Temporal Integration Theory, Schizophrenia, and the Lateralised Paced Auditory Serial Addition Task

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Abstract

The Paced Auditory Serial Addition Task (PASAT) was lateralised for the purpose of investigation into hemispheric specialisation for temporal integration. A right ear advantage (REA), representing a left hemisphere (LH) advantage in normal participants, was predicted due to the sequential nature of the PASAT, the previous finding of a REA by Norman (1984), and Miller's (1996) theory on the LH specialisation for delayed axonal conduction. The REA was also expected given other abundant evidence on LH superiority for the processing of temporal information (Bradshaw & Nettleton, 1981; Bryson, Mononen, & Yu, 1980; Elfgren & Risberg, 1998; Gordon, 1978; Leek & Brandt, 1983; Prior, Kinsella, & Giese, 1990; Robinson, & Solomon, 1974; Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998). However, no REA was found in the present research. Careful precision in randomising and counterbalancing arithmetic outcomes, removal of the digit seven because of its two-syllable pronunciation, and the randomisation of ear of presentation and stimulus presentation rate, possibly eliminated procedural artefacts that were present in Norman's (1984) study. Therefore, despite the sequential nature of the PASAT it now appears to lack efficacy for research into temporal integration.

Other findings from the present research instead showed support for the hypotheses of the right hemisphere's (RH) specialisation for vigilance (Coslett, Bowers, & Heilman, 1987; Dimond, 1979; Heilman & van den Abell, 1979, 1980; Howes & Boller, 1975; Ladavas, Del Pesce, Mangun, & Gazzaniga, 1994; Ladavas, Del Pesce, & Provinciali, 1989; Loring, Meador, & Lee, 1989; Pardo, Fox, & Raichle, 1991; Simos & Molfese, 1997; Whitehead, 1991; Wilkins,

Shallice, & McCarthy, 1987; Yokohama et al., 1987). For normal participants a left ear advantage (LEA) was found and more clearly demonstrated with an unpredictable task condition and with the faster presentation rates (1.2 & 2.0 s) of the lateralised PASAT. The LEA was shown with both the same ear stimulus pairings (LL) and the left then right pairings (LR). Inferior performance with the right then left (RL) stimulus pairings was found in the unpredictable task condition and another task condition in which the side of stimulus presentation was predictable.

Clinical participants (i.e., participants with a history of schizophrenia) did not demonstrate a LEA, and they showed no difference compared to normal controls in performance with the right ear (LH). However, the clinical participants did manifest a particular disadvantage when stimulus processing required a shift from left to right ear (LR), but not the reverse (RL). The clinical participants manifested the LR deficit in the unpredictable and predictable task conditions. This LR disadvantage bears some resemblance to a previous finding, using the Visual Reaction Time Task, of a lateralised deficit in disengaging attention from the left visual field. Some researchers (Bustillo et al., 1997; Posner, Early, Reiman, Pardo, & Dhawan, 1988; Posner & Raichle, 1994; Wigal, Swanson, & Potkin, 1997) interpret this LR deficit as a problem of slowness of responding by the LH (right visual field) after having attention oriented to the opposite field. However, the findings in the present research of a LEA for normal controls (i.e., LL and LR), a relative deficit with RL for normals, and no difference in right ear (RR) performance between controls and clinical participants, and notably with the unpredictable condition, suggests an alternative interpretation. The LR deficit in schizophrenia may instead be due to difficulty in disengaging from the left visual or auditory field rather than impaired performance with the right

field. The LR deficit may be as a result of dysfunction of vigilance, which is normally attributed to greater proficiency of the right hemisphere.

In addition, opposing trends were observed for the clinical participants compared to the normal participants at particularly slow presentation rates, and with the predictable task condition in which stimuli were presented singularly to each hemisphere. Clinical participants showed a worsening of performance with the task. Normal participants demonstrated better performance with this task compared to another task condition, much like the standard PASAT, in which both ears received a stimulus simultaneously. These trends reflect Hellige's (1987, 1993) model of cross-hemispheric integration in which it is hypothesised that for normal participants single hemisphere processing has some advantage with lighter tasks. These trends also reflect the possibility that people with schizophrenia, in slow stimulus conditions, have difficulty whereby they unnecessarily over engage both hemispheres, which wastes attentional resource that could otherwise be utilised for various other aspects of ongoing processing.

Preface To Research

The interest for this research had two sources. Initially it came from my postgraduate training in clinical and research psychoendocrinology, which began in 1979 and continued in the 1980s, with John Money (Professor Emeritus, The Johns Hopkins University School of Medicine).

Our hormonal regulatory systems (e.g., the hypothalamic-pituitary-adrenal axis; the hypothalamic-pituitary-thyroid axis; and the hypothalamic-pituitary-gonadal axis) depend on feedback from one part of the axis to another in the form of pulsatile secretions of hormones into the blood stream. Disruptions to these systems can have notable effects on physiological development and behaviour. I found it fascinating how the fidelity of these systems depend on a well regulated and ' timely ' feedback loop. I then began to consider how timing is most likely also important in the complex human functions of cognitive processing and communication, but perhaps not sufficiently analysed or accounted for in many psychometric tests.

The second source of interest in this research came from my training and post clinical qualification experience in normal and clinical psychology. Learning about and interacting with persons with thought form disorders distinguishable from content disorders, such as in schizophrenia, led me to consider that these disorders may in part be naturally occurring instances of dysfunction in the timing functions of cognitive processing.

In 1982, when I was attempting to develop a master's thesis based on the above, Geoff White (then my supervisor at Victoria University of Wellington; currently Professor at Otago University, New Zealand) was experimenting with temporal paradigms of learning in pigeons. He had come across the Paced Auditory Serial Addition Task (PASAT) and suggested that I may

somehow use it to begin examining my ideas, as above.

Since the PASAT was initially developed in the 1950s and adapted as a clinical test in the 1970s (see section on The History of the PASAT) there has been much development of theory and research into brain lateralisation and specialisation. By 1982 some of this theory and research had begun reconceptualizing the left brain versus right brain dichotomy in terms of the left hemisphere being more specialised for temporal components in 'verbal' processing rather than the right hemisphere being simply 'non-verbal' by default (see sections headed Hemispheric Specialisation, and Hemispheric Specialisation for Temporal Processing). Accordingly, in 1983 I decided to adapt the PASAT in creating a lateralised version to examine its usefulness in investigating my ideas and current theory on hemispheric specialisation. When I began reviewing the background theory to the PASAT I found that the theories on temporal integration by Lashley (1937) and Hearnshaw (1956) had already conceptualised temporal processing from both psychophysiological and language and communication perspectives respectively. MacNeilage (1999) has stated that he considers Lashley's theory to be the most significant this 20th Century for cognitive neuroscience, but that it has largely fallen on deaf ears. Hence, it has taken some years for me to feel some vindication for selecting temporal integration theory as a basis for my own research. Further support has come from Miller's (1996) book on hemispheric specialisation being based also on axonal conduction time. Miller based his theory on postulates by Hebb (1949), who was a student of Lashley's. (See section headed Temporal Integration Theory for a review of the theory.)

Accepting the notions that temporal integration theory unifies to some extent various systems

of human functioning, partially bridges the Cartesian split between 'mind and body', and applies to human communication, can be easily criticised as being very simplistic. However, in my view, the theory should not be simply interpreted as meaning there is some central time mechanism (i.e., 'clock') for all individual human systems. Instead, the theory can be interpreted as indicating that there exists for probably all systems, specific to each function, some reliance on each component working in a 'timely' way. Furthermore, that for each system the governance of 'timely' functioning has an innate origin (e.g., genetic and prenatal). It is also interesting to note that recent neurophysiological research has begun to identify how brain neurons work in an integrated way by means of not only proximity but also via temporal resonance, that is, similar frequency of transmission (Freund, 1997).

Hence, in 1983, I selected the PASAT to investigate cognitive temporal processing since it originated from theory that preceded but suited my own ideas. I adapted the PASAT (i.e., lateralised version) so as to test its utility in light of developments in research and theory on brain hemispheric specialisation (e.g., left hemisphere specialisation for processing of temporal components in verbal information). My Master's thesis at that first stage of research was completed in June 1984 and is reviewed within this current thesis. Because of the typical exigencies of beginning a clinical career, furthering my speciality training in psychoendocrinology, marrying and starting a family, and moving between two countries, it took until 1990 to revisit this research at a doctoral level. Continuation of the above exigencies meant this research had at times been suspended. However, in the interim another colleague (Mark Stewart) became interested in this research and so completed a Master's thesis in 1995. His work is also reviewed within the present thesis.

Since 1984, other researchers have identified and attempted to rectify potential weaknesses in the standard PASAT (see section on The History of the PASAT). Hence, the present study was a re-examination of the utility of the PASAT for investigating temporal integration theory, and necessitated an upgrading of the test for research into hemispheric lateralisation. It also included participants with a personal history of schizophrenia in acknowledgement of Lashley's (1937) point that often we cannot directly observe temporal integration except when it is dysfunctional. There is now quite substantial evidence to show abnormal hemispheric functioning in schizophrenia. (See section headed Dysfunctional Hemispheric Processing in Schizophrenia.) The problem in hemispheric functioning, for temporal processing in particular, was therefore used as a clinical basis for examining temporal integration theory and the lateralised PASAT.

The present research programme started with a complex mixed design experiment in which the lateralised PASAT was used with both clinical and control participants. However, at the conclusion of the first experiment it became evident that the lateralised PASAT was not delivering as hypothesised on the basis of temporal integration theory and gave contrary results to those found in 1984. Instead, the results indicated that attentional processes, rather than temporal integration, were being evoked and only at the fastest parts of the test. Thus, the latter two experiments of the present research aimed to re-examine results from the first experiment which suggested the involvement of right hemisphere attentional processes rather than left hemisphere temporal integration processes. Another problem found during the first experiment was the ever increasing difficulty in recruiting volunteers who had a history of schizophrenia but not other complications, such as head injury or a history of using non-prescribed substances. Hence, the latter experiments were restricted to using non-clinical participants only.