SHORT REPORT

Practice effects on the preprogramming of discrete movements in Parkinson's disease

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Abstract

The effects of practice on the simple and choice reaction times (RTs) of Parkinson's disease (PD) and control subjects in a discrete aiming task were analysed. For controls, practice led to a selective decrease in choice RTs, as has been reported previously. An opposite effect was seen in the PD group, with little change in choice RTs and substantial reduction in simple RTs. The results suggest that PD subjects can use advance information to initiate discrete movements more rapidly, but that this ability to "preprogramme" movements requires practice. Reconciliation of these results with studies reporting an inability to preprogramme in PD are made in a discussion of task characteristics which may allow or preclude preprogramming.

From the studies which have examined movement planning in Parkinson's disease (PD)¹⁻¹⁷ has emerged some consensus that PD patients can use a predictive strategy in tracking tasks, although less efficiently than normal controls.^{4,16} It has been asserted, however, that PD patients are unable to use advance information to initiate discrete movements more rapidly, shown by the absence of shorter reaction times (RTs) in simple as opposed to choice conditions.^{1,2,11} Sheridan, for example, states "The RT data . . . substantiate systematically the findings of Flowers,⁷ Evarts *et al*⁶, and Bloxham *et al*² in showing that Parkinsonian patients seem unable to make use of advance task information to reduce their RT."¹¹ In contrast, our own data show no evidence of selective slowing of simple RTs in PD patients, nor evidence that advance information is used abnormally.¹²

We present a reanalysis of RT data which partly reconciles these dichotomous findings. Specifically, we provide evidence for differential effects of practice of choice and simple RTs of PD patients, and draw attention to the task-dependent nature of programming in PD.

Methods

Data from an earlier study (which includes a fuller account of the methods)¹² were examined

together with data not previously analysed for effects of practice on simple RT and on three different levels of choice RT. Eight PD and eight control subjects with no known neurological disorder were used. PD subjects were taking Sinemet alone, or in combination with dopamine agonist or cholinergic drugs. Seated subjects made discrete aiming movements with the left or right index finger to one of eight targets, from left or right "home" keys situated in the middle of two parallel rows of four "target" keys. These rows were parallel to the mid-sagittal axis and were arrayed on a horizontal surface. Each trial began with both left and right index fingers on their respective home keys. The ensuing movement had to be made with only the left or right hand, towards or away from the body, and have one of two extents (3.5 or 7.0 cm), depending on the position of the target. Eight light-emitting diodes (LEDs) were displayed on a vertical surface in front of the subject in the same spatial configuration as the keys. Subjects moved when a single target LED was illuminated. This signal was preceded two seconds earlier by a one-second "precue", which denoted the subset of possible targets. The precue consisted of the illumination of one, two, four or eight LEDs, respectively providing complete, partial or no advance information on the required movement.

Before data collection, subjects carried out 192 movement practice trials under CRT conditions, moving as quickly and as accurately as possible to one of the eight targets in response to the illumination of the corresponding LED. All targets were used an equal number of times in a quasi-random order, with no precue.

Subjects then carried out two blocks of trials including full, partial or no advance information conditions (one; two or four; or eight targets precued, respectively). These blocks were administered for practice but were identical to subsequent experimental blocks, except for the availability of visual information (see below). For current purposes they are treated as blocks one and two of a series of eight. Subsequent testing took place on a second and (in some cases) a third day. On the first block, full vision of the targets was allowed. Thereafter, a head-mounted "visor" occluded the lower half of the visual field, so that movements were made under visual open-loop conditions. Subjects could view the targets before and after each trial, however, by tilting the head downwards. This allowed them to update a "visual

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Table Parkinson's disease group cumulative mean RTs for SRT and 2-choice CRT conditions

		Number of blocks over which data is accumulated							
SRT	X	1	2	3	4	5	6	7	8
	SD	477	460	454	439	433	424	417	415
CRT2	X	512	484	486	483	483	479	475	472
	SD	88	99	87	82	78	79	77	75
t		1.30	1.12	1.87	2.52	2.88	3.62	4.02	4.09
p		ns	ns	ns	<0.05	<0.05	<0.01	<0.01	<0.01

SRT: simple reaction time; CRT2: 2-choice reaction time; t: value of *t* for paired *t*-test; p: probability level; X: group mean; SD: between-subject standard deviation.

map" of the target key layout.

Data from one PD subject was excluded since marked symptom fluctuations made an analysis of block data impracticable. Reported here are mean RTs for simple and three levels of choice conditions, excluding trials on which the RT or MT exceeded the mean value for that subject on the second practice block. These criteria were applied post-hoc to the two practice blocks.

Results

Reaction Times in Discrete Aiming

Practice affected the two groups differently. The figure shows that controls improved much more in 4- and 8-choice RTs than in the simple RT (SRT) condition. The declines averaged 9.9, 8.9, 8.0, and 5.2 ms per block for the 8-, 4-, 2-choice RT and SRT conditions respectively. This is compatible with previous reports of selective choice RT reductions in normal controls.¹⁸

The PD group, by contrast, showed no such reduction in choice RTs. Indeed, the benefits of practice were more evident in SRTs. Average reductions for the 8-, 4-, 2-choice and SRT conditions were -3.2 (representing an increase), 2.4, 7.9, and 13.3 ms per block. This differential SRT benefit was shown in the interaction between block and number of choices: $F(21,126) = 2.43$, $p < 0.005$. Moreover, the RT slopes were significantly steeper

with fewer choices, the linear component of the block effect interacting significantly with the number of choices: $F(1,6) = 40.11$, $p < 0.001$.

Practice effects for the PD group were thus opposite to those for controls. Moreover, there were significant differences between groups in a) the interaction between blocks and number of choices, $F(21,273) = 3.06$, $p < 0.0001$; and b) the linear component of this interaction, which compares the slopes of the RT functions for the groups, $F(1,13) = 7.6$, $p < 0.05$.*

Note that for both groups RTs temporarily rise in the third block (the first block on the second day for all but one control). This temporary decline represents the "warm-up decrement" widely reported in the acquisition of motor skills.¹⁹ Also, the withdrawal of visual information about the target after one block did not prolong RTs, which decreased for both groups.

To illustrate the implications of these results for the interpretation of experiments in which different amounts of data are collected, a "simulation" analysis was performed. Average PD RTs for simple and 2-choice conditions were calculated cumulatively for one to eight blocks and compared with paired *t*-tests (see table). For 1, 2 or 3 blocks, SRT and 2-choice RTs were not significantly different at even the 0.1 level. For 4 or 5 blocks, the difference was significant at the 0.05 level, and for 6, 7 and 8 blocks, this difference was significant at the 0.01 level. This divergence results from practice, not from greater power in the statistical analysis, since an equal number of means were used in each *t*-test.

Discussion

These analyses have implications for interpreting RT data in Parkinson's disease. First, they suggest that PD subjects can indeed use advance information to initiate movements more quickly (preprogramming), given enough familiarity with the task. The benefit of advance information does not appear early in practice, however, since smaller SRT-CRT differences are still present. If losing the ability to preprogramme movements is a direct mani-

Figure Mean reaction times as a function of practice for a) control group and b) PD group, for simple and three levels of choice reaction time conditions. Break between blocks 2 and 3 indicates end of first day of testing. SRT: simple reaction time. CRT2, CRT4, CRT8: number of choices in CRT conditions.

*Since the comparison of eight control and seven PD subjects results in an unbalanced design, these analyses were repeated with data discarded from the control subject with the largest choice RT reduction (that is, the control whose data was most unlike the PD group). The results were very similar: Group $\times$ choice $\times$ block interaction: $F(21,252) = 3.20$, $p < 0.0001$; linearity of block effect in this interaction: $F(1,12) = 6.04$, $p < 0.05$.

festation of the disease, then it should not reappear with practice. It seems that the tendency not to preprogramme initially may represent a secondary, indirect consequence of PD, with several possible causes. PD subjects may start by using a single strategy for CRT and SRT movements, planning each after the response signal, but subsequently learn to use a preprogramming strategy for SRT motions. This strategy, while not optimal, requires less effort and attention, and would yield small CRT-SRT differences of the kind previously reported.^{1,2,6,11}

In reasserting our conclusion that patients with PD can preprogramme discrete movements, we point also to those studies which show either selectively prolonged choice RTs in PD,¹⁰ or similar simple RTs for PD and control subjects,¹⁷ or, minimally, show reductions in RT for PD subjects when given an appropriate warning signal.^{1,8}

Both groups showed some practice benefit for 2-choice RTs. If the primary effect of practice for PD subjects is learning to preprogramme, why do they show improvement in 2-choice RTs as well as SRTs? Perhaps some preprogramming was possible even in these 2-choice conditions. In one third of these cases, the two choices were the identical targets on the left and right sides. Subjects may have engaged in parallel programming of the two limbs, withholding the movement of one of the limbs after the response signal. Another third of these trials were to pairs of adjacent (long and short) targets using a known limb in a known direction, which may also have permitted some preprogramming.

These results contrast strikingly with those of Pullman *et al.*²⁰ in a study of RT effects for different plasma concentrations of levodopa. These authors recently reported a selective reduction in choice RTs in PD for higher levodopa levels, SRTs being not significantly affected. Why might practice benefit SRTs and not CRTs, while medication reduces CRTs but not SRTs? One possibility is that response selection mechanisms, which are present in CRT tasks, use dopaminergic pathways, while preprogramming mechanisms might be carried out by non-dopaminergic pathways. This explanation would be compatible with the notion that some features of the disease, exemplified by an initial reluctance to preprogramme, are really secondary to the pathophysiology of PD.

Differences in task characteristics may account for the finding of evidence for preprogramming in some studies and the failure to do so in others. For example, the results in the study by Sheridan *et al.*¹¹ suggest an inability to preprogramme in PD. The task, unlike that reported here, required the "internalisation" of an arbitrary input-output relationship, namely the distance moved by a cursor on a screen per unit of distance moved by the hand-held lever. It would seem that a subject would have difficulty preprogramming motions with this device until this gain relationship had been well learned.

Incomplete learning of this aspect of the task

might explain why PD subjects had movement times of between 900 and 1600 ms, while in our task the PD movement times were about 550 ms. Indeed, the long MTs and discontinuous trajectories in Sheridan's study might stem from the type of visual closed-loop strategy characteristic of an incompletely learned task, which is often replaced by an open-loop strategy.²¹

These results emphasise the importance of elucidating motor learning and adaptation in Parkinson's disease (and other movement disorders) since conclusions about control deficits may be influenced by the extent to which learning has taken place. This study confirms the findings of Frith *et al.*²² that motor learning can occur in PD, but abnormalities of motor learning and adaptation in this disease remain largely uncharted.

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