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An investigation into a new aesthetics of scientific data visualisation

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Introduction

Visualisation makes it possible to identify patterns in data to enhance understanding. This can be classified into types such as data visualisation, information visualisation, scientific visualisation and information graphics. Visualisation in this paper is defined as data visualisation, which includes information visualisation and scientific visualisation, as proposed by Post, Nielson and Bonneau (2003). This paper therefore seeks to investigate the role of visualisation across a range of the contexts.

Traditional visualisation, according to data structures, types and size, focuses on meaning for understanding as an efficient means of communication. It enables users to communicate data accurately and quickly. However, research has increasingly argued that an aesthetic consideration of visualisation can add value to the perceptive aspect and improve the accessibility of communication (Cawthon & Moere 2007; Norman 2004; Tractinsky 2004). For example, a beautiful visualisation can attract users to engage more deeply in decoding information from data.

This paper therefore develops a visualisation conceptual framework that proposes a relationship along a continuum between communication and aesthetic experience. The framework demonstrates the relationship between the characteristics of communication and aesthetics, the typical forms they take, and how they are perceived by an audience. Based on this framework, a new aesthetic approach to visualisation that integrates the aesthetics of traditional Chinese *yijing* aesthetic is proposed.

Traditional visualisation

The main purpose of traditional visualisation is to clearly communicate information effectively and efficiently through graphics (Friedman 2008; Wijk 2006). Visualisation aims to apply visual forms to display facts or patterns hidden inside abstract data. Those facts or patterns may include natural phenomena in scientific visualisation, for example, weather models or the structure of the human body. This process of visualisation emphasises the functional and usability requirements for easy comprehension (Gaviria 2008).

Traditional forms of visualisation used in pure communication include diagrams, charts, graphs, waveforms and 3D animation. All forms share similar characteristics: recognition, readability and meaning. Those characteristics of form are moderated by the key criteria for effectiveness related to accuracy of communication and efficiency in terms of the speed at which meaning is extracted. In this process, users may be able to quickly and accurately recognise, read and understand the meaning of visualized data through the organized form. Figure 1 is a typical example of this, demonstrating how traditional visualisation can be used to enhance communication. This represents data in the form of a graph displaying Napoleon's march to Moscow in 1812-1813. It uses X and Y coordinates to represent the kilometers (KM) marched and the number of survivors. The graph displays the information in a manner that emphasises the massive loss of life in a clear and unambiguous way showing how the number of survivors halved every 360KM (Mernagh n.d.).

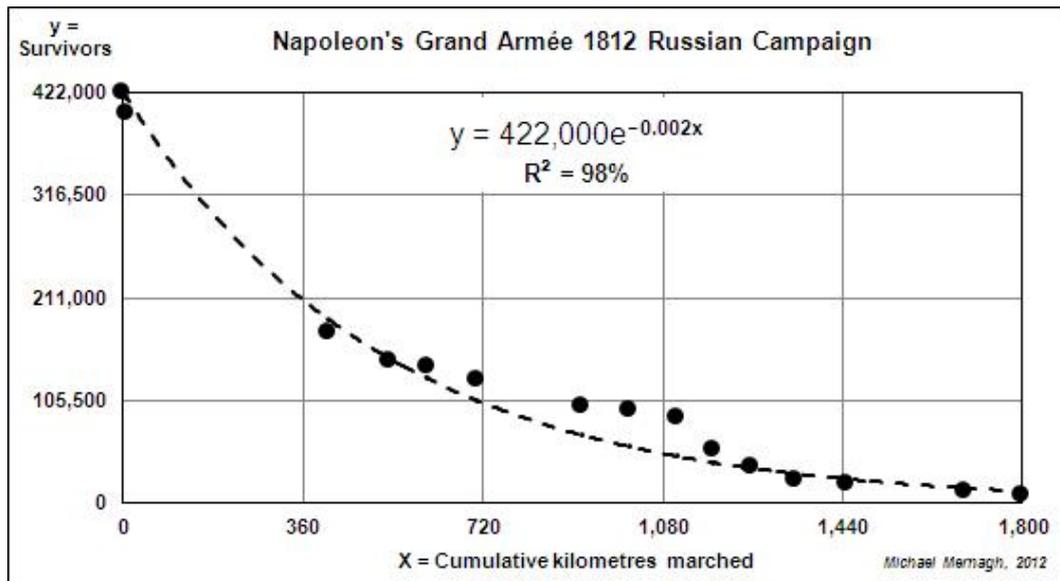


Figure 1: The Mathematical model and graph of Napoleon's March to Moscow - Michael Mernagh (Mernagh n.d.)

Nielson, Shriver and Rosenblum (1990) describe the value of graphical display as a basis of scientific visualisation serving as a tool to enhance the interpretation of scientific data (Cunningham, Brown & McGrath 1990).

EEG data visualisation (Figure 2) is one example of scientific data visualisation, which is typically communicated using a waveform. Figure 2 details the shape of waveform with frequencies and bands showing electrical activity over time. As such, it is more readily understood compared to reading directly from raw numerical data (Lang 2008). This highlights the importance of recognition and readability in effective communication through the process of data organisation.

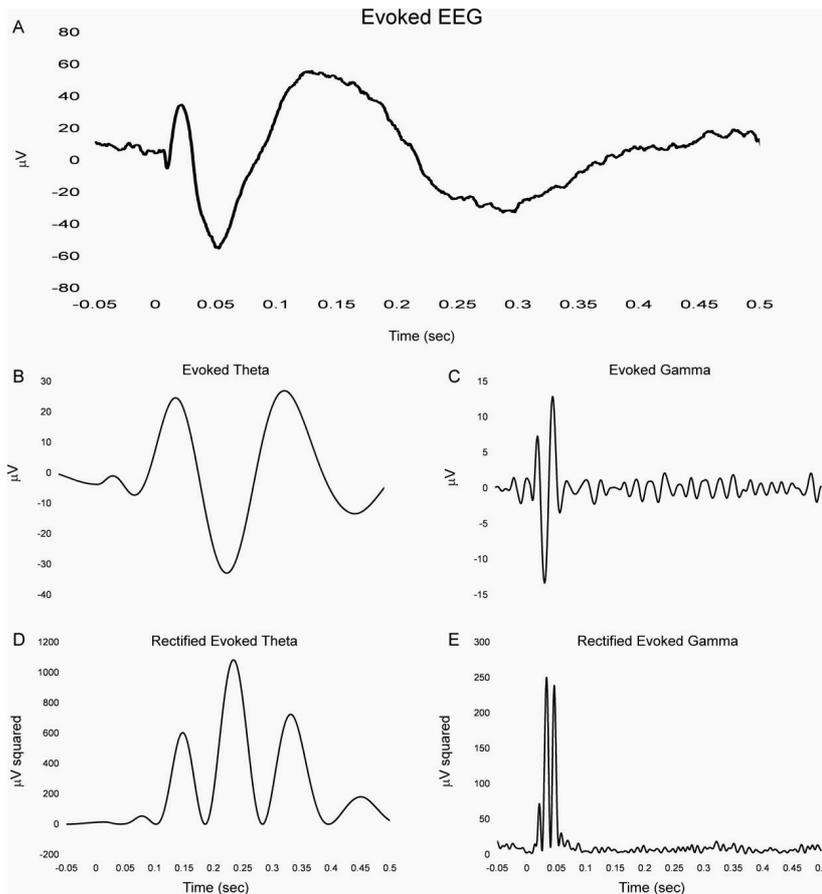


Figure 2: The diagram shows a pattern of wake-to-sleep in which the waveform presents frequencies from wake to stage 1 (Carskadon & Dement 2011)

Aesthetics and visualisation

Organised data can do much to aid communication but by its very focus on efficiency and accuracy, tends to ignore the role of viewers beyond their physiological and cognitive capacity to understand content. Aesthetics introduces concepts of sensation, feeling, or perception (Cooper 1997). Immanuel Kant suggests that aesthetic experience is a subjective judgment on whether an object is beautiful, which depends on the viewer's subjective experience and not the object itself (Crawford 1974). The concept of aesthetics has been long known to have a relationship with a human's perceptual experience of objects, in which pleasure or displeasure might be felt in response to interaction with an object. These, therefore embrace less tangible concepts such as beauty, elegance and sublimity (Janaway 2006).

The concept of aesthetics has been gaining attention as a means to promote a positive effect in viewers that enhances experience and amplifies the ability to

interpret information. This has been recognised within the discipline of design, where research has demonstrated that visual attractiveness is a major factor in how people engage with content (Gaviria 2008). If visualisation has a high aesthetic value, users may be encouraged to engage in a deeper level of interpretation (Lang 2008). For example, Figure 3, designed by Charles Joseph Minard, portrays the same data as that of Figure 1, specifically Napoleon’s March to and from Moscow. The difference is that Minard’s representation of Napoleon’s campaigns has an aesthetic quality incorporating balance, elegant handwriting and colour coherence. The two simple bands in the middle of the map represent the size of the army. The shape of the two bands adds visual impact by emphasising the massive reduction in the size of the army in comparison of that at the beginning of the war. In a sense, this representation conforms to Tufte’s “minimalist” concept of aesthetic theory in the design of visualisation. Visual elements that are unnecessary, useless and non-informative to information communication should be avoided (Tufte 2001). However, the contrast between the width of the bands highlights the massive devastation of the army and promotes a stronger emotional engagement in the subject matter.

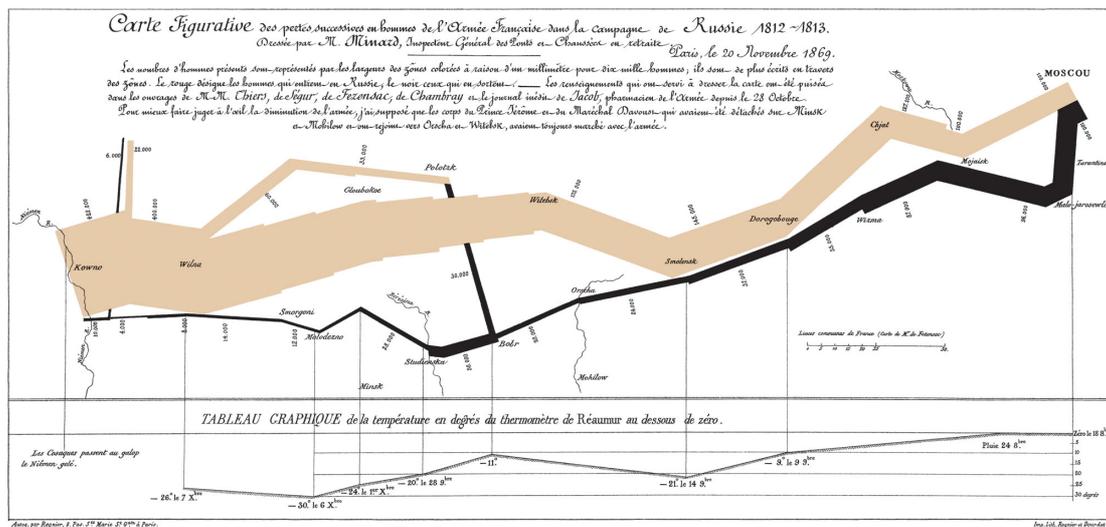


Figure 3: Charles Joseph Minard’s Napoleon’s Campaigns (Tufte 2001, p. 176)

Applying aesthetics to visualisation has the ability, therefore, to invoke a sensation on two levels. Firstly it can promote the traditional focus of visualisation on accuracy, efficiency and effectiveness, which is valuable in scientific data visualisation (Card, Mackinlay & Shneiderman 1999). At the same time, it can be used to prompt a subjective experience in the form of an emotional response. This need not be pathos.

Norman (2004) suggests that eliciting positive emotions can also enhance learning and creative thought.

Tateosian, Healey and Enns (2007) concur with this, emphasising a role for creativity in aesthetic visualisation to engage users' attention in reaction to a stimulus. They argue that artistic techniques such as abstract representation and brush strokes techniques have been used to enhance aesthetic perception of visualisation through non photo-realistic forms.

An aesthetic approach to visualisation is therefore quite different from traditional methods. The latter emphasises the perception of communication with speed and accuracy. The first emphasises the perception of experience (Card et al. 1999).

This paper suggests that traditional Chinese *yijing* aesthetic is one form that can be used to demonstrate this, enhancing the perception of experience by fusing subject and object and promoting pleasure and engagement.

Chinese *yijing* aesthetic

Yijing is a traditional Chinese aesthetic notion that refers to 'an exceptional state of mind' or 'an artistic conception' (Li 2009). The concept of *yijing* emphasizes the expression of an artist's inner emotion through representation of their subjective experience to the natural world (Zhang 2005). Li (2009) contends that *yijing* is similar to the Western concept of "empathy" that involves "the melding of the appreciating (or creating) self with the appreciated (or created) object" (Li 2009, p. 152). The phenomenon of "empathy" in Chinese aesthetics is called "*qing jing jiao rong*" [情景交融], which is the fusion of feeling and scene, or the unity of self and object (Li 2009; Zhang 2005).

The *yijing* aesthetic has been applied to several artistic applications: literature, poetry, language, visual art and music (Liao 2011). In traditional Chinese painting, *yijing* constitutes criteria for the judgment of the value of the artworks (Liu & Bralewskiz 2010). For example, a 'good' traditional Chinese painting usually possesses the *yijing* aesthetic quality, which is linking to a perfect melding of poem and image (Zong 2005). *Yijing*, therefore, can be considered as a means by which aesthetic media such as painting can be integrated into visualisation to promote a positive subjective response aligned with its inherent values.

Proposed conceptual framework

The conceptual framework in Figure 4 displays the relationship between the communication-based and aesthetic approaches to data visualisation. It is argued that this framework can be used to inform design principles for data visualisation.

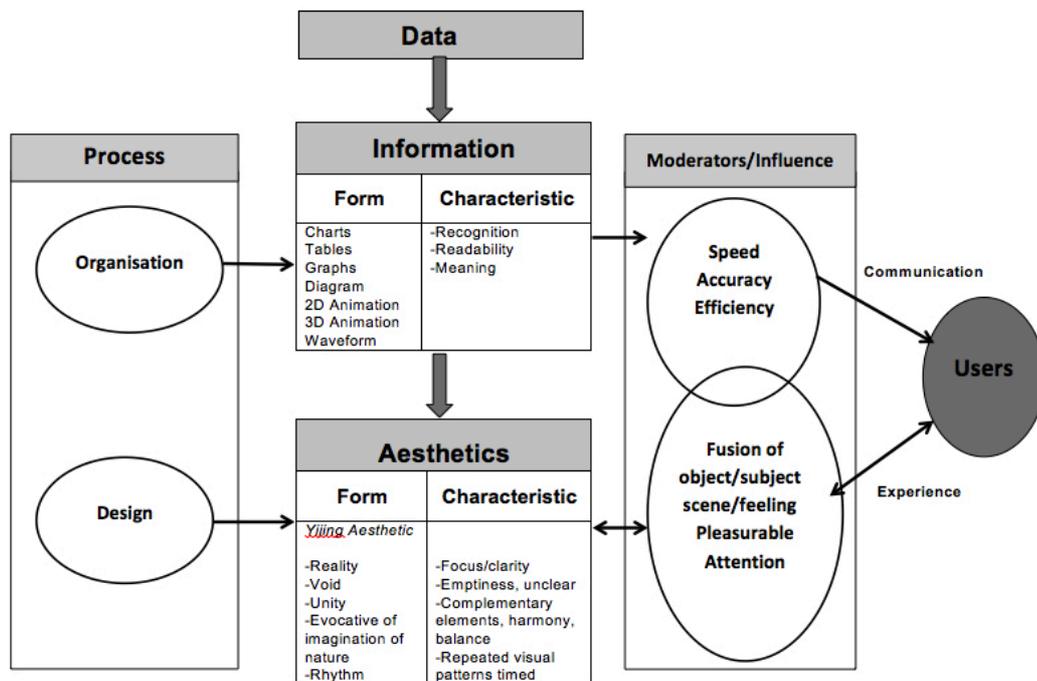


Figure 4: The proposed visualisation conceptual framework

It is an axiomatic approach in that it represents a vertical data continuum, from data, through information, to aesthetics. Each is a higher level of processing undertaken, initially through organisation, through to design. As the complexity of the data is reduced, the emotional experience of the user is enhanced, with the horizontal axis delineating the processes inherent in developing the two forms of representation on the left, with the user on the right. The interplay between the user and the representation is portrayed as factors that moderate or influence perceptions. While communication is primarily influenced by the need for speed, accuracy and efficiency, the user's experience is amplified by engaging with a more aesthetic representation. It is fair to say, therefore, that the quality of the experience varies due to the nature of representation. Clear information promotes understanding while aesthetics promote pleasure and engagement. Inevitably some relationship still exists between the need for communication and emotional engagement, though it would be

expected that the objective communication elements may become increasingly ambiguous as a subjective emotional response is elicited from the user. Key to this framework, too, is the differentiation between pure organisation and design as the main processes in generating the representation, with the latter process integrating aesthetic characteristics. Both information and aesthetics are defined by recognisable characteristics, though the forms may vary. Some information is best organised in tables, for example, while EEG data is typically represented as waveform. In this framework, the *yijing* aesthetic achieves the specified characteristics of unity, harmony and so on through specific forms of reality, void and rhythm, unity, and the evocation of imagination of nature. Reality can be understood as tangible objects, which are represented as a realistic form with a focus on clarity. These 'real' objects constitute the most important parts in an image in terms of information. Void can be understood as emptiness or unclear objects, considered as the less important parts in an image. Void and reality have a complementary existence. This balance generates a visual rhythm that brings emotional harmony between subjectivity and objectivity, and evokes imagination.

Design of aesthetic visualisation with the *yijing* aesthetic

As an instantiation of the model proposed in Figure 4, a design has been undertaken that investigates the relationship between communication-focused waveforms and experience-focused *yijing* aesthetic. The study uses sleep EEG data as source for visualisation design. Seminal to human experience, Parman (1991) indicates that dreaming has many different connotations, such as divinatory, deceitful, preposterous, mad or delightful. Sleep is also a somewhat mysterious phenomenon, which aligns well with the ambiguity of aesthetics and is also often associated with creativity. As such, it forms an ideal medium for exploring aesthetics, particularly given the strong historical fascination with dreams or dream imagery within the Art disciplines (Shapiro, Sherman & Kryger 2013).

The source of the study

The sleep EEG data used in this study has been sourced from the PhysioBank (Goldberger et al. 2000) with permission from Dr. Bob Kemp in The University Medical Centre, Leiden, The Netherlands. For the convenience of this study, selected sleep EEG data segments has been pre-captured and truncated in parts to ensure an adequate variety of sleep patterns. EDFbrowser software was selected for the study as it promotes ease of accessing and editing the data (Figure 5).

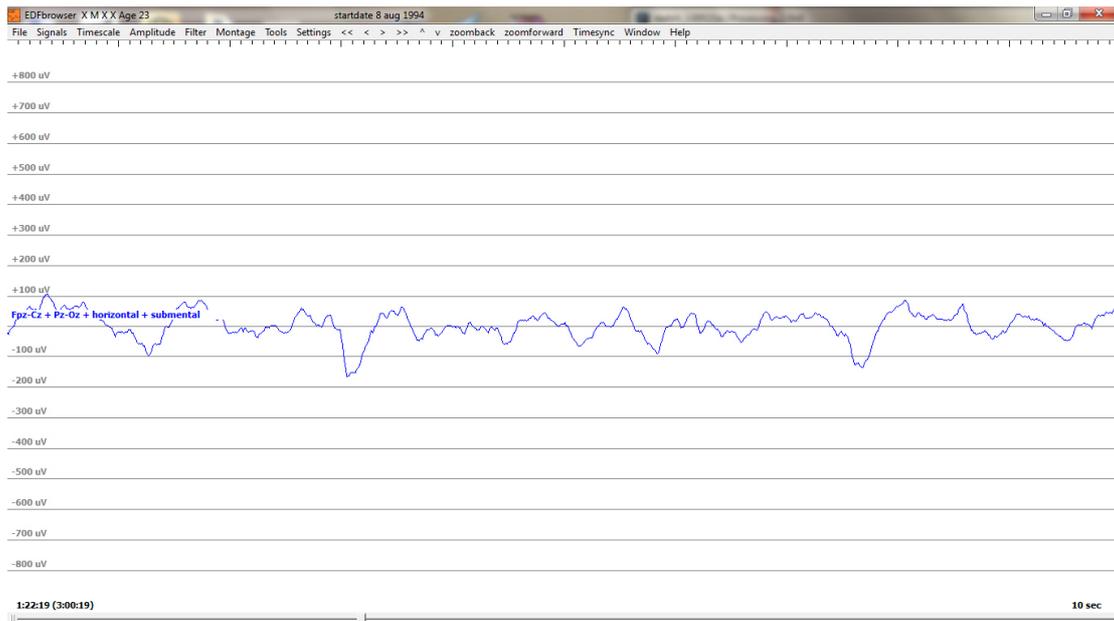


Figure 5: The screen shot of sleep EEG data visualisation as waveform by EDFbrowser software

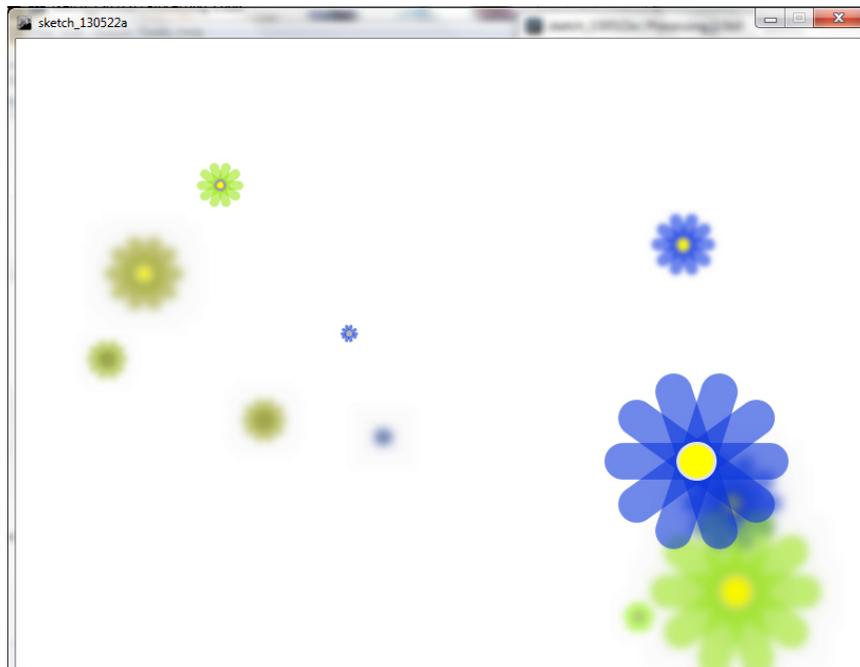
Approach to design

With *yijing*'s focus on nature as reality, the image of the flower has been selected as the representation of sleep EEG data. The flower is a particularly resonant symbol and one that has been used in a wide range of creative forms. For example William Wordsworth's *Daffodils* focuses on that flower to symbolise the author's poetic self in terms of his connection with the natural landscape within a Romantic paradigm (*Analysis of the Poem "Daffodils" by William Wordsworth 2011*). As such, it aligns with *yijing* while embracing universal quality of life, beauty and self.

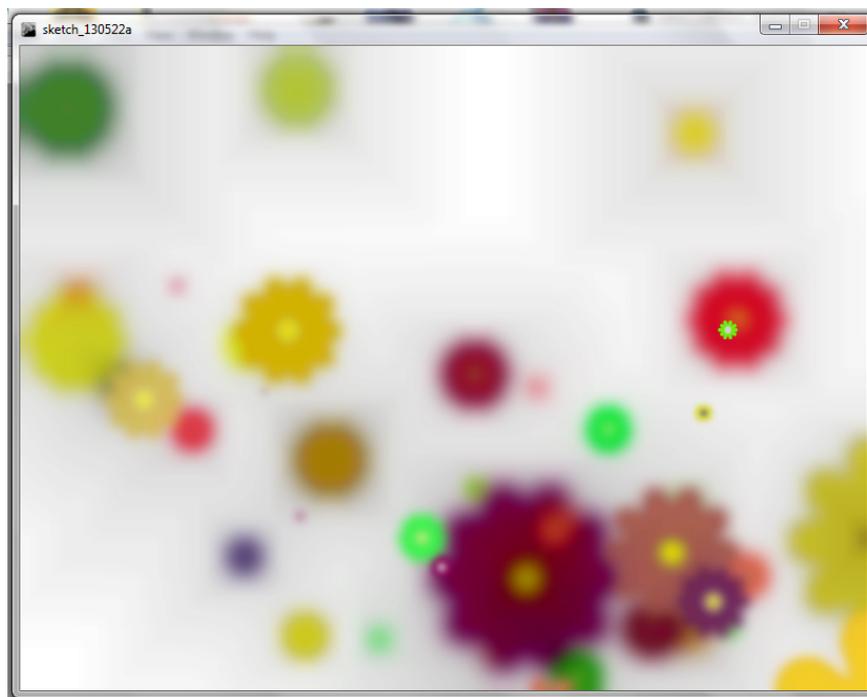
Based on the framework, we designed a visual representation of sleep EEG data through animation. Each flower in the animation is an instance of data, with the size of flower indicative of the number. The larger the value of each piece of EEG data, the larger the flower that appears on screen. The position of flowers is randomly represented and the flowers gradually fade into the space. This randomness is aligned with the unconscious ideations that emerge in dreams during sleep.

Figure 6 shows how the flower images act within the notions of reality and void, with the reality of the flowers, contrasting with the void of the initial white space. As the data appears in the animation (Figure 6A), the flowers gradually blur and fade to provide a space for the imagination (Figure 6B). The repetition of this over time

creates a complementary rhythm of visual patterns, promoting a harmony and visual melody of colour and form.



(A)



(B)

Figure 6: The screen shots of sleep EEG data visualisation with the *yijing* aesthetic

This design is an experimental work that specifically seeks to explore the evocation of the imagination through applying aesthetics to data visualisation. As such, the

focus is not primarily on efficiency of communication. Rather, the inherent ambiguity of the animation is embraced. Nevertheless, it is an accurate depiction of the data, which allows for recognition of the concept of sleep within a broader aesthetic interpretation. It is proposed that any deficit in accuracy and efficiency of communication is addressed through enhanced perception and sensation of experience.

Conclusion

The study explores how data, information and aesthetics operate as a communication continuum. It has been shown that visualisation can enhance communication through organisation with a focus on speed, efficiency and accuracy while current research has highlighted the role of aesthetics in integrating perception and sensation to create an emotional relationship that engages deeply with users.

The conceptual framework described here promotes a new aesthetic approach to data visualisation that has the potential to enhance the end user experience. By applying the form of the traditional Chinese *yijing* aesthetic to scientific visualisation using sleep EEG data, a creative work has been developed that integrates traditional Chinese philosophy with a focus on void and reality, unity, rhythm and the evocation of imagination in terms of natural themes. The product will allow the forms and characteristics of information and aesthetics to be interrogated in a manner that identifies the key organisational and design principles required not just to communicate concepts but to create a heightened experience for users when they integrated into data visualisation.

References

- Analysis of the Poem "Daffodils" by William Wordsworth* 2011, viewed 12 August 2013, <http://www.studymode.com/essays/Analysis-Of-The-Poem-Daffodils-By-872022.html>
- CARD, SK, MACKINLAY, JD & SHNEIDERMAN, B 1999, *Readings in Information Visualization: using vision to think*, Academic Press, San Francisco, CA, USA.
- CARSKADON, MA, DEMENT, WC 2011, 'Normal Human Sleep: An Overview', in MH Kryger, T Roth & WC Dement (eds), *Principles and practice of sleep medicine, 5th edition*, Elsevier Saunders, Philadelphia, PA.
- CAWTHON, N, & MOERE, AV 2007, 'Qualities of Perceived Aesthetic in Data Visualization', Paper presented at the Conference on Designing for User eXperiences (DUX'07), Chicago, Illinois, viewed 27 November 2012.
- COOPER, DE 1997, 'Introduction' in DE Cooper (eds), *Aesthetics: the classic readings*, Blackwell Publishers Ltd, Oxford, UK.
- COX, D 2006, 'Metaphoric mappings: the art of visualization' in P Fisher (eds), *Aesthetics Computing*, The MIT Press, Cambridge, Massachusetts.
- CRAWFORD, DW 1974, *Kant's Aesthetic Theory*, The University of Wisconsin Press, Wisconsin.
- CUNNINGHAM, S, BROWN, JR, & MCGRATH, M 1990, 'Visualization in science and engineering education' in GM Neilson, BD Shriver & LJ Rosenblum (eds), *Visualization in Scientific Computing*, IEEE Computer Society Press, California.
- EHRlichman, RS, GANDAL, MJ, MAXWELL, CR, LAZAREWICZ, MT, FINKEL, LH, CONTRERAS, D, TURETSKY, BI & SIEGEL, SJ 2009, 'N-methyl-d-aspartic acid receptor antagonist-induced frequency oscillations in mice recreate pattern of electrophysiological deficits in schizophrenia', *Neuroscience*, vol. 158, no. 2, pp. 705-712.
- FRIEDMAN, V 2008, *Data visualization and infographics*. viewed 2 September 2013, <http://www.smashingmagazine.com/2008/01/14/monday-inspiration-data-visualization-and-infographics/>
- GAVIRIA, AR 2008, 'When is information visualization art? Determining the critical criteria', *Leonardo*, vol. 41, no. 5, pp. 479-482.
- GOLDBERGER, AL, AMARAL, LAN, GLASS, L, HAUSDORFF, JM, IVANOV, PCh, MARK, RG, MIETUS, JE, MOODY, GB, PENG, CK, STANLEY, HE, 'PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals', *Circulation* 101(23): e215-e220, 2000 (June 13).
- JANAWAY, C 2006, *Reading Aesthetics and Philosophy of Art - selected texts with interactive commentary*, Blackwell Publishing, MA, USA.

- LANG, A 2008, 'Aesthetics in information visualization', Paper presented at the media information advanced seminar on information visualization, viewed 19 April 2013.
- LI, Z 2009, *The Chinese Aesthetic Tradition*, University of Hawaii Press, Honolulu.
- LIAO, TL 2011, '意境－王梦鸥先生的语言美学', (*Yijing: Mr. Wang meng-ou's Aesthetic of Language*), *淡江中文学报*, vol. 25, no. 1, pp. 131-172.
- LIU, S & BRALEWSKIZ, TW 2010, *Chinese Landscape Inspiration – "Yijing"*, viewed 10 March 2013, <http://www.fem.uniag.sk/acta/download.php?id=1014>
- MERNAGH, M n.d., *Napoleon's Russian Campaign - 200 years on*, viewed 20 September 2013, <http://www.significancemagazine.org/details/webexclusive/2038005/Napoleons-Russian-Campaign---200-years-on.html>
- NIELSON, GM, Shriver, BD & Rosenblum, LJ (ed.) 1990, *Visualization in Scientific Computing*, IEEE Computer Society Press, California.
- NORMAN, DA 2004, *Emotional Design*, Basic Books, Cambridge, MA.
- PARMAN, S 1991, *Dream and culture: an anthropological study of the western intellectual tradition*, Praeger Publishers, New York.
- POST, FH, NIELSON, GM & BONNEAU, GP 2003, *Data visualization: the state of the art*, Springer Science+Business Media, New York.
- SHAPIRO, CM, SHERMAN, D & KRYGER, MH 2013, 'Sleep in art and literature', in MH Kryger (eds), *Atlas of clinical sleep medicine*, Elsevier Health Sciences, London.
- TATEOSIAN, LG, HEALEY, CG & ENNS, JT 2007, 'Engaging viewers through nonphotorealistic visualizations', Paper presented at the Proceedings of the 5th international symposium on Non-photorealistic animation and rendering, viewed 23 February 2013.
- TRACTINSKY, N 2004, 'Towards the study of aesthetics in information technology', Paper presented at the Twenty-Fifth International Conference on Information Systems, viewed 4 November 2012.
- TUFTE, ER 2001, *The visual display of quantitative information*, Graphics Press, Connecticut.
- WIJK, JJV 2006, 'Views on Visualization', *IEEE Transactions on Visualization and Computer Graphics*, vol. 12, no. 4, pp. 421-432.
- ZHANG, W 2005, '宗白华意境理论的继承和贡献', (The Inheritance and Contribution of Zong Huabai's *Yijing* Theory), viewed 16 April 2013, <http://www.kyoai.ac.jp/college/ronshuu/no-05/cho.pdf>

ZONG, B 2005, '美学散步', (A Walk with Aesthetics), Shanghai People's Press, Shanghai.