Neural Bases of Focusing Attention in Working Memory: An fMRI Study Based on Group Differences

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Working memory supports a variety of daily activities that require the storage and processing of information. Most of our daily activities require the dual process of storing information on the one hand then processing information on other hand. This dual process often requires the person to focus attention to one thing and also inhibit others that is unnecessary for the task being performed.

This dual process is crucially required for higher cognitive brain functions, such as language comprehension. While reading a text, in order to comprehend the contents, readers likely search for the most important word, that is, the focus word, which provides an advantage during integration of the text. As well as focusing attention on the important word, the readers inhibit attention to other words not important to comprehending the sentence. Thus, while reading sentences, we continuously focus attention and inhibit attention in succession.

In the present research, using fMRI, neural substrates for focusing of attention in working memory were investigated. To explore this focusing effect, two kinds of reading span test (RST), focused and non-focused, were performed. In the focused RST (F-RST), the target word to be maintained was a focus word of the sentence. In the non-focused RST (NF-RST), the target word was not a focus word of the sentence. Figure 1 shows attention control differences needed between F-RST and NF-RST during both reading the recognition phase.

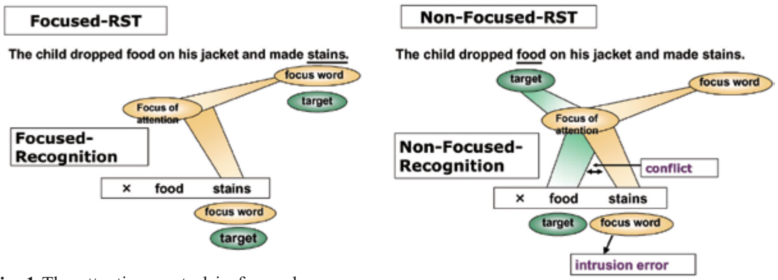

Fig. 1 The attention control in focused-RST and non-focused-RST during reading (upper) and recognition (lower) phase

Under both RST conditions, significant activations were found in three main regions: left dorsolateral prefrontal cortex (DLPFC); anterior cingulate cortex (ACC); and left superior parietal lobule (SPL) (see Fig. 2). In addition, fMRI signal changes increased in the left SPL under NF-RST conditions. These findings suggest that the neural substrates of focusing attention are based on SPL and ACC-DLPFC networks. Furthermore, there were group differences in focusing effect between high-span subjects (HSS) and low-span subjects (LSS). HSS showed superior focusing effects supported by SPL control compared to those in LSS.

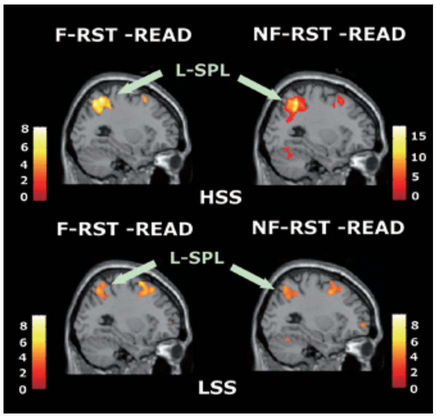

Fig. 2 Activated areas on the sagittal plane of brain im-ages (x= -26) under F-RST and NF-RST condition. Upper panel shows activated areas averaged across HSS and lower panel shows those across LSS.

Cupric Oxide as a Magnetically-induced Ferroelectric with High-T_C

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The nomenclature 'multiferroics' has coined for materials showing magnetic and ferroelectric ordering simultaneously. In multiferroics, one can expect the coupling between the magnetic and dielectric properties as well as their control by the application of magnetic and/or electric fields. In the past few years, a new class of multiferroics have been discovered, wherein non-collinear spiral magnetic order (Fig. 1) induces ferroelectricity. In these multiferroics, it is not too much to say that the origin of the ferroelectricity is driven by magnetism (magnetically-induced ferroelectricity) and is completely different from that in conventional ferroelectrics. However, most of known magnetically-induced ferroelectrics operate only at low temperatures [ferroelectric Curie temperature (T_C) < 40 Kelvin]. To develop magnetically-induced ferroelectrics with higher-T_C, we combined two of the most important recent themes in studies of strongly correlated electron systems; i.e., studies of 'high-T_c superconducitivity in cuprates' and 'multiferroism'. We propose in this paper that cuprates having large magnetic superexchange interactions can be good candidates for magnetically-induced ferroelectrics with high-T_C. In fact, we demonstrate ferroelectricity accompanied by a spiral magnetic ordering in an simple copper oxide, CuO, which is known as a starting material for the synthesis of high-T_c cuprates. CuO shows a spiral magnetic ordering (inset of Fig. 2) below 230 K, and posseses multiferroic nature with a remarkable high-T_C (T_C = 230 K), as shown in the main panel of Fig. 2. This result provides a new route to develop magnetically-induced ferroelectrics with high-T_C.

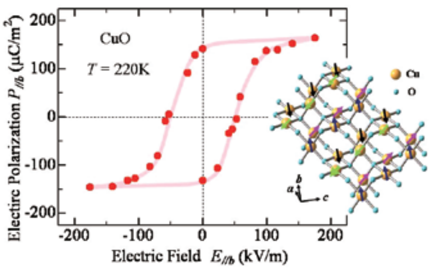

Fig. 2 Evidence of ferroelectricity in CuO. (Main panel) Electric polarization as a function of electric fields applied along the *b* axis at 220 K in CuO. Pink line is a guide to the eyes. (Inset) A schematic illustration of the crystal structure and the spiral magnetic structure of CuO. Arrows denote Cu magnetic moments. The spiral magnetic structure appears at temperatures between 212 K and 230 K, and induces ferroelectricity.

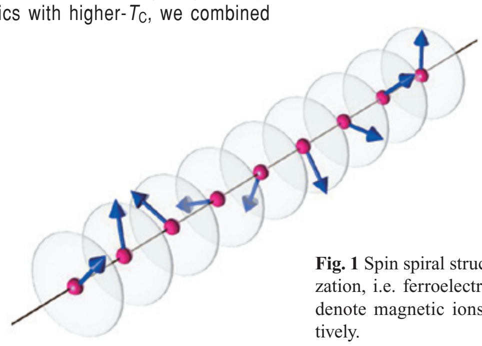

Fig. 1 Spin spiral structure which induces electric polarization, i.e. ferroelectricity. Red circles and blue arrows denote magnetic ions and magnetic moments, respectively.