill 2006). Identifying these neuronal areas active during specific intellectual graphical tasks could form a robust database used to support the examination of possible misconceptions in graphical learning within an Irish context as part of future work.

References

Delahunty, T., Seery, N. and Lynch, R. (2012a) 'An Evaluation of the Assessment of Graphical Education at Junior Cycle in the Irish System', *Design and Technology Education: An International Journal,* 17(2), 9-20.

Delahunty, T., Seery, N. and Lynch, R. (2012b) 'The growing necessity for graphical competency', in *PATT 26*, Stockholm, June 26-30,

Elkins, J. (2008) *Visual Literacy,* London: Routledge.

Farah, M. J. (1984) 'The neurological basis of mental imagery: A componential analysis', *Cognition,* 18, 245-272.

Gill, H. S., O'Boyle, M. W. and Hathaway, J. (1998) 'Cortical Distribution of EEG Activity for Component Processes During Mental Rotation', *Cortex,* 34, 707-718.

Heywood, I. and Sandywell, B. (2012) *The Handbook of Visual Culture,* London: Berg.

Humphreys, G. W. and Bruce, V. (1989) *Visual Cognition: Computational, Experimental and Neuropsychological Perspectives,* London: Lawrence Erlbaum Associates Ltd.

Kosslyn, S. M. (1973) 'Scanning Visual Images: Some structural implications', *Perception and Psychophysics,* 14, 90-94.

Marks, D. F. and Isaac, A. R. (1995) 'Topographical distribution of EEG activity accompanying visual and motor imagery in vivid and non-vivid imagers', *British Journal of Psychology,* 86, 271-282.

Mirzoeff, N. (1999) *An Introduction to Visual Culture,* London: Routledge.

Molle, M., Marshall, L., Wolf, B., Fehm, H. L. and Born, J. (1999) 'EEG complexity and performance measures of creative thinking', *Psychophysiology,* 36, 95-104.

Neill, M. G. (2006) *Human Neuropsychology,* 2nd ed., Harlow: Prentice Hall.

Nunez, P. L. (1995) *Neocortical Dynamics and Human EEG Rhythms,* New York: Oxford University Press.

Osaka, M. (1984) 'Peak Alpha Frequency of EEG during a Mental Task: Task Difficulty and Hemispheric Differences', *Psychophysiology,* 21(1), 101-105.

Rescher, B. and Rapplesberger, P. (1999) 'Gender dependent EEG-changes during a mental rotation task', *International Journal of Psychophysiology,* 33, 209-222.

Roberts, J. E. and Bell, M. A. (2003) 'Two- and three-dimensional mental rotation tasks lead to different parietal laterality for men and women', *International Journal of Psychophysiology,* 50, 235-246.

Rowan, A. J. and Tolunsky, E. (2003) *Primer of EEG,* Pennsylvania: Butterworth Heinemann.

Seery, N., Lane, D. and Canty, D. (2012) 'A Comparative Study Exploring the Impact of Assessment Criteria on Eliciting Graphical Capability', in *ASEE Annual Conference and Exposition*, San Antonio, Texas, June 10-13,

Ward, J. (2010) *The Student's Guide to Cognitive Neuroscience,* 2nd ed., East Sussex: Psychology Press.

Wilson, G. F. and Fisher, F. (1995) 'Cognitive task classification based upon topographic EEG data', *Biological Psychology,* 40, 239-250.