

## Dual Task Interference in Parkinson's Disease

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### Abstract

Performing two tasks simultaneously (dual task performance) is a frequent activity in human life. Patients with Parkinson's disease (PD) commonly have more difficulty performing dual tasks than healthy people. To date, research on the mechanisms of dual task interference in PD remains sparse. A recent study by Wu and Hallett in 2008 investigated the central neural correlates of dual task interference in PD, and demonstrated that dual task interference in PD is due to multiple reasons. First, the limitation of capacity of attentional resources is exceeded; second, PD patients perform tasks less automatically compared with normal subjects; and third, the central executive may be defective. However, our knowledge of this phenomenon is still far from complete and needs further investigation.

### Keywords

Parkinson's disease, dual task, functional magnetic resonance imaging (fMRI), brain activity, attentional resource, automaticity, central supervisor

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Performing two tasks simultaneously (dual task performance) is a frequent activity in human life. However, performing dual tasks can be difficult. When people attempt to perform dual tasks, performance is generally impaired, manifested by increased errors or reaction times compared with when the tasks are performed individually. Such a deterioration of performance is defined as dual task interference.<sup>1</sup>

The underlying mechanism of dual task interference is still unclear. It has been described as a competition for attentional resources,<sup>2</sup> or competition for information-processing mechanisms.<sup>3</sup> Three of the most influential explanations are capacity-sharing, bottlenecks and cross-talk.<sup>1</sup> These are 'attentional' models, with the term 'attentional' referring to the focus of mental activity on a task.

The capacity-sharing model is based on the assumption that attentional resources are limited. When people perform two tasks simultaneously, resources must be divided between the tasks. How attention is divided between the two tasks relies on several factors, including task complexity, familiarity and importance. According to this model, dual task interference occurs only if the available resource capacity is exceeded, resulting in a decline in performance on one or both of the tasks.<sup>2-4</sup>

The bottleneck theory refers to the idea that certain critical mental operations must be carried out sequentially. A bottleneck arises when two tasks require a critical mental operation at the same time-point.<sup>5</sup> By contrast, the cross-talk model assumes that task similarity reduces dual task interference because use of the same pathway increases the efficiency of processing by using less attentional resource capacity.<sup>4-7</sup>

Patients with Parkinson's disease (PD) commonly have difficulties in performing movements. This problem becomes more prominent during their performance of complex movements, including dual tasks. Schwab et al.<sup>8</sup> described that PD patients have particular difficulty executing two motor tasks simultaneously. This problem is more obvious when patients perform different motor acts with each hand. For example, a patient may be unable to draw a triangle with his or her dominant hand while squeezing a bulb with the other hand, or he or she may be very slow in performing simultaneous tasks, such as flexing the elbow and pinching the thumb and index finger at the same time.

Benecke et al.<sup>9,10</sup> found that when PD patients were asked to perform rapid elbow movements combined with a simultaneous or sequential hand movement, they showed a marked slowing of movement greater than that seen in each task individually. By contrast, there was no decrement of performance in normal subjects when two tasks were combined. This deficiency correlated better with clinical measures of bradykinesia, and improved more impressively after administration of L-Dopa than the slowness in each component movement.<sup>11</sup> Similar observations have been described in several subsequent studies.<sup>12-14</sup>

The problem of performing two tasks simultaneously in PD patients is not confined to motor tasks. It can also be observed in cognitive tasks or combined cognitive and motor tasks.<sup>15,16</sup> For example, Brown and Marsden found that PD patients had an increase in reaction time on the Stroop task when performing a resource-demanding secondary task simultaneously.<sup>15</sup> These observations suggest that the difficulty of performing two tasks at the same time in PD patients is not a purely motor problem. Impaired dual task

performance was also reported during gait in PD patients.<sup>17,18</sup> Dual task interference can also be observed in postural control when PD patients perform a secondary task simultaneously.<sup>19–22</sup> For example, Morris and colleagues demonstrated that a concomitant verbal–cognitive task significantly deteriorated postural stability in PD.<sup>19</sup> Ashburn and co-workers found that a greater postural sway was present in PD patients who were fallers while completing a distracting cognitive task.<sup>20,21</sup>

An adequate understanding of the deficiency of PD patients in performing two tasks simultaneously is important. It may help in the development of optimal therapy strategies. However, to date, research on the mechanisms of dual task interference in PD remains sparse. It has been assumed that PD patients either have a limited attentional resource that interferes with their ability to execute more than one task at the same time, or that they have difficulty in switching this resource between tasks.<sup>15,23</sup>

An alternative explanation is that the attentional resource is relatively intact but the patients perform the tasks less automatically than normal subjects. Patients may use more resources for each single task to compensate for deficient function of the basal ganglia. Each task would consume more of the attentional resource, leading to difficulties in performing two tasks at the same time.

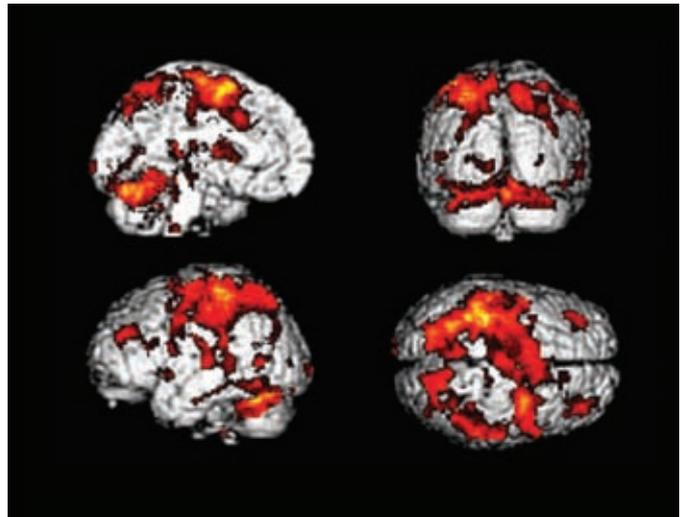
It has also been suggested that difficulty in performing a dual motor task in PD patients may be caused by sensorimotor interference between motor programmes,<sup>24</sup> whereas difficulty in performing a dual cognitive task may be caused by a central executive deficit.<sup>25</sup> In addition, as using various secondary tasks can have different influences on performance of dual tasks,<sup>26</sup> it has been suggested that various dual tasks may not share the same neural mechanisms.

A recent study from our group has clarified some of these matters concerning dual task interference in PD, such as to what degree the ability of dual task performance in PD patients is defective, whether practice can improve their performance of dual tasks and, importantly, the central neural correlates of the problem in PD.<sup>27</sup> To answer these questions, we asked PD patients to perform some dual tasks combined with sequential right-hand movements and different secondary tasks, including a visual letter counting task or a left-hand tapping task.

The dual tasks were set up with different levels of complexity. After extensive training, most healthy subjects could perform all dual tasks correctly. By contrast, most patients could perform only the simpler dual tasks with high accuracy. This finding demonstrated that PD patients have more difficulty than healthy people in performing dual tasks. However, they can still execute some relatively simple dual tasks correctly after extensive training. We found no difference when patients performed a motor or cognitive dual task together with a primary motor task, which suggests that various secondary tasks may not necessarily induce different dual task performance in PD patients.<sup>22,24</sup>

Normal subjects can perform sequential movements automatically after training, and remaining brain resources are sufficient to maintain the performance of a secondary task. By contrast, PD patients have more difficulty in performing movements automatically and require more brain processing resource to

**Figure 1: Brain Regions Activated While Performing Dual Task of Sequential Movement/Visual Letter Counting After Training in Patients with Parkinson's Disease**



Results were thresholded at  $p < 0.05$  (with multiple comparison correction) and rendered over a standard anatomical brain.

Source: Wu and Hallett, *J Neurol Neurosurg Psychiatry*, 2008;79:760–66.

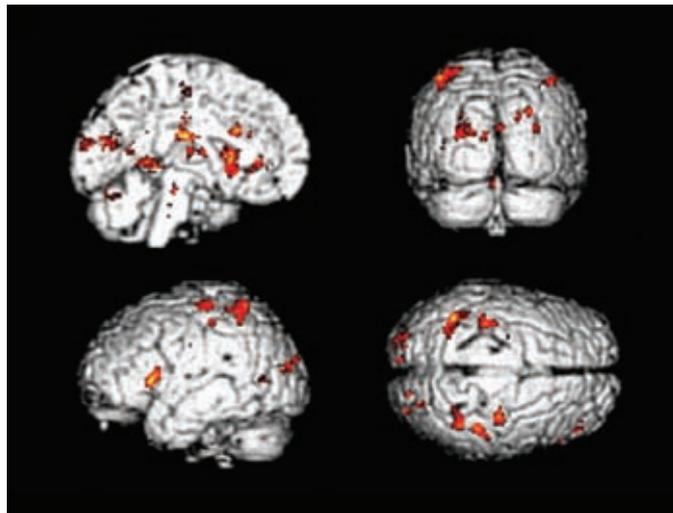
compensate for basal ganglia dysfunction to perform automatic movements.<sup>28</sup> Therefore, even if attentional resources may be relatively intact, PD patients will still have difficulties performing two tasks at the same time.

Using functional MRI (fMRI), our study found that both before and after training, for both normal subjects and patients, performance of a dual task of sequential movement/letter counting was associated with activations of the left primary sensorimotor cortex (SM1), bilateral premotor area (PMA), bilateral parietal cortex, bilateral precuneus, bilateral dorsal lateral prefrontal cortex (DLPFC), supplementary motor area (SMA), cingulate motor area (CMA), basal ganglia, bilateral cerebellum and occipital cortex (see *Figure 1*). Brain regions activated while performing the dual task of sequential movement/tapping were similar, but with activity in the right SM1 instead of the occipital cortex. The observation that the pattern of brain activity was similar in different dual tasks suggests that different dual tasks may not necessarily employ different neural mechanisms.

After training, in patients bilateral parietal cortex and PMA were less activated compared with before training (see *Figure 2*). In normal subjects, there was less activation in the bilateral PMA, bilateral parietal cortex and pre-SMA. There was less activity after training compared with before training (see *Figure 2*), which indicates that training improves performance and makes brain activity more efficient in executing dual tasks. This observation supports the presumption that diminished dual task interference may correlate with reduced resource demands of the tasks.

Dual task interference is always substantial at a low level of practice; however, after extensive practice it is reduced and even disappears.<sup>29,30</sup> After practice, brain capacity was no longer exceeded in normal subjects, and they could perform the dual tasks accurately. By contrast, although not behaviourally different, PD patients required greater activation than normal subjects to perform the simpler dual tasks.

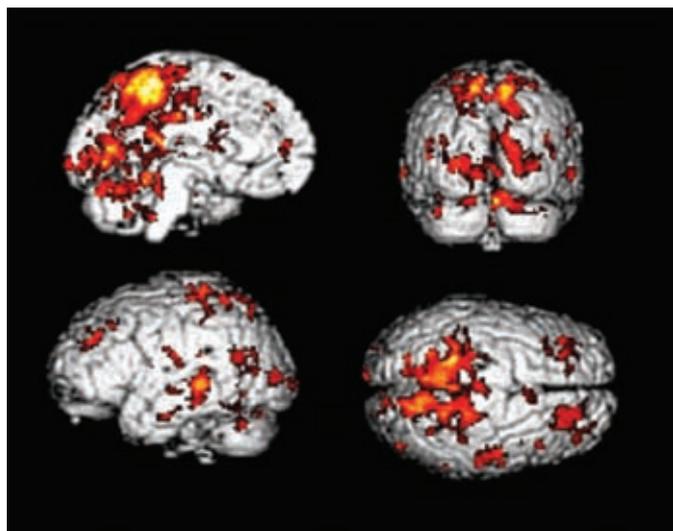
**Figure 2: Brain Areas More Activated at the Before-training Stage than at the After-training Stage When Performing Dual Task of Sequential Movement/ Visual Letter Counting in Parkinson's Disease Patients**



Results were thresholded at  $p < 0.05$  (corrected) and rendered over a standard anatomical brain.

Source: Wu and Hallett, *J Neurol Neurosurg Psychiatry*, 2008;79:760–66.

**Figure 3: Brain Areas More Activated in Parkinson's Disease Patients than in Normal Subjects During Performance of Dual Task of Sequential Movement/ Visual Letter Counting at the After-training Stage**



Results were thresholded at  $p < 0.05$  (corrected) and rendered over a standard anatomical brain.

Source: Wu and Hallett, *J Neurol Neurosurg Psychiatry*, 2008;79:760–66.

Patients had greater activation in the bilateral DLPFC, middle frontal gyrus, bilateral PMA, bilateral parietal cortex, bilateral precuneus, bilateral temporal lobe, occipital lobe, bilateral cerebellum, thalamus and cingulate gyrus compared with normal subjects when performing dual tasks (see *Figure 3*). No area was more activated in normal subjects than in patients.

Several of these areas, such as the prefrontal cortex,<sup>31–34</sup> middle frontal gyrus,<sup>31,34,35</sup> parietal cortex,<sup>34–36</sup> temporal lobe<sup>36</sup> and cerebellum,<sup>35</sup> have been shown by various studies to be associated with dual task

performance. The prefrontal cortex, especially the DLPFC, is important in attention<sup>37</sup> and performance monitoring,<sup>38</sup> and is involved in the allocation and co-ordination of attentional resources.<sup>31</sup> The parietal cortex is involved in attention, working memory and executive processes.<sup>39,40</sup>

The PMA and cerebellum are associated with temporal organisation or control.<sup>41,42</sup> More activity in these regions in patients correlating with their poorer performance further indicates that the difficulty of PD patients in performing the dual task is due to a requirement for more brain resources. Possibly, for the more complex dual task the limitation of capacity was exceeded in most patients; thus, they could not perform the more complex dual task correctly, and dual task interference still existed.

It has been observed that dual task interference is associated with overlapping cortical activation; the larger volume of overlap is accompanied by greater interference.<sup>43</sup> The study that showed this also found that brain regions activated by sequential movements overlapped with the secondary task in several locations. However, no difference in the overlapping areas – either between the groups or between the before- and after-training stages within each group – was observed, which suggests that the decreased dual task interference may not be due to less overlapping of the two single tasks. Dual tasks could be executed without significant interference even when the two tasks activated overlapping brain regions. Moreover, the significant inability of patients to execute dual tasks was not due to a larger area of overlap.

It is still controversial whether there is a central supervisor<sup>44–46</sup> or not<sup>47</sup> while performing dual tasks. We found that the bilateral precuneus was additionally activated in dual tasks compared with single tasks in patients and aged normal controls.<sup>48</sup> However, in our study in young healthy subjects, we found that no additional area was activated in performing the same dual tasks; all areas activated in the dual tasks were also activated by one or both of the component tasks.<sup>49</sup> These observations suggest that in PD patients and aged normal subjects, the precuneus may be activated as a central supervisor for dual task execution.

Wenderoth and colleagues also found that the precuneus was additionally activated in executing bimanual motor tasks compared with performing unimanual movements.<sup>50</sup> Presumably, PD patients and aged normal controls need to recruit additional brain areas to compensate for their difficulty in executing dual tasks. By contrast, in young normal subjects an additional central supervisor is not necessary because these dual tasks are relatively easy for them. The precuneus was more activated in PD patients than in normal subjects, which suggests that patients may need more brain effort from a central executive to perform dual tasks. This phenomenon was detected not only while simultaneously performing a motor task and a cognitive task, but also during performance of two motor tasks simultaneously. Therefore, it is possible that the deficit of the central executive may exist in PD patients during performance of various dual tasks.

An additional finding from that study is that there are more activations from the sum of two single tasks than that from the dual task. These results indicate that neural activity of the dual task is less than a simple addition of the activations of the two component

tasks. Some neural resources might be shared by the component tasks in order to execute the dual task efficiently.

Our studies demonstrated that practice can diminish dual task interference and improve performance in PD patients. Moreover, dual task interference in PD is due to multiple reasons: first, the limitation of attentional resources capacity is exceeded; second, PD patients perform the tasks less automatically compared with normal subjects; and third, the central executive may be defective in PD. These findings are really helpful to our understanding of dual task interference in PD. However, our knowledge of this phenomenon is still far from complete. For example, why PD patients have difficulty in switching attentional resource between tasks is unclear, and the central mechanism of this problem needs further investigation. ■



Tao Wu is an Associate Professor of Neurobiology in the Department of Neurobiology at the Beijing Institute of Geriatrics, Xuanwu Hospital. His main research interests are using functional neuroimaging methods and other techniques of clinical neurophysiology to understand the physiology of normal human voluntary movement and the pathophysiology of different movement disorders, especially Parkinson's disease.



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