Background

Trained in experimental psychology at the University of London, and subsequently in psychophysics at the University of Leipzig, Germany and electrophysiology at the Max-Planck Institute for Cognitive Neuroscience, also in Leipzig, Mark A. Elliott is an experimental psychophysicist with backgrounds in general psychology and cognitive science. Mark's scholarly lineage originates in the German Gestalt Schools, reflecting scientific and philosophical interests in the structure of psychological function, expressed in terms of the 'microcognition' of that function. The term microcognition refers to the lowest level of cognitive operation, i.e. the level directly translatable into the operation of neural systems. Consequently and given the brain is a complex dynamical system, microcognition is specifically concerned with the dynamics of mechanisms – neural and psychophysical - that bring about psychological function. This is a relatively niche research area, novel and therefore innovative. Given parallel developments in neuroimaging and the psychiatric sciences (including genomics), alongside theoretical developments in the psychological sciences, this research area represents a major near-term future agenda because of it's parametric relationship to both psychological as well as neurophysiological datasets. Because of his focus on paradigm design, Dr. Elliott's work is currently one of the leading research agendas in this field.

Dr. Elliott's scientific work in this area is referenced in the internationally standard, undergraduate textbook: Gleitman, H., Gross, J., and Reisberg, D (2011) Psychology 8th Edition, WW Norton & Company, New York, NY. (p.196). In addition, his work is recognised as seminal, leading to his 2005 election to the post of President of the International Society for Psychophysics. In a similar vein, Dr. Elliott was elected by unanimous vote by Ful Professors in the Faculty of Design to the post of Full Professor in the Faculty of Design at Kyushu University, Fukuoka, Japan. Kyushu University is currently ranked 128 worldwide and 32 in Asia (2017-18 QS rankings).

Dr. Elliott was a founding member of the Neurosciences Cluster and formerly Chair of the Applied Clinical Neurosciences Subgroup of the National Centre for Biomedical Engineering Sciences (2006 - 2010). In December 2012, the Neurosciences Cluster was recognised as a Centre of Excellence in Neurodegeneration by the international COEN initiative (http://www.coen.org/home.html). Otherwise, Dr. Elliott has sat on various national and international committees concerned with academic and scientific development, including committee roles for the European Union.

Dr. Elliott's work has featured in a number of research agendas: clinical research has included investigations of schizophrenia, autism-spectrum-disorder, central-auditory-processing disorder, specific-reading and language-impaired children as well as stroke-lesioned patients. Basic research has focused on examining the cognitive microstructural dynamics of visual and auditory representation using experimental methods alongside some EEG and neuroimaging. This interest has evolved into studies of the dynamics inherent in art and music, as well as investigations of microstructural dynamics in mechanisms coding art and music.

Experimental studies of dynamic mechanisms for perceptual representation

Dr. Elliott has made several seminal contributions to science: his PhD concerned design and testing a paradigm to isolate and measure the dynamics of 'visual binding'. The term visual binding refers to the combining of different aspects of sensory data (i.e. colour or spectral frequency, spatial orientation and/or movement of contrast signals) to form composite, 'object' representations. The term 'binding' is also used to refer to the neural algorithm required for different neuronal assemblies to combine their activity such that their combined activity comes to represent all aspects of the perceived object as a singe pattern of neural activity. The neural algorithm concerned is believed to be either the synchronization in phase of neuronal firing, or the regular frequency of synchronized neuronal firing across the assemblies responding to different aspects of the perceived object. Both neurophysiological as well as electrophysiological data indicated that firing frequencies in the range 30-70 Hz were most commonly associated with neural binding. However, there was no definitive behavioural correlate that supported this theory.

Elliott and Müller, (1998) developed a novel paradigm, which showed that by synchronizing and repeating different aspects of a stimulus object within a flickering matrix, visual binding became more efficient, but only at particular flicker frequencies in the 20-100 Hz band. Elliott (2014) provided a follow up to this study with two important findings: binding was more efficient for stimulus frequencies that periodically interacted in phase - identifying the importance of a slower rhythm, while the conditions under which these effects were recorded encouraged binding to develop slightly ahead of, i.e. protentive of repeating stimulus presentation. Other work using this paradigm identified $GABA_A$ergic interneural activity as instrumental for binding (Elliott, Giersch & Seifert, 2006, see also Giersch, Elliott, Boucart, & Vidailhet, 2010), with a dynamic neural code closely matching the dynamic characteristic of stimulus presentation (Elliott & Müller, 2000). In addition, examination of the electroencephalogram (EEG: Elliott, Hermann, Mecklinger & Müller, 2001; Elliott, Conci & Müller, 2005) reveals a complex frequency-following response, which nonetheless relates arithmetically to the frequency of stimulus presentation. In addition, using this paradigm, Becker, Elliott and Lachmann (2005) have shown that children with dyslexia experience impaired visual binding processes that may be related to their reading disorder.

Subsequent work (e.g. Aksentijevic, Barber & Elliott, 2011) has extended upon this paradigm to show similar, frequency dependent binding effects concerned with the integration of harmonic tones in auditory stimuli. This paradigm is currently used in conjunction with high-density magnetoencephalographic (MEG) recording (du Bois, Elliott et al., work in progress), which shows, similar to the visual-binding paradigm, an analogue frequency-following response.

The work carried out by Dr. Elliott and colleagues extends across laboratories he established in Leipzig and at the Ludwig-Maximilians University in Munich, as well as in Galway, Ireland. This research examined the dynamics of binding operations using experimental intervention was seminal in answering the question “is binding causally related to the tendency for neurons to synchronize firing when responding to different aspects of the same object?” Prior to his studies, this question had remained unanswered for over 20 years. The paradigm designed to answer this question provides a firm basis not only for intervention and manipulation of other and of more complex cognitive functions (see also Elliott & du Bois, 2017; du Bois and Elliott, 2017), but also for parametric equivalence with brain recording and other biological data, including data derived from analysis of the genome.

<u>Restoring visual function in the cortically blind</u>

Development of paradigms aiming to manipulate dynamics and thereby alter brain and psychological function have lead Dr. Elliott and his team in Munich to examine for residual visual function in cortical blindness and the seek to improve visual function (Seifert, Falter, Strasburger & Elliott, 2010; Elliott, Seifert, Poggel & Strasburger, 2015). In these studies, patients with visual field defects were stimulated with a square matrix pattern, either static, or flickering at frequencies that had been found to either promote or not promote ‘blindsight’. Blindsight refers to visual detection or discrimination performance of stimuli presented in the blind visual field that is significantly better than at chance, although patients frequently cannot report having a visual experience. Comparison between pre- and post-stimulation perimetric maps revealed an increase in the size of the intact visual field but only for flicker frequencies previously found to promote blindsight. These changes were temporary but dramatic – in two instances the intact field was increased by an area of ~ 30 deg^2 of visual angle. These results indicate that not only does specific high-frequency stimulus flicker promote blindsight, but that intact visual field size may be increased by stimulation at the same frequencies. In other words, this reseach showed that sight can be temporarily restored if the visual system is stimulated at particular stimulus-presentation frequencies.

<u>Emergent visuo-spatial structure from temporal dynamics</u>

Dr. Elliott has also developed empirical models of elementary perceptual representation that derive almost exclusively from dynamical systems structure. Again, novel experimental methods, with EEG are used as the basis for data fro which models were developed. Becker and Elliott (2005, also Becker, Gramman, Müller & Elliott, 2009; Elliott, Twomey & Glennon, 2012) showed that while we generally assume that conscious visual states represent the interaction of spatial structures in the environment and our nervous system. This assumption is questioned by circumstances where conscious visual states can be triggered by external stimulation that is not primarily spatially defined. They found that subjective colors and forms are evoked by flickering light while the precise nature of those experiences varies over flicker frequency and phase. What’s more, the occurrence of one subjective experience appears to be associated with the occurrence of others. While these data indicate that conscious visual experience may be evoked directly by particular variations in the flow of spatially unstructured light over time, it must be assumed that the systems responsible are essentially temporal in character and capable of representing a variety of visual forms and colors, coded in different frequencies or at different phases of the same processing rhythm. In EEG studies it was shown, using independent-component analysis (ICA), that a reduction in amplitude variance is consistent with subjective-pattern formation in ventral posterior areas of the electroencephalogram (EEG). The EEG exhibits significantly increased power in the 4-6 Hz range and 46-48 Hz (for subjective experiences of points and circle patterns) or the EEH comprises a series of high- frequency harmonics of a delta oscillation (spiral patterns). On the basis of these data, subjective-pattern formation may be described in a way entirely consistent with identical pattern formation in fluids or granular flows. Dr. Elliott and his colleagues proposed subjective-pattern structure to be represented within a spatio-temporal lattice of harmonic oscillations. These bind topographically organized visual-neuronal assemblies by virtue of low-frequency modulation.

The psychological 'Moment'

The aforementioned studies lead to a series of studies of direct relevance to work planned at Shanxi Normal University. These studies have focused upon the temporal window within which we experience the moment 'now', also referred to as a perceptual or psychological moment. This was originally proposed by the Estonian biologist Karl-Ernst von Baer in 1860, and there has been evidence for the very brief, temporal quantization of perceptual experience at regular intervals below 100 ms in work published in the early 1930's. Elliott, Shi and Sürer (2007) presented the first modern empirical data in support of earlier concepts of minimal "psychological moment" of between 50 and 60ms duration. According to historical theories, within the psychological moment all events would be processed as co-temporal. More recently, a link with physiological mechanisms has been proposed, according to which the 50–60ms psychological moment should be defined by the upper limit required by neural mechanisms to synchronize and thereby 'bind' all of the different aspects of current perceptual event structure.

The data of Elliott et al., (2007) therefore present two ideas: in the first, psychological moments have a minimum duration of around 50 – 60 ms [as indexed by the point of subjective equality (PSE) located in this range]. This is consistent with historical estimates and is replicated across several studies (Elliott et al., 2007; Schmidt, McFarland, McDonald, & Elliott, 2008; Giersch, Lalanne, Corves, Seubert, Shi, Foucher, & Elliott, 2009; Elliott & Shanagher, 2010; Schmidt, McFarland, Ahmed, McDonald, & Elliott, 2011. See also Giersch, van Assche, Lalanne, & Elliott, 2013 and Elliott, & Giersch, 2016, for reviews).
In the second idea, it is logically necessary for all binding operations to be accomplished successfully within 50 ms for experience of the moment 'now' to consist of coherent and identifiable perceptual and/or mental content.

With respects to both ideas, the paradigm developed by Elliott et al., (2007) is capable of providing measures that can categorically differentiate individuals by virtue of task performance and according to several key psychological dimensions, including clinical symptoms. First it is necessary to describe what participants are required to do.

Participants are asked to report the simultaneity or asynchrony of two target bars which change luminance at the same time (simultaneously) or with a delay of between 10-120 ms. This change follows a rapidly presented 'premask', comprising a number of additional bars appearing on screen, within which, the two target bars appear either at the same or at slightly different times. However, participants cannot report the relative onset times of the two bars. Idea one therefore, refers to the explicit response made by participants to their experience of the interval (or not) between the changing luminance of the bars. Idea two refers to the effects of bar-onset synchrony or asynchrony on that experience. Typically (Elliott et al., 2007; Schmidt et al., 2008; Elliott & Shanagher, 2010; Schmidt, et al., 2011), asynchronies engender a bias against responses 'simultaneous' but only for very brief intervals between bar-bar luminance changes. This interval is from 0-23 ms, which is a period reported in the neurophysiology literature as the time over which, many neurons attempting to precisely synchronize firing during dynamic assembly formation, may vary.

<u>The psychological Moment in special populations</u>

With respects to special populations and regarding idea one: Giersch et al., (2009) and Schmidt et al., (2008; 2011) have both shown clear evidence of patients with psychosis or diagnosis of schizophrenia with the PSE between bar-bar event simultaneity, or asynchrony, to be at around double the PSE recorded from healthy participants (see both Giersch et al., 2013 and Elliott, & Giersch, 2016, for detailed review). This is true also for first-episode psychotic patients indicating the extended psychological moment is present at disease onset. In a variant of the paradigm described here, Falter, Elliott and Bailey (2012) report PSE's in adults with autism-spectrum disorder to be between 35 and 40 ms.

In all of these special populations, there is a categorical difference in the magnitude of the psychological moment, in schizophrenia and psychosis it is significantly larger than in healthy controls and in autism, it is significantly smaller. This suggests (i) that the psychotic experience may be influenced by a change in the patient's experience of 'usual' event structures in time, such that events that ordinarily occurred successively, suddenly seem to co occur, apparently without reason. This must have a detrimental effect on mental health and exacerbate the psychotic state.

In autism, there is less time than in healthy controls to bind neural responses to events and this may result in 'stimulus over selectivity', or the tendency to concentrate attention to small details in the perceptual scene rather than the bigger picture.

With respects to special populations and regarding idea two: Elliott and Shanagher (2010) found that for children with specific reading disability (SRD or dyslexia), thresholds were as control participants, however, these children were more susceptible to the effects of bar onset asynchrony, which biased against reports simultaneity over a larger range of intervals between the reportable changes in bar-bar luminance. This indicates that for SRD children basic binding processes are weaker than in controls. This would make sense if one also assumed reading ability may be impaired if basic mechanisms responsible for perceptual organisation are impaired. This conclusion is similar to that discussed in Becker et al., (2005, mentioned earlier), who also measured visual binding in dyslexic children.

Note, that experimental developments based upon the paradigm described here and carried out in the laboratory of Anne Giersch in Strasbourg (see Elliott & Giersch, 2016) also identify a more fine-scaled, serialized process structure within the psychological moment. Our data suggests that not all events are processed as co-temporal within the psychological moment and instead, some are processed successively. This evidence questions the analog relationship between synchronized process and simultaneous experience and opens debate on the ontology and function of "moments" in psychological experience.

Selected bibliography

- Du Bois, N., & Elliott, M.A. (2017). The temporal dynamics involved in object representation updating to predict change, *Progress in Brain Research* (in press) doi: 10.1016/bs.pbr.2017.06.009
- Elliott, M.A., and Du Bois, N (2017) Dynamical constants and time universals: a first step towards a metrical definition of ordered and abnormal cognition, *Frontiers in Psychology*, 8:322. doi :10.3389/fpsyg.2017.00332
- Elliott, M.A., & Giersch, A. (2016). What happens in a moment. *Frontiers in Psychology*, 6:1905. doi: 10.3389/fpsyg.2015.01905
- Elliott, M.A., Seifert, D., Poggel, D., & Strasburger, H. (2015). Transient increase of intact visual field size by high-frequency narrow-band stimulation, *Consciousness and Cognition*, **32**, 45-55. doi:10.1016/j.concog.2014.09.003
- Elliott, M.A. (2014). Atemporal equilibria: pro- and retroactive coding in the dynamics of cognitive microstructures. *Frontiers in Psychology*, 5:990. doi:10.3389/fpsyg.2014.00990
- Giersch, A., van Assche, M., Lalanne, L., & Elliott, M.A. (2013). On Disturbed Time Continuity in Schizophrenia: An Elementary Impairment in Visual Perception? *Frontiers in Psychology*, 4:281. doi: 10.3389/fpsyg.2013.00281
- Falter, C.M., Elliott, M.A., & Bailey, A.J. (2012). Enhanced Visual Temporal Resolution in Autism Spectrum Disorders. *PLoS ONE* **7**(3): e32774. doi:10.1371/journal.pone.0032774.
- Elliott, M.A., Twomey, D., & Glennon, M. (2012). The dynamics of visual experience, an EEG study of subjective pattern formation, *PLoS ONE*, **7**(1) doi: dx.plos.org/10.1371/journal.pone.0030830.
- Aksentijević, A., Barber, P.J., & Elliott, M.A. (2011). Process timing and its relation to the coding of tonal harmony *Journal of Experimental Psychology: Human Perception and Performance*, **37**(5), 1628-1642.
- Schmidt, H., McFarland, J., Ahmed, M., McDonald, C., & Elliott, M.A. (2011). Low-Level Temporal Coding Impairments in Psychosis: Preliminary Findings

and Recommendations for Further Studies, *Journal of Abnormal Psychology*, **120**(2) 476-482. PMID: 21553943.

- Elliott, M.A., & Shanagher, L. (2010). Temporal event-structure coding in developmental dyslexia: evidence from explicit and implicit temporal processing. *Psihologija*, **43**(4) 373-387.
- Giersch, A., Elliott, M.A., Boucart, M., & Vidailhet, P. (2010). Some cognitive effects of Benzodiazepine administration. A review and therapeutic implications, *Pharmacology and Therapeutics,* **126**, 94-108. PMID: 20138190.
- Seifert, D., Falter, C., Strasburger, H., & Elliott, M.A. (2010). Bandpass characteristics of high-frequency sensitivity and visual awareness in blindsight, *Consciousness & Cognition*, **19**, 144-151 PMID: 20129798.
- Giersch, A., Lalanne, L., Corves, C., Seubert, J., Shi, Z., Foucher, J., & Elliott, M.A. (2009). Extended visual simultaneity thresholds in patients with schizophrenia*. Schizophrenia Bulletin*, **35**, 816-825 PMID: 18359954.
- Becker, C., Gramman, K., Müller, H.J., & Elliott, M.A. (2009). Electrophysiological correlates with the perception of subjective colors. *Consciousness and Cognition*, **18**, 266-276. PMID: 18602838.
- Schmidt, H., McFarland, J., McDonald, C., & Elliott, M. A. (2008). Comparing temporal event-coding in patients with first episode psychosis and chronic schizophrenia. *Schizophrenia Research*, **102**(2), 107-108.
- Foucher, J.R., Lacambre, M., Pham, B.-T., Giersch, A., & Elliott, M.A. (2007). Low time resolution in schizophrenia: longer windows of simultaneity in visual, auditory and bimodal stimuli. *Schizophrenia Research*, **97**, 118-127. PMID: 17884350.
- Elliott, M.A., Shi, Z., & Sürer, F. (2007). The effects of subthreshold synchrony on the perception of simultaneity. *Psychological Research*, **71**(6), 687-693. PMID: 16614834.
- Elliott, M.A., Giersch, A., & Seifert, D. (2006). Some facilitatory effects of lorazepam on dynamic visual binding. *Psychopharmacology*, **184**(2), 229-238 PMID: 16374601.
- Becker, C. & Elliott, M.A. (2006) Flicker induced colors and forms: Interdependencies and relation to stimulation frequency and phase. *Consciousness and Cognition*, **15**(1), 175-196. PMID: 16054838.
- Becker, C., Elliott, M.A., & Lachmann, T. (2005). Evidence for impaired visuo-perceptual organization in developmental dyslexics and its relation to temporal processes. *Cognitive Neuropsychology*, **22**(5), 499-522.
- Elliott, M.A., Conci, M., & Müller, H.J. (2003). Prefrontal cortex maintains visual information in very short-term oscillatory persistence. *Behavioral and Brain Sciences*, **26**, 733-734.
- Elliott, M.A., & Müller, H.J. (2000). Evidence for a 40-Hz oscillatory short-term visual memory revealed by human reaction time measurements. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **26**(3), 703–718. PMID: 10855427
- Elliott, M.A., Herrmann, C.S., Mecklinger, A., & Müller, H.J. (2000). The Loci of 40-Hz visual-object priming mechanisms: A combined electroencephalographic and reaction-time study. *International Journal of Psychophysiology*, **38**(3), 211-225. PMID: 11102664.

- Elliott, M.A., & Müller, H.J. (1998). Synchronous information presented in 40-Hz flicker enhances visual feature binding. *Psychological Science*, **9**(4), 277-283.