SHORT REPORT

An unusual enhancement of motor performance during bimanual movement in Parkinson's disease

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Abstract

In both clinical and laboratory tests, patients with Parkinson's disease have considerable difficulty in performing different manual tasks simultaneously with the two hands. The present study reports on an unusual enhancement in performance under such conditions in a substantial proportion of patients tested. When performed at the same time as repetitive tapping tasks, the ability to rapidly place pegs in holes improved in almost half of the patients compared with unimanual performance of the peg task. Various possible explanations are considered for this unusual finding. The two most plausible, and testable, relate to either the withdrawal of attention from the task permitting a more automatic mode of execution, or a facilitation provided by sensory feedback from the simultaneous tapping task. (*J Neurol Neurosurg Psychiatry* 1998;64:813–816)

Keywords: finger tapping; Purdue pegboard; dual-task; attention

Schwab *et al*¹ and others subsequently^{2–8} have described an impaired ability of patients with Parkinson's disease to perform two simultaneous motor actions. Problems are most obvious when patients carry out different motor acts with the two hands. Any task under visual guidance (for example, drawing¹) tends to be relatively unaffected, whereas a task that is less dependent on vision (for example, repetitively squeezing the hand) tends to show marked deterioration. In a previous study⁹ with a small group of patients with Parkinson's disease ($n=7$), controls, and other patient groups, we used rapid placement of pegs into holes (visually guided), and repetitive finger tapping (non-visual). Overall, the findings were similar to those already described, with the patients with Parkinson's disease showing a pronounced deterioration in the tapping task under bimanual testing. Unexpectedly, the patients with Parkinson's disease seemed to show a small improvement in performance in the peg placement task compared with single handed performance. All other groups, including controls, showed a small deterioration in

this visually guided task. Here we report a study to assess the extent of this effect.

Subjects and methods

SUBJECTS

Forty patients with Parkinson's disease participated in the study (26 men and 14 women, mean age 59.3 (SD 10.0) (range 38–77) years). All except two were right handed. The mean duration of illness was 11.7 (SD 7.1) (range 1–22) years. The sample covered a range of disease severity from Hoehn and Yahr¹⁰ stages I to V. Most (45%) were in stage III, with 30% in stages I–II, and the remaining 25% in stages IV and V. All had a clinical diagnosis of idiopathic Parkinson's disease, based on standard criteria.¹¹ All were currently receiving or had been receiving levodopa/dopamine agonist medication. The mean daily dopamine dose (as levodopa or equivalent) was 744 (SD 431) mg. The patients' mean mini mental state examination (MMSE)¹² score was 28.5 (SD 1.7) (range 24–30). A sample of 26 neurologically healthy controls was also assessed, recruited from local subject panels, relatives, and friends of the patients (seven men and 19 women, mean age 62.7 (SD 12.5) (range 31–77) years). All except three were right handed.

PROCEDURE

The procedure was as described previously.⁹ Task 1 was peg placement using the Purdue pegboard.¹³ Subjects had to pick up metal pegs (3×25 mm) one by one from a well in front of them, and place the pegs in a vertical row of holes drilled into a board. Subjects performed the task three times, once with the right hand, once with the left hand, and once with both hands simultaneously (from two wells into two parallel rows of holes). On each occasion the subjects had to place as many pegs as possible in a 30 second period. A total score for the two hands in the unimanual condition was calculated (PEG_U), plus a total for the two hands in the bimanual condition (PEG_B). Task 2 involved repetitive tapping of the index finger. Performance was measured with a standard 150 g microswitch with 4 mm travel. As with the peg placement task, the tapping task was performed three times, once with the left hand, once with the right, and once bimanually. Once again, total unimanual (TAP_U) and bimanual

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Received 16 September 1997
and in revised form 17 November 1997
Accepted 19 November 1997

Unilateral and bilateral performance of the two groups on the tapping and peg placement tasks (mean (SD))

	Controls (n=26)	PD (n=40)	t(df)	p Value
Peg placement:				
Unimanual (PEG _U)	29.2 (3.6)	15.7 (6.9)	t(61.2)*=10.4	<.0001
Bimanual (PEG _B)	23.8 (4.3)	10.5 (5.8)	t(62.6)*=10.7	<.0001
PEG _U -PEG _B	5.5 (2.8)	5.3 (3.7)	t(64.0)=0.25	>.10
PEG _B as % PEG _U	81.2 (9.3)	66.6 (24.3)	t(54.2)*=3.4	<.001
Tapping:				
Unimanual (TAP _U)	299.8 (64.8)	201.0 (60.8)	t(64.0)=6.3	<.0001
Bimanual (TAP _B)	292.7 (59.9)	180.3 (63.8)	t(64.0)=7.2	<.0001
TAP _U -TAP _B	7.1 (19.4)	20.7 (13.3)	t(64.0)=-2.4	<.05
TAP _B as % TAP _U	98.3 (7.6)	89.2 (13.3)	t(63.1)*=3.5	<.01
Combined tasks:				
PEG _C	26.9 (4.1)	15.7 (7.2)	t(62.9)*=8.1	<.0001
PEG _U -PEG _C	2.3 (2.8)	0.0 (3.3)	t(64.0)=2.9	<.01
PEG _C as % PEG _U	92.4 (9.3)	104.6 (38.1)	t(45.9)*=-1.9	<.06
TAP _C	237.8 (74.1)	96.9 (50.3)	t(39.9)*=8.5	<.0001
TAP _U -TAP _C	61.9 (45.8)	104.1 (47.7)	t(64.0)=-3.6	<.001
TAP _C as % TAP _U	78.7 (14.9)	47.2 (17.9)	t(64.0)=7.4	<.0001
PEG _U -PEG _C (subjects (%)):				
Improvement (PEG _C >PEG _U)	11.5	42.5		
Change (PEG _C =PEG _U)	15.4	10.0	χ ² (2)=7.2	<.05
Deterioration (PEG _C <PEG _U)	73.1	47.5		

*t Value and df calculated for samples with unequal variance. p Values for two tailed test.

(TAP_B) scores were calculated for the 30 second period.

In addition to the bimanual peg and bimanual tapping tasks, the subjects also performed two bimanual tasks combining peg placement and tapping. In one they tapped with the left hand while placing pegs with the right, and in the other they tapped with the right hand and placed pegs with the left. In these combined conditions, subjects were instructed to try to do both tasks as well as they could, and not to concentrate on one to the exclusion of the other. As before, total scores for the two hands were calculated for each of the combined tasks (PEG_C and TAP_C).

Subjects received a 30–60 second break between each of the conditions in the different tasks. Testing took about 10 minutes in total. Before testing, all patients were withdrawn from their normal antiparkinsonian medication. Testing typically took place in the morning, and patients were requested to withhold their medication on waking until after testing was complete. The mean time since their last medication was 11.2 (SD 3.5) hours. All subjects gave informed consent.

Results

Table 1 shows the results from each test condition. In addition to the total scores, the measures of bimanual performance are expressed as absolute difference (PEG_U-PEG_C), and percentages of unimanual performance (PEG_C/PEG_U×100).

The overall motor performance on both the tapping and peg placement tasks was significantly impaired relative to controls. This was true for both unimanual and bimanual performance under the single task conditions. For PEG_U, the patients managed to place only half as many pegs as the controls. In PEG_B, both groups showed a similar and significant overall decline in performance of just over five pegs between the two hands (Parkinson's disease: $t(39)=9.1$, $p<0.0001$; controls: $t(25)=7.1$, $p<0.0001$). However, because the patients' unilateral performance was inferior to the controls, this absolute difference between the con-

ditions represented a significantly larger percentage decline.

For the TAP_U, the patients were again impaired, producing significantly fewer taps. In the TAP_B, both groups produced fewer taps than unimanually. However, the absolute decline was significant only for the Parkinson's disease group (Parkinson's disease: $t(39)=4.9$, $p<0.0001$; controls: $t(25)=1.87$, $p<0.08$). This is also reflected in the percentage decline.

In the combined task (tapping with peg placement), TAP_C showed a pronounced deterioration in both groups relative to TAP_U. The control group's performance was 78.7% of their unimanual performance, whereas for the patients TAP_C was only 47.2% of TAP_U. A different pattern was found for pegboard performance under the combined conditions. The controls showed a small but significant drop in the number of pegs placed (PEG_C) relative to PEG_U ($t(25)=4.2$, $p<0.0001$). The patients, by contrast, showed identical mean performance under the two conditions ($t(39)=0$, $p=1.0$). However, when translated into percentage change on an individual basis, there was a small mean improvement in the patient group's performance under the bimanual condition. Whereas the absolute change in performance differed significantly between the two groups, the mean percentage change just failed to reach conventional significance ($p<0.06$), due largely to the high level of variability. The result, however, is consistent with the other findings.

These effects are not fully represented by considering mean scores. Figure 1 shows the distribution of the absolute difference (PEG_U-PEG_C) for individual subjects in each group. The control subjects tended to show a bias towards deterioration in the number of pegs placed in the combined condition, whereas the Parkinson's disease group's distribution was more symmetric about the zero (no difference) point. Subjects were classified as showing improvement in the number of pegs placed (PEG_C>PEG_U), no change (PEG_C=PEG_U), or a deterioration (PEG_C<PEG_U). The percentages in each group are shown at the bottom of the table. Whereas only a minority (11.5%) of controls showed improvement in the combined condition, almost half (42.5%) of the patients showed such a change.

Finally, the relations between aspects of task performance and disease factors of duration, levodopa dose, and stage of illness were examined using Spearman's rank correlation coefficients. High levels of association were found between duration and stage of illness with measures of both peg placement and tapping ($r>0.63$, $p<0.0001$ for measures of peg placement and $r>0.49$, $p<0.002$ for tapping). This was the case for either task performed unimanually or bimanually. By contrast, performance was unrelated to dose of levodopa ($r<0.20$, $p>0.10$). However, when performances in the combined tasks relative to the unimanual tasks (either difference scores or percentages) were considered, no significant associations were found with any of the clinical variables ($r<0.28$, $p>0.10$ in all cases).

Distribution for Parkinson's disease (PD) and control groups (expressed as group percentages) of absolute difference scores between unilateral peg placement score and peg placement while tapping.

Discussion

As shown previously, under combined task conditions, patients show a dramatic deterioration in the task *not* under visual control, in this instance tapping. What has not been previously reported is that a considerable proportion of patients showed an improvement in the visually guided task—peg placement. Two possible explanations can be considered. The first involves the attentional demands of the tasks, whereas the second involves their coordination and timing.

Actions vary in the degree to which they demand the conscious allocation of attention for their performance. "Attention" is an active and demanding process, and our attentional capacity is limited. Typically, if we try to divide our attention between two tasks, neither will be performed as well as they would be if performed with maximal and undivided attention.¹⁴ The degree of interference, however, will depend on the attentional demands of the two tasks. A largely automatic task could be carried out simultaneously with a more demanding task with little or no interference either way. When both tasks demand significant attention, interference will be found.¹⁵ Repetitive tapping is a relatively automatic task in normal subjects, although even they showed small amounts of interference. In the patients, interference was much more pronounced for the tapping task. Within an attentional framework this could mean that the tapping task was more demanding, the pegboard task was more demanding, or that the subjects had fewer overall attentional resources to allocate.¹⁶ The idea that tapping, and other simple repetitive movements, are less automatic in patients with Parkinson's disease has been suggested previously.¹⁷

Although such a traditional attentional interference account could explain the pro-

nounced deterioration on the tapping task it would not predict any improvement on the pegboard task. However, if we propose that the patients are having to attend more or "try harder" in placing pegs, even in the single task condition, we can ask whether more attention is necessarily better. Instances exist in normal subjects in which such attention may interfere with skilled action. While running down stairs, thinking about what the legs are doing can lead to catastrophic results. For professional golfers, thinking about their putt during its action can seriously interfere with performance. Therefore, skilled visually guided tasks may have an optimum level of attentional allocation. Too little, and the fine on line control is compromised. Too much, and it affects the natural, automatic execution of the skilled elements.

Such a phenomenon might account for the improvement of the patients on the combined peg task. The concurrent tapping task (which is more difficult in the patients) served to withdraw some of the "excess" attention from peg placement, bringing the level of allocation closer to the optimum for skilled performance.

Although such an attentional model may fit the data, other possible hypotheses exist. For all except highly skilled people, there is a major problem in producing simultaneous movements at different rates or rhythms, unless the frequencies are simple harmonics. Even if it can be achieved, the actions can only be sustained by considerable allocation of attention, and there is a tendency for the two movements to become synchronised.¹⁸ Both tasks in the present study involved rhythmic actions, tapping more obviously so. Attempting to perform them simultaneously might lead normal subjects to reduce the maximal rate of one or both tasks until the two frequencies could be expressed as simple harmonics (for example, 10 taps for every one peg). However, this

simple hypothesis again fails to provide a useful account of the patient data. It seems unlikely that the patients were able to increase their peg placement rate, to help achieve such synchronisation. As with the attentional account, it is necessary to look beyond the simple models for possible mechanisms that might explain the present results. Patients with Parkinson's disease can produce simple repetitive movements of different frequencies with a high level of accuracy, although there are limits at the upper levels, and the overall rate may be more variable,¹⁹ with periods of freezing and festination, and by a gradual decrease in the amplitude of the response. These same characteristics are seen in more complex rhythmic actions such as walking and writing. Problems are particularly acute when the patients have to rely on their own internal mechanisms for maintaining rhythm and regularity, and performance can be improved by an external pacing signal.^{20, 21} In the present study, patients could have used sensory feedback from the tapping task—either auditory or kinaesthetic—to drive the repetitive rhythmical elements of the peg placement task at a faster rate than they were normally able to perform. Patients often report using tricks such as whistling or humming a tune to sustain rhythmical actions such as walking, suggesting that self-generated, as well as external cues, can be useful. Equally of course such strategies might work by diverting attention as hypothesised above.

Thus we are left with two possible explanations for the present unusual finding—one based on the withdrawal of attention to permit a more automatic execution and one based on a self cueing of rhythmical movement. Although the present data do not allow us to distinguish between the two hypotheses, they would be relatively easy to test. For the attentional hypothesis, the nature of the concurrent task could be changed from tapping to another attention demanding task not involving manual control—for example, mental arithmetic. If the hypothesis is correct, then manipulating the attentional demands of the secondary task should produce systematic effects on pegboard performance. In a similar way, the cueing hypothesis could be tested by manipulating the timing characteristics of the secondary task. Subjects could be given a fixed rate of tapping, rather than having to tap at a maximal rate, with variations in this rate having systematic effects on peg placement.

Future research should seek to replicate the finding and further define its limits, particularly whether it extends to more important actions such as walking and writing. If the phenomenon can be reproduced and the mechanisms elaborated, it could have important implications for the development of more efficient physical therapy for Parkinson's disease.

This project was financially supported by the Medical Research Council and the Wellcome Trust.

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