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Research Report

Brain activity associated with dual-task management differs depending on the combinations of response modalities

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ABSTRACT

Several functional imaging studies have demonstrated the importance of fronto-parietal network in dual-task management. However, neural correlates underlying the difference in intensity of dual-task interference between the same and different response modalities remain unknown. Therefore, we investigated the relationship between brain activity associated with dual-task management and the combinations of response modalities. We used the dual-task requiring bilateral finger responses (DT-same condition) and that requiring finger and oral responses (DT-different condition) to visual and auditory stimuli. The right premotor cortex, precuneus and right posterior parietal cortex were significantly activated in the DT-same condition. The neural activities in the right premotor cortex significantly correlated to the delayed responses in the DT-same condition relative to the single-task conditions, indicating that the right premotor cortex is partly associated with dual-task management (i.e., the regulation of information flow). In addition, neural activity in this brain region was significantly higher in the DT-same condition than in the DT-different condition, suggesting that the difference in intensity between the same and different response modalities is partly associated with difference in the load on the premotor cortex between the DT-same and DT-different conditions. The significant activation of the parietal cortex also differed between the DT-same and DT-different conditions. These results demonstrate that brain activity associated with dual-task management differs depending on the combination of response modalities and that such a difference in brain activity, particularly in the right premotor cortex, might be partly associated with the difference in intensity of dual-task interference between the DT-same and DT-different conditions.

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1. Introduction

Many researchers have been interested in how the human brain processes two things simultaneously (dual task) (Telford, 1931; Smith, 1967; Pashler, 1994; Sigman and Dehaene, 2005). In a dual-task condition, the response to each component task is slower than that in a single-task condition. In particular, the response to the second stimulus is often delayed when stimulus onset asynchrony (SOA) is reduced. Such delayed responses are explained by assuming of dual-task interference or the psychological refractory period (PRP) (e.g., Telford, 1931; Welford, 1952; Pashler, 1994). It is suggested that delayed responses in a dual-task condition are associated with the management of two concurrent tasks in the brain such as a coordination of information flow and a divided attention to two input modalities in preparation for dual-task execution (Baddeley, 1986; Pashler, 1994; De Jong and Sweet, 1994; De Jong, 1995; Tombu and Joliceur, 2003, 2005). The most accepted theory of dual-task interference is the bottleneck model. In this model, processing for response selection in one task is interrupted as long as that in the other task is carried out in the central stage (Pashler, 1994). Recently, functional neuroimaging techniques have been applied to clarify the neural mechanism associated with dual-task interference. Several researchers reported that the activities in the frontal and parietal cortices in dual-task conditions increase as compared to those in single-task conditions (D'Esposito et al., 1995; Herath et al., 2001; Szameitat et al., 2002; Erickson et al., 2005). It was also reported that neural activities in these brain regions in a dual-task condition were significantly higher than the summed neural activities in single-task conditions, indicating that some additional processing for dual-task management occurred in the frontal and parietal cortices (Schubert and Szameitat, 2003). Szameitat et al. (2002, 2006) suggested that the prefrontal and parietal cortices were associated with a coordination of information flow. Erickson et al. (2005) found that the right prefrontal cortex were associated with the preparatory processes such as dividing attention to two input modalities. Marois et al. (2006) observed that neural activities in the frontal and parietal cortices were sensitive to manipulation of dual-task costs. These previous neuroimaging studies suggested that the fronto-parietal network plays an important role in dual-task management. In these previous studies, the combinations of response modalities were common (finger–finger responses) (e.g., Herath et al., 2001; Szameitat et al., 2002; Erickson et al., 2005). However, dual-task interference occurs when the combination of response modalities is different (e.g., Pashler, 1990; Lien et al., 2005). Therefore, it remained unclear whether a common brain network managed dual tasks regardless of the combination of response modalities. In addition, the effect of response modalities on dual-task interference has long been discussed in psychological studies, because dual-task interference can be eliminated or markedly reduced when two tasks use very different responses (e.g., finger–oral responses). To explore this phenomenon, the multiprocessor model is proposed (e.g., Allport et al., 1972; Allport, 1979; McLeod, 1977). In this model, dual-task interference does not occur when responses differ, because independent cognitive systems are involved in the performance of two tasks. However, precise investigations by several researchers have showed that PRP effects occur when the combinations of response modalities are different (Pashler, 1990; Lien et al., 2005). At least, it can be said that the intensity of dual-task interference differs depending on the combination of response modalities. Ruthruff et al. (2001) also reported that the amount of decrease in dual-task interference after training was very large when

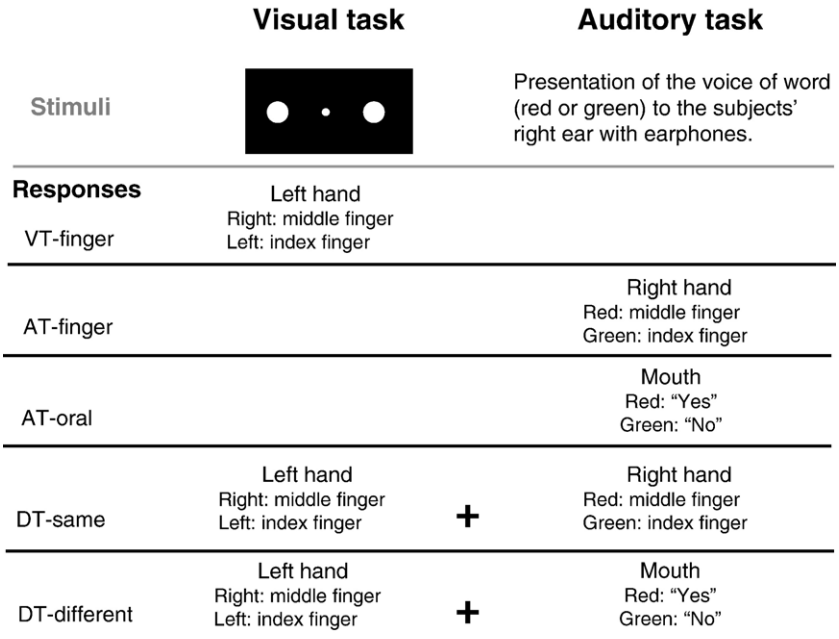

Fig. 1 – Protocol for dual and single tasks used in this study. The top row shows the stimuli used in the dual and single tasks. Each row below the top row shows response modalities.