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Advances in modern mental chronometry

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Mental chronometry encompasses all aspects of time processing in the nervous system and constitutes a standard tool in many disciplines including theoretical and experimental psychology and human neuroscience. Mental chronometry has represented a fundamental approach to elucidate the time course of many cognitive phenomena and their underlying neural circuits over more than a century. Nowadays, mental chronometry continues evolving and expanding our knowledge, and our understanding of the temporal organization of the brain in combination with different neuroscience techniques and advanced methods in mathematical analysis. In research on mental chronometry, human reaction/responses times (RT) play a central role. Together with RTs, other topics in mental chronometry include vocal, manual and saccadic latencies, subjective time, psychological time, interval timing, time perception, internal clock, time production, time representation, time discrimination, time illusion, temporal summation, temporal integration, temporal judgment, redundant signals effect, perceptual, decision and motor time, etc. It is worth noting that there have been well over 37,000 full-length journal papers published in the last decade on a variety of topics related to simple and choice RTs, etc. This amounts to approximately 3800 papers per year, or roughly 10 papers per day (source: PubMed, similarly Thomson Reuters Web of Science). There are comprehensive reviews that deal extensively with the history of mental chronometry, experimental methods and paradigms, stochastic models, etc. as well as its relationship to other psychological and physiological variables, neuroscience methods and clinical applications (Laming, 1968; Posner, 1978, 2005; Welford and Brebner, 1980; Townsend and Ashby, 1983; Luce, 1986; Meyer et al., 1988; Robbins and Brown, 1990; Schall, 2001; Mauk and Buonomano, 2004; Smith and Ratcliff, 2004; Jensen, 2006; Gold and Shadlen, 2007; Linden, 2007; Grondin, 2010; Merchant et al., 2013; Allman et al., 2014).

The aim of this research topic is to provide an overview of the state of the art in this field—its relevance, recent findings, current challenges, perspectives and future directions. Thus, as a result, a collection of 14 original research and opinion papers from different experts have been gathered together in a single volume. They outline a selection of unsolved problems and topics in mental chronometry mainly within the context of the human visual system as well as the auditory system. One of the unsolved problems is the functional role of power laws in RT variability and in the study of timing. Power laws are ubiquitous in many complex systems, and their experimental validity and theoretical support represent a fundamental aspect in many disciplines, such as in biology, physics, finance, etc. In this theme issue, the papers of Ihlen (2014), Medina et al. (2014), Rigoli et al. (2014) and Shouval et al. (2014) address different aspects of power laws, namely, multifractal analysis on RT series; an information theoretic basis of RT power law scaling; Fourier-based power law correlations (“$1/f$ noise”) in a tapping task and its comparison with other physiological processes (e.g., heartbeat intervals); and a log-power law model of the firing rate of neurons in interval timing.

A second unsolved problem involves RT-based methods and research into RT distributions. RT distributions are typically positively skewed and often exhibit long right-tails in the time-domain.

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A long-standing issue deals with the shape of RT distributions, their intrinsic stochastic latency mechanisms and neural basis. Sequential-sampling models are a common approach widely used in human RTs and simple decision making (Smith and Ratcliff, 2004). Diederich and Oswald present a RT sequential-sampling model for multiple stimulus features based on an Ornstein–Uhlenbeck diffusion process (Diederich and Oswald, 2014). In a different type of analysis, the work of Harris et al. introduces an alternative approach to examine very long RTs in the rate-domain (i.e., 1/RT). These authors investigate the shape of choice RT distributions and sequential correlations using autoregressive techniques (Harris et al., 2014). In general, RT distributions exhibit faster RTs under summation/facilitation tasks when two or more redundant signals are available as compared with a single signal or sensory modality (e.g., binocular vs. monocular vision), usually called redundant signals effect. The work of Lentz et al. examines binaural vs. monaural hearing performance under noise masking tasks using modeling techniques based on the concept of workload capacity and different processing mechanisms (e.g., serial vs. parallel, etc.) and stopping rules (Lentz et al., 2014). Within the same redundant signals paradigm, Zehetleitner et al. study bimodal (audio-visual) facilitation effects using sequential-sampling models (Zehetleitner et al., 2015).

Regarding the human vision system, the work of Wegener et al. examines the visual attention mechanisms using colored stimuli (random dot patterns), and they have presented a novel three-step model of attention to predict the corresponding RT distributions (Wegener et al., 2014). The work of Murd et al. exemplifies the used RTs in conjunction with visual evoked potentials in the detection of visual colored stimuli (Murd et al., 2014). There are also studies focusing on the auditory system, including the work of Nakajima et al. that investigates the foundations of time perception using a time illusion based on an overestimation of a second time interval preceded by a first time interval or time-shrinking effect (Nakajima et al., 2014). Mitsudo et al. present recorded magnetoencephalogram signals in tasks that require to judge temporal gaps in tones and have discussed their implications in the organization of the auditory cortex (Mitsudo et al., 2014). Within the same time perception paradigm, Mioni et al. show a detailed review on temporal dysfunctions in traumatic brain injury patients (Mioni et al., 2014). The present theme issue also includes the work of García-Pérez who introduces a unified model to analyze different psychophysical tasks in time perception and estimation of the psychometric function (García-Pérez, 2014).

We hope this research topic will provide a useful framework and an up-to-date set of papers for further discussion on mental chronometry within the human brain.

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