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Exploring Brain Activation of Single-Digit and Double-digit in Familiar and Unfamiliar Numerals: A Functional MRI Study

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Abstract

The ability to symbolise numbers using numerals is unique to humans and the acquisition of this ability needs to be done via learning [1]. Repeated exposure to sensory input can result in learning-induced alterations to the brain, forming memory engrams that are crucial for memory storage and retrieval [2]. Familiarity is an important factor that affects memory performance because familiar stimuli tend to have stronger memory strength with pre-existing knowledge representation stored in long-term memory, while unfamiliar or novel stimuli do not [1,3]. Past studies have suggested a few putative Number Form Area (NFA), located in the ventral occipitotemporal gyrus, are involved in processing visual number symbols [4 – 6]. It has been put forward that the acquisition of the semantic information of the numerical symbols might be a prerequisite for the activation of the NFA. However, much of its semantic information remains unknown. Figure 1 presented the conceptual framework of the present study.

The present study aims to explore the brain activation associated with familiar and unfamiliar numerals of single-digit and double-digit. The targeted population of the present study will be Malaysian young adults between the age ranges of 18 to 30 years old. The present study will employ a quantitative cross-sectional observational research design. In particular, a within-subjects experimental study design with two factors: type of familiarity (familiar vs. unfamiliar) and the number of digits (single-digit vs. double-digit), will be used to measure the dependent variables including reaction time, accuracy, and brain activations of each participant in all experimental conditions: (1) familiar single-digit, (2) familiar double-digit, (3) unfamiliar single-digit, and (4) unfamiliar double-digit. An fMRI block design paradigm will be utilised, where the participants will be presented with single-digit and double-digit familiar (Chinese) numerals and unfamiliar (Arabic) numerals during the learning (encoding) phase and will be asked to complete the forced-choice memory task during the memory (retrieval) phase. In the experiment, participants' structural and functional brain images will be collected using 3-Tesla Achieva MRI Scanner (Achieva, Philips, the Netherlands). Behavioural measurements such as reaction time and accuracy of the answer will be recorded based on the responses given by the participants during the fMRI task. Two-way repeated-measures ANOVA tests will be performed to compare the mean difference in reaction time, accuracy, and brain activation between the conditions. The brain activation will undergo pre- and post-processing using Matlab MATLAB software, Statistical Parametric Mapping 12, CONN toolbox and MarsBar toolbox.

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A significantly shorter reaction time and higher accuracy are expected to be observed in familiar as compared to unfamiliar conditions because familiar stimuli are being encountered relatively often in different contexts, which are likely to have broader retrieval contexts and stable mental representation stored in the long-term memory. Besides, it is predicted that brain areas such as the thalamus and the NFA will be highly engaged during the familiar conditions because thalamic nuclei have been reported to underpin familiarity memory [3] and the NFA has been put forward to hold a role in processing meaningful visual numerical symbols [4]. As for unfamiliar condition, the hippocampus and prefrontal cortex (PFC) is predicted to be highly engaged because unfamiliar numerals do not have pre-existing representation stored in the memory, thus it may trigger an active memory encoding process during the learning phase. The retrieval of memory of unfamiliar stimuli at a more recent time point after learning is thought to heavily rely on the hippocampus subregions and the PFC that are highly engaged during the memory encoding process.

In conclusion, significantly better memory performances will be observed with familiar numerals as compared to unfamiliar numeral conditions. Differential neuronal activations will be observed between familiar and unfamiliar numeral conditions.

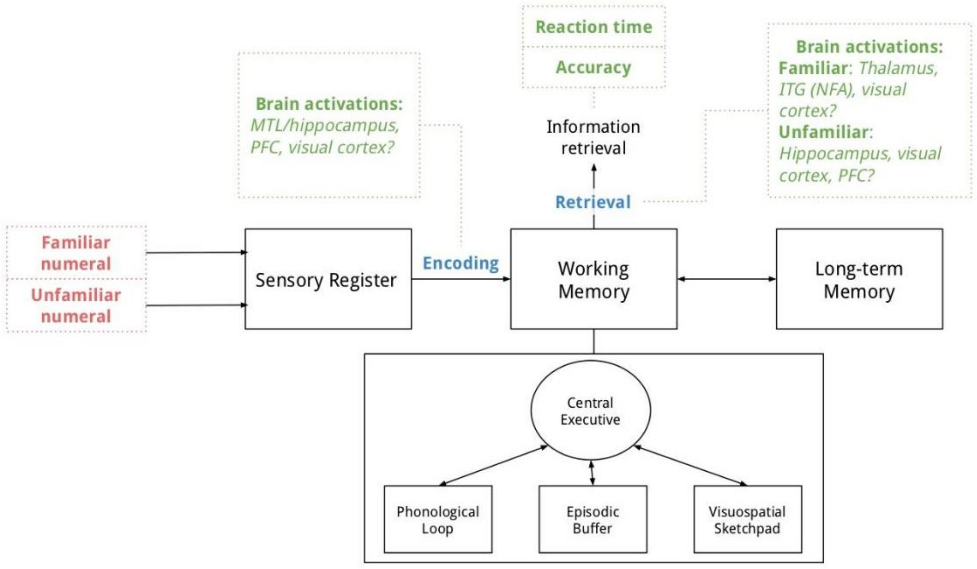

Figure 1. The conceptual framework presents the memory storage and memory formation process

Keywords
Familiarity, Numeral, Memory

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