Abstract

Although numerous studies have closely examined the processes by which working memory (WM) updates and maintains information, there has been a paucity of research examining the switching mechanism between these two WM functions. O'Reilly & Frank (2006) proposed that the switching process is governed by a WM "gate" that opens the gate to switch WM function from maintenance to updating and closes the gate to reverse the process. It is noteworthy that subsequent studies have consistently observed an asymmetry between opening and closing the WM gate. This asymmetry is manifested as a higher time cost but a lower error rate when closing the WM gate than when opening the gate. Until now, this asymmetry and the WM gating process have not been well understood. The objective of my dissertation was to elucidate the essential components of WM gating processes that determine the asymmetry between opening and closing. In particular, the roles of inhibitory control (on the state of the WM gate switches from) and intentional control (on the state the gate switches to) were investigated. A total of four studies were conducted in stages. The first study extracted the neurophysiological constituents of WM gating processes. The second study investigated the difference in effort investment between WM gate opening and closing. Another two studies further explored the causality of the asymmetry via brain stimulation methods.

All studies replicated the behavioral asymmetry between gate opening and closing (lower error rate and higher time cost for gate closing). A common neurophysiological pathway of the WM gating cascade from the ventral stream to the frontal cortex was revealed, suggesting that WM gate opening and closing follow common steps of inhibition of the previous gate state and reactivation of the required gate state. Nevertheless, the ventral stream distinguished residual preceding gate activation, whereby a stronger preceding gate state (open) remained highly activated before closing than gate-close state before opening and subsequently affected inhibitory control over it. Additionally, distinct frontal activities were observed between opening and closing, indicating a switch of attention to different sources. Strong intentional control was involved to direct the attention to sensory information during gate opening. These findings suggest that the opening of the WM gate is more effortful than the closing of the WM gate, which is perceived as more natural and effortless. It is likely that the human brain tends to maintain the WM in a closed state, and this default tendency to close the WM gate may be the origin of the asymmetry in gating performance. This knowledge sheds the light on the mechanism of WM controls and suggests a potential for predicting the developmental patterns of WM and WM deficiencies in psychiatric disorders.