The abnormal proprioceptive guidance of human voluntary movements in patients with Parkinson's Disease; implications for physiotherapy management.

A thesis submitted to the University of Manchester for the degree of Doctor of Philosophy in the Faculty of Medicine, in the year 2000, by Brenda Lövgreen, of the Department of Biological Sciences.

√

CONTENTS

Page number

Abstract.

The abnormal proprioceptive guidance of human voluntary movements, in patients with Parkinson's Disease (PD); implications for physiotherapeutic management.

The thesis is organised in three main sections. Part 1 (chapters 1 and 2) describes the rationale for physiotherapy intervention for the motor disorders of PD, and is followed by an investigation of this intervention. Initially a questionnaire was issued to 28 physiotherapists in the North of England and Wales, and 25 were completed and returned. The main findings were (a) the principal referral source of PD patients was from medical consultants (38% of total referrals), (b) the assessment formats most frequently employed (65% of respondents) was a modified version of the PD Society rating scale, (c) 59% of respondents chose the Bobath approach to treatment, (d) outcome measures were utilised by 76% of respondents for whom the Webster rating scale or a locally designed measure were the most popular, (e) the need for post graduate training was a commonly identified issue and (f) there was a lack of association between (i) referral source and assessment formats, and (ii) treatment approaches and outcome measures. Secondly as part of a UK-wide assessment using the Delphi process and data collected from follow-up structured interviews the author performed an analysis of aspects of physiotherapy management at selected clinical sites in North Wales. The Delphi process (consensus was extremely high between rounds, 91%, n=74) highlighted the need for early referral to physiotherapy for PD patients, the use of standardised assessment forms, an ecclectic approach to treatment, the inclusion of a multidisciplinary key worker and patient involvement in setting treatment goals. The structured interviews confirmed these issues.

In Part 2 (chapter 3) laboratory-based experiments were performed to compare submodalities of proprioceptive sensation, namely, the senses of (i) force production (Experiment 1) and (ii) weight or heaviness (Experiments 2 and 3) in patients with PD and age-matched controls isometric elbow flexor forces was tested. In each trial, one arm was designated the reference limb whose contraction level (5% or 10% of the individual's maximum voluntary contraction) was controlled by the subject using visual feedback of force production. Subjects attempted to generate an identical force using the other arm, designated the test side, in the absence of associated visual feedback. Across group analysis of data, pooled from the two reference levels, indicated that subjects produced significantly greater forces on the test side, irrespective of whether the test limb corresponded to the dominant/non-dominant or clinically better/worse side. In addition PD patients tended to make greater bilateral force-matching errors: the group mean error index of the patients was approximately twice that of the controls.

In experiments 2 and 3, the abilities of parkinsonians and age-matched controls to discriminate bilateral differences in weights, lifted and supported by voluntary elbow flexion were investigated. During each trial, one arm served as the reference limb and the other arm as the test limb. The Best Pest method was used to estimate classical psychophysical measures (difference limen, DL; point of subjective equality, PSE; Weber ratio, WR). Values of the DL, a measure of threshold for detection of bilateral weight differences, pooled across test sides were significantly greater for the PD groups. The patients' values also tended to be more variable. In neither group did test side (dominant/non-dominant, clinically better/worse) significantly affect performance. The results of experiments 2 and 3, in combination, strongly suggest that PD produces disturbances of proprioception. Recommendations for further research are identified.

In part 3 (chapters 4 and 5) an evaluation of the following physiotherapy approaches was made (1) biomechanical (including exercise therapy), (2) mental planning and preparation, (3) relaxation therapy and (4) strategy development (including cues) using a single case system design for 4 patients. Effects of each of the forms of treatment were found to be clinically beneficial and that of the biomechanical approach was statistically significant (using the two standard deviation band test). The implications from the component parts of the thesis are discussed in terms of clinical governance and an evidence base for practice. In addition the research findings have been considered for future physiotherapeutic implementation.

A List of tables and figures.

Declaration:

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or institute of learning.

Signed: ....

Brenda Lövgreen

Date: 25 . 05 . 2000

Autobiographical Details.

The author qualified as a Chartered physiotherapist in 1969, and obtained a Diploma of Teaching in Physiotherapy, 1974. In 1991 a Master's degree in Science was attained from the University of Manchester. The areas of research undertaken for the Master's degree related to proprioceptive control of movement in normal subjects and patients with cerebellar disorders. The author became a founder member of the Physiotherapy Research Society, and holds membership to the Society for Research in to Rehabilitation and affiliation membership of the Physiological Society. Currently a member of the national Physiotherapy Evaluation group in Parkinson's disease (PEP).

The author received the first scholarship from the H.S.A. for a physiotherapist to undertake a Ph.D. The author has been employed as a Senior Teacher in Physiotherapy at Manchester Royal Infirmary from 1991 to date, and was presented with CMHT scholarship to present her research at an International Conference in St. Petersburg in 1997.

Abbreviations.

ACPC	Association of Chartered Physiotherapists in the community.
ACPIN	Association of Chartered Physiotherapists interested in neurology.
AGILE	Association of Chartered Physiotherapists working with the elderly.
BG	Basal ganglia.
BLS	Bradykinesia laterality scores.
CNS	Central nervous system.
CPD	Continuing professional development.
CSP	Chartered Society of Physiotherapy.
DoH	Department of health.
EBM	Evidenced based medicine.
EPDS	European Parkinson's disease society.
GABA	Gamma amino butyric acid.
GPe	Globus pallidus externus.
GPi	Globus pallidus internus.
HMSO	Her Majesty's Stationery Office.
H&Y	Hoehn and Yahr.
MMSE	Mini mental status examination.
MTPT	N-methyl-4-phenyl-1,2,3,6-tetrahydropyridine.
M1	Primary motor cortex.
NHS	National health service.
PD	Parkinson's disease.
PDS	Parkinson's disease soceity United Kingdom.
PEP	Physiotherapy Evaluation Project in Parkinson's disease
PEPE	Physiotherapy Evaluation Project in Parkinson's disease, in Europe
PMC	Pre-motor cortex.
PWS	Plastic wrist support, weight holder
RCP	Royal college of physicians.
SMA	Supplementary motor cortex.
SSA1	Somatosensory area 1.
SSA11	Somatosensory area 11.
SNpr	Substantia nigra, pars reticulata.
SNpc	Substantia nigra, pars compacta.
ST	Sub-thalamic nucleus.
UK	United Kingdom.
VPLc	Vental posterior lateralis nucleus of the thalamus.
VA	Ventral anterior nucleus of the thalamus.
VL	Ventral lateralis nucleus of the thalamus.
WHO	World health organisation.
WRS	Webster rating scale.

Psychometric statistical terms:

SID	Subject identification number.	WR	Weber ratio
UT	Upper threshold .	DL	Difference Limen.
POE	Point of Objective Equality	PSE	Point of Subjective Equality.
LT	Lower threshold	IU	Interval of uncertainty.

Acknowledgements

I would like to express my sincere thanks to the following people who have facilitated my course of study:

- Central Manchester Healthcare Trust and the Principal of the Manchester School of Physiotherapy, for assistance towards funding of the fees, and allowing time towards the opportunity to undertake a PhD course of study.
- Hospital savings association for the scholarship in conjunction with the research department of the CSP (Chartered Society of Physiotherapists).
- Glaxo-Welcome and Roche pharmaceuticals, and especially to Professor Plant and colleagues from the Evaluation Project, who have offered peer support, advice, and friendship, as we have worked together at an exciting time in the history of our profession.
- All my teaching colleagues, administrative staff and the Librarian, from the Manchester School of Physiotherapy, for their continued support and encouragement.
- The staff from the Dept. of Neurology (MRI), in particular Dr W Schady and Dr JPR Dick, Consultant Neurologists, for assistance with accessing patients, support and research space.
- To the Dept. of Biological Sciences and their staff, in the University of Manchester, in particular, the technical expertise, computational and electronic support from Mr J. Banks; to Dr C. McCrohan, and also to the other academic staff of the department and Mr W Manning, who have offered help in many ways. From the Dept. of Psychology, Dr D. O'Boyle for his interest and advice with some statistical aspects, and also to Dr Cousins.
- The staff of the Electronics and Mechanical Workshops of both CMHT and the University of Manchester, for their technical expertise and assistance.

Most importantly:

- The patients and subjects who volunteered and gave their time for data to be collected.
- My husband Jon, our three children Emma, Guy and Holly (at the same time they have all been undergraduates themselves) and family, and friends during this time who have shown the love and support to enable me to undertake this course of study.
- Dr F.W.J. Cody.

  As a supervisor, his skills in several areas are equal to the academic ability and expertise that is his by virtue of his commitment and years of experience. He has the ability to facilitate experiential learning, and to support a colleague, through the development of the research protocols and data collecting. His availability and dedication at a high level was always a constant feature, and this was sustained over the course. Dr Cody has offered sound guidance and constructive comment at all stages over the last few years. Detailed planning and teaching precision in data collection, have been part of his skills which have been demonstrated, tempered with encouragement, a sense of humour and perspective; much needed commodities at several stages of the process. I feel very honoured to have been able to share in his enthusiasm for neurology. With his guidance and example I have been able to develop skills of my own in this area. My gratitude to him is immeasurable, as are my sincere thanks.

Dedication.

I would like to remember my former teacher and friend, Miss PJ Waddington, BA, FCSP, Dip.TP, who was inspirational in both her treatment of the neurologically disabled patients, and in her encouragement and support for my application to undertake a Ph. D. This thesis is dedicated to her memory.

CHAPTER 1.

An overview of Parkinson's disease and the rationale for physiotherapy intervention.

After a brief introduction, this chapter is presented in two main sections. The first (1.i) is an overview of the epidemiology, aetiology and manifestations of Parkinson's disease with a summary of the available treatment approaches. The second section (1.ii) introduces the rationale of physiotherapy intervention for patients with Parkinson's disease.

Introduction.

"Movements make man. Uniquely we can write and talk. Our every day lives depend on precise control of the muscles that produce finger movements and speech sounds"

(Cody, 1995).

Human voluntary movements are complex, precision actions relying on the integrity of the nervous system for their planning, execution and control. The nervous system is organised for the integrative actions of the system to produce coordinated and skilful movements of every day functional activities. As a physiotherapist the author has observed many patients who are unable to move, or to control their movements. Disorders of movement, in the chronic degenerative diseases of the nervous system such as Parkinson's disease (PD), are areas in which management by the physiotherapist has been traditionally prescribed.

The role of the physiotherapist is to optimise the abilities of a patient with PD to achieve their full potential. The focus of intervention by the physiotherapist will not affect the cause of this disease, but the functional impairments of these movement disorders may be addressed (Chatterton and Lövgreen, 1999).

THE AIMS OF THE THESIS:

1.To investigate the effect of abnormal proprioceptive guidance of human voluntary movements in patients with Parkinson's disease.

2.To find the specific problems they have in utilising proprioceptive information in the decision making processes of comparing bilateral activity. Implications from these studies can be used in helping to reinforce the choice of therapy approaches in the future.

3.To investigate physiotherapy practice and associated issues for PD patients.

4.To test the intervention of physiotherapy practice, by single case study design in PD.

5.To identify evidence-based theory of physiotherapy practice for PD patients from the literature, experimental evidence and single case design and relate these findings to support the evidence base of the theory of appropriate interventions.

1:i Parkinson's disease.

James Parkinson, in 1817, first described the features of the "shaking palsy". This is characterised by slow deterioration of the basal ganglia, which leads to an "akinetic-rigid syndrome", usually with a rest tremor, accompanied by a flexed posture, a shuffling gait, and reduced balance (Marsden and Obeso, 1994). The classical diagnostic features of the disease are based principally on the presence of tremor, rigidity, bradykinesia and balance (or postural) instability, due to the depletion of dopamine-producing cells in the basal ganglia (Marsden, 1994). The differential diagnosis of parkinsonism has PD as its main cause, although other aetiologies may present with these same movement problems for which treatment and prognosis will be different from those of cases of idiopathic PD.

The pathology of PD.

The severity of PD correlates well with the extent of degeneration in the substantia nigra pars compacta of dopaminergic neurones. These dopamine producing cells appear to regulate the functioning of the "direct" and "indirect" pathways of the basal ganglia, leading to a loss of spontaneous movement (Marsden and Obeso, 1994). Depression has been linked to patients with PD and 33% of patients have been reported with dementia in later stages. There are also inherited variants of the disease.

Epidemiology.

This disease is predominantly, though not exclusively, a condition affecting the older generation. In the United Kingdom there are 100 in 100,000 of the population and the number rises steeply after the age of 50 to approximately 500 in 100,000 of the population (Marsden and Obeso, 1994). There are approximately 75,000 new cases of Parkinson's disease diagnosed in Europe each year, with an estimated six million patients suffering from this condition (de Rijk, Tzouri, Breteler, Dartigues, Amaducci, Lopez-Pousa, Manabens-Bertran, Alperovich and Rocca, 1997). There were fundamental problems with the combined European study (de Rijk et al, 1997) in which these data were collected. In the design, homogeneity of study populations and classification of the diagnosis were not selected prior to the study. A retrospective review, therefore, produced variation in the prevalence rates from 10 to 450 per 100,000 of the population. However, it demonstrated that there was a similar distribution between the sexes, although it did appear that males were more likely to come forward for treatment than females, which may explain why some studies may have initially indicated a higher incidence in males than in females. All the studies revealed a frequency distribution showing an increased prevalence with age. A significant number of the European population are thought to be undiagnosed in the general population (de Rijk et al, 1997). Marsden and Obeso (1994) commented that the world populations are similarly affected by this condition except that the incidence may not be as high in China or Africa.

Aetiology.

The cause of Parkinson's disease is still open to speculation; toxins, infection and trauma with their cumulative effects are constantly being considered as causative agents. Theories have been presented as to the possible causes that lead to the occurrence, at a histological level, of reduced numbers of dopaminergic-producing neurones in the substantia nigra pars compacta. Rothwell (1996) proposes a diminution of these cells to less than 20% of their former number before onset of the symptoms. Present speculation that this diminution was due to the aging process alone is not substantiated, as positron emission tomography (PET) results show that dopaminergic cells are not automatically decreased with advancing years (Playfer, 1997). Heredity was considered to be a factor. Some speculation has hinted at environmental agents being causative. These toxins may be cumulative over the years or quite dramatic in rapidity of onset, as was the case of the drug abusers from the West coast of America in the 1980's. A sudden incidence of these young people, known to be substance abusers, developing parkinsonian-like symptoms following their taking a supply of a pethidine analogue, MPTP (N-methyl-4-phenyl-1,2,3,6-tetrahydropyridine) was observed. The destination of this drug had been the dopaminergic cells in the basal ganglia, which had been selectively destroyed. The resulting damage was to the mitochondrial respiratory enzymes of these dopaminergic cells, and was later found to parallel the enzymatic problems in idiopathic PD (Playfer, 1997). Larger amounts of the toxins also cause damage to the dopaminergic and adrenergic neurones in general.

Medical and surgical management.

Historically there has been controversy associated with medication for PD. Hoehn and Yahr (1967) discussed the uncertainty of the effectiveness of the medication then available, suggesting it was due to the variability in the presentation of signs and symptoms of the condition. Continuing advances in the understanding of the basal ganglia have promoted areas for pharmacological development. PD is a neurological condition in which drug therapy has a definite role, in reducing some of the effect of the depletion of dopamine producing cells. The most effective of these drugs is Levo-dopa (Sinemet), an agent capable of passing across the blood brain barrier (Cutson et al, 1995). It is usually prescribed in the early stages but as it has many side effects, together with wearing-off problems, cocktails of medication are prescribed to offset these associated, unpleasant side effects. The cost to the National Health Service (NHS) in provision of medication for this population in the United Kingdom (UK) is estimated to be £500 million per annum, out of a total NHS expenditure of £40 billion; the cost of physiotherapy for these patients is approximately 1.5 million pounds (Oxtoby, 1982). The estimated costs in financial terms of the carers, if they were to be funded, would be three times the drug budget (Oxtoby, 1982).

Current medical management.

Parkinson's disease is largely reliant on drug prescription. As the manifestations of the disease may fluctuate hourly in relation to medication (Morris, Matyas, Iansek and Summers, 1996), it is advisable to record patient medication and time since the last dose on the assessment sheet. This will allow re-assessment of function at comparable times. Treatment is directed at improving the quality of life by attempting to restore dopamine depletion with dopamine pre-cursors or dopamine agonists. The regime is complicated by the fact that reduced dopamine leading to the features of bradykinesia and akinesia also causes excess cholinergic activity, with this leading to further movement disorders of tremor and rigidity. Anti-cholinergics are often prescribed to combat this, but after a time the patient becomes less responsive to these medications, and may start to exhibit an "on-off" phenomenon. Higher dosages of these drugs can lead to dykinesias (severe unwanted involuntary movements), and side-effects may also present as cognitive disturbance and hallucinations (Fredericks and Saladin, 1996).

Surgical intervention.

Newer surgical prospects are undergoing consideration as treatment interventions with two major aims: the first to stop or slow down the disease process, and the second to treat the complications of the drug therapy (Obeso and Guridi, 1997). The success of surgical intervention lies in accurate determination of the target tissue and correct placement in the surgical lesion (Obeso and Guridi, 1997). Many new associated supporting-techniques to surgical intervention can now assist with the procedure. It is documented in Obeso and Guridi's editorial (1997) that full support from the multi-disciplinary team is needed both pre- and post-operatively for optimum results. The implantation of foetal tissue is continuing to be investigated.

With all these progressive attacks against dopamine deficiency and the resultant signs and symptoms, the future for the condition could appear hopeful. Sadly, however, this is not the case. Drug therapy is not the panacea which the literature may suggest. Multiple difficulties present with drug therapy from the drugs wearing-off to intolerance problems, and major, multiple side-effects which in turn may also require supportive drug therapy (Cutson et al, 1995). The presenting signs and symptoms leave the patients with declining motor, autonomic, and possible intellectual dysfunction, as well as the side-effects a chronic degenerative condition can bestow (Marsden, 1994). Until a treatment is devised to treat the cause of the condition and reverse the signs and symptoms of PD, there is a void between drug therapy restrictions and the patients' requirements.

As the elderly population is increasing, and therefore the numbers with PD are increasing, one has to ask what else is available to help address these problems displayed by the parkinsonian patient, and to improve the quality of life for them and their carers. The condition is primarily one of movement-related functional disorders, and this should be a direct target for physiotherapy.

1.ii Rationale for physiotherapy intervention.

The advent of clinical governance in the Health Service requires an evidence base for therapeutic intervention; clinical effectiveness of physiotherapy for Parkinson's disease is no exception.
Normal voluntary movements contain elements of skill, precision, timing and purpose which are appropriate to the situation. These movements can be modified in several ways to allow the individual to function under differing circumstances. The upper limbs predominate in prehensile and expressive activities, while the lower limbs are the basic sources of locomotion. The trunk musculature is also equally affected by PD (Cohen, 1993). Injury or disease processes affecting the control of movements manifest themselves as functional deficits for the patient (Handford, 1986). The presentation of the movement problems in PD is diverse, as parkinsonian patients with Parkinson's disease may also have complex musculo-skeletal and/or other pathological conditions (with the onset of advancing years). The patient is entitled to the facilities of the health care system to assist with the rehabilitation process.

Rehabilitation.

Rehabilitation has been defined as :

"an active process by which those disabled by injury or disease achieve a full recovery or if full recovery is not possible realise their optimal physical, mental and social potential and are integrated into their most appropriate environment"

(World Health Organisation, 1979).

Disability is recognised as a "social state not a medical condition" (Royal College of

Physicians, 1992). It has been acknowledged that drug therapy alone is not the only treatment for PD (Weiner and Singer, 1989) and that early referral to physiotherapy is beneficial (Comella, Stebbins, Brown-Thomas and Goetz, 1994). PD as a primary motor disorder, should be a target for physiotherapy (Denny Brown, 1968, cited by Rothwell, 1994). Referral to physiotherapy is recommended in the early stages of the disease by some physicians (Turnbull, 1992; Chesson, Macleod and Massie, 1996). However, it is more common for referral to happen as the disease progresses into the later stages (Oxtoby, 1982). The opportunity is then lost to initiate a preventative treatment strategy (Plant, Lovgreen, Ashburn, Handforth and Kinnear, 1999). The Parkinson's Disease Society (PDS) through its regional meetings has made frequent requests for physiotherapy, and the patients' voices were heard emphasising this at the European Parkinson's Disease Society (EPDS) meeting in Stockholm in 1996.

The philosophy of care has been assimilated by the health care professionals to include the holistic approach. These modern approaches also include the patients' involvement to encourage motivation and to facilitate empowerment by the patient. Quality of life measures (HMSO, Health Services Research Unit 1994; Jenkinson, Peto, Fitzpatrick and Hyman, 1995) are utilised and can now be of value to ascertain the problem areas for these patients and their carers (Kausar and Powell, 1996). The World Health Organisation recommends patient involvement in care planning alongside that of the professionals (Baker, Fardell and Jones, 1997).

Clinical effectiveness.

Extreme financial pressures on physiotherapy provision are continuing (HMSO, The White Paper, 1998). In response, the profession is establishing a firm research ethos to enable its practitioners to provide the evidence base to support the justification and rationale for its inclusion (CSP, Clinical Effectiveness Strategy, 1997). This supporting evidence must show that the effects of physiotherapeutic intervention are demonstrable quantitatively and are not due to chance, or the placebo effect (Twomey, 1996). In an editorial, Culham (1998) spelt out the need for clinical effectiveness and the subsequent costs must be justified.

A transformation in the research paradigm towards outcome measures is postulated by Jette (1995) as a basis for providing measurable outcomes in physiotherapy research. Objectivity in physiotherapeutic assessment is advocated as a standard (Plant, 1996). Changes in funding for research in the rehabilitation of patients must be facilitated to allow "purchasers, providers and clients" to address the relevant questions in the appropriate way to provide informed decisions about therapy purchase (Plant et al, 1999).

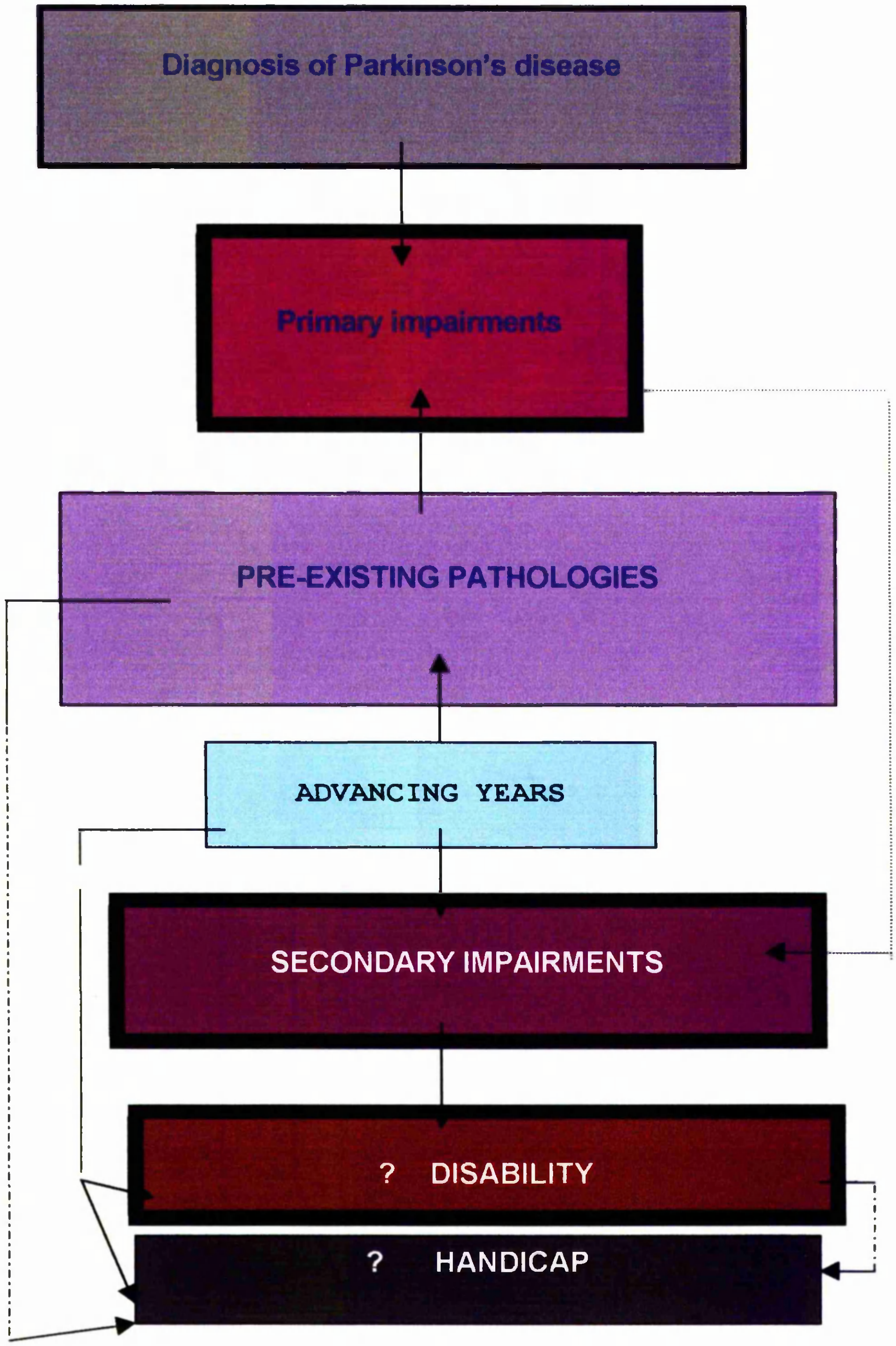


Figure 1. The pathway showing the main stages of the chronic degenerative process in Parkinson's disease and its probable course.

Physiotherapy Management.

Physiotherapy has a significant role to play in the management of PD, having much to contribute both in the long and short term (Schenkman, Cutson, Kuchibhalta, Chandler and Pieper, 1997; Chesson et al, 1996). It should be integrated with all other appropriate interventions to ensure consistency of approach, reinforcement of treatment aims, and the development of compensatory strategies, thereby benefiting the patient whilst reducing the burden of care for both the carer and the health service (Kausar and Powell, 1996; Zarit and Zarit, 1996).

Movement disorders experienced by people with PD may be classically those of initiating, maintaining, and changing from one sequence of movement to another. Movement problems may not only be of a physical origin, but may have their source in deficits of communication and/or cognition, a holistic approach to assessment is therefore necessary (Schenkman and Butler, 1989). The emphasis of treatment will vary during the course of the disease (Figure1). In the early stage, coping with the impact of diagnosis, patient education, the promotion of a healthy lifestyle, and good habits relating to posture and regular activity are of paramount importance. The main emphasis at this stage of the disease is on prevention, by attempting to slow down the rate of deterioration and increase the plateau phase as a baseline level of activity (Plant et al, 1999). Early referral is necessary so that these aspects of management can be established prior to the onset of significant movement deficits (Mackay-Lyons and Turnbull, 1995; Plant et al, 1999).

Patients may be reassured that they may exercise safely as it has been established that cardiovascular and metabolic responses to exercise are the same in patients with early stage PD as in their age-matched controls (Protas et al, 1996).

In the middle stage of disease progression, as motor impairments become more pronounced, it is necessary to begin correcting the movement disorders. The secondary problems that arise from these disorders, e.g. soft tissue shortening, loss of confidence, and weakness through disuse, must also be addressed (Chatterton and Lövgreen, 1999). Functional re-education of movement should include all aspects of the patient's lifestyle (Jenkinson et al, 1995). Social isolation leading to fears of not being socially accepted has a large impact on patients with movement problems. This was most apparent where group activities were concerned (Oxtoby, 1982). The emphasis here is on keeping the patient as active and independent as possible. Physiotherapy departments often produce their own information and advice sheets (Chatterton et al, 1999).

In the later stage as the disease progresses, the emphasis in management will inevitably move towards a corrective and compensatory approach. The patient will require more assistance to perform exercise programmes at home or in the physiotherapy department. Compensatory strategies may need to be taught to overcome irreversible or severe movement deficits. Aids and adaptations may need to be supplied to promote independent function. Close liaison with the other members of the multidisciplinary team to ensure appropriate prescription of aids is paramount. This may involve home visits by the community therapists (Plant et al, 1999).

As the patient moves into the later stages of the disease a more compensatory approach is required. Treatment moves from active assisted activities towards more passive treatment as the patient becomes less able to participate.

There are implications for the role of physiotherapists as the physical and related psychological aspects of the condition change. This suggests an extension from the pure movement disorders to a more holistic approach (Kausar and Powell, 1996; Willis, 1997). The carer's subjective burden also has important implications for the therapist (Zarit and Zarit, 1982; Payton and Nelson, 1996).

It is the author's experience that patients with Parkinson's disease, unlike other patients with degenerative neurological conditions such as multiple sclerosis, are poor at initiating contact with the therapist. Therefore the onus should be on the therapist to maintain contact (Chatterton et al, 1999).

Clinical Guidelines.

There are established guidelines for clinical practice in the management of neurological and elderly patients. Recommendations have been published by the Association of Chartered Physiotherapists Interested in Neurology (ACPIN) in 1995 and by the Association of Chartered Physiotherapists With a Special Interest in Elderly People (ACSIEP) in 1991. Treatment of patients with PD should be assessment-based, taking an holistic and individualised approach to meet patients' needs. It should involve joint goal-setting between therapist and patient (Greenfield, Kaplan and Ware 1995; Baker et al, 1997). Details have been published by the European Federation of Neurological Society's Task Force (1997) to set standards for neurological rehabilitation. The Society recognised that there were variations in care and recommended minimum provision for the neurological services. It advised the professional bodies, health services and governments to give serious consideration to more investment in this field, to the benefit of the neurologically-disabled.

Physiotherapists, as independent practitioners were granted legislative support in 1976 to take direct referrals of patients, but the physiotherapists working in the National Health Service (NHS) tend to receive referrals from other colleagues in health care. These referrals are not allowing immediate access to physiotherapy, for assessment and treatment for these patients as soon as the patient is diagnosed, nor as soon as the physiotherapist would like (Baker et al, 1997).

Patients and carers can be supported in chronic degenerative diseases by the inter-disciplinary team, after diagnosis of this condition (Keith, 1998). The physiotherapy profession recognises the opportunity to initiate a preventative strategy in the early stages (Plant,1998) This should run alongside the provision of recurrent intervention at later stages, where the rate of deterioration and secondary mobility problems of a musculoskeletal nature tend to appear, due to the poverty of movement which is known to develop in this condition (Oxtoby, 1982).

Referral practice.

The access to service provision has no recognised model (Chesson et al, 1997) and the referral routes are various in terms of who actually refers the patient (Plant et al,1999), and when this referral occurs in the time-scale of the disease (Mutch, Strudwick, Roy, and Downie, 1986; Weiner and Singer, 1989). The identified problems and the necessary interventions requested were as various as the modalities of physiotherapeutic intervention currently in practice (Plant et al, 1996); the results of this study are found in chapter 2.

There is some evidence in the literature for the support of physiotherapeutic intervention for the later stages in this disease (Kamsma, Brouwer and Lakke, 1995; Protas et al, 1996). In the Care of the Elderly (HMSO, 1994) there has already been established a strong preventative role by the profession, for secondary problems associated with reduced mobility (Ruuskanen and Ruppila, 1995; Ketelaars, Huda and Schlosser, 1997; Wright, Cross and Lamb, 1998). These issues on referral practice will be considered in depth in chapter 2.

Assessment.

The assessment of patients leads to the formulation of a problem list for planning appropriate treatments. Treatment should be assessment-based according to ACPIN (1995). This group was responsible for setting the professional standards in neurology. Guidelines for assessment content have been laid down by the ACPIN (1995). Frequent re-assessment is necessary to evaluate efficacy of treatment, to identify the need for modification, and to ensure that pertinent issues are addressed. There is a tendency within the profession for physiotherapists to use assessment procedures that are individual to their own practice or institution (Plant et al, 1996). However, standardised forms do exist. One such form is available from the PD Society, the PDQ-39 (Franklyn, 1986). Other scales commonly used by physiotherapists include the internationally recognised Webster Rating scale and Hoehn and Yahr staging (Plant et al, 1996).

PD does not just affect the motor systems (Rothwell, 1994). Assessment procedures, therefore should give an overview of the general status of the patient, as well as addressing all relevant physical aspects. This should include functional ability with reference to initiation, sequencing, timing and quality of movement, posture, balance and underlying muscle tone. Soft tissue length and extensibility (Williams, 1990) are other important considerations. Respiratory function and exercise tolerance should feature in assessment of overall function. The relevance of autonomic disturbances affecting activity must also be considered (Protas et al, 1996).

A model for assessment is presented by Schenkman, Donovan, Tsubota, Kluss, Stebbins and Butler (1989) which acknowledges the composite effects of impairments: physical, psychological, and social. Standardised scales such as the Webster scale, Parkinson's Disease Society Scale, and the Functional Limitations Profile (Wade, 1994) may be utilised. The interdisciplinary team must work together to identify problems and to develop appropriate treatment strategies (Plant et al, 1999; Chatterton and Lövgreen, 1999).

Table 1. The overall aims of physiotherapy management:

1. *Ensure* each patient is functioning to maximal potential.
2. *Maintain* the patient at the highest level of functional independence for as long as possible.
3. *Slow the rate of decline* and *delay the onset* of movement problems within the constraints imposed by the disease process.
4. *Prevent* the secondary complications of immobility.
5. *Educate* both the patient and carers to enable them to take the lead role in their physical management.

To achieve these aims (Table 1) it is necessary for patients with PD to be referred to the physiotherapist on diagnosis, or even before diagnosis is confirmed. An open referral system is advocated where initial referral should be for a life-time, not just for a course of treatment. The patient should be free to contact the physiotherapist whenever necessary to arrange for reassessment and treatment as appropriate (Plant et al, 1999).

The whole focus of the thesis and its research is to identify from literature sources, experimental evidence and expert practitioner input an evidence base for neurological physiotherapy treatment intervention in PD. Chapter 1 lays the literature focus for the background to the study, chapter 2 identifies the consensus of expert opinion of physiotherapy practice and chapter 3 explores the normal and abnormal integration in PD patients of proprioceptive information in isometric and movement related decisions. Chapter 4 focuses in the testing of some physiotherapy approaches for PD patients. Chapter 5, draws together the results of the research to formulate a pathway for influencing a change in practice.

CHAPTER 2.

An investigation into referral practice, treatment approaches and associated issues in physiotherapy, for patients with Parkinson's disease.

This chapter is presented in three sections: 2:i is a survey investigating the referral for physiotherapy and its provision for PD patients in the north west of England and North Wales; the second part, 2:ii, considers the investigation and the evaluation of referral practice and the third part, 2:iii, the identification of physiotherapeutic intervention (with associated issues) by structured interviews on a national scale.

INTRODUCTION.

The paucity of evidence on physiotherapeutic intervention in the neurological management of patients has become evident in the way in which the profession is encouraging special interest groups to form, to study an area of medicine in depth. The way forward from this paradigm leads to practitioners developing highly competent skills for treatment of these patients. A cost-effective approach is extremely important for the purchasers of health care.

Section 2:i Questionnaire survey.

The north west of England and North Wales each have a multidisciplinary interest group in Parkinson's disease. These multidisciplinary groups host study days for professionals in these regions, and provide a forum for developing research intervention (Miller, 1991; Kitzinger,1995). The focus group meetings facilitated information collection and discussion. A questionnaire was developed to identify current clinical practice by therapists in areas of the north of England and Wales.

The aims of the questionnaire were to identify:

I) the pattern of referral for physiotherapeutic intervention,

2) the types of assessment procedures,

3) the provision and treatment approaches,

4) the outcome measures,

5) the restrictions to therapy provision.

Method.

This section includes the compilation, piloting, issue, collection and a plan of the data analysis of the questionnaire.

Research design.

The author and a colleague from the same profession undertook a literature search and then developed a questionnaire from the findings (Munn and Drever, 1990). The questions (page 23) were generated from the literature and from concerns raised by the organisers of the multi-disciplinary group conference. The basis of questions asked was predominantly to identify issues of physiotherapeutic referral and the subsequent practice.

Construction of the questionnaire.

Design features were incorporated to support the completion and return of the questionnaire as recommended by Oppenheim (1992) and Hicks (1995). These features included the number of questions being under 30, clarity of wording, and instructions for completion. The cost of the questionnaire was kept to the use of paper and photocopying, as the issue and its collection were by respondents' collection and return, so no postal costs were involved.

Question design was restricted to closed questions where factual information was sought. Some questions had the option "other" allowed, which facilitated extra information to be gathered, if the options were not applicable to a particular therapist.

Piloting of the questionnaire.

The questionnaire was piloted on two neurologically-based physiotherapists in the author's own hospital. This pilot study identified a completion time of approximately eight minutes. One question was modified for clarity (number 1) and then it was re-piloted on a third colleague from the same hospital. No further changes were made, and the full questionnaire is presented on page 23.

The questionnaire was printed on yellow paper, as this helps to distinguish it and minimise the risk of loss amongst sheets of white paper (Oppenheim, 1992).

The sample population.

A sample of convenience (Oppenheim, 1992) was approached, it being the physiotherapy conference delegates. The assumption was that since they were attending the conference, these physiotherapists were interested in providing the best service for PD patients. A factor which may have produced a biased sample however, there was little opportunity to find a group of therapists with this interest in PD at that time. The physiotherapists were all treating a caseload of patients with PD. Their backgrounds ranged in age and employment (some working in hospitals, care of the elderly units, the community and day care centres) from some newly qualified staff to more senior therapists with higher professional status. The latter information was obtained from the delegate attendance lists.

The PD Conference Questionnaire for Physiotherapists. June, 1996.

Qu.1 Tick the most common source of referral.

Geriatricians ....

General Medicine Consultants...............

Neurologists ....

General practitioners.............................

Others (please state) ....

Indicate what percentage of referrals are from each referral source:

Geriatricians /Care of the Elderly............

General Medicine Consultants...............

Neurologists ....

General practitioners.............................

Others (please state) ....

Qu. 2 ***Tick which of the following assessment formats you use?***

Modified PD Society scale.....................

The PD Society scale..........................

Both of the above...............................

Other (please state)............................

Qu.3 ***The following are a selection of Physiotherapeutic approaches you may choose for treating a patient with PD.***

a.Rank these choices on a scale of 1-5, where 1 is the most preferred choice.

Bobath...................................

Conductive Education...............

Flewitt-Handford......................

Others(please state).................

Combinations of above.............

b. Do you provide a home based exercise schedule? Yes / No ....

Qu.4 ***Which outcome measures do you use*** **? Please tick those used.**

Webster rating scale................

Hoehn and Yahr staging............

PDSociety scale.......................

Others (please state).................

Combinations of the above.........

None.....................................

Qu.5 ***Rate, on a scale of 1-7*** **(where 1 is the most important)** ***which of the following do you think are <u>the restricting factors for you</u> in the treatment of PD patients?***

Staffing levels............................

Session constraints......................

Space.....................................

Equipment...............................

Transport...............................

Training for staff.......................

Lack of referrals.......................

The questionnaire was issued at a Conference in 1996, held at a district general hospital in North Wales. Present at this "Multi-disciplinary Conference on Parkinson's Disease" were many different professionals involved in the care of patients with PD. The afternoon workshop was designed to promote multi-disciplinary involvement, and communication skills between the professions. The conference was informed of the existence of a questionnaire, by the announcement from the author at the end of a presentation during the morning session, that it would be available for being answered after the 2.30 p.m. session. All physiotherapists were invited to collect a questionnaire from the lectern, in the lecture theatre, complete it and return it before the start of the 3.00 p.m. session. Confidentiality was assured and anonymity was offered as no names were asked for on the questionnaire, and its return was via a box located at the side of the theatre entrance.

Data analysis.

The data from the five questions are presented in the results section. Following receipt of the completed questionnaires, the data from all the respondents were collated on a spreadsheet and descriptively analysed. The results were prepared as percentages of responses and then displayed in tabulated form (Tables 2-5), data from question five being presented as a pie chart (Figure 2). An attempt was made to see if there was any association between the issues of assessment formats and referrals, and between treatment approaches and outcome measures (Tables 6 and 7).

Results and Analysis.

Response rate: Twenty five questionnaires were collected, each being completely answered, by the end of the allocated time period. A total of 28 physiotherapists were on the list of delegates. The data were subsequently analysed. The results from the study reveal variety in the sources of referral (Table 2), modalities of assessments (Table 3), approaches to treatment (Table 4) and, if used, outcome measures (Table 5). The final question addresses the results from the fourth question, which was asking for information related to support systems for practice and the results are displayed as a pie chart (Figure 2). Respondents could chose more than one option in completing the questions therefore the percentage figures given in the Tables 2-5 and Figure 2 represent the total selection of options by all the respondents collectively.

<u>Question one</u> . The results are displayed in Table 2.

Table 2 illustrates the percentage by the disciplines (indicated in the left-hand column) of patients referred for physiotherapy. The largest group of patients was referred from general medical consultants, at 38%. There was an almost equal referral from geriatricians (21%) and general practitioners (18%). There were substantially fewer (13%) from neurologists. Other referrals (10%) were made by multidisciplinary team members, carers, and directly by patients.

Table 2. Referral sources for physiotherapy.

Referral source	% of referrals
Geriatricians / Care of Elderly	21%
General Medical Consultants	38%
Neurologists	13%
General Practitioners	18%
Others	10%

Question two related to the assessment formats in use and Table 3 shows the variety of responses.

Table 3. The assessment formats in use by the respondents

	% of use
Modified PD Society	65%
PD Society scale	22%
Both of the above and locally designed scales	13%

The PD Society scale is a global scale measuring many aspects of function in PD patients, having multiple sections (Wade, 1994) and somewhat time consuming to complete. The most widely used was the modified PD Society scale (65%). The modified scale was used by therapists to measure movement related functions. This scale was found to be adapted by particular departments, where physiotherapy assessment formed a large input into the initial assessment by the consultant and the multidisciplinary team. In 13% of cases clinicians incorporated several types of assessment formats into their practice including individually developed, non-validated measures.

Data from question three are displayed in Table 4.

The various treatment approaches shown to be highlighted by the literature were obviously in use by the therapists. The Bobath approach was the most widely utilised, at 59% (this is a neurophysiological approach which focuses on the restoration of normal movement). The next most frequently applied technique (15%) showed combinations of several modalities being selected. The exercise based intervention, the Flewitt-Handford approach, was the next most common usage (10%) with some inclusion (9%) of "other". The term "other" was found to include the use of sensory cues and mental preparation for movement and the least frequent approach to be used was the conductive education at 7% (this approach is a holistic "way of life" approach which includes practice and repetition of actions, feedback from the therapist and inclusion of a multidisciplinary focus for intense periods of time). The conductive education approach also focuses on leisure and relaxation.

Table 4 . The treatment approaches in use by physiotherapists

Bobath	59%
Conductive education	7%
Flewitt-Handforth	10%
Combinations of above	15%
Other	9%

Question four investigated the outcome measures in use. One group of therapists, 26%, identified *not* using outcome measures. Of the remaining three quarters, the most popular was the Webster rating scale (Webster,1968) at 20% and the locally designed outcome measures were equally used Table 5. The locally designed outcome measures were not described or identified by the respondents.

Table 5. The outcome measures in use.

Outcome measures used	
Webster rating scale	20%
Hoehn and Yahr scale	15%
PD Society scale	15%
Combinations	4%
Other (locally designed)	20%
None	26%

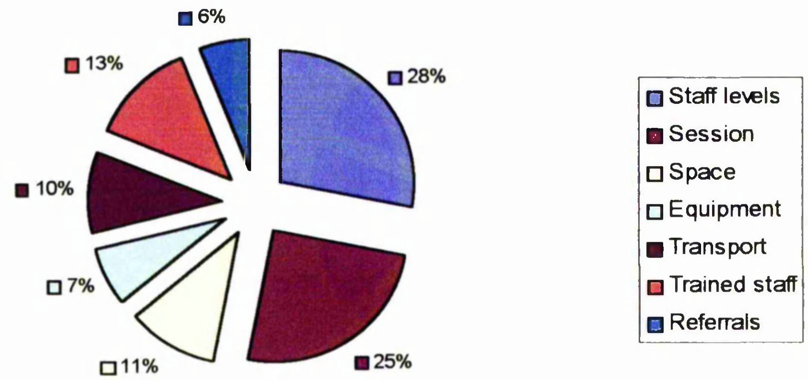


Figure 2. A pie chart showing the percentage contributions of the factors restricting physiotherapy provision. The term 'Session' indicates a restriction on the number allowed for a patient. The term "Referrals" indicates a lack of referrals. Question five requested information about difficulties in providing a physiotherapy service for the PD patients. The results are presented as a pie chart (Figure 2).

Other information received from the back of the questionnaire sheets is reported verbatim as follows:

"training needs are impossible to fulfil due to lack of post-registration training courses"
"staffing levels make it difficult to attend training sessions in working hours"
"interested in learning which outcome measures to use"
"close contact by the interdisciplinary team members offers great support to newly qualified staff".

The most restrictive factor (28%), perceived by the group, was staffing levels being lower than those needed to provide the service. In some areas (25%) there was a restriction in the number of sessions of treatment permitted for a patient. 13% of respondents identified problems relating to lack of specific training to treat PD patients. The lack of referrals was low as an issue, identified by only 6% of the respondents as a problem.

Associated issues relating to service provision of physiotherapy:

Descriptive statistics were employed to display associated issues. The way in which the results for this section are displayed has a common underlying structure.

For each 'issue' the choice of options is displayed as a percentage of the 'issue', e.g. Table 6 shows the choice of the assessment formats ('issue') by the respondents. The pie chart was constructed by calculating the percentage of the different referrals sources .All the following pie charts and bar charts in this section were thus calculated.

i) Assessment formats and referrals.

A related "issue" for the type of assessment formats in clinical use is considered in this text to be associated with the actual referral source. The assessment formats and referral sources formed the first association (Table 6). The three choices of assessment formats by the respondents were considered against the sources of referral. However, assessment formats did not seem to associate well with referral sources as the respondents taking referrals from the medical consultants did not always use the same assessment formats (Table 6). No pattern or specific association was therefore identified on these two issues of referral practice and assessments.

Table 6. Referral practice and associated issues of assessment formats.

Referral source	Modified PD scale	PD scale	PD, modified PD scale and locally designed scales.
Care of the Elderly Consultants	43%	nil	57%
General Medical Consultants	17%	68%	15%
General Practitioners	8%	nil	92%
Consultant Neurologists	22%	32%	46%
Others	10%	nil	90%

Table 6 indicates the assessment formats for each of the referral sources. The referrals from Care of the Elderly indicate two assessment formats are in use, those of the modified PD Scale and a combination of this scale and the PD scale. Referrals from general medical consultants revealed all three scales were in use, although the PD scale was in the majority (68%).

ii) The consideration of the next association is of the comparison of the treatment approaches and outcome measures is shown in Table 7.

Table 7. Treatment approaches and outcome measures.

Outcome measures	Bobath approach	Conductive Education	Flewitt-Handforth	"Other",e.g. cues, mental planning
WRS	2%	Not used	44%	10%
H & Y	Not used	Not used	Not used	Not used
PD scale	12%	42%	18%	13%
Combinations	6%	Not used	26%	Not used
Locally designed	4%	58%	7%	68%
None	78%	Not used	5%	9%

Key: WRS- Webster rating scale, H& Y- Hoehn and Yahr rating scale.

The data showed that from respondents where Bobath was chosen as the treatment of choice, many of them did not use outcome measures. In the cases of 'no outcome measures', the rest of the respondents did not produce a pattern or trend of agreement on the choice of treatment approaches and outcome measures.

"Other" treatment approaches were identified as strategies and mental planning, and the use of cues.

Discussion.

The focus group established a multi-variate approach demonstrating no consistency in terms of referral patterns, treatment approaches, outcome measures or management strategies, was identified. Basically the data are identifying the current state of play and emphasise the discrepancies in the health service from one department to another, even demonstrating in one instance, lack of consistency within a department (one respondent noticed different practice after joining her current hospital and found each therapist had an independent choice of management for the PD patients: there was no departmental policy.)

Reliability and validity issues must be considered.

The issues of sample bias need to be considered as a threat to external validity of the project. It is difficult to obtain a sample of physiotherapists who are interested, experienced and currently practising with PD patients. The sample may not reflect the population as a whole but internal validity is strong as the therapists were all currently treating a caseload of PD patients. Validity of the sample was also secured in that the questionnaires were completed by therapists and this was secured by its administration and collection. Postal questionnaires always raise the doubt of exactly who filled in the questions. There is no way of verifying that last point with postal questionnaires.

The method of issue of the questionnaire gave the respondents no time to discuss the questions with colleagues so the responses were individual and not collective, again supporting the internal validity. The data requested were given anonymously, so that no single physiotherapist or department was identified. There was, however, no guarantee that the information received had been supplied by a physiotherapist with a known level of experience. However, ethically, strict anonymity could not be offered as there was a list of conference delegates, but no coding was introduced or attributable in matching the respondents to the list of names (Oppenheim, 1992). Payton and Nelson (1996) offer comment relating to validity issues, about the appropriateness and authenticity of the sample population.The standardisation of the sample is reasonably secure, in that the therapists were all sufficiently interested in PD to attend the study day and were all treating PD patients. Back-up interviews are recommended by Hicks (1995) and Munn and Drever (1990) to increase the reliability.

Closed questions, of which there were four, lead to a reduced chance of bias during collation and interpretation by the researcher (Haggerty, 1996).

Reliability of the measurement tool would be enhanced by its re-issue to larger numbers of therapists, under the same conditions.

The results from the questionnaire raise the issue as to the extent to which the variability is related across centres. Could it be that variation exists on the location (i.e. day hospital or community setting) of the treatment intervention, from in-patient to community based or day-care centres, or is the difference determined by factors such as the training at under-graduate and post-registration levels of the different therapists? A department may have policy decisions to regulate numbers of sessional treatments. There may also be different attitudes towards post-graduate training which may preclude staff having access to the support for an evidence base to therapy with measurable outcomes.

Table 2 illustrates the percentage of patients referred by the disciplines which demonstrated that PD patients are managed by different medical specialists, although it does not seek to identify why the patient was referred to the medical practitioner in the first instance (as PD may not have been the actual problem for which the patient was seeking help).

The section of the questionnaire exploring the types of assessment formats in use (Table 3) yielded a variation, the most widely used being the modified PD Society scale. This was found to be adapted to particular departments, where physiotherapy assessment formed a large input into the initial assessment by the consultant and the multidisciplinary team. The details had been modified to these ends.

The third question sought to identify the actual physiotherapy technique chosen (Table 4) and showed a preferred response to the Bobath approach (this has a neurophysiological basis for the technique, and relies heavily on the patient experiencing normal movement sensations to facilitate quality movement control). The second most commonly used technique was an eclectic approach of combinations of all available and suitable techniques. The issue of undergraduate training may explain the approach preference of the therapist.

Question 3 considers the type of interventions. The Flewitt- Handford approach is predominantly exercise therapy based. Where "other" is designated it was found to encompass a mechanical approach to movement and might have included sensory cues. Conductive education is an approach from Hungary, and only a few "trainers" of this approach are found in the country. The choice of approach may be limited due to availability of training opportunities as was raised by several staff on the questionnaires.

In assessing the effect of treatment, both short and long term, outcome measures are necessary. Four outcome measures (Table 5) scored similarly with representation of 15-20% between the Hoehn and Yahr, Webster Rating scale, the PD Society scale, and locally designed scales. 4% of centres used combinations of measures, selective to a particular patient. These centres had no overall policy. Some centres (26%) used none of the measures. No objective outcome measures were identified; however, there are very few referred to, in the literature or known to the author (of these measures in neurological practice).

Conclusions:

1. Referral sources, treatment approaches and outcome measures were identified.
However, little association was identified either between referral practice and assessment formats, or between preferred treatment interventions and outcome measures.
2. Restrictions to physiotherapy provision identified low staffing levels, and a restriction on the number of sessions allowed for patients to be the most frequent problems with the service.
3. Individual informal feedback raised the issue of lack of specific post-registration training courses.

The conclusions from this preliminary study emphasise the need for the identification of a model of good practice, to encompass consistency in assessment, treatment approaches and the evaluation of interventions. This information can only be provided by a sound evidence-based research programme, or the physiotherapy treatment of PD will no longer be sought by health care purchasers in the future (HMSO,The White Paper, 1998).

The answers to the issues raised about variability cannot be addressed by this particular questionnaire, but pose research questions for the future. It may be that variability is a good indicator of practice, in that it would allow for each patient to have the most flexibility in his/her management, as long as the management was appropriate, efficient, and cost effective.

The need is therefore to provide a model of best practice, which will identify the most efficient treatment approaches, the best assessment and the most appropriate outcome measures and promote greater consistency. This would be advantageous in terms of patient satisfaction and efficiency for the National Health Service. Prescription of practice is not being suggested but the flexibility for the clinician to chose appropriately as the patients' needs change is being highlighted. The results from this study were presented as an abstract and in poster form at the Inaugural World Conference of Research into Neurological Rehabilitation in Newcastle on Tyne (Lövgreen et al, 1996).

2:ii The physiotherapy evaluation project.

The following year (i.e. 1997), the Chartered Society of Physiotherapy (CSP) was contacted by the Parkinson's Disease Society (PDS) and asked for a list of chartered physiotherapists with an interest in PD. The CSP identified physiotherapists who were interested in and/or researching into PD, and passed this information to the PDS. An invitation followed for the author to join the group at a meeting at the PDS headquarters in London, to discuss the feasibility of forming a working party to address the two main research questions:

1. How is physiotherapy for Parkinson's disease evaluated?

2. What comprises best practice physiotherapy in Parkinson's disease?

The author saw the opportunity as an extension of the research from the study in section 2:i, and welcomed the chance to join the group.

The core group.

From the original 24 CSP members, a self-selecting number (6) of physiotherapists then formed the core working party for the physiotherapy evaluation project (PEP). After discussion and preparation, a research grant proposal was formulated and submitted to a large pharmaceutical company (Glaxo-Wellcome). This was accepted and the group secured £86,000 for the project. Intellectual property rights were agreed to be held by each individual member. The discussions and formulation of the proposal led to decisions being made as to how to approach the investigation in seeking the available evidence. The following aims and objectives were formulated.

The aims of the PEP :

1. To identify a best-practice model in the United Kingdom (UK).

2. To produce a consensus document which details the best service model and treatment modalities used by physiotherapists in the UK, and to disseminate the findings at appropriate stages.

These would be served by formulating the objectives.

The objectives of the PEP:

1. To identify the main components of a physiotherapy service for patients with PD, including a format to describe them accurately.

2. To ascertain from key professionals and managers the structure and function of the organisation of services for patients with PD, including the perception and experiences of professional roles and responsibilities, and their interactions.

3. To describe clinical activity using local data e.g. outpatient activity, physiotherapy

records and community services.

4. To produce a flow chart of care pathways including criteria for access to the physiotherapy, source of referral and issues around discharge, and access to long-term care.

5. To obtain views from PD patients and carers in each site to ascertain their experience of, and needs from physiotherapy services.

The part of the project by the author is summarised in Table 8, these areas of the PEP are presented here in this chapter .

Table 8. The areas of sole responsibility the author had in the PEP.

1.To identify referral practice, by the Delphi process, which leads the to writing statements for the structured interviews (point 3).
2.To identify the concept of physiotherapy "expert" in the field of Parkinson's disease, which would guide the selection of the sample for the Delphi.
3.To identify criteria for selecting centres for case study visits with the follow up interviews.
4.To carry out structured interviews at one of these sites (point 3), with a group of clinicians and managers, and analyse the data.

The structured interviews are the tools for the data collection method. The information collected will refer to details about current practice, treatment approaches and theoretical background from clinicians at selected sites. The sites will be selected as centres of good practice as indicated from the Delphi.

Methodology of the Delphi process.

The PEP group was geographically scattered and regular group meetings were scheduled with individual contribution being organised in between meetings. The work load was divided and members at each stage had specific contributions of highlighted areas to prepare and present back to the group at specified dates. Between meetings, collaboration was achieved by post, fax, electronic mail and telephone. Training and briefing sessions were organised as research methodologies were identified (training was required for the Delphi process, case study approach and telephone interviews: Jones and Hunter, 1995; Kitzinger, 1995; Barriball, Christian, White and Bergen, 1995; Jones, 1995). An invitation was made to a statistician to become a permanent member of the team at this stage. The group formulated an overall plan for the research methodology outline (the Delphi process, Table 12) of the project, and divided it into stages 1 and 2.

The author will concentrate only on the referral section in chapter 2. The following phases were identified to fulfil the aims.

Stage 1 Phases of the Delphi process.

A literature search using the Medline, Cinhal and therapy databases from the current year to 1980 was carried out and relevant papers were discovered. These papers were critically evaluated to identify aspects of referral practice. The results are presented in Tables 9,10 and 11. From the literature emerged the view (as is held by many clinicians) that both patients and carers can be supported in chronic degenerative diseases by the inter-disciplinary team, after diagnosis of the condition. The physiotherapy profession recognises the identified problems and the required intervention. The World Health Organisation recommends patient involvement in care-planning alongside the professionals (Baker, Fardell and Jones, 1997), a philosophy which has been assimilated by the health care professionals to incorporate a holistic approach. This poses the question of why 53 % of patients are asking for further physiotherapy when only 71 patients out of 201 (35%) were being referred by GPs, and 74 patients out of 201 (37%) from consultants (Chesson, Macloed and Massey, 1996).

The author devised a framework for the literature search: Issues to be addressed,

i. The referral source

ii. The time of referral in the disease process

iii. The reason(s) for referral

iv. The intervention required.

The referral source.

The literature searching provided a meagre but varied response to the main four issues about referral of patients. Table 9 shows a summary of the appropriate papers investigated, and compares the type of literature in terms of research design and the professional group(s) encountered. On some occasions it was the patient actively seeking referral rather than a professional request for therapy (Chesson et al, 1996; Plant et al, 1999).

The timing of referral in the disease process.

The timing of referral for physiotherapy shows a non-specific model. Table 10 reflects these differences, where early, intermediate, late and non-specific time interventions have been charted and reported in the literature. The group of authors advocating early stage referral

(Mutch, Strudwick, Roy and Downie, 1986; Weiner and Singer, 1989; Turnbull, 1992; Schenkman and Butler, 1989) is reflected by patient request and physiotherapy preference.

Table 9. The sources of referral to physiotherapy for patients with PD.

Authors and Date	Type of literature/ Research design	Referral by professional group
Chesson et al (1996)	1	A, D,E, F, C, P
Turnbull (1992)	6	C,P
Weiner (1989)	7	E
Lövgreen et al (1996)	1, 7	A, B, C, D, E, F, C,P
Marsden (1994)	3	non-specified

Key to Table 9 The type of literature Key to the referring group.

1. qualitative (questionnaires/ structured interviews)	A General practitioner
2. editorial	B Consultant physician
3. review	D Consultant neurologist
4. experimental design	E Care of the elderly consultant
5. published letter (peer reviewed journal)	F Other therapist
6. reference book	C Carer
7. conference publication	P Patient

Plant et al (1999) state quite powerfully that physiotherapy has an important role to play in preventing the secondary problems of these patients by maintaining musculoskeletal activity for as long as possible, and thus slowing down the rate of decline. The view of some medical specialists appears to be that referral is only justified when drug therapy fails, or ceases to be effective, or when secondary musculoskeletal problems present. The details of referral were well documented in the Chesson et al (1996) study. The referral reasons were also highlighted, and gaps were identified by managers in the way records of patients were kept. This prevented a fuller picture emerging for all the sources of referrals. No specific definitions in the literature are available for the stages of "early", "middle" and "late". It is generally assumed in practice they are guidelines rather than specific measurable stages.

Table 10 Referral timing.

Authors	*early referral*	*intermediate referral*	*late referral*	*non-specific time of referral*
Chesson et al (1996)	*	*	*	*
Turnbull (1992)	***			
Plant (1996)	***			
Lövgreen et al (1996)		*	*	*
Marsden (1994)		*	*	
Weiner (1989)	***			
Mutch et al (1986)	***			
Schenkman (1989a)	***			
Playfer (1997)				*

The * indicates the timings of the referral stages, and / or *** the advised preferential stage of referral.

The identification of specified reason(s) for referral .

Patients were referred for multiple problems, ranging from those specifically identified as primary motor problems, to those of secondary, psychosocial complications of generally reduced mobility, associated with ageing and immobility. The literature offered many different aspects and could not easily be compared as terminology in use was variable. Several authors used terminology including disability (Mutch et al, 1986; Marsden, 1994; Hopkins, 1994; Playfer, 1997) whilst others discussed mobility related complications (Weiner and Singer, 1989) and others focused on specifics (Oxtoby, 1982; Schenkman et al, 1989; Chesson et al, 1996).

Many authors purely mentioned "referral to physiotherapy" or commented that patients "may require physiotherapy". Table 11 indicates the selection of reasons for referral offered by the authors (listed on the left hand column of the table). The key to Table 11 gives the many reasons for patient referral. The responses show (with the exception of number 13, where drug therapy was no longer proving effective), the required over-all aims of therapy. At this stage, one has to identify that many medical colleagues will have referred patients for the above reasons to physiotherapists. Also, referrals come at intermediate to the later stages of the disease as well.

Table 11. The identified authors' reasons for referral

AUTHORS	THE MAIN REASONS FOR REFERRAL
Chesson et al (1996)	6, 7, 8
Schenkman et al, (1989a)	1,2,3
Weiner and Singer (1993)	4,5,13
Playfer (1997)	9
Gibberd (1986)	10
Marsden (1994)	10, 11, 12

The key to table 11 The reasons for referral for physiotherapy.

1	strategies for self management
2	prevent / retard secondary complications (eg musculoskeletal /respiratory)
3	"physical techniques to delay onset of disability"
4	motivation
5	improve sense of well being
6	improve quality of life for carer
7	increase mobility, "have exercises", reduce pain
8	assessment (reason not specified)
9	slow down progression
10	falls
11	locomotor
12	non specific referrals
13	drugs no longer effective

In the literature very little is identified as a focus for physiotherapy to have a strong preventative role for these predominantly late onset problems. Yet in the care of the elderly the need has been shown for encouragement to continue activity for as long as possible, and early intervention is the accepted norm (Hollis,1989; Duncan, Studenski, Chandler and Prescott,1992).

Consensus in the Delphi method.

The next stage was the "Consensus" method of gathering information. The consensus method, commonly used in health service research, allows for synthesis of information when there is little or insufficient evidence in the literature on which to make a decision. It allows access to a larger range of information by harnessing expert opinion to facilitate decision making (Jones and Hunter, 1995). The Delphi process and the expert panel are two of the sub-sections chosen for the PEP evaluation.

The Delphi method is a survey method of research that allows for structured group discussion and decision making amongst acknowledged experts. It prevents the problems of dominance of a particular character in a group, so that even the more reticent voices can be counted (Jones et al, 1995). This is known as a consensus method because, unlike meta-analysis, it can synthesise published information which is inadequate for such methods, or which exists in the form of the unpublished insights of experts. The stages in the Delphi process are indicated in Table 12 (modified from Jones and Hunter, 1995).

Identification of the expert panel.

The process of identification of the physiotherapists with special knowledge and experience in Parkinson's disease was the first step. Definitions from the literature revealed what was meant by the word expert . From this basis, the criteria for the expert panel were assembled.

The term "expert" is frequently referred to in the literature and in common parlance. All the terms relating to the concept of expert are used synonymously in the literature. A definition of expert is somewhat flexible and has different interpretations according to its context. An expert is a term with a meaning, and when used in clinical fields it can refer to a multitude of attributes, although it lacks clear definition (Jasper, 1994). An operational definition cited by Bousfield (1997) suggests the term means "defining attributes of possession of a specialised body of knowledge and skill; extensive experience in a field of practice; highly-developed levels of pattern recognition and an acknowledgement by others in the profession". The Oxford dictionary defines the word expert as "trained by practice", from the Latin past participle 'expertus' of the verb experi, whose noun means actual observation of, or acquaintance with, facts or events, and the knowledge or skill eminating from this (Collins, 1965). Alongside the word "expert" are clinical specialist, clinical expert, and advanced practitioner, also emerging as a term allied to the concept of expert (Skeil, 1995); the extension from this is the legal expert witness, having no definition, but relying on a clinical expert with legal training (Ryan, Wade, Nice, Shenefelt and Shepherd, 1996).

Bousfield (1997) advocates the clinical nurse specialist as an experienced practitioner who strives to be in a position which influences patient care and utilises advanced knowledge and leadership skills in a multi-disciplinary environment.

Table 12. Stages of the Delphi process

RESEARCH QUESTION	What is current best practice in physiotherapy with patients with PD in relation to treatment modalities and service delivery?
SELECTION OF EXPERTS	Senior 1 physiotherapist (or above) with at least 2 years experience of treating patients with PD Current PD workload
1st ROUND OF DELPHI	Framework for literature review by PEP members. Categorisation of findings, under framework headings. Questionnaire statements drafted. Review of statements by sample of experts.
2nd ROUND OF DELPHI	Participating experts comment on and rate statements in relation to what (i) occurs in current practice (happens/ doesn't happen) (ii) what should occur in ideal practice (desirable / undesirable).
3rd ROUND OF DELPHI	Participating experts re-score statements in relation to ideal practice in light of feedback from group respondents (comments and ratings).
RESULTS ANALYSED FOR AGREEMENT AND DEGREE OF CONSENSUS	Published as interim report / Stage 1.
REPORT ON FINDINGS	Report issued to sponsors, steering group and line managers of the PEP group.
TEST RESULTS IN CASE STUDIES	Structured interviews performed, results analysed: triangulated by final analysis and disseminated to the patients, the profession, colleagues, health care managers and the sponsors.

Criteria for the definition of a physiotherapy expert.

In order for a physiotherapist to qualify, by title or definition, as an "expert" he/she should have:- (i) a professional qualification with at least two years experience in a senior post, and (ii) specialist practitioner training as a post graduate qualification (as a minimum requirement).

The sample group.

Locating the experts was the next stage, which was achieved by contacting :

a) Special Interest Groups (SIG) of the CSP, where physiotherapists with special interests in neurology (ACPIN), care of the elderly (AGILE) and community based therapists (ACPC) are registered;

b) the CSP data base;

c) experts known to the PEP partners;

d) the PD Society, and drug companies specialising in PD medication.

The 'Frontline' and 'Therapy Weekly' publications carried the details of the search for experts in this field. A total number of 72 experts was identified. (Data from the Delphi survey produced the confirmation of the expertise as a 'cognitively interested' physiotherapist.) It was considered that this number of 72 (with the exclusion of the PEP members) was probably the total sum of experts in this field; therefore they represented almost a full population for survey. These therapists were working in various settings from in-patient to community areas, in the National Health Service and in private practice, and some in academic settings with a clinical workload. Variation was also noted in the time since they had qualified (as most of them were known of by the PEP members) and their research backgrounds, the latter being identified from publications.

The method of statement formation.

From the literature sources, the predetermined focus of areas was considered and reflected in the statement formation. When planning statements, the evidence from the literature is often rated or ranked for its quality (Hicks,1995). Randomised controlled trials, meta-analysis and systematic reviews are of the highest order, followed by case controlled studies. Uncontrolled studies and consensus are the least-highly rated (Jones and Hunter, 1997). There was a lack of quality evidence in the literature and the statements were generated from what *was* available, allowing for this to be modified after input from the experts (after stage 2 of the Delphi). Where gaps were identified in the literature, general statements were formulated. On examination of the list of statements, it was decided that they were bland and would only show the lowest common denominator of clinical practice. The importance of this lowest denominator is acknowledged, but best practice was sought.

The format for these statements had its origins in the research work of the Intercollegiate Stroke Working Party (ISWP, 1996). Expert participants were asked to rate standards, on the basis of whether they agreed that a point should be audited in a stroke service. An acceptable response rate to the statements was put forward by Walker (1996) indicating that a 70% response rate or higher is acceptable for a postal questionnaire, and they suggest that an equivalent, if not a higher rate is necessary for a consensus from a Delphi survey.

The target of a 70% response rate was set. It was considered that the Delphi process would allow quality in the evidence of practice to emerge. Part 2 was planned, which allowed an extra format of "vignettes" of practice (role play situations to consider a paper-patient and carer situations) to be included to allow for in-depth and quality aspects to be covered. ("Paper patients" are written scenarios of clinical features presented as an anonymous case study.) The statements and vignettes were to form the basis of the document for consideration by the panel of experts. This consensus of ideas is necessary for devising a questionnaire, which was required for the structured interviews, those being at 3 selected sites and telephone interviews at 8 other locations. The framework for presenting statements was rethought and constructed around four areas, these being:

CONTEXT: if, where and how physiotherapy is delivered; this was the referral section previously.

REASONS: why physiotherapy is employed.

ACTIONS: what physiotherapy comprises.

EFFECTS: the outcomes of physiotherapy.

The notion of success (Flick et al, 1998), was employed in the second part to structure responses to statements in relation to vignettes. This enabled the unacceptably long list of potential aims and treatment options in the early drafts of part 2 to be more focused. Only in part 1 were participants asked how a statement related to their current practice and if it would be desirable or undesirable in an ideal world. In relation to all other statements, experts were asked to agree or disagree with the statement. It was planned that the package would illuminate the context of current practice, and allow a consensus to be reached on an ideal context, the purpose of physiotherapy, what it should comprise, how it should be measured and how these parameters might change as the disease progresses. The expert consensus gained from these Delphi processes would facilitate and guide the ensuing research in the form of a questionnaire for the basis of a structured interview at case study site, to generate high quality evidence. The issues about referral now fall into the Context section.

The Delphi process and agreement.

A consensus gives an extent to which people agree about a certain issue. What does the term 'agreement ' mean in the Delphi context? Agreement includes two aspects, firstly the extent to which each respondent agrees with the issue under consideration (this is rated on a numerical scale or categorical scale) and secondly the extent of agreement with the other experts in the group, i.e. the consensus element (assessed by statistical measures of average and dispersion). Agreement with statements is usually expressed by using the median and consensus assessments using inter-quartile ranges for continuous numerical scales (Jones and Hunter, 1995).

Rating versus ranking.

A ranking will provide a clear priority list, but will not show any intervals between the items. A rating scale is more flexible but reduces the need for comparison of items (Walker, 1996). The necessary arithmetical calculations are difficult to derive. As well as these two features, Miller (1991) advocates allowing space for an individual to comment (the concept of "open" questions in a qualitative study).

The statements were written as standards, with an invitation to comment in a bi-polar rating scale of 1-9. The ranking utilises a descriptor of "happens/ doesn't happen" on the 1-9 scale and a consensus of "desirable/undesirable" on a 1-9 scale (see the example in Table 13).

The use of a 9 point scale allows for greater variation in expression and can be accommodated, particularly in a Delphi framework, allowing a further round (or rounds) for refinement. A 9 point scale offers quarter points for analysis, allowing for a possible bi-modal distribution and is therefore more informative in the analysis than 5 or 7 point scales.

Table 13 An example of the format of the statements.

Question 1.i	Statement	Comment here	Ranking
Referral			
	On diagnosis all patients with PD are referred to a physiotherapist.		Happens / Does not Happen 1 2 3 4 5 6 7 8 9 Desirable / Undesirable 1 2 3 4 5 6 7 8 9

The total number of statements on referral aspects were 4, out of the total of 30 on the whole list. The other statements in this section also use the above format, (forming questions 2-4) which are set out in a similar way (appendix I).

Qu 1.ii Physiotherapy review of the patient is available for all stages of the disease.

Qu 1.iii Written guidelines are supplied to the patient (and carer) for self referral back to physiotherapy.

Qu. 1.iv The frequency of review (re-referral) is organised flexibly according to an individual's need.

Consensus.

Walker (1996) stated there was no standard threshold for consensus and suggested stability had been achieved once the change between rounds was less than 15%. From a study of gross motor performance a pre-specified consensus by 66% of respondents reaching agreement was suggested as acceptable; the larger the standard deviation, i.e. the more the spread of scores, the weaker the consensus.

There seems little factual recommendation from the literature on a specific level for consensus, but all authors seem to advocate a higher level of consensus to be more acceptable than a lower one, even though they have difficulty agreeing the parameters. A percentage agreement of consensus also appears to be advised and it should be preset before data collection.

Controlled feedback is issued as a form of private ranking to each individual participant, in the form of the individual's response and the group's response (Jones and Hunter, 1995). The controlled feedback of the group's response and the individual's is a feature of the consensus methods. This process of iteration allows the individual to change their opinion during the rounds of the Delphi; it must be made clear to the individual that they need not conform to the group's response. The Delphi technique allows the researcher to ask for evidence of the nominated out-liers as justification for their responses.

CONTEXT

The pilot study on the statements for the referral aspects was tested by a sample of convenience, i.e. experts from the local hospital; who were then excluded from the final study. Slight amendments were then made to the letter of introduction accompanying the statements.

Round 2 of the Delphi Process - (the first postal round).

The statements were issued by post to the expert panel of 72 physiotherapists, together with an explanatory letter and a date for return of these first round postal responses. All respondents were informed of the confidentiality of the data and the analysis, and informed that the final results of the study would be circulated to the participants.

Data analysis.

For nominal data, as the statement responses produce, the author defined that when statements have been ranked on a 9 point scale, the groupings are as illustrated in Figure 3.
If all ratings fall within one of these groups, then it represents strict agreement; if views arescattered then consensus is less strong. If ratings fall in two zones then the bimodal distribution shows two preferred areas of agreement, not one. If one excludes an extreme out-lier in each section, then the agreement may be stronger, and this is allowed by explaining that one individual is exaggerating the dispersion (Miller, 1991; Jones, 1995; Jones and Hunter, 1995).

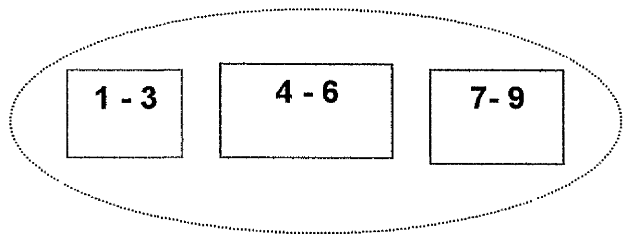


Figure 3 The categorising of the nominal data responses. The score has a range of 1-9 which is subdivided into three groups. The score 1- 3 represents agreement , 4- 6 represents equivocality and 7- 9 represents disagreement.

The data for the first postal round are displayed as box and whisker plots. The box and whisker plots show the summary of the data points based on the median, quartiles and extreme values (Figures 4 and 5). The box plots are formed from the "boxes", which contain the 50% values falling between the 25th and 75th percentiles. The "whiskers" are the lines that extend from the boxes and show the lowest and highest values, excluding the out-liers. The median is at the mid-point of the box. Half the observations lie above and half below this line (Hicks, 1995). Data from round 3 of the Delphi are displayed as a table (Table 14) to show the inter-postal round changes of consensus.

Results.

The Interpretation of Round 2 of the Delphi process.

Primary consensus relates to the first postal round and the final consensus to the second postal round.

The 54 respondents had been qualified for a mean of twenty years, and many showed their commitment to service development and continued professional development, with 70 %

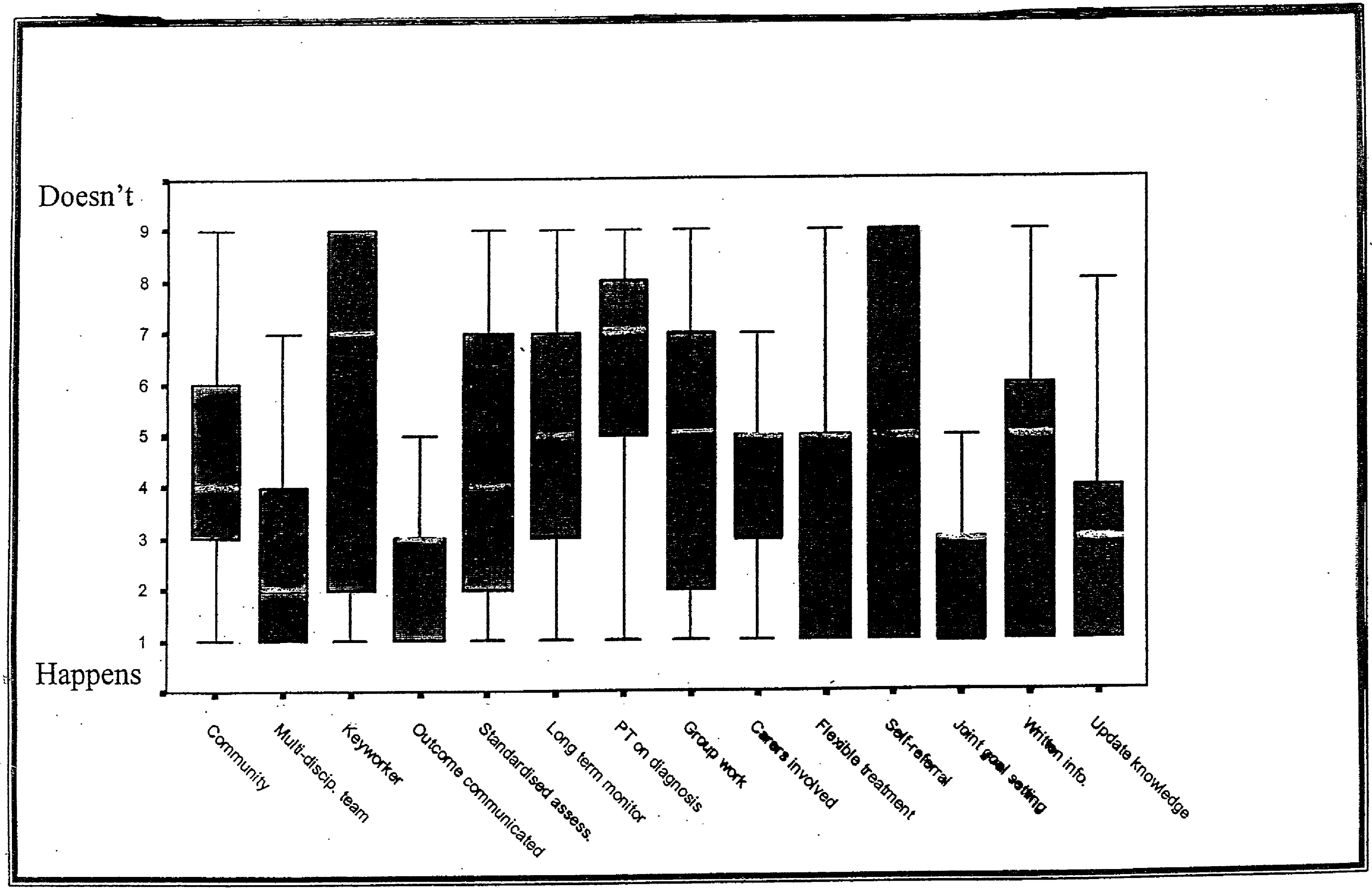


Figure 4. The consensus view of 54 clinicians who were questioned in the 1st postal round of the Delphi relating issues of practice in terms of whether practice happens or not.

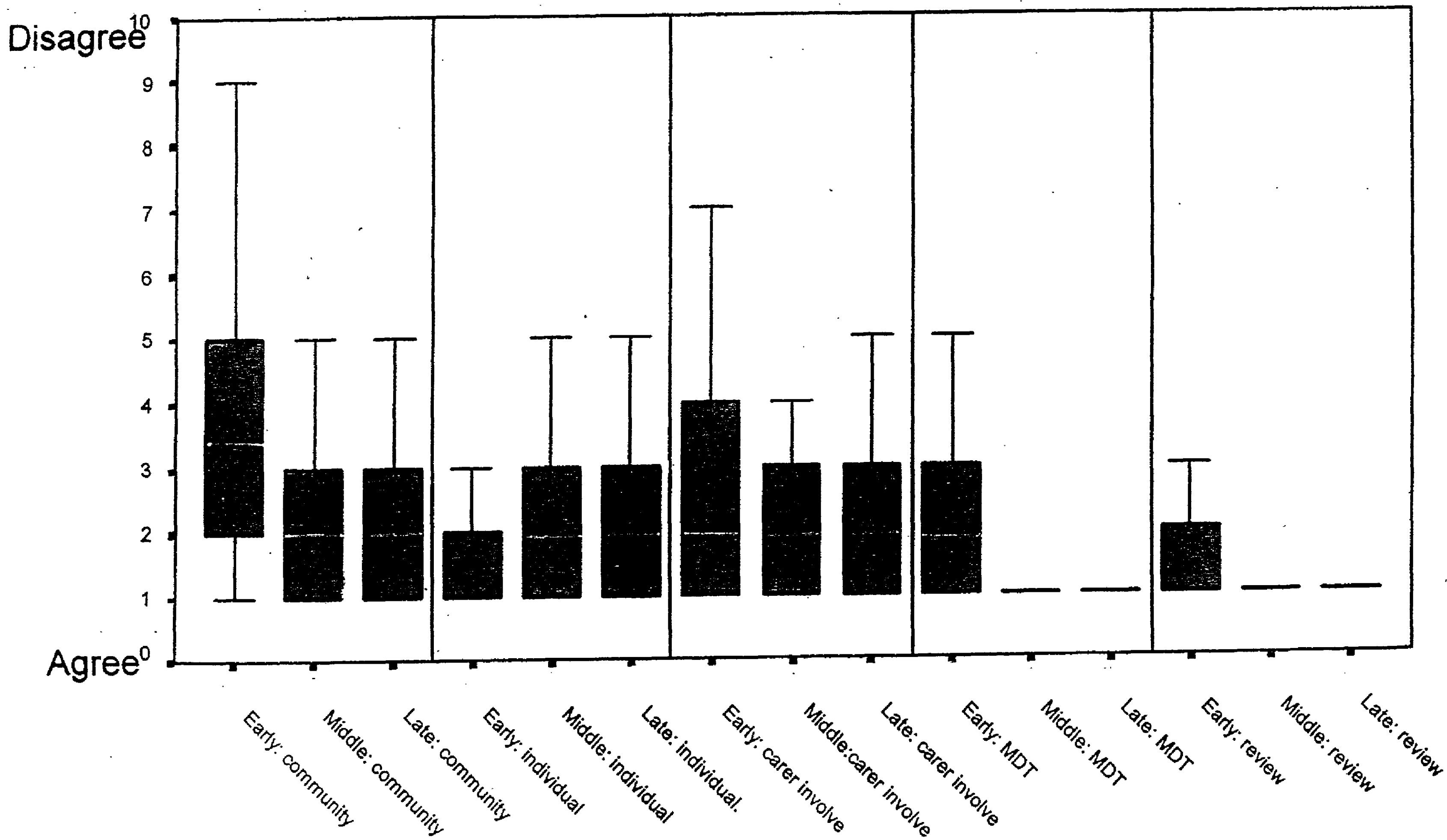


Figure 5. The consensus view of 54 clinicians who were questioned in the 1st postal round of the Delphi relating issues of practice in terms of whether practice was desirable or not.

having been on post-registration courses. The results from the first postal round show a response rate of 75% (54 out of 72) while the figure pre-set for acceptance was 70%. The results of the first postal round are displayed as box and whisker plots (Figures 4 and 5). Figure 5 represents the Context section, where the issue of whether the event desirable or undesirable is displayed.

Table 14. The primary and final consensus, and inter-round changes for what happens.

Variable	Primary consensus %	Final consensus %
C	71	94
MDT	89	98
K	46	88
OC	92	94
SA	86	92
LTM	82	92
PT	82	92
GW	56	90
CI	86	94
FT	83	88
SR	65	88
JGS	94	96
WI	74	92
UK	98	98

Table 14 shows the consensus for the two rounds and the variables considered.

C-community, **MDT**- multi-disciplinary team, **K**- key worker, **OC**-outcome communicated, **SA**-standardised assessment form, **LTM**- long- term monitor, **PT**- physiotherapy on diagnosis, **GW**- group work, **CI-** carers involved, **FT** – flexible treatment, **SR**- self referral, **JGS**-joint goal setting, **WI**- written information, **UK**- update knowledge.

The primary consensus points for the first postal round can be described, as well as being quantitatively and graphically displayed. In Figure 5 the values of 1 for the middle and late involvement of the multidisciplinary team, and for the middle and long term review were highly desirable by all respondents. On the issue of 'happens/does not happen', a variable distribution shows, in Figure 4, that some events happen but this is not the case for all. For example, the communicated outcomes and joint goal setting were factors occurring regularly, as was updating of knowledge. The feeling of what was desirable, and what was actually happening in practice therefore showed a discrepancy. In about 50% of cases patients were not being referred for early intervention.

The results from the second postal round were received from 49 of the 54 experts to whom the second postal set of statements were issued, making this a response rate of 91%. A stronger consensus was obtained with this second round (Table 14).

More than 50% of respondents showed that they linked into the community, they were working in multi-disciplinary teams, were communicating outcomes, involved carers, organised flexibility in treatments. They were involved with the setting of joint goals and updating knowledge.

Events occurring in 50% of the expert responses were identified as, long-term monitoring of the patient's condition, group activities, self-referral and the supply of written information. The issues of a key worker and initiation of physiotherapy on diagnosis were not happening with any frequency at all. The key worker and self referral data showed a bi-modal distribution. The intervention of physiotherapy was considered by the experts to be 'desirable' against all the statements. On the issues of multi-disciplinary team working, joint goal setting and updating of knowledge, there was a 100% agreement of desirability.

The respondents confirmed that all statements were highly desirable and therefore a consensus amongst experts was achieved (Table 14).

2:iii Semi-structured interviews.

The interviews were considered the methodology of choice to test the data collected by the Delphi process at the centres designated as case study centres. Semi-structured interviews require the research question(s) to be identified and a series of questions then need to be formulated to address these issues. The objectives for the next stage reflect a progression in the investigation.

Objectives:

1. to identify main components of a physiotherapy service for patients with Parkinson's disease, including a format to describe them accurately.

2. to ascertain from key professionals and managers, the structure and function of the organisation of services for patients with Parkinson's disease, including perception and experiences of professional roles, responsibilities and interaction.

The selection criteria

After the Delphi results were analysed the criteria for the selection of the clinical sites were produced. These sites would enable data to be collected from the clinicians, the patients' notes and from patients and carers. In the full PEP the data from all sources could be triangulated for confirmation of practice issues. The author chose the criteria to select the 3 sites (case study centres) for structured interviews by the team, and the 8 sites to be telephoned for interview.

These centres should reflect successful practice where the response rate to the Delphi document, (CONTEXT, section) yields scores in which over 90% were in the 1-3 range noted in the sections, i.e. a) 'happens / does not happen', responses of 1- 3, and b) 'desirable / not desirable' responses of 1-3. This would enable sites to be accessed that had responded in the Delphi that good practice was identified and also it was occurring.

Additional criteria were also suggested to gain a spread of sites across the locations where a patient may be treated and that these should also reflect a socio-economic mix, by applying additional criteria (Table 15) to those which had been available from the first screening and emerged as centres of good practice.

Table 15. The additional criteria.

A	1. In-patient.
	2. Community-based.
	3. Both in-patient and community centres.
B	1. Single physiotherapist service
	2. Multi-disciplinary team approach
C	If all the above criteria are fulfilled there may be a case for considering a geographical /socio-economic variable.

Preparation of questions for the case study visits.

Three forms of data collection were planned. One was from the clinicians, one from the managers, and the third, from the patients receiving treatment. The author was responsible for collecting data from the clinicians' group by structured interview.

A questionnaire was devised from the statements (pp54,55) and responses in the Delphi

they were administered to the clinicians, and service manager and senior managerial physiotherapists respectively, at three selected sites (to maintain confidentiality they are not specifically identified in the text). These three sites were chosen as they fulfilled the criteria stated above. The author visited a site in North Wales, whilst colleagues visited the other two chosen sites, one in the south and one on the north east coast of England; the patient based interviews were carried out by a suitably qualified research assistant who also carried out the telephone interviews.

The semi-structured interviews at selected sites.

To validate the results of the postal questionnaires from the centres of good practice, a series of semi-structured interviews were scheduled, one set of interviews by the author in one of the three selected centres. Two different members of the PEP group carried out the same interviews at the two additional identified centres. (The data from all these three centres would be collated by the PEP group collectively.) In this chapter the structured interviews relate only to the centre visited by the author with only these results being presented.

The aims of the research were:

1. to identify what constitutes good practice physiotherapy in Parkinson's disease
2. to investigate the evidence base underpinning the practice.

Methodology.

The theoretical aspects of the semi -structured interview.

The interview is a method for reconstructing subjective theories; the term subjective theory relates to the knowledge the interviewee has about a topic (Hicks, 1995). The questions are the methodological aid for the interviewer to elicit these subjective theories.

Open-ended and closed questions.

The advantages of open questions lie in the rich data that can be collected. There are fewer limits imposed by the researcher. It is easier to construct this kind of question as one does not have to establish comprehensive response categories. The drawbacks to these questions are the greater complexity of their analysis. The respondents may offer more peripheral responses, and may have problems expressing themselves. More time and thought may be needed for these responses and the respondents may choose to answer very superficially so that a threat is posed to external validity.

Content analysis.

The coding for the analysis is presented in Table16. A broad definition of content analysis is offered by Haggerty (1996) as a technique for making inferences systematically and objectively. This method employs the systematic analysis of qualitative data in a reliable manner so that generalisations can be made. It aims to produce a detailed systematic recording of the themes and issues emerging in the responses, and link these themes under a category. This method, if used cautiously, is a valid method for approaching verbal data, and an awareness of the possible problems supports its use (Flick and Uwe, 1998). Content analysis has its supporters and opponents, but used alongside other statistical procedures it will add to the analysis. The problems in interpretation of the language may open validity issues if the interviewer and interviewee use a different interpretation of the meaning. The interviewer may not interpret the responses with the exact meaning that was intended and a recording error may then lead to invalid data analysis later.

There were six stages in the content analysis (Robertson, 1995). The first was to produce the research question, the second was to decide on a sampling strategy, and the third was to refine the recording unit. The next stage revolved round the construction of categories for analysis, testing the coding on samples of text and assessing reliability in the fifth stage. The final stage was carrying out the analysis.

The objectivity in analysis is performed according to a set of rules whereby two or more researchers can identify the same results from a study. Systematic analysis includes all data, whether or not they support the researcher's hypothesis. The term generality must relate to issues that have a theoretical basis. The unit of content (character) may be a word, symbol, theme, character, sentence or paragraph; pilot testing of the appropriate character is necessary before the data collection (Haggerty, 1996).

Question types.

Closed questions force the respondent to choose one response; such questions may be quicker and easier to answer and analyse. The closed question allows for group comparison. There are problems with validity, and closed questions force a certain direction and do not allow for self-expression. The potential responses listed by the researcher may not actually include the most appropriate response. The data are analyzed as quantative data (nominal /ordinal) by percentages, frequency tables, descriptive statistics, and cross-comparisons between categories. The open and closed questions each have their strengths and a mixture of the two is often the most appropriate.

The interviewer guides the session by addressing each area with open questions (the interviewee in answering spontaneously can express these theories when open questions are used), and following on with closed (or confrontational) questions. The latter probe in depth, and allow the interviewee to analyse critically the information that has been given previously, which adds to the structuring of the interview (Flick and Uwe, 1998). The contribution to the development of the interview is facilitated by the structuring of contents and allowing expansion on the identified theories. The difficulties of this method of data collection and analysis are shown in the extensive methodological input and the problems of subjective interviewer bias and interpretation.

Researcher training.

Since a qualitative study depends so much on the human judgement and discipline of the researcher (Tutty, Rothey and Grimmel, 1996) it is important that appropriate training of the researcher is undertaken to reduce this bias. The author has considerable experience of interviewing patients and analysing the findings in an objective way. (This has been further developed by supervision of undergraduate research projects and in-service training for this project).

Precautions to ensure consistency of recording.

Some authors suggest weighting of information as familiarisation with the interview occurs after the first few sessions. To address this point the author undertook a pilot run through on two subjects, as identified later in the text. The pilot allowed for the testing the data sheets and modifying them in an appropriate way to facilitate and ensure consistency. The planned recording technique allows for accurate reporting of data. Rules for coding of information were laid out before the data collection began. This would enable another researcher to identify the same interpretation as the researcher conducting the interview. Conventional formulae are utilised to indicate, for example, comments which are transposed verbatim and those which are summarised. Other symbols are included to incorporate delay in response, or non-verbal intuitive responses. Information collected when the interviewee has volunteered and is alone with the researcher can be considered as more dependable than when collected in a group situation (Tutty et al, 1996).

There is a need for the coding dimensions to be set out before the researcher conducts the interview. The sheet contains the dimensions and criteria within each dimension. The numerical counting of occurrence and frequency is also important. The author identified these criteria and laid them out for the PEP members to follow.

Table 16 Dimensions for the coding

Codes	Explanation
" "	Reported verbatim
' '	Reported summarised
( )	Seconds of silence
<u>aaa</u>	Stress or emphasis
'hhh'	Audible intakes of breath
(words)	Parenthesis transcription, interviewer's best guess.

These codes were used during the data collection and in the transcription stages.

Reliability and validity issues.

This type of analysis must allow for two researchers to identify the same results from a study. Reliability requires both the codes and the researcher to be checked. There are three aspects of validity which must be addressed. Concept validity is demonstrated if the categories reflect what they claim to reflect. Empirical validity seeks for external sources of evidence to support the findings from the content analysis, and phenomenological validity ensures that the point about the researcher interpreting what was said by the participants in the way it was meant.

Preparation of questionnaires for the case study visits.

The author formulated the two questionnaires from the Delphi statements. One was to be administered to the four senior, expert physiotherapists at the sites and the second questionnaire to the physiotherapy managers (who were also, on occasions, actually treating PD patients) following ethical approval. The managers could be asked for factual data relating to the service provision, and the clinical therapists would be asked about the practice issues. The questions are presented on the following pages.

The application for ethical permission.

The centre was identified from respondents' postal returns of the Delphi and the individuals' contact addresses were sought. Explanatory letters were prepared and sent to the site. Contact was made with the appropriate physiotherapy staff by telephone to discuss the project. A named senior physiotherapist and a Care of the Elderly Consultant volunteered for their names to be placed on the ethics committee forms (this was a requirement of the ethics committee at the site). The author was invited to attend the meeting of the ethics committee and present the research proposal. Ethical permission was granted the next day.

It was necessary, because of the time pressures on the author and the other two PEP members, for another researcher to undertake the patient interviews at all three locations. A research assistant was employed and trained to administer the structured interviews with the patients and managers.

Pilot study.

The final version of the questionnaire for the semi-structured (and telephone) interviews was produced (pages 54, 55) and the author piloted this on two appropriately qualified colleagues from a local hospital. After the preliminary courtesies, the timing of the questionnaire was found to be between 19 and 24 minutes. No changes were needed and the explanatory letters were prepared for sending to the site to arrange appointments.

Questions for the structured interviews with the clinicians

1.Do you treat patients with PD? Yes / No
2.Do you treat PD patients in groups? Yes /No . If yes ,What format

3.For each problem, please explain the cause, approach and theoretical background to those approaches.

Problem	What do you think are the main causes of:	What approach do you use in your treatment sessions for this problem:	Do you have a theory about how your treatment affects the causes of the problem:
Poor Posture			
Gait a. freezing b. shuffling/ festinating			
Inability to move and roll in bed			

4. Do you modify your treatment for PD patients with
a. depression Yes______ No______
If yes, how?
b. dementia Yes_____ No ______
If yes, how?
Information.
5.Do patients ask for any information on the following:
a. PD Yes____ No____
b. your physiotherapy services/ department Yes____ No____
c. other services or departments Yes____ No____
6.What information are you able to give your patients?
Please indicate if this is given in verbal(V)
written form (W)
or combination of both(B).
7.Do you give your patients a home exercise programme?
a. always
b. never
c. Sometimes
d. **8.Are you part of a team of staff treating people with PD?** Yes____No____
Who are the team members?
How do they communicate?
eg written reports
medical notes
formal meetings
informal meetings
other____
Is there a leader?__________
Who is it ________________
Do you think the team works?
9. Rate how well the overall service for PD works
(0= Poor, 5= Excellent)

0______________________________5

Questions for the Structured interviews to the managers.

The managerial position of the interviewee...................

1. a.What population does the physiotherapy service cover?

   b.How many staff are in post ?

   c.Are there any vacancies in the staff numbers? How many vacancies are there in the staff areas where Parkinson's disease patients are seen?
2. How many PD patients are referred each year?
3. Who refers these patients for physiotherapy?
4. How soon after diagnosis are these patients referred for physiotherapy?
5. Does the department have a restriction on the service provision in terms of limited numbers of treatment sessions per patient? If so, how many?
6. How many staff are allocated to treat the PD patients?
7. What grades of seniority are these staff?
8. Does your department allow funding and time release for training and updating of staff?
9. Is this, (8), through in-service and /or external courses?
10. Do you have a policy for standardised assessments formats?
11. Do you have a policy /criteria for review and discharge?
12. Do you have a self referral system in your department team manager?

Planning the interview schedules.

Subsequently appointments were made with the four clinical physiotherapy experts and the three managers (who were located on two sites within the Hospital Trust). A follow up letter was sent confirming the arrangements.

The managers held the following positions:- head of department and the deputy head of department, and the superintendent physiotherapist for the community. The questionnaire was issued by semi-structured interviews and took approximately 20 minutes to complete.The data were analysed later. The structured interviews were carried out over a period of two days and the data were collected and immediately transcribed, onto pre-prepared sheets and collated later in the day.

Presentation of the results and data analysis.

The data from the clinicians' and managers' interviews are presented in the results section as a series of Tables (17- 23, and 24 respectively). The results are presented from the four clinicians (A, B, C and D) and analysed by descriptive statistics. From the raw data sheets a series of tables and figures were organised to represent the responses. Each question had its responses (quoted in the tables as a verbatim text) presented in sequence.

Question 1. This was a simple yes/no response to ascertain whether the clinician treated patients with PD. All responded that this was the case.

Question 2. This question related to the individual or group treatment of patients. Only one clinician used group therapy. This was for groups of patients at the PDS meetings, rather than for patients who had been referred to the physiotherapist directly.

Question 3. This question posed a multiple-part task. There were four clinical scenarios presented and the cause of each, and the treatment approach with the underlying theory, was asked for. The question is presented as a series of tables in which each scenario is considered separately (Tables 17-23).

The reasons given for the abnormal movement problems (in the question) spread from the physical effects of reduced mobility, from loss of extensibility to the difficulty in the initiation of movement (Table 17a). The intellectual side of movement control, also had an effect, and presented as fear. The treatment approaches were all based on the assessment of the underlying cause of the problem. The exercise approach was the most commonly utilised intervention, and facilitation was also mentioned. The latter is performed by the therapist initially and later progresses to active involvement by the patient. The background theory was elicited with supplementary, facilitatory questions, e.g. "Could you tell me what you mean by...?", and "Could you explain why...?"

Clinical scenarios were presented as "poor posture, gait (freezing and festinating aspects) and inability to roll over". These functional actions are basic to normal life; every physiotherapist treating PD will have come across them frequently in practice. Responses from the four clinicians as to the probable causes, treatment choices and theoretical background showed different thoughts as to the cause; these ranged from muscle imbalance, to stiffness and inability to generate movement. They all agreed, however, that assessment was necessary to identify the cause, and had similar views on the treatment approach being directed to address the cause of the poor postures. Suitable treatment approaches were identifed by three clinicians as being mobilisation techniques, whether passively applied by the therapist or by active exercises (Protas et al, 1996) being performed by the patient. The clinician B, advocated the use of self-correction by the patient, using mirrors to assist the process. The main features here stem from the use of strategies as the most frequent treatment intervention and all of the clinicians advocated this approach for freezing issues. Detail of actual strategies, other than "visual and verbal", did not emerge from this questioning.

The geographical location for the onset of the freezing episode was identified by three respondents. All four clinicians offered different reasons for the presenting features in gait, although there was considerable agreement as to the approaches chosen to address the freezing aspect; the use of strategies was the common theme (Ype, Weibo, Bruwoer and Johannes, 1995) Two clinicians advocated a bio-mechanical approach to the festinating problems.

Table 17. The responses of clinicians A- D concerning the probable causes, treatment approaches and background theory that they use for the movement related problems of posture (Table 17a), gait (Table 17b) and bed mobility (Table17c) which were addressed by question 3a.

Table 17a Question 3a. Poor posture.

Probable Cause(s)	Treatment Approach(es)	Background Theory
Clinician A. Imbalance. Stiffness.	*A of C* Strengthen muscles. Mobilise joints by exercise.	Medication "wearing off". Loss of freedom of movement causes stiffness and imbalance.
B. Muscle weakness.	*A of C.* Progressive strengthening exercises. Use of mirrors for correction. Teaching awareness.	Medication is needed, to give freedom of movement for intervention by the therapist.
C. Stiffness. Anxiety.	*A of C.* General mobility exercises.	Treatment does not affect the pathology, uses what is left. Encourage activity in patient's own environment.
D. Inability to initiate movement. Difficulty to move in normal patterns.	*A of C.* Mobilise "tight" areas. Facilitate normal active movement (passively). Then activity.	Plasticity based. Re-use pathways and maintain what patient "has".

Assessment of the cause of the problem *(A of C).*

Factors other than purely physical ones emerged, such as the effect of reduced socialisation and its impact on movement; also the anxiety level of the patient was considered a major problem.

An eclectic approach is the theme for the intervention strategies, with active exercises coming through strongly as a basis of intervention.

There was agreement that reduction in flexibility (stiffness) was the problem here for the resulting inability to roll in bed. General consensus was apparent that the approach to treatment was basically one of rotation, followed by the patient's active practice of trunk rotation exercises. The deficiency in the clinicians' theory behind the approaches was noted; although clinical experience for the justification (though not scientific) was strong for the treatment approaches selected.

Question 3b. This part of the question attempts to reveal the clinician's theoretical background knowledge of the treatment interventions identified in question 3a. The responses from each clinician are presented as separate tables (Tables 18a-d).

Table 17b Question 3a. Gait: i) Freezing and ii) Festinating gait

Probable Cause(s)	Treatment Approach(es)	Background Theory
A i) Inability to initiate movements, especially in different environments i.e. changing direction. ii) Small range movements.	i) Strategies to unlock freezing, ii) Repetition, iii) Work in patient's environment. iv) Practice heel/toe, and larger step movements.	?Cognitive strategy. i) Normal movement experiences to control movement problems. ii)? Neuroplasticity
B i) ?Changes in in-put to CNS, ii) Not experiencing normal movement. iii) Poor posture.	i) Specific strategy for individual. ii) Gait re-education, larger steps and heel/toe work. iii) Exercises as appropriate	i) Practice, repetition and home exercises. ii) Bio-mechanical principles. Fear of moving out of base of support.
C i) Apprehension. ii)Fear of falling.	i) Verbal and visual cueing, changing strategies ii) Reduce anxiety, with practice in safe environment.	i) Reduced social contact ? Lack of motivation ? Lack of soft tissue ext-ensibility. ii)? Anxiety.
D i) "Wearing off" of medication. ii) Poor balance	i) Provide a strategy. A of C. ii) Work on problems identified. iii) Balance retraining.	i) Overcoming a block in normal pathway. ii) Carry over of skills from treatment.

Table 17c Question 3a. Inability to roll over.

Probable Cause(s)	Treatment Approach(es)	Background Theory
A Stiffness.	A of C. Passive, then active rotation.	Re-education of normal movement.
B Loss of trunk rotation.	Passive then active, general rotation exercises.	?Not sure.
C Stiff pelvic and spinal joints.	Passive, then active control encouraged, active exercises for trunk rotation in sitting.	I know it works, but not why.
D Rigidity , Spinal joints, stiff.	Mobilise in lying (passively), Then, active exercises.	?Not sure.

Consistent themes emerged about the multi-disciplinary input and involvement, and carer inclusion. The physiotherapists felt able to expand on some aspects of the theoretical background to treatment. These were, however, considerable gaps in the underpinning theory, which are reflected in the literature.

The next four Tables (18a-d) one for each clinician where data are from question 3b which was asking about the level of intervention. The lack of certainty in the theoretical background, flags up the need for well structured and rigorous postgraduate training.

Table 18. The responses for the different clinicians are presented separately in Tables 18a-d. The responses of the clinicians A- D concerning the aspects of background theory relating to primary and secondary impairment, and nature of disability and handicap in PD which are addressed in question 3b. A summary of the treatment aims is related to maintaining the mobility as high as the patient can tolerate, and to minimise the chance of the ensuing immobility.

Table 18a Question 3b. Background theory - Clinician A

Primary impairments (direct results of the disease, e.g. rigidity)	By-passing damaged pathways Practice and training to a specific goal ? neuroplastic changes
Secondary impairments (complications of the disease process e.g. loss of soft tissue extensibility)	Disuse and lack of confidence, reduce ability, leading to stiffness and shortening of muscle tissue.
Disability	The Carr and Shepherd approach, which incorporates a skills transfer (from treatment session to functional activities).
Handicap	This is a bigger issue than just the input from physiotherapy, the multidisciplinary team is needed at this stage.

Table 18b Question 3b. Background theory- Clinician B

Primary impairments (direct results of the disease, e.g. rigidity)	? Neuroplasticity. Assess what is under voluntary control, Encourage activity of patient and build on the small progress in many functional activities.
Secondary impairments (complications of the disease process e.g. loss of soft tissue extensibility)	Often leads to reduced social contact, lack of motivation, and reduced movements. Joints stiffness and reduced length of soft tissues.
Disability	Approach at a functional level. ? Work with carer. Use a motor relearning approach
Handicap	May focus on quality of life issues Whole multi disciplinary team involvement Short, intensive bursts of treatment

Table 18c Question 3b. Background theory- Clinician C

Primary impairments (direct results of the disease, e.g. rigidity)	Plasticity based. Encourage active movements as soon as patient is facilitated to do this. Re-use pathways.
Secondary impairments (complications of the disease process e.g. loss of extensibility)	Neural control, lack of co-ordination of the stages in activity, Reduced range of movement may lead to Muscle shortening.
Disability	Functional activities working at impairment level. Work in patient's environment, with carer.

<u>Question 4.</u>

Aspects of depression and dementia and its influence on treatment: the inclusion of this question was to ascertain whether there was a modification needed to treatment, and if the patient was depressed or demented. If a change was incorporated, the nature of the change was requested. The responses are documented in Table 19. The clinicians found this area of practice to be poorly documented in accessible literature and spoke, after the interview was over, about the close support network the team offered its members in these cases. There was concern that appropriate training for these aspects of the disease were needed.

Table 18d Question 3b. Background theory- Clinician D

Primary impairments (direct results of the disease, e.g. rigidity)	Based on plasticity Encourage active use and maintain what patient has in terms of movement. Re-use pathways, encourage repetition.
Secondary impairments (complications of the disease process e.g. loss of soft tissue extensibility)	Lack of stringing together the normal control of movement. Patient then has reduced range of movement, which leads to inactivity and reduced soft tissue extensibility.
Handicap	Maximise quality of movement. Other factors fit in here, e.g. the multidisciplinary team inputs, Motivation, Support of carer
Disability	Maximise quality of movement, Motivation, support of carer.

Table 19. Question 4. Aspects of depression and dementia and its influence on treatment.

Do you alter treatment in Patients with	If so, how?
i) Depression:	
Clinician A Yes	Offer more time for patient to talk. Discuss with consultant.
Clinician B Yes	May be a discussion session, no "hands-on" treatment that time.
Clinician C Yes	Work with clinical psychologist. ?Medication issues/ consultant. Shorter time sessions/ home visits
Clinician D Yes	Referral to clinical psychologist
ii) Dementia	
Clinician A Yes	Needs to be seen more often.
Clinician B Yes	Difficult to handle. Needs very committed relatives and carers who need support from the team.
Clinician C Yes	Talk to GP
Clinician D Yes	Clinical psychologist referral. Time to talk to patient and carer to increase.

Table 19. Clinicians' views relating to aspects of depression and dementia and the influence on treatment are expressed as well as the strategies employed to deal with these issues.

Question 5.

This question was asking for factual details of the information provided by the therapist. The results are illustrated in Table 20. Each clinician's responses are in vertical columns.

The results indicate that referrals from the PD clinics allow the patients to have access to the services of the department and information is supplied directly at this point. Referrals from other sources by pass this system, of information giving, and the patients were found to be in need of further information.

Advice was often asked about home based assistance mostly from just from one therapist, as it was she who supplied the domiciliary branch of the service.

Table 20 Question 5. Information Sources.

Do patients ask for information on the following ?	Clinician A.	B.	C.	D.
Parkinson's disease	Yes	Yes, at the PD Society branch meetings	Yes	Yes, about the way the disease progresses
Physiotherapy services in their area	Patients provided with this at clinic attendance	Only when patients referred from "outside" PD clinic.	No	No
Other services or departments	yes	All other services are presented at PD clinics.	Told of them in clinic	Yes, especially related to home help/ assistance.

Table 20 identifies the responses of clinicians A-d in terms of advising the patients about the disease process and local services.

Question 6 refers to the advice given by the therapists to the patients. The question was open-ended and the comments vary.

Table 21. The responses of clinicians A-D are displayed as four separate tables (Table 21a-d) in respect of question 5.The details are given of the information issued by the therapist and the mode of its delivery.

Table 21a Question 6. Responses to information provided by the therapist A, including the mode of delivery.

Information	Advice on the condition, explanation of the problems, discuss goal and how team works.
Mode of delivery	PD Society meetings. Verbal and written (exercise sheet specific to patient).

Table 21b. Question 6. Responses to information provided by the therapist B, including the mode of delivery.

Information	Attempt to offer what is asked/ refer to other team member. Explanation of problems (with disease) and treatment approaches.
Mode of delivery	Combination, written and verbal.

Table 21c. Question 6. Responses to information provided by the therapist C, including the mode of delivery.

Information	Relating to their movement problems. Advice on exercise. How to contact department.
Mode of delivery	Exercise sheet, written. Verbal .

Table 21d. Question 6. Responses to information provided by the therapist D, including the mode of delivery.

Information	The PD Society- what it can offer. Social services- structural modifications
Mode of delivery	Community therapist, written and verbal.

Each clinician identified their chosen method, which may reflect some slightly different work situations as three were hospital based and one was in the community. All respondents offered information in both written and verbal formats to the patients. The information given had some variety and included

(1) the type of exercise prescription,

(2) how to contact the department for further physiotherapy input, and

(3) social services facilities.

Question 7, relates to the supply of home exercises. The responses are outlined in Table 22. The clinicians were in agreement, 100%, that exercises for well-being were a separate type of exercise and were given to all patients. Some therapists, 50%, also felt it important to identify specific need from assessment, then issued particular types of exercise as well. The choice of "never " was not used by any of the therapists.

Table 22 Question 7. The issue of home exercises

Frequency	**Clinician A**	**B**	**C**	**D**
Home Exercise always prescribed	General activity always advised	Yes. Used as outcome measure.	General exercises, yes	Yes
Home Exercise sometimes prescribed	Specific exercises.		More specific exercises may be issued as well.	

Table 22 presents the responses of clinicians A- D, in response to question 7. The issue of the prescription of home exercises as being always or sometimes prescribed is addressed.

<u>Question 8</u>. Addresses the multidisciplinary team and its perceived effect.

The question was in several subsections; indicated in the left hand column of the table. The question and the results are tabulated in Table 23.

Table 23 Question 8. The multidisciplinary team and its perceived effect

	Clinician A	**B**	**C**	**D**
Do you work in a team?	Yes, community team	Yes	Yes	Yes
Who are the members?	PT, OT, ST. PD Nurse, Consultant, GP	As for A. Plus: Dementia therapist, social worker, psychologist.	Consultant, PT,OT,ST, Nurse, (others as needed)	As B, Plus dietician as needed.
How do they communicate?	Informally, telephone, written reports.	Written reports, medical notes, informally, meetings	After clinics ward rounds, written and verbally.	After rounds, clinics, Verbally, Informally and case notes.
Is there a leader, if yes, from which profession?	Consultant for the Community	Consultant Care of the Elderly	Associate Consultant	Consultant Care of the Elderly
Do you think the team works?	Yes	Yes	Yes	Yes

Table 23 presents the responses of clinicians A-D in addressing question 8, which details the presence of teams, the component members, the communication strategies, the leaders and the effectiveness of the team. PT, physiotherapist, OT, occupational therapist, ST, speech therapist and GP, general practitioner.

The question revealed a very comprehensive approach for the team and its extended contacts. Communication between team members was of a varied nature. There was agreement on the different team members, and some other professions were identified who may be accessed if needed. All were in agreement that the team worked.

<u>Question 9.</u> This question asked for a rating of how well the service performed.

The clinicians all gave their service a high score in terms of evaluating it. When asked on what grounds they had made this decision, the responses varied from :

"no-one has complained",

"the staff are happy together as a team ",

"the patients tell us our service is better than others in the hospital".

They had no quality framework on which to base these decisions. The decisions were purely subjective in nature.

Table 24 **The results of the managers' questionnaire.**

	Manager A	Manager B	Manager C.
1a	234,000		
1b	35 full time equivalents		
1c	1 full time post		
1d	nil		
2	? data difficult to access	*	**
3	Consultants/GP,District Nurse Carer/ Patients directly.	Ditto, plus Other therapy professionals	Ditto, as A.
4	Yes. Soon as possible after referral.	Soon as notified, if pat-ient on general wards.	Soon as identified if at day centre
5	No. as needed	As needed	No financial restrictions/(Staffing numbers in post)
6	3 specifically. (neurology dept.)	Many , if patient on general units	Any member at day centre.(4)
7	Senior 1 &11, Community Supt.		
8	yes	Ditto	Ditto
9	Both, as required by individual	Ditto	Ditto
10	No. Senior Clinician has choice.	Senior clinician from that area will decide.	Follow on with present format
11	Yes, approx 3 monthly.	Yes, 3 monthly. More often if needed.	As appropriate for each individual. But always at six months if not more frequently.
12	Yes, after diagnosis.	Yes, after 1st referral from "medical personnel".	Not prior to diagnosis.

Table 24 * Patients may go on to the general wards for other reasons for admission, and then be treated by staff on those units. ** Patients may be referred for day care for other problems, but may also need treatment for PD. The data from the structured interviews from the managers are displayed numerically. The question number is in the left hand column and each

manager was given a code number of A, B and C. The managers A and B were located at the acute hospital and C was at a day-care centre for the Care of the Elderly.

Results of the Managers' structured interviews.

Data from the closed questions (Table 24) produced the factual information about the service and policy decisions that influence delivery of physiotherapy to the patients. The analysis from these data is discussed and integrated, in relation to the service provision, in the next section. Manager A was the sole recipient of the first question, as this was information requested prior to arrival, because it may have been stored on a computer data base.

DISCUSSION.

The analyses from both the consensus and the structured interviews are presented in this section, as practices are teased out and a model of good practice can be constructed.

The Aims of the Study.

The aims of the PEP study were to identify a best practice model of physiotherapy and to produce a consensus document which details the best practice model of treatment modalities used by physiotherapists. When the full picture emerges, by the collation of data from all the structured interviews and from the patient interviews, the aims of the full study will be realised. This discussion, however, will focus on the results of the research carried out by the author alone.

Methods.

A selection of methodologies had been included, for relevant data collection, to achieve the aims of the project. The consensus was achieved by the Delphi process. The literature searching produced the basis for the statement formation. The searching revealed that a lack of quality information was a potential source of problems. A gap in the literature was identified. An attempt to access information of a suitably high quality reflected the lack of sound research and publication in this field. The particular features of this technique of statement formation, asking for opinion (desirable/undesirable) and fact (happens/does not happen) could substantiate the sparse literature or refute its claims. There was no objective gold standard by which to identify the experts. A definition of "expert" was therefore produced from literature and standards of comparable disciplines. Identification of these "experts" allowed the team to know of their identity, but they were guaranteed the confidentiality of their responses and places of work. This prevented potential ethical problems, and they gave consent by returning the completed list of statements. However, the validity of their responses could not be 100% as there is no certainty with a postal questionnaire that any one person has completed it. Structured interview techniques could have addressed this issue if time and finances had allowed. External validity was high as the sample had been selected in the way described. It guaranteed the selected respondent providing the data. The reliability of the method of the Delphi consensus would have been stronger if the study was repeated at a later stage. The sample was recruited from the whole population (with the exception of the research team) therefore the results should be generalisable to the whole British clinical field of experienced physiotherapists working with PD patients.

The consensus gave a) confirmation of the views expressed in the literature regarding statements 1, 2, 3, and 5, b) new findings of the treatment interventions utilised in statement.

Statements supported by the experts with agreement at 91% level as to what best practice comprised after the second postal round are as follows:

1. early referral to physiotherapy, on diagnosis if possible (Playfer, 1997),
2. the physiotherapist being part of a well structured multi-disciplinary team (Schenkman and Butler, 1989), thereby facilitating easy referral to other colleagues and minimising ensuing problems that may hinder intervention unless addressed in their early stages,
3. the involvement of the patient and carer in the setting and planning of treatment goals (Ryan et al, 1996),
4. the treatment interventions being considered best if an eclectic approach to treatment was chosen; interventions were most appropriate when provided as short bursts rather than on a continual basis,
5. the intervening period being supported by an exercise programme (Handford, 1986; Protas et al, 1996).

The structured interviews.

Validity in terms of the respondent's identity is supported, in that the "face to face" interview allows confirmation that the respondent is identifiable as fulfilling the criteria laid down. Interviews held in private tend to allow the respondent to supply more realistic views than in a group situation (Hicks, 1995).

Reliability is addressed by colleagues transcribing the data in the same way and being uniform in coding of the data. Training in structured interview techniques assisted with standardization aspects of the methodology (Hicks, 1995). The validity of the centre being one of best practice should have been tested prior to the in-depth structured interviews being carried out. On reflection, this could have been done by triangulating some of the patients' notes with some questionnaire responses, and interviewing other members of the disciplinary team.

The results of these interviews show the agreement in managerial support for the clinicians to provide the service. The centre was selected from the statement returns, as a centre of good practice in that it supported desirable happenings and identified that the "desirable " was taking place. This assumed that the centre was one of good practice. Further validity of this being the case could have been tested prior to the in depth interviews by sampling some patients' records and to check if the staff responses were supported in their documentation.

Interpretation of the question responses alongside the findings of the Delphi.

Question 1 allowed validation of respondents being active in treating patients with PD. This initial yes/no response question was paramount to support the validity of the data provision.

Question 2 investigated if patients were treated as individuals or in groups. This information would be needed for the analysis because treating patients in different settings, solely, or in groups will influence treatment approaches; it would invalidate the interpretation if the assumption was made that patients were treated in one way or another, without this being confirmed.

The theoretical background to these treatments has little commonality, but as different causes were put forward it is hardly surprising. A huge variety of theoretical background was introduced as evident from Table 18b. For example, clinician C offered the suggestion that pure physical causes may not be the sole reason for the problem.

Agreement of the cause and treatment approaches, offered little in the way of the theory underpinning practice. Clinical experience confirms the effectiveness of these techniques in some cases. Rothwell (1996) has made reference to deep receptors producing contra-lateral inhibition when the limb is subjected to passive rotation supporting that type of approach.

Addressing the theoretical basis for treatment interventions identified a gap in theoretical aspects of evidence based approaches as supported by Skeil (1995), which became apparent from the question (3b), relating to background theory (Tables 18a-d).

Why is there such an apparent diversity and lack of knowledge in the profession relating to the background theory in practice? It may be due to the combination of many factors. Firstly, it may be the undergraduate teaching and clinical training of clinicians as an initial source of the problem. In this study however, the clinicians held senior posts and had many years of clinical experience. Could it therefore be that there is a lack of reliable research evidence or that its availability proves to be the stumbling block? Clinicians' motivation and professionalism may also be restricted by financial issues. For example, the costs of courses and the time costs to release the staff (clinicians who trained on a diploma course do not have any training in research methodology) may restrict the learning of skills to access and critically appraise research literature. Secondly, facilities such as libraries and electronic systems are not commonplace, nor are they in suitable locations for ease of access for therapy staff in the Health Service. The lack of those facilities alone may lead to restricted availability of research findings.

Thirdly, the motivation of clinicians could be supported by the availability of back up support by systems such as the Cochrane databases. Where evidence has been reviewed it is now beginning to filter into the service. Fourthly, it may be that with clinical governance emerging the new contracts will include support for professional development in line with contracts for medical personnel. The latter issue may provide the facilities as well as the need for learning the relevant skills.

The reasons given for primary impairments again identified the lack of consistency in knowledge and understanding relating to the rigidity. The four clinicians based this phenomenon on neuroplastic changes, and were not able to offer additional information. Treatment approaches for this motor sign showed consistency in approach, agreeing that encouragement of active movement was advised. The commonality of approaches and the experience that therapists have gained led them to feel that they could have beneficial effects, albeit of a short term duration, by interventions that facilitated rotation. The approaches all have rotation issues as their basis. For example, the trunk has been identified as needing to undergo passive rotation, active-assisted rotation and then active exercises to reduce the effects of rigidity. None of the clinicians could explain how the techniques worked and there was also a lack of awareness of the importance of measuring, which tools to use, and the effects of interventions other than in a subjective way. There is a gap in the departmental policy where outcome measures are not being noted, and included as part of the quality measures of performance.

The identified causes of a secondary impairment, i.e. of loss in extensibility, was thought to be due to disuse and lack of confidence whilst moving. Some suggestions came forward relating to a downward spiral of mobility, weakness, lack of further activity, and more stiffness resulting. As a consequence of the reduced activity, a loss of social contact was offered by one clinician as an exacerbating factor to further compound the problems for the patient. All four respondents advocated a common approach of working with the patient in his/her own environment to treat the problem. Should this be the point at which a patient and carer are offered some respite care, or day hospital support so an increase in social interaction and professional involvement can occur? The potential lack of social integration has a bearing on motivation and maintaining levels of activity in the later stages of the disease. This may be an appropriate stage to consider activity from the therapists for example, in a community setting linked to the PD Society meetings that are held as part social and part informative sessions. The issue of handicap realised the collective suggestion of the need for the involvement of the multi- disciplinary team, as well, at this stage.

Question 4. The aspects of depression and dementia were introduced into the scene by this question. The results in Table 19, show strong agreement that shorter interventions, allowing more time for discussion, and also support for the carers would be needed, if depression was a feature. When dementia had been identified it was considered, by 3 of the clinicians, that this symptom required expertise from the team as well, to be included alongside shortened sessions of physiotherapy. These other members of the team for example may have been the neuro-psychologist and the GP. The author was introduced to a specialist nurse, who was known as the dementia therapist, on a professional visit to the hospital; this practitioner worked alongside any members of the team involved with patients who were suffering from dementia. This initiative seemed to support other staff in circumstances where specialist training was important.

Question 5. This question was asking about the type of information supplied to the patients and Question 6, related to the detail and its mode of issue. The therapists had supplied relevant information to the patient when the patient was attending the PD clinic. However, it was noticed that if the referral route was from another source then this information had not always been issued. Individual clinicians gave collective information, but this was also tailored to the patients' needs, and written and verbal modes of delivery were utilised. Common information sheets and exercises written as prescription could be prepared in advance and issued to all patients, and updated at regular intervals. There is a newly developed computation package that has been installed into some physiotherapy departments, which has a bank of exercises that can be selected and printed out for individual patients (PhysioTools).

Question 7 identified the existence of home exercise prescription. All therapists issued some form of home exercise programme. The reasons for the issue of exercises ranged from maintaining general fitness to providing a programme of specific actions to be practised for the individual. Perhaps the rural setting of the health authority studied led to the patients needing to be self sufficient in their home activities and exercise regimes. An open referral system and long term review policy would support this approach, which was a feature of the service. Pure self referral as an initial point of contact for physiotherapy may be available to patients of fund holding general practitioners, but as yet there were no plans for direct self referral in the first place.

Question 8 focussed on the perceived effects of the multi-disciplinary team. There was unanimous agreement that the clinicians thought their team worked and it was an effective team, with strong communication links and close contact between the members. The interesting comment was that "the team had received no complaints from patients or other staff". Thus the team felt that the lack of criticism indicated that the team worked well, but there was no objective system or quality framework for its evaluation. Perhaps, as mentioned earlier, the recording of outcomes would be a start.

High agreement was found between the supporting management team and the staff treating patients. The approach of comparing the data from these two sources may have shown discrepancies in the management and staff views; however, this was not the case. The comparison demonstrated that there is good communication and discussion in planning, provision of staff and training. The managerial attitudes and support for the clinicians have been identified, including a lack of apparent financial restrictions.

With the support in financial terms and from the management, the therapists have the necessary backing to develop their skills and knowledge. However, future training requires some branch of the profession to provide the courses and learning situations, the management side the need is to provide the incentives.

These issues will be highlighted in relation to physiotherapy management in chapter 5.

Conclusions.

The conclusions from the author's areas of responsibility identified the following:

1) within the practice of specialist physiotherapists, the provision for patients with Parkinson's disease is variable, and the knowledge and evidence base of the interventions is scant.

2) the lack of early referral to physiotherapy

3) a key worker being identified for the team

4) an eclectic approach to treatment.

The PEPgroup identified the following points from the end of the first stage of the study and offered these conclusions:

1. A definition of physiotherapy in Parkinson's disease has been formulated from the PEP project group

"The purpose of Physiotherapy is, to maximise functional ability and minimise secondary complications through movement rehabilitation, within a context of on-going education and support for the whole person". (Plant et al, 1999).

2. A framework for service delivery has been produced (Chapter 5). This framework bridges the service provision, from the administrative section to the practising physiotherapists and then to the patients. The framework should inform the decision-making process of purchasers, practitioners, providers and service users.

3. There is an established need for continuing professional development opportunities, in physiotherapeutic practice.

4. An eclectic approach to treatment is deemed most effective. The challenge to researchers and practitioners is how to best define this approach.

5. The effect of physiotherapy can, and should, be measured in relation to the specified aims of treatment.

Dissemination of the findings of the PEP has been made via invited key note lectures at conferences, presentations in the form of posters at several conferences with published abstracts and some papers are currently being presented to journals for adjudication. The group members, apart from the author are: Professor Plant, Dr Ashburn, Diana Jones, Felicity Handford and Ellie Kinnear.

CHAPTER 3.

"The execution of voluntary movement requires an ongoing awareness of the internal and external environment, a motor plan or strategy, and axonal connections through which the cerebral cortex can exert its influence on the musculoskeletal apparatus"

(Morecraft and Van Hoesen, 1996).

Introduction.

This chapter introduces the background to force generation, the dimensions of sensation, and the production of kinaesthesia, focusing on basal ganglia function, and dysfunction with the resultant abnormalities of movement in Parkinson's disease. The interesting issue is how the healthy CNS can sense the amount of force generated in movements and how it may use this to modify the ongoing motor programme particularly with movement degradation as in basal ganglia dysfunction. Although the cardinal neurological signs of PD and those which typically provoke physiotherapy intervention, are within the motor domain, the co-existence of sensory defects is being acknowledged. Several authors have argued that observations in PD patients such as limb instability in the absence of vision (Chouza, Scaramelli, Alijanati, de Medina, Coamanona, Lorenzo and Romeo,1986), impairments in detecting upper limb and mandibular movements (Schneider, Diamond and Markham,1987) and reduction in size of movements during vibratory stimulation (Rickards and Cody,1995) may be partly due to ineffective proprioceptive processing and/or failure of sensorimotor integration.

The following experiments address related proprioceptive submodalities, namely, the sense of force generation and the heaviness or weight (of external objects). Initially a quantitative description of force estimation, using matching of bilateral loads, was obtained and secondly measurements of heaviness perception using psychophysical measures in both PD patients and controls was carried out. The observations from the experiments on this new submodality were used to test the impairment of proprioceptive judgement in PD.

According to Alexander and Crutcher (1990) normal movements require three features; the correct muscles must be activated, appropriate ones deactivated (Berardelli, Dick, Rothwell, Day and Marsden, 1986), and the correct amount of force generated. Judging a weight of an object depends on how well the central nervous system (CNS) generates a force to support the weight, the accuracy of the sensory mechanism which tell the CNS how much force is being generated and the processing of this sensory information by higher cognitive centres in estimating accurately the amount of this force.

3.i Force generation in normal muscle.

Muscle tissues exert their effect by generating forces which enable the body parts to move, or provide stability for others. The number of muscle fibres being recruited for a motor action is dependent upon the number of motor units being activated which is dependent on the forces required for an action(Henneman, 1974; Gandevia and Rothwell, 1987; Ghez, 1991; Fredericks and Saladin, 1996). The larger the number of fibres stimulated the larger the forces being generated; this is fundamental to normal muscle control (Henneman, 1974).

The control of the motor neurones, which determines recruitment order, is by the density of synaptic input and the level of input resistance to the motor. The duration and type of exercise influence the type of muscle fibres recruited. Recruitment is used to increase the force of contraction and match the metabolic characteristics of muscle tissue to its demands, just as increasing the frequency modulation of an individual neurone fibre will increase the motor unit force generated (Fredericks and Saladin, 1996). There may be different levels of control in the CNS which are regulating force generation in complex tasks (Ingvarsson, Gordon and Forsberg, 1997).

The muscular system as a precision instrument.

The ability to use the muscular system as a precision instrument depends on its ability to develop and release various intensities of force at appropriate speeds, when manipulating objects or performing tasks. Accurate internal representation of the required force is needed for such tasks. An isometric contraction generates forces but no movement of the body parts; an isotonic contraction produces movement at a steady force (Kandel, Schwarz and Jessel, 1991). In normal ageing, structural changes occur in muscle tissue (Pedersen, Backman and Oberg,1991) and many PD patients are elderly, which may add to their problems of force generation. In PD there is a less well organised grading of contractile forces.

The timing of force initiation.

The pre-planning stages involve the selection of the correct movement in time and the activation of that pattern. Marsden (1980) claimed the striatum receives sensory information from widespread areas of the neo-cortex and processes this information as part of the role of subconscious planning. No straightforward relationship between response force and its time production was found by Wascher, Verleger, Vieregge, Koch and Kompf (1997). Corcos, Chen, Quinn, McAuley and Rothwell(1996) suggest two components necessary to control isometric force: (i) a pulse that initiates the contraction and is related to the rate of force changes, (ii) a stimulus, in proportion to the required target force.

3.ii Sensory information and its perception.

In an attempt to interpret the results of the experiments some general principles of sensory processing in the CNS need to be considered.

"Man's ability to discriminate sensations depend on the ability to perceive the presence or absence of a given stimulus, under certain conditions and to detect changes in that stimulus, if one or more of its dimensions are altered" (Corso, 1970).

This quotation relates to perceptual abilities in terms of the threshold and the differential threshold, respectively. Consider how humans make sensory decisions. The sensory mechanisms involved in weight discrimination are sensory receptors, pathways and areas of the brain where this information has been sent. The basal ganglia have an important role in the conscious perception of sensation with their role being impaired in PD (Gordon et al, 1997).

What does the brain and its consciousness make of this sensory information? One way of studying this perception is by psychophysical measurement. The study of perception and sensation led to the investigation of mental processing as a scientific study. The early devotees of this philosophy, from both sides of the channel, advocated that all knowledge came through sensory experience. The origins of experimental psychology were founded by academics, for example Weber, Fechner and Helmholz.

The reception of a stimulus may differ but there was always: a physical stimulus, transmission of the events of the stimulus in producing a nerve impulse and, lastly a response to this message (Savage, 1970; Weber, 1834 cited by Ross et al, 1978). Two models of analysis followed, and are known today as psychophysics and sensory physiology (Kandel et al, 1991).

Sensation.

Sensation is received from many sources, from the environment and from the individual's own internal environment. There is a range of conscious perception of sensations from some sources and less from others (Corso, 1970; Savage, 1970). In the three experiments in this chapter, the role of the integration of kinaesthetically generated information and cutaneous sensation is highlighted, as is weight discriminatory ability.

The studies relating to the investigation of sensation were begun in the last century by Weber and then modified later by Fechner and Helmholtz, who laid the baseline for sensory psychophysics (Appendix II). The major link with Fechner's mathematical reasoning involved the concept of threshold or Limen; the minimal amount of energy or change of energy that could be detected by an individual.

The early psychophysicists' work indentified that there were four aspects/attributes of a stimulus leading to a sensation, those being: i) modality (quality), ii) intensity, iii) duration and iv) location (Savage, 1970).

i) A modality describes a sensation which is generated from a form of energy; there are five different modalities of sensation, each having sub-modalities. There have been many investigations into various modalities over the last two centuries, the focus in this chapter is on force matching and weight discrimination.

ii) A sensory threshold is the lowest stimulus that a person can perceive and can be derived from a mathematical calculation. When a person is offered a range of stimuli of a progressively greater intensity, the results of the person's recognition of receiving the stimuli can be plotted as the percentage of times the detection is noted. The relation is termed the psychometric function. Two stimuli of different intensities, such as a one kilogram (kg) weight and a two k weight, can be identified. However, a subject may not be able to distinguish between a kilogram in weight if the range of weights was 51 kg and 50 kg. The difference of 1 kg in both cases was the same, but the estimates were across different ranges.

iii) The duration of the sensation is defined as the relationship between the application of a stimulus and the length of the time of the perceived intensity.

iv) Perception of a stimulus at a specific anatomical point is possible by the intact human CNS, there is also the ability to perceive two stimuli which are adjacent to each other. The latter feature was described by Weber as the two-point threshold of discrimination. The motor system needs an accurate internal representation of the weight of an object in order to scale the forces necessary for its manipulation. Mass or weight judgement is therefore important for the action-perception coupling of the neural and musculoskeletal systems.

Muscle activity and a sense of force.

Weber's (1843) earlier studies (cited by Ross and Murray, 1978) demonstrated the ability to discriminate weight was better when the weights were actively lifted, rather than when they were passively supported by the hand. The findings advocate the sense of force perception being more accurate during active muscle contraction, a voluntary muscular exertion being contributory to the perception process (Bell, 1834, cited by Flanagan, 1996). Reports by Kilbreath and Gandevia (1991) suggest that perception of forces involved in the lifting of weights, may be contributed to by the muscles not directly involved; these authors also contributed the findings that if more than one digit simultaneously took part in a similar lifting task, then the perception of the lifted weights increased.

Kinaesthetic information (sensory information generated during movement).

During actively (and passively) generated movements, sensory receptors will fire in response to that movement. This information is transmitted to the central nervous system (CNS) which leads to the processing and interpretation of the signals. The interpretation is perceived as the joint(s) having been moved (Burgess and Wei, 1982) and that the muscles have generated forces. Sensation is generated during movement which facilitates the on line comparator (feedback) function, for slow movements to be regulated and refined (Figure 6). Accurate positional sense was suggested by Sherrington, at the turn of the century, to be a result of multiple sensory afferents from articular, cutaneous (Weisendanger and Miles, 1982) and contractile tissue receptors (Day, Marsden, Obeso, Rothwell and Traub,1981; Marks, 1997). Stein (1974) describes sensation as the physical process of information transmission, and perception as a person's private experience of that sensation. Receptors responsible for generating the information belong to several groups called the kinaesthetic receptors, which are i) the muscle spindles, ii) the Golgi tendon organs, iii) the joint receptors and iv) the cutaneous receptors.

There is controversy over which receptors contribute the most to the sense of kinaesthesia although there is agreement that the spindle probably delivers its impulses to the cortex for perception at a conscious level. If vibration, which is known to be a powerful activator of the spindle is applied to muscles it is interpreted as false position and /or rate of movement by the brain (Cody, Lovgreen and Schady, 1990; Cody, Lovgreen, Richardson and Schady,1990). Thalamic relays for proprioception and cortical receiving and association areas are important elements in the neural circuitry.

The somatic sensory cortex and its functions related to movement.

The somatic sensory cortical region is the site where proprioception is perceived, and the sensing of force production and movements occurs. Even at very slow velocities of joint action, the brain can detect movements (Taylor and McCloskey, 1990). The signals in primates (Mountcastle, Lynch and Georgiopoulus, 1975) from the muscle spindles relay to area 3a (Brodmann's numbering). If lesions occur in the primary somatic sensory area (SSA1), the following deficits are present: loss of discrete localisation of stimulation; inability to discern precision in pressures applied to the body; inability to judge the weight of objects, and inability to judge the shapes, forms and textures of objects (astereognosis). Brodmann's areas 5 and 7b lie posterior to the SSA1, and have the function of deciphering sensory information.

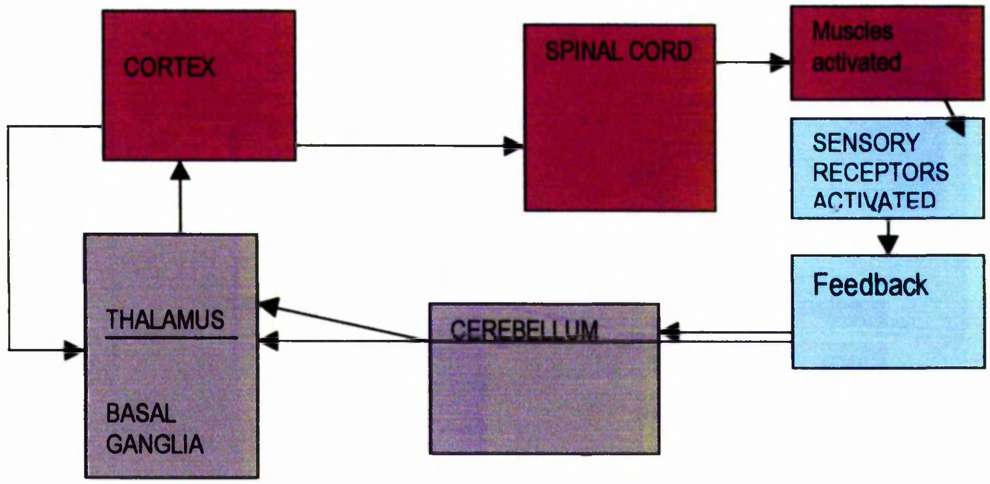


Figure 6a

The production of pre-programmed slow (pursuit) movements has the closed loop comparator action, which is reliant on sensations generated during movement.

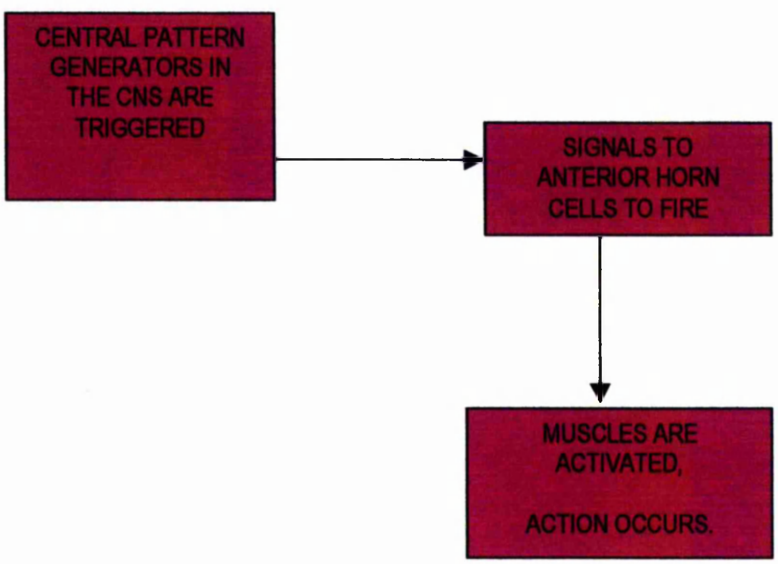


Figure 6b. The open loop (ballistic) movements are not dependent on sensory feedback.

Area 5 of the cortex receives cortico-cortical inputs from, SSA1, whereas area 7b receives from the somatic sensory association area (SSA11). The functions of these areas may be that they contain high order command neurones in the command processes leading to movement, or that they may receive corollary discharges from the pre-central areas (Halsband and Freund, 1990). Heaviness sensation depends more on the perceptual role of corollary discharges (central neural copies of motor command signals) than on other forms of proprioception (Matthews, 1992).

Judgements of motor responses.

In the adaptation of forces that is required whilst manipulating an object, a vital input is received from the cutaneous receptors. The interpretation of the surface of the object to be held supplies the CNS with an added dimension in force control (Martin and Jessel, 1991).

The tactile system dependent on pressure for its activation is an important component in the three experiments that follow in this chapter. The classical work on stimulus thresholds for pressure was performed by von Frey (Woodworth, 1938). Some examples of the values for absolute pressure thresholds for regions of the skin are as follows: finger tips = 3, anterior surface of the forearm = 8, posterior surface of the forearm = 33 and the sole of the foot = 250 g/sq. mm (Woodworth, 1938). In the experiments described in the thesis the skin over the palms and the anterior forearms formed the recipient surfaces for pressure to be applied.

How may this sense of force production be interpreted?

Gordon, Ingvarsson and Forssberg (1997) proposed that scaling of manipulative forces mainly involves the cortex and cerebellum and is particularly concerned with input from the basal ganglia (Gordon et al, 1997). These authors suggested that the basal ganglia could be more involved with axial musculature. During lifting tasks as used in experiments 2 and 3, both distal and proximal muscle groups are involved. Efference copies (corollary discharges) are associated with all motor actions in the nervous system (Granit, 1972; Jenmalm and Johansson, 1997). Copies of the instructions sent to the cord are correlated to the commands. This is the feature of internal feedback and is filed as an efference copy. In addition the corollary discharges, copies of messages sent to the spinal alpha and gamma motor neurones in the anterior horn of the cord (Moore, 1987; Kandel et al, 1991), are used by the CNS in interpretation of the afferent impulses.

The information of forces produced is decoded from three different sources of afferent information. These are: (i) the peripheral sensing of skin deformation and joint angles (Boyd and Roberts, 1953; Moberg, 1983; Zia and Cody, 1995), (ii) the peripheral sensing of muscle forces by the GTOs (Proske, 1981), (iii) muscle lengthening by the muscle spindles (Prochazka, 1996).

Gandevia and Rothwell (1987) showed that there was a marked improvement in a person's sense of position when an active movement has been produced by muscle contraction, rather than when being passively performed by the clinician. These results suggest that positional sense depends upon feedback and efference (corollary discharges) copies of action. Stein (1995) explains this as " you know where your arm is because your sensory systems are informed where you intended to put it and you know it got there because the proprioceptors and others tell you of this."

A related sensation is the "sense of effort", which is believed to be important in weight discrimination tasks (Sanes and Shadmehr, 1995). Estimation of the sense of effort and the judgement of an object's weight depends on matching the motor signals going to the active muscles with the proprioceptive discharges coming back from the limbs about the tension in the muscles and the generated movements (Stein, 1995). The feedback is usually employed to correct or adjust learned programmes for slow movements. This facility is provided by the feedback system (figure 6, modified from McGear and McGear, 1980, cited by Kandel et al, 1991). Motor learning and skill acquisition rely in part on the proprioceptive and cutaneous feedback received during the movement.

Perception of a sense of effort may be affected by fatigue, as after carrying a load for a prolonged time the weight feels heavier than at the initial lifting of it. This is because muscles have to contract more powerfully as the muscle fatigues to achieve the same force (Pederson et al, 1991). It is known that a loss of ability to accurately estimate weights follows fatiguing contractions (Sharpe and Miles, 1992).

Kinaesthetic information.

There are two kinds of movement in terms of speed, namely slow or pursuit, and fast or ballistic movements (Figures 6a and b). The slow movements rely heavily on feedback input of the ongoing movement for correction (Cody et al, 1990a). The movements used in the following experiments are of the slow type and reliant on feedback (Figure 6a). By contrast ballistic movements are entirely dependent on pre-existing motor programmes, i.e. are pre-programmed (Figure 6b). The motor programme is a set of instructions which are organised prior to muscle action. One set of these relays to the cord, and another to the comparator in the CNS. The latter are known as efference (corollary discharges) copies, and are associated with all motor actions in the nervous systems (Granit, 1972; Jenmalm and Johansson, 1997).

Copies of the instructions sent to the cord are correlated to the commands and filed as an efference copy. These can be triggered with the correct timing sequence for the action to be carried out.

There is direct sensory input to the immediately adjacent areas of the primary motor cortex (Morecraft and Van Hoesen, 1996). The indirect way for other sensory inputs to reach the motor cortex is via the thalamic afferents. Information from the dorsal columns travels via the thalamus to the sensory cortex; cortico-cortical connections from the sensory association cortex synapse with the pre-frontal motor areas, and information also travels from the spino-cerebellar pathways to the thalamus. The VPLo nucleus also relays information to the motor cortex.

3.iii The basal ganglia.

An abnormality in the sense of weight discrimination and motor problems may be linked. Anecdotal evidence in PD shows patients have different problems in manipulatory tasks and abnormalities in the accuracy of force production, which may be related to an inability to judge force production accurately. It is known that kinaesthetic disturbances in PD and somesthetic function include deficits in proprioceptive processing (Schneider, Diamond and Markham, 1987). Patients were found to show abnormalities in the judgement of movements and in maintaining steady position holding tasks. This difficulty could be due to abnormal force estimation and the abnormality of controlling both upper limbs in bilateral tasks has been established; it is one of the justifications for testing the participants in the following experiments.

The contribution made by any one part of the CNS to the overall function of the CNS is probably most apparent when it becomes deficient. The normal functions of the basal ganglia are inherently most involved in the cortical regulation, sensory interpretation and motor control of movements. Studying their proposed normal involvement facilitates an explanation of their dysfunction in patients with Parkinson's disease.

Basal ganglia function per se is not as yet fully understood, but information about its functions and its possible role in sensori-motor control can be identified from two major sources. The first is from experimentation on animal models and cellular studies; the second being from conditions that present with basal ganglia dysfunction. With this in mind, the normal functioning of this CNS group of nuclei will be addressed first, and latterly the damaged or diseased basal ganglia with its resultant movement disorders will be considered.

The hypothesised functions of the basal ganglia.

In homo sapiens, the basal ganglia prove a difficult point for direct access due to their anatomical location, deep in the bases of the cerebral hemispheres. It is impossible to isolate the activity of this region without considering the interplay it has with the other structures, and therefore trying to identify the functions of the basal ganglia, in isolation, is not an easy task. Many scientists have studied individual cells and animal models in attempts to identify the role of the basal ganglia.

The anatomical pathways and afferent inputs to this region have been established, but the fuller picture is yet to emerge (Figure 7). Rothwell (1996) put forward the four hypotheses for basal ganglia function from the literature:

1. The basal ganglia work by dis-inhibiting areas of the motor system and thus allow movement to occur. The main features of this idea are that the continuous high discharge rate of the neurones of the substantia nigra pars reticulata and the internal globus pallidus provide a tonic braking action on cells of the motor thalamus.

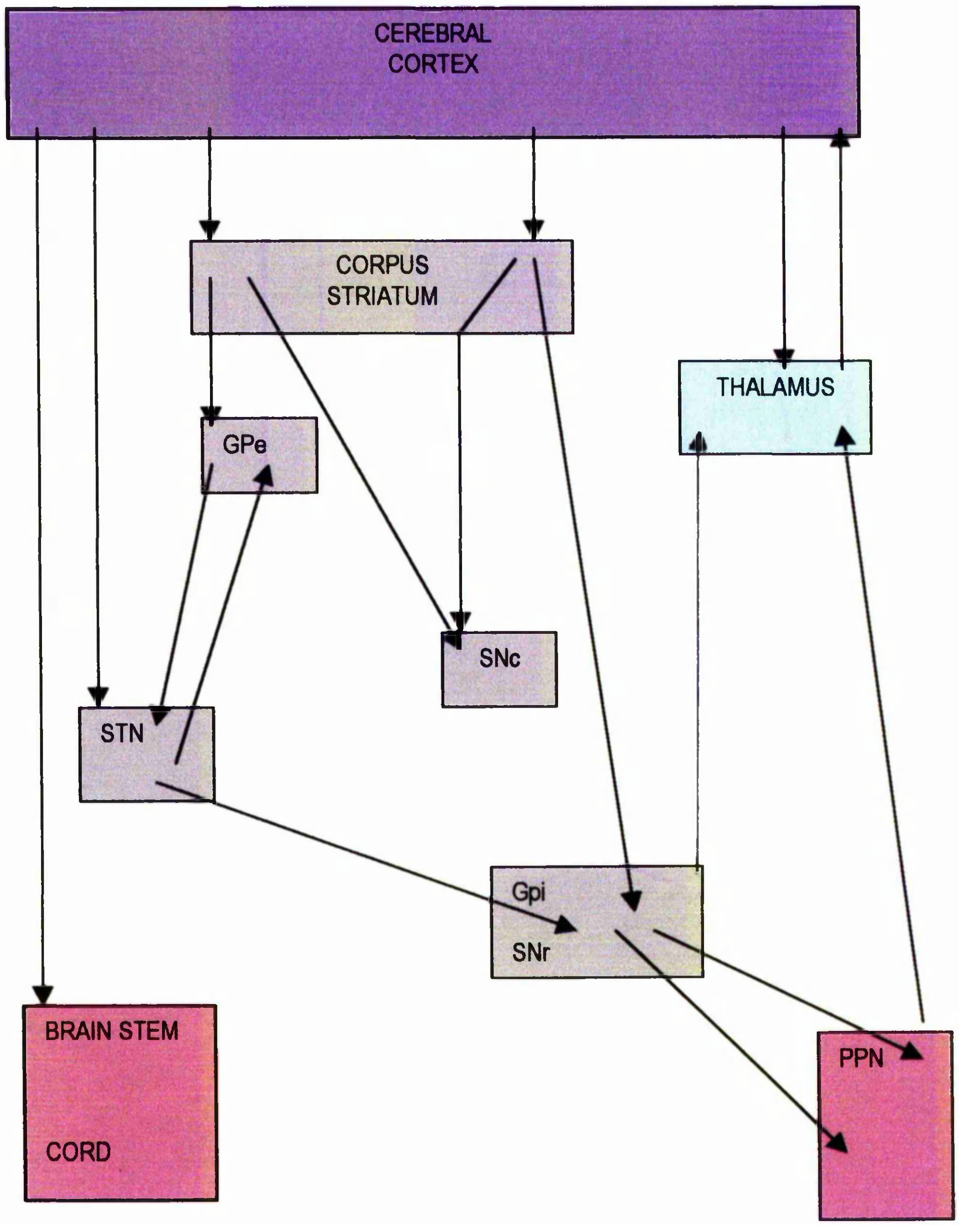
2. This hypothesis proposes increased basal ganglia activity (unlike the first) during movement rather than a decrease, and was postulated by Mink and Thach (1991). Accordingly, the basal ganglia are viewed as turning off unwanted postural activity so that voluntary movement can occur.

3. Alexander, Delong and Crutcher (1992) following on from the 2nd hypothesis, have suggested that the discharge of basal ganglia neurones is related to many different aspects of movement, performing not one but several different aspects of movement at the same time. Their study showed activity of the basal ganglia not only during the execution phase of movement, but also in the reflecting of preparatory activity prior to movement. The theory that the brain does not work in a serial way appears to be supported by this argument. Whilst not only performing one function after another, but also, simultaneously like a major anatomical loop; suggesting that other systems have miniature versions of similar firing patterns with their neurones linking the CNS circuitry together.

4. The fourth hypothesis alludes to the view that the basal ganglia are involved in the execution of sequences of movement. Information which has been collated from clinical observation of patients, and conditions such as PD lead into to this theory. These patients display worse performances of a complex activity than they do of the components that combine to form the movement.

There are four major loops, the focus here is on the motor loop (Figure 8).

Figure 7. **Schematic diagram of the main circuits of the Basal Ganglia.**

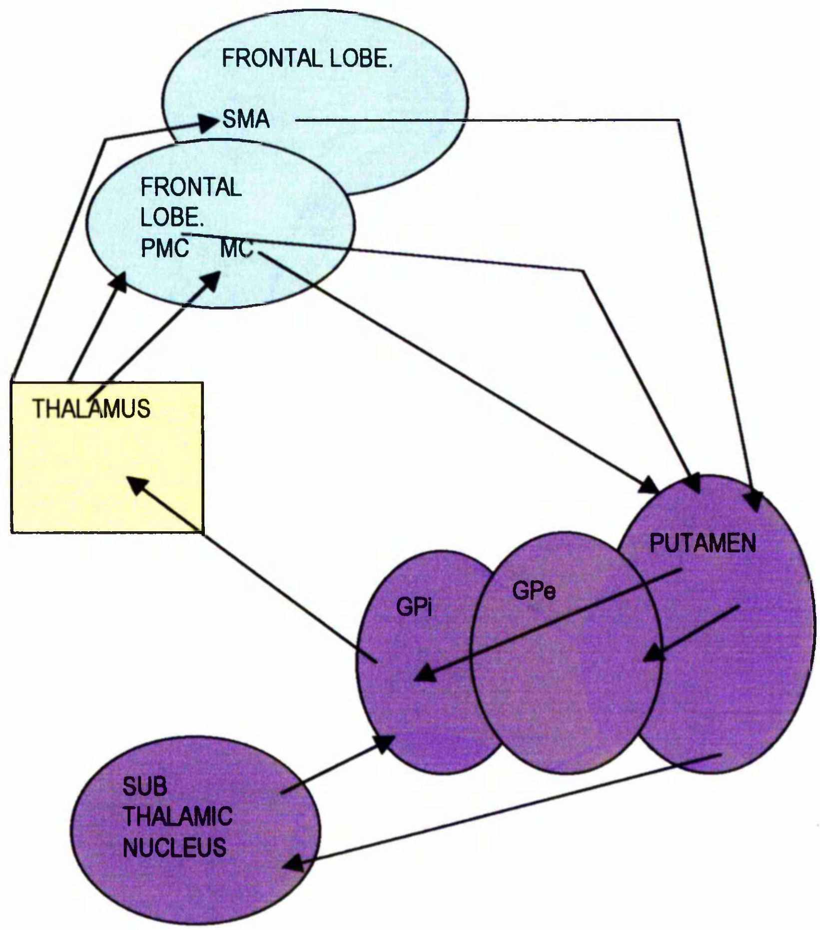


Key .

Gpe	globus pallidus externus
Gpi	globus pallidus internus
SNc	substantia nigra pars compacta
STN	subthalamic nucleus
PPN	pedunculopontine nuclei

Modified from Alexander and Crutcher, 1990.

Figure 8. A schematic diagram of the motor loop of the basal ganglia.



Key: SMA supplemenary motor area
PMC premotor cortex
MC motor cortex
GPi globus pallidus internus
GPe globus pallidus externus

All arrows represent direct connections.

Modified from Alexander and Crutcher, 1990.

The activity from the loops is channelled to the specific nuclei of the thalamus. The afferent inputs to the basal ganglia are from the cortex. The striatum is the receptive area of the basal ganglia, receiving afferents from the pre-motor cortex to the ipsilateral putamen, and from the prefrontal cortex bilaterally to the caudate. Functional segregation in the striatum is generally considered to be present as the neurones in the putamen respond to movement, and those in the caudate are involved with more cognitive processing. The overall function of the motor loop is disinhibition of specific thalamic nuclei and excitation of the specific cortical regions, thereby facilitating cortically initiated movements (Alexander and Crutcher, 1990).

There may be several roles for the motor loop (Fredericks and Saladin, 1996):

1. controlling slow changes in neural activity modulating the tonic activity of the cortex.
2. a fast regulating role to control the timing and sequencing of movement (Sheridan, Flowers and Huller, 1987).
3. providing a trigger for outflow of preparatory activity for the supplementary motor cortex (SMA) (Rogers and Chan,1988).
4. possibly providing a cue to trigger the end of a movement and pre-cue the next in the sequence.

There may be some regulation in the amount of activity occurring simultaneously across the motor circuits. When a person is learning a new movement task, the blood flow to the putamen and globus pallidus has been found to rise significantly, this suggests that these two regions may become active in the automatisation of movement (Phillips and Stelmach, 1996). The basal ganglia control of motor patterns involves many muscle groups at one time, not just single muscles. 55% of the cells in the SMA are active prior to activity being recorded in the motor cortex (Phillips and Stelmach, 1996).

If there is a comparator function of the basal ganglia (Meara, 1994) between proprioceptive feedback and the efference motor plan, it may explain why the high gain of movement-related, sensory information may act as a trigger to turn off an action at an appropriate time.

The GPi seems be involved with a broad influence on motor control in aspects of higher-order planning of movements, through the SMA and the vental premotor cortex, and more specific movement parameters through the motor cortex (Fredericks and Saladin, 1996). It is possible that the direct pathway from the GPi and SNr may activate a motor pattern and the indirect pathway might suppress a conflicting pathway.

It has been suggested that the basal ganglia have a role in the control of the more central (axial) musculature through the brain stem; the basal ganglia input to the cortex facilitates the control of more distal manipulative movements (Fredericks and Saladin, 1996).

3:iv PD and its sensori-motor disorders.

Parkinson's disease is the result of impairment of the basal ganglia, and presents in particular as disruption of the motor circuit (Benecke, Rothwell, Dick, Day and Marsden, 1986 and 1987; Chevalier and Deniau, 1990; Carey and Burghardt, 1993; Beckley, Panzer, Remler, Ilog and Bloem, 1995; Ingvarsson et al, 1997). In PD the features of akinesia and bradykinesia may present (Marsden, 1994). There may also be disturbances of voluntary movements of a secondary nature, those being excessive movements of the drug-related dyskinesias. The other two classical features of the disease, tremor and rigidity are not easily explained. Traditionally PD has been considered as a primary motor disorder. However there is increased recognition of sensory difficulties which may contribute to the movement disorders.

Akinesia is understood to feature as a problem in the preparatory phase of movement. Reaction times (response latency) studies confirm this. Abnormalities of the Bereitschaftpotential (Dick, Rothwell, Day, Cantello, Buruma and Gioux, 1989), the electrical activity occurring before movement, indicate that the SMA may have preparatory activity deficits. Blood flow studies show the reduction in cerebral blood flow to the SMA in PD patients, which can be reversed with appropriate medication. This would explain the delay in preparatory parts of motor control in this population (Caligiuri, Heindel and Lohr, 1992; Giladi, McMahon, Przdborski, Flaster, Guillory, Kostic and Fahn, 1992; Georgiou, Iansek, Bradshaw, Philllips, Mattingley and Bradford, 1993; Kunesch, Schnitzler, Tyercha, Knecht and Stelmach, 1995; McIntosh and O'Boyle, 1995; Gordon et al, 1997).

Akinesia may be due to insufficient dopamine delaying the preparatory processes (Blin, Ferrandez, Pailhous and Serratrice,1991), rigidity, attentional disturbances and depressive moods in the later stages of the disease process (Taylor et al, 1987; Chevalier and Deniau, 1990).

Bradykinesia.

Those patients with bradykinesia often present with slow and hesitant movements, showing increased reliance on visual feedback (Gordon et al, 1997). Hallett and Khoshbin (1980) describe the PD patients who may have difficulty energising the muscles, in terms of activation and co-ordination. The findings of many studies show that patients cannot produce movement forces as quickly, smoothly, or as accurately as normal controls (Jones,Phillips, Bradshaw, Iansek, Bradshaw, 1992; Phillips et al, 1994; Kunesch et al, 1995). The every-day problems this causes are, for example, an inability to produce the correct force for precision grips, and the undershooting of directed movements. The situation is confounded when more complex movements are attempted (Stelmach and Worringham, 1988; Stelmach and Philips, 1991).

Hallett and Khoshbin (1980) considered bradykinesia to be the result of insufficient muscle energy, so the first burst of activity on the EMG was not sufficiently large to produce rapid movement and, therefore, additional bursts of activity were needed. This was refuted by Berardelli et al (1986), who reported that patients produced similar sized EMG bursts to normals, but more slowly.

Marsden (1994) offered the explanation that it was due to failure of the motor planning which led to the force decrement and the resultant weakness, with rigidity in the antagonistic muscles. Peripheral factors such as the mechanical (visco-elastic) properties of muscle may have an additional impact, as would fatigue and musculoskeletal abnormality, during failure in visuo-motor tracking activities (Warabi, Noda, Yanagiaswa, Tashiro and Shindo,1986; Marsden, 1994). The study sample for their experiments was non-uniform, in that patients were presenting with differing severities of the disease: from grades I to IV on the Hoehn and Yahr rating scale. Generalising about the results must take the non-uniformity into account

Tremor is also a problem for many of the PD patients. About 70% of PD patients exhibit tremor. Tremor can be seen after movements and at rest. In PD the tremor varies from a resting tremor (pill rolling, 4-6Hz) to a higher frequency on action (6-8 Hz). It may be that this tremor is not purely due to a basal ganglia lesion. Factors such as stress make the tremor worse, and the patient apparently loses the tremor in sleep, or with purposeful activity.

Surgical lesioning of the thalamus has been demonstrated to reduce tremor in some experimental cases (Obeso and Guridi, 1997), in both PD and cerebellar disorders. Stereotactic surgery to the nucleus ventralis intermedius (VI) is known to relieve tremor. However, there is no apparent connection with the basal ganglia, from blood flow studies, as suppression of the resting tremor by stimulation of the thalamic nucleus (VI) leads to reduction in cerebellar activity. On this basis, a proposal is put forward that tremor is driven from the increased activity of the cerebellum not the cortex (Lammare and Joffrey, 1979). There is some debate as to where in the CNS tremor is driven. Lesions of the nigrostriatal dopaminergic pathway together with the cerebellar rubro-thalamic circuits may lead to this phenomenon.

Thalamic dysfunction is known to contribute to the presence of tremor. In PD the thalamus fails to receive normal stimulation from the diseased basal ganglia and possible impairments of motor and cognitive functions can arise from this disturbance of the gate control mechanism of the thalamus (Marsden, 1994). Tremor characteristics are different in isotonic and isometric contractions in Parkinson's disease; tremor is thought to be an underlying clinical feature even though it may not always be visible on assessment (Logigian et al, 1990). Rigidity is an increase in co-activation, or lack of inhibition of the resistance to stretch when a limb is moved passively. Unlike spasticity rigidity is distributed between both the flexors and extensors (Rothwell, 1995). Rigidity may be reflexive in origin, with some uncertainty in its actual mechanism, which has been shown to be abolished when the dorsal root is inactivated by anaesthesia (Neilson, Kagamihara, Crone and Hutborn, 1992).

There is no evidence for enhanced excitability of the mono-synaptic reflex, as it has been shown that the clinical testing of tendon reflexes yields no increase in response compared to normal subjects (Rothwell, 1996). This tends to suggest perhaps, that a supra-spinal mechanism, such as the long latency stretch reflexes, may offer an explanation. It is possible that the direct pathway from the GPi and SNr may activate a motor pattern and the indirect pathway might suppress a conflicting pathway. This speculatively may be the difficulty for PD patients, in whom rigidity is a problem as the antagonistic muscles are not inhibited and co-contraction exists. Rothwell (1996) suggests that when a limb is manipulated by a clinician several pathways contribute to the overall reflex response of the muscles.

Sensory problems associated with PD.

Old principles of sensory testing from Weber and Fechner's times are still inherent in some aspects of current experiments. The theory behind their work is continued in experiments 2 and 3. Gordon et al (1997) proposed that scaling of manipulative forces mainly involves the cortex and cerebellum and is particularly concerned with input from the basal ganglia (Gordon et al, 1997). These authors suggested that the basal ganglia could be more involved with axial musculature. During lifting tasks as used in experiments 2 and 3, both distal and proximal muscle groups are involved.

The following issues related to the author's experiments and to previous weight discrimination experiments will be now be considered. The study by Oberlin (1936) cited by Corso (1970) investigated a range of weights to be lifted from 25-600 g, and different joints were chosen as the prime movers. The results showed an uncertainty in the threshold between 3g at the lower end of the weight range to 45g at the upper end of the scale. The greatest sensitivity to the weights was shown when the joint moving during the task was the more proximal (gleno-humeral) joint and the least by the more distal (wrist) joint. The elbow was selected as the joint to be tested in experiments 2 and 3.

Age and sensitivity to responses in weight matching was investigated, alongside the sex of the individual, in weight discrimination activities by Danziger and Botwinick (1980). There were two groups of older (61-82) and younger (16-31) subjects who were asked to lift two weights successively, and were asked to decide if the two weights were the same or different; their responses indicated that the younger males were better at the task than the older males, although it may have been due to differences in the older males' ability to be more critical in their selection than were the younger males. A general performance by the males compared to the females showed the males to be better. In Ross and Roche's (1987) study a difference was noted in the superior performance of the males to the females, although no indication of age groups were mentioned.

A study by Watson, Turpentoff, Kelly and Botwinick (1979) indicated no real differences was demonstrated between the younger and older subjects tested, other than a general caution by the elderly in making sensory decisions. The sex of individuals has been considered in experiments on weight discrimination as already mentioned by Danziger and Botwinick (1980), and Ross and Roche (1987).

Upper limb dominance was considered by Ross and Roche (1987) and Brodie (1989a,b). The results of Ross and Roche's study (1987) showed no preference for handedness in the female group, but the male subjects demonstrated superiority with their dominant hand. In Brodie's experiments (1989a) the non-language hemisphere gave increased performance in weight discrimination tasks of the hand it controlled. The experiment by Nishizawa (1991) studying female students found no laterality preference during performance in weight discrimination tasks, although he considered that directed attention played an important role in the decision making process.

The influence of altered gravitational fields was studied via a space lab mission by Ross et al (1986), and also by Ross and Roche (1987). The study in 1986 revealed that mass discrimination was impaired under zero gravity conditions compared to 1G. The later experiment (1987) tested participants before and after flight schedules. The pre-flight thresholds were found to be higher than the immediate post- flight levels. There are major differences in the interpretation of these results than there are in any tests at normal gravitational levels.

EXPERIMENT 1 : Force matching

This experiment investigated the ability of patients, with Parkinson's disease, to match the forces generated in one limb compared to the other limb.

3:i INTRODUCTION

Patients with PD have complained of and been observed to fatigue rapidly in functional activities. This may be associated with an increased sense of effort when trying to perform a task. If so, patients with asymmetry of bradykinesia, rigidity and/or tremor in the upper limbs might experience a greater sense of effort with the more severely affected limb during weight matching and weight discrimination activities.

The aim of this experiment was to test whether PD patients with asymmetry in the upper limbs demonstrated a) an increased sense of effort in bilateral force matching experiments in the more affected limb and b) a poor matching accuracy than non-neurologically affected controls. If patients with asymmetrical bradykinesia demonstrate an increased sense of effort, is this due to failure of the proprioceptive control of the afferent feedback or distortion of the corollary discharge mechanism?

The research questions to be addressed in the experiment were:

1. Did the accuracy of bilateral force matching vary with the reference value?
2. How accurately could the participants match the test value to the contra-lateral reference value?
3. Is there any evidence that PD patients were worse than the controls in terms of accuracy?

Hypothesis:

1. Asymmetrical patients have an increased perception of sense of effort while performing an identical task with the clinically worse upper limb compared to the other side
2. Patients' performance is more inaccurate than that of the controls.

3:ii METHODS

The sample. Four patients with idiopathic PD and six controls were studied. All subjects gave written informed consent prior to the testing, and local ethical approval was granted. The PD group had a mean age of 64 years, there being 3 males and 1 female. The Hoehn and Yahr (1965), scores were within grades II and III, with Webster rating scores (WRS) (Webster, 1968) showing slowness confined to one side and slight resting tremor and no rigidity at rest. The bradykinesia laterality scores (Wade, 1994) were also assessed and displayed as a percentage slowness of the less affected limb. The cognitive status was established to be within normal levels with a Mini Mental Status Examination (MMSE) (Folstein, Folstein and McHugh, 1975). These details are displayed in Table 25.

Table 25. Personal and clinical details of the sample group.

	age	*gender*	*Bradykinesia Laterality Score*	*Hoehn & Yahr*	*Webster Scores worse affected side**	*M.M.S.E*	*years since diag-nosis*
Patient							
CH	**63**	**M**	**R 5% slower**	**II**	**R 4**	**30**	**6**
SA	**67**	**F**	**L 25% slower**	**III**	**L 7**	**28**	**3**
CA	**55**	**M**	**R 10% slower**	**II**	**R 4**	**29**	**3**
WI	**71**	**M**	**L 18% slower**	**II**	**L 3**	**27**	**2**
Control	***age***	***sex***	***Control***	***age***	***sex***		
SE	**41**	**F**	**JL**	**49**	**M**		
HR	**74**	**M**	**JO**	**62**	**M**		
JR	**75**	**F**	**CR**	**36**	**F**		

*The Webster scores relate to bradykinesia, tremor and rigidity, only. All participants were right handed. The patients were all stabilised on their medication and the data were collected when the patients felt the medication to be at its most effective. The mean age of the patients was 64, which was not significantly different from the controls. The controls were 3 males and 3 females with a mean age of 56 years (Table 25).

Validity of the clinical assessment procedures was assured by the researcher having been trained to an appropriate standard before any measurements were undertaken of the clinical tests.

1. The bradykinesia laterality scores (BLS).

This test is used to measure the difference in speed of movement between one upper limb and the other; it ascertains which upper limb is the slower and by what percentage. The total percentage slowness of one upper limb compared to the other is a unique, clinical measure for that individual. There are three parts to the test and finally the scores are subjected to a mathematical calculation to give the percentage result.

Testing Procedure.

The patient was seated opposite the clinician and given instructions for each phase of the test. Two practice movements of each part are allowed. The researcher used a pre-typed sheet for data collection and a stop watch.

Movements tested :

1. Rapid alternating movements

(i) Thumb to finger tip: the patient was told to place the forearms in a mid prone position, resting on the table in front of the patient. The thumb touched the tip of the index finger for the start of the sequence. This was the position for the counting for each new sequence. The patient was told to use the thumb pad to successively touch each of the finger tips in sequence finishing at the little finger, then returning the thumb to the index finger directly for the next sequence. The patient was told to start with both hands simultaneously and to keep the movement going until the researcher says stop. The total number of full sequences for each hand was noted for a 20 second period.

(ii) Alternating palms face up and down: the hands were placed, palms down on the respective thigh for the start of the sequence. The patient was instructed to turn the forearms as fast as possible (alternating pronation and supination movements) so that the palms touch the thigh and then become palms up for the next move. The whole sequence was counted as 1 unit. The patient was told to start the hands moving at exactly the same time and then to keep the action going until told to stop. The total number for each hand was noted during a 20 second period.

(iii) Dot touching: an A3 sized sheet of paper was marked with 2 dots, one at the left hand side of the sheet and the other on the right hand side; the dots were 25 cms apart. The patient was seated at the table (the left hand was laid on the thigh) and the right index finger was positioned at rest, on the right hand dot. The patient was instructed to move the hand so as to touch the other dot with the tip of the same index finger, then returning to the right hand dot as fast as possible. This counted as one sequence. The number of full sequences in a 20 second period was counted. The test was repeated with the left hand.

The calculating of the results was as follows, for each hand.

The score from (iii) the dot touching, was divided by 2. This value was added to the scores of (i) the thumb touching and (ii) the palm alternating. This sequence was repeated for the other side. After both sides have been calculated, the following formula was then used:

a. The score for the better hand was divided by the score for the worse hand.

b. This figure was then placed into an equation where 1 was subtracted from it and then the figure was multiplied by 100%.

c. The resulting figure represents the percentage slowness of the worse hand.

2. The Hoehn and Yahr Scale .

The clinical gradings of Parkinson's disease by this method are well known to all neurologists and identify the stages of the disease (Hoehn and Yahr, 1965); they are used to assess the stages I to V of the disease, by describing the features of the progression. Each grade basically divides the stages from I, being the onset stage to grade V, being the most severe. A brief outline only of each stage is described here in the text.

Grade I is the early phase where unilateral signs and symptoms appear.

Grade II involves bilaterality of signs and symptoms.

Grade III includes the onset of balance problems and abnormality of postural reflexes.

Grade IV is a progression to reduced mobility and the patient may even be in need of a wheelchair.

Grade V is the most handicapped stage and the patient is virtually bed-ridden.

The test is universally recognised, and patients are categorised for the experimental procedures

3. The Webster rating scale (WRS).

This is a clinically used scoring system for identifying a level of functional independence (Webster, 1968). The scoring can be identified at a glance, because the score of zero means no impairment and the higher scores relate to the existence of problems. This scale covers the multiple presentations of the movement disorders, such as tremor, rigidity, bradykinesia, which can be measured for each side; but it is non selective in its entirety, as it gives equal weighting to the autonomic feature of sebhorea as it does to the movement disorders. However, it is quick and fairly standardised in its use and well known clinically. Table 25 shows only the WRS movement scores for bradykinesia, rigidity and tremor.

4. The Mini Mental Status Examination (MMSE).

A test that can distinguish between a patient being cognitively impaired or not, is a pre-requisite to experimental procedures, where the patient has to make decisions and movements on command. In each of the experiments the controls and patients were all tested with this procedure to ascertain "normality" in cognitive terms. The test involves the patient answering a series of questions related to aspects of cognition, attentional issues and memory, together with manipulative tasks from written and verbal instructions. The sections are scored and a maximum of 30 marks can be achieved. The "normal range" is set between 30 and 24 (Folstein et al, 1975). The score of 24 is the cut off for dementia.

Experimental design.

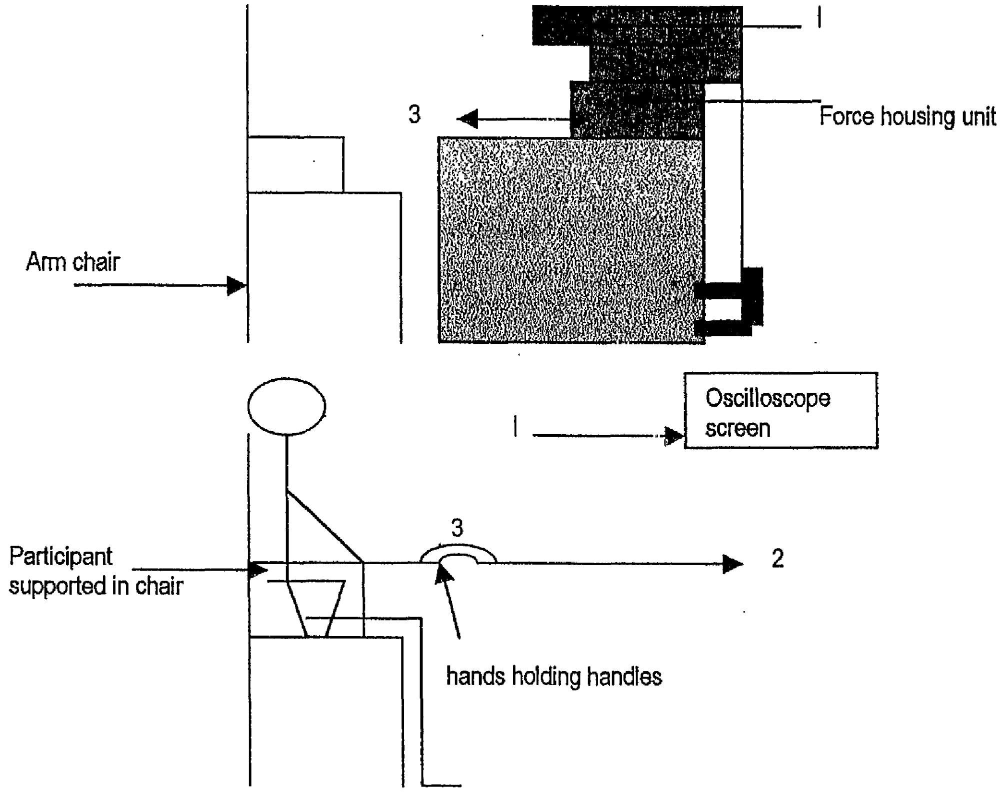
Participants were seated in front of a raised table, with feet fully supported and chair height adapted to the patient's comfort. Participants were tested with a hand held dynamometer to ascertain their maximum force production for grip strength (Chesson et al, 1996). The mean of 3 readings was noted. Two identical wooden framed units were positioned on the table in front of the patient (Figure 9).

Each unit had a channel to support the upper arm, which allowed positioning with the glenohumeral joint in flexion; the elbow was flexed and supported on a foam wedge. The upper arm was secured by two soft leather supports that wrapped around the arm from the housing unit. The wooden frame housed a force transmission facility, attached via a transducer to a handle. The forearm was supinated to allow the hand to hold this handle. The transducer was connected to an oscilloscope screen positioned directly above the framework which could be seen by the participant. Gripping and pulling of the handle caused a deflection of a beam on the patient's oscilloscope. The beam's movement was the product of the generated signal from the force transducer. The transducer was also connected to a second amplifier and oscilloscope which allowed the signals to be displayed on the operator's oscilloscope screen. This second amplifier was out of the visual gaze of the participant.

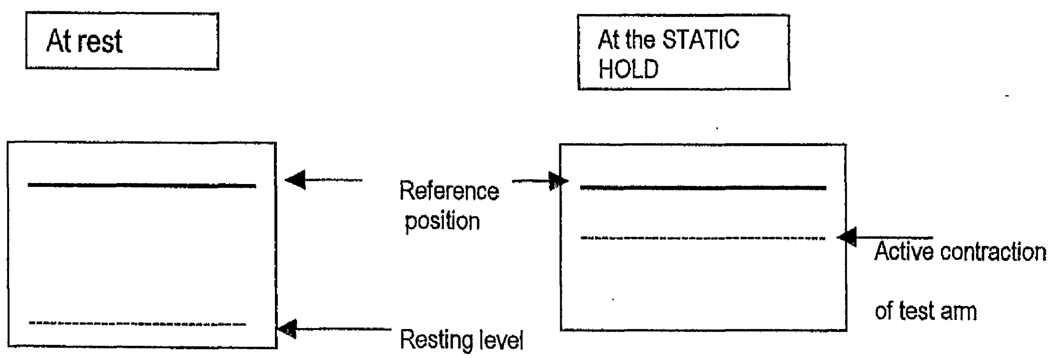
Calibration details.

Prior to each experiment, calibration of the two transducers was performed and details recorded. Sensitivity details of this were noted, as it was needed in the subsequent calculations, as the patients would be working at low percentage ratios of a maximum possible contraction. The values were recorded. From these values the 5 and 10% levels (of the maximum contraction force) of the dominant limb were calculated and these were assigned the reference values. The calculations of the percentage force values were only made from the dominant limb, and these values were applied to both test sides throughout the experiment. Thus the reference values were the same for each side.

Figure 9 The experimental arrangements for the equipment.



The participant's view of the oscilloscope screen before starting the procedure and at the static hold of the task.



Key:
1 participant's oscilloscope screen
2 metal rope attached to the force transducer, in the housing unit
3 handles attached to metal rope.

Experimental procedure.

Acclimatisation to the testing procedure.

Prior to the experiment participants were given a short practice period to learn what was required of them and to measure the maximum voluntary elbow flexion contraction.

Setting the reference force.

1. One arm acts as reference arm; the other arm acts as test arm.

2. The subject actively flexed the elbow of the reference arm against a force transducer under isometric conditions, to a pre-selected level of contraction whilst watching an oscilloscope display of force production. The subject was then requested to maintain a steady contraction.

3. The subject now actively flexed the elbow of the test arm to attempt to achieve the same level of flexion force as that being maintained by the reference arm, in the absence of visual feedback. Thus, the subject tried to match the strength of contractile force of the two arms (i.e. equivalent sense of effort for the two sides).

The procedure was repeated for the 5 and 10% reference force levels, both arms acting as the test arm. Measurements were taken from the operator's and the participant's oscilloscope for all trials. The sequences were repeated in a pseudo-random order, six times for each of the two target values.

The following instructions were given to the participants:

1. to pull as hard as possible with the dominant right hand against the handle and to see the beam on the oscilloscope move, and then they were asked to let go.

2. to then repeat the activity with the non-dominant hand, when no movement of the beam appeared. This sequence was repeated twice. The participant was shown the reference level (the static beam) on the oscilloscope screen whilst the beam associated with the right hand was set at a baseline (Figure 9).

When the participant was ready the next instructions were given:

1. to pull with the right arm and try to superimpose the two beams on the screen in front of you. Then hold that position of the limb (contraction).

2. to pull with the left arm using the same amount of force as the right arm is doing, hold this for a second, and then let go with both grips.

To allow the testing of the opposite side, the lead from the transducers was changed so the patient could now see the reference beam, relating the left hand, on the screen, (the previous beam representing the right was absent). The sequences and the instructions were given as before except, the left hand had to initially try to superimpose the two beams, and then the right arm had to try and match the pull of the left arm.

The data were recorded at each trial and later analysed for each of the six trials at the 5% and 10% levels, for both the right and left reference sequence.

3:iii RESULTS AND STATISTICAL ANALYSIS.

The results are presented in the form of Figures 10 - 14 and Tables 26-29, and analysed in the following text.

Figures 10 and 11 plot the individual mean values of the 5% and 10% of the maximum force generated by the dominant arm by each participant. These values were used as reference values in the testing phase.

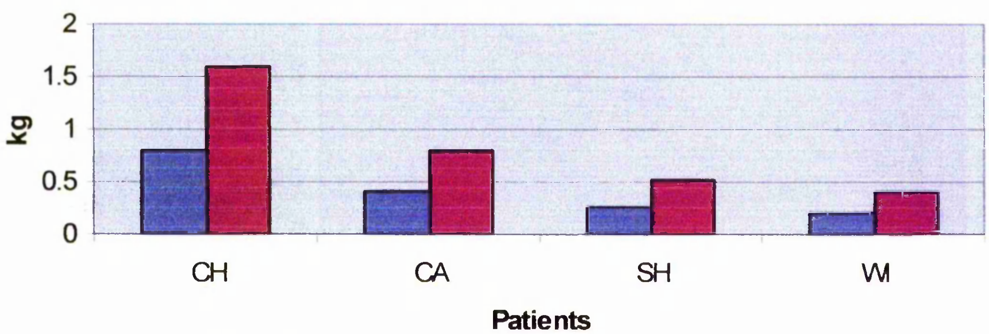


Figure 10. This figure shows the mean values for the patients' 5% (blue) and 10% (pink) of the maximum forces generated by the dominant limb.

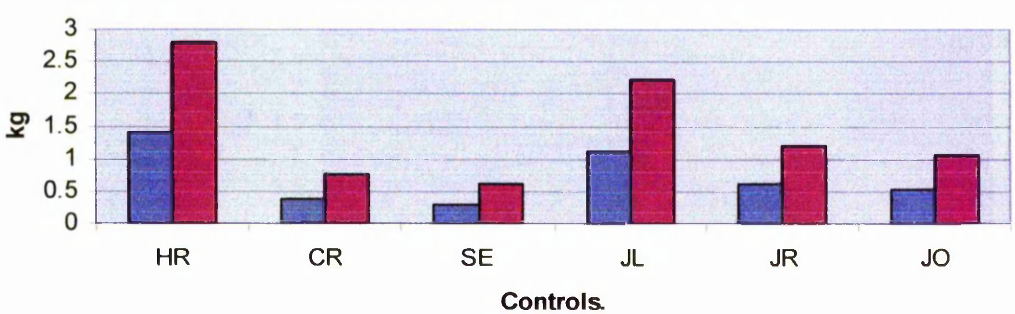


Figure 11. This figure shows the mean values for the 5% (blue) and 10% (pink) of the maximum force of the controls' dominant limb.

Figures 10 and 11 show the PD patients' range of the 5% of the maximum forces generated to be between 0.2 kg and 0.8 kg, and for that of the controls to be between 0.3 kg and 1.4 kg. Tables 26-29, show the mean values of the six trials for each test arm at both reference levels. The mean difference was calculated by subtracting the mean reference value from the mean test value. The error index is expressed as the mean difference divided by the reference value and is displayed in four tables (Tables 26-29).

Table 26. The 5% of maximum force values with the left arm as the test side

PATIENTS	LEFT arm **TEST** side (kg)	RIGHT arm **REFERENCE** side (kg)	***DIFFERENCE*** (T-R=D) (kg)	**ERROR INDEX** (DIFFERENCE DIVIDED BY REF.)
CH	1.40	0.50	*0.90*	1.80
CA	0.48	0.38	*0.10*	0.26
SH	2.66	1.61	*1.05*	0.65
WI	1.66	1.71	*-0.05*	-0.02
CONTROLS				
JR	0.46	0.32	*0.14*	0.44
CR	0.93	0.60	*0.33*	0.55
SE	0.32	0.43	*-0.11*	-0.25
JL	0.93	0.43	*0.50*	1.16
JO	0.48	0.53	*-0.05*	-0.09
HR	3.06	1.33	*1.73*	1.30

Table 27. The 5% maximum force values with the right arm as the test side

PATIENTS	RIGHT arm **TEST** side (kg)	LEFT arm **REFERENCE** side (kg)	***DIFFERENCE*** *(T-R=D)* (kg)	**ERROR INDEX** (DIFFERENCE DIVIDED BY REF.)
CH	1.26	0.60	*0.66*	**1.10**
CA	1.45	0.72	*0.73*	**1.01**
SH	5.12	1.28	*3.84*	**3.00**
WI	1.83	2.76	*-0.93*	**-0.34**
CONTROLS				
JR	0.53	0.36	*0.17*	**0.47**
CR	0.55	0.93	*-0.38*	**-0.40**
SE	-0.25	0.52	-0.77	**-0.50**
JL	1.20	1.41	*-0.21*	**-0.14**
JO	-0.09	0.65	*0.21*	**0.32**
HR	1.30	0.60	*0.80*	**1.33**

The results show that both groups tended to produce greater forces with the test side, irrespective of whether the test side was right or left. Across the groups and for data combined for the two (5%

and 10%) reference levels and trials in which each side served as the test arm, participants produced greater forces on the test arm (p=0.03, paired t-test).

Table 28 The 10% maximum force values with the left arm as the test side.

PATIENTS	LEFT arm TEST side kg	RIGHT arm REFERENCE side kg	*DIFFERENCE (T-R=D) kg*	**ERROR INDEX** (DIFFERENCE DIVIDED BY REF.)
CH	1.38	1.36	*0.02*	**0.75.**
CA	0.88	0.26	*0.62*	**2.38**
SH	2.95	2.08	*0.87*	**0.42**
WI	2.16	3.13	*-0.97*	**0.31**
CONTROLS				
JR	0.42	0.49	*-0.07*	**-0.14**
CR	1.60	1.06	*0.54*	**0.51**
SE	0.91	1.23	*-0.32*	**-0.26**
JL	1.46	1.80	*-0.36*	**-0.20**
JO	1.11	1.38	*-0.27*	**-0.19**
HR	3.20	1.60	*1.60*	**1.00**

Table 29. The 10% maximum force values with the right arm as the test side.

PATIENTS	RIGHT arm TEST side(T)	LEFT arm REFERENCE side (R)	*DIFFERENCE (T-R=D)*	**ERROR INDEX** (difference divided by Ref.)
CH	1.32	1.41	-0.09	-0.06
CA	0.4	0.48	-0.08	-0.17
SH	5.43	1.35	4.08	-3.22
WI	1.96	2.9	-0.94	-0.32
CONTROLS				
JR	0.79	0.72	0.07	0.097
CR	1.86	1.86	0	0
SE	1.00	1.11	-0.11	-0.099
JL	1.46	1.00	0.46	0.46
JO	1.28	1.26	0.02	0.015
HR	1.86	0.93	0.93	1.00

For the PD patients the highest disparity of the group mean test to reference weights (described as a ratio, indicating the scale of the difference between the two sides) was 1.97 for the test arm right at 5% reference force (Figure 12). For the PD patients the lowest test to reference ratio was 1.61 for the test arm left at 10% reference force. For the controls the highest test to reference ratio was 1.52 with the test arm left at 5% reference force.

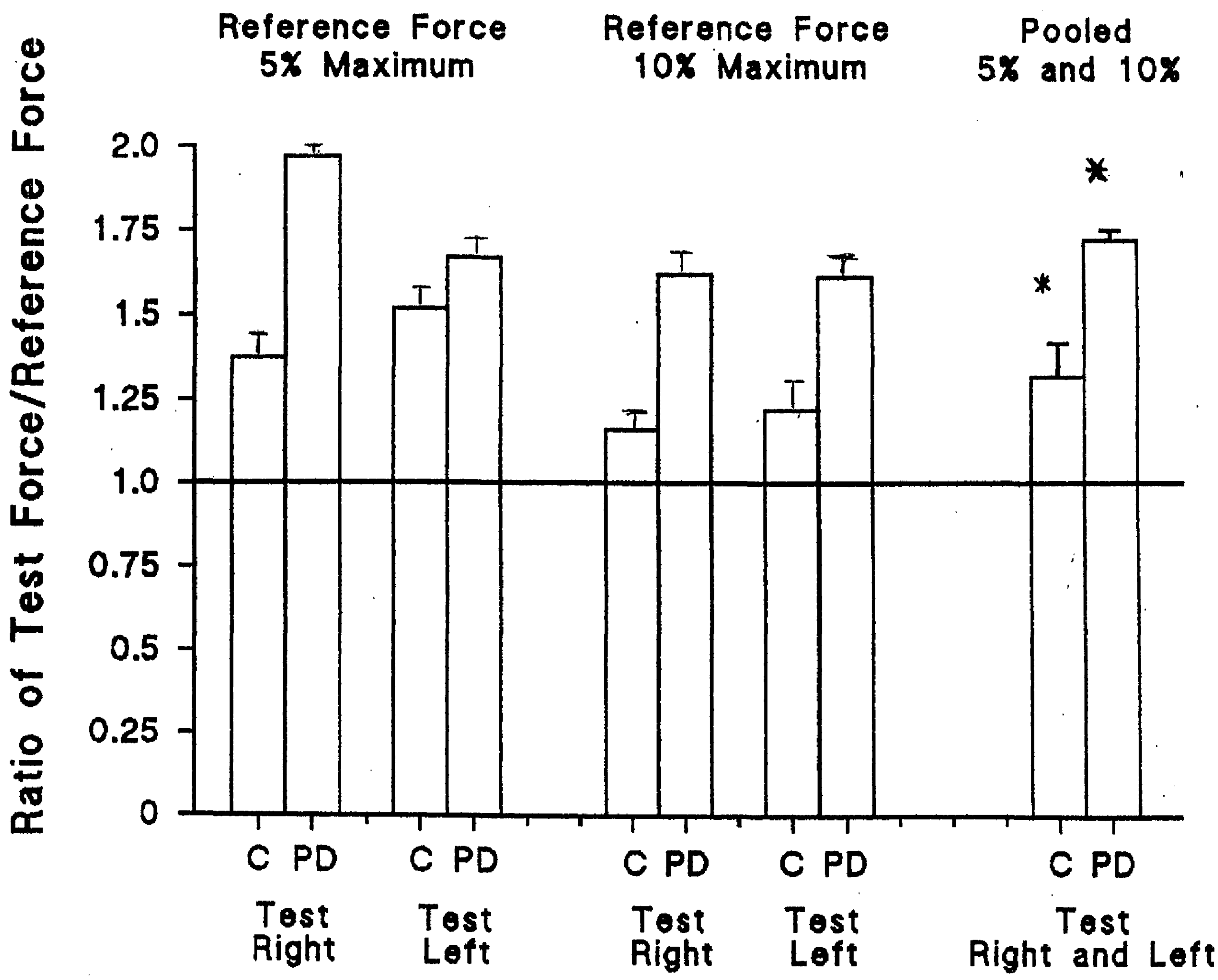


Figure 12. The test force/reference force ratios (group mean, +/- SEM) for the two groups, controls (C) and the patients (PD), at the two reference forces (5% and 10% maximum) and for the right and left arms serving as test sides. * indicates a significant difference between test and reference forces for data pooled across groups, reference levels and sides.

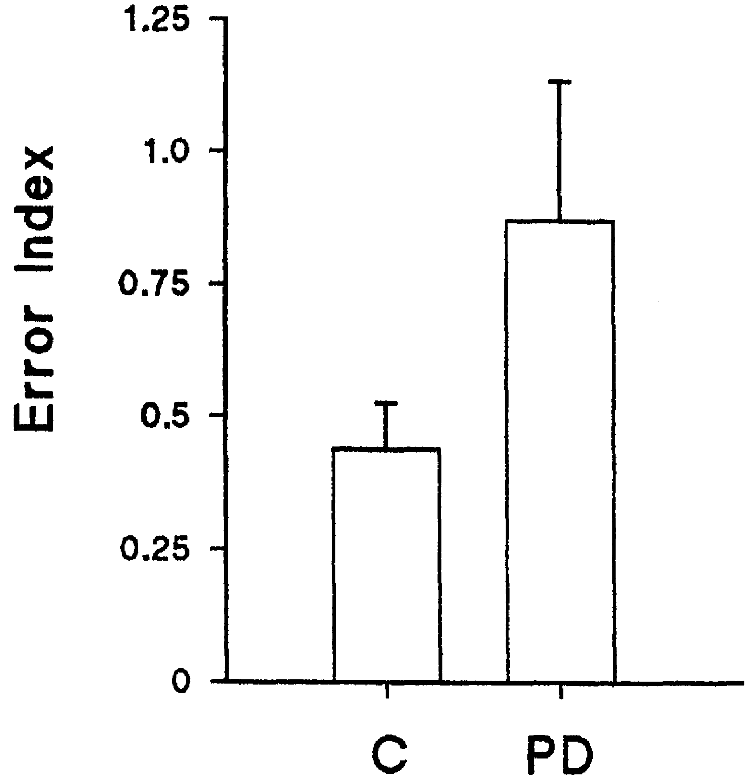


Figure 13. The error index (mean +/- SEM) for the controls (C) and the patients (PD)groups, calculated from data pooled for the two reference forces and for trials in which each side served as test arm.

For the controls the lowest test to reference ratio was 1.16 with test arm right at the 10% reference force. These data could be interpreted as when the 5 and 10% levels were pooled the patients' value was 1.72 and the average was an over-estimation of 70%, whereas for the controls the value was 1.31 providing an average of 30% over-estimation of the task.

Figure 12 represents the mean test force to reference force ratio values for both groups and both test arms and across both 5% and 10% trials. The horizontal line on the graph represents the unitary value of one, so all data points shown are above this line and are consistently greater than unity. Figure 12 is the histogram of group means, the error bars are significant only for the pooled columns.

The Error Index.

The mean error index for the PD group (0.87) was approximately twice that of the controls (0.44). Figure 13 demonstrates the error index for the pooled data of both test arm sides, and both reference levels for the two groups.

Individual patient performances

The patient "SH" showed consistent high errors across the trials with both left and right sides as test limbs, the test arm right had twice the error ratio as the opposite side. The data were consistent with the clinical sores for this patient: the Webster scores were 7 for movement signs and the Hoehn and Yahr scale was grade III. The BLS score indicated the left arm to be slower than the right.

Patient "CA" performed better with the test arm being the right, clinically the Webster score showed the right arm to be the worse. Patient "CH" had slightly lower levels of the error ratio with the right test arm than the left, having clinical scores worse on the right. Patient "WI" demonstrated only slightly higher levels of errors with the left arm as the test arm compared to the right, and had clinical scores of the left side being slower than the right, and worse on the right from the Webster scale.

CONCLUSIONS.

- The bilateral force matching performance of the PD patients resembled that of the controls in that participants in both groups produced greater forces on the test side.
- This suggests both groups of participants generally overestimated the extent of voluntary elbow flexor contraction on the reference side.
- The mean error index of the PD patients although not significantly different, was approximately twice that of the controls (0.44) for data pooled for the 5 and 10 %, and for both test arms.

The discussion section follows experiments 2 and 3.

<u>The development of Experiment 2 (and experiment 3) from experiment 1.</u>

To further test proprioceptive discrimination ability the second and third experiments were designed. The purely isometric laboratory based experiment 1 was somewhat contrived and not indicative of a functional task. The matching of lifted weights was considered a more functional approach, where decisions about matching bilateral forces associated with the lifting of weights could be made. The different types of actions involved would facilitate measures for the sensitivity issues of sensory discrimination in the next two experiments. Classical psychophysical measures were included for the purpose. Relatively pure activation of the Golgi tendon organs in experiment 1 would be assisted by activity from other kinaesthetic receptors in 2 and 3, as these tasks utilise both isotonic and isometric actions. Visual feedback would be denied and the static or isometric phase of elbow flexion following the lifting of a weight was used to test the decision phase of the bilateral matching of weights. This type of activity is reflected in everyday actions.

EXPERIMENT 2: Weight discrimination.

This was an experiment to investigate a) a sense of weight discrimination in a group of Parkinson's disease patients and their controls and also b) the effects of age (across a sixty year age span) on discrimination with a group of healthy subjects.

3:i Introduction.

The ability to judge the weight of objects and knowing how to apply correct forces to them when controlling the action relies heavily on a sense of weight discrimination. The proprioceptors' input and corollary discharges are interpreted by higher centres as a sense of position and movement. This interplay is also utilised when the weight of an object is being estimated (Stein, 1974). To judge the weight of an object the amount of muscle effort to lift it must be assessed . This assessment involves a matching of the motor signals and the feedback of the forces generated in the limb (Cody, Lovgreen and Schady, 1990).

Perception of a sense of effort may not always be reliable because other cues may mislead the brain, such as vision of the shape and size of the object (Corcos et al, 1996). Muscles that are tired may also lead to false estimations, because more activity in terms of neural signals is needed to generate the effective force required in tired muscle by activating more motor units (Pedersen et al, 1991). Abnormal inputs to the CNS through experimentally interfering with proprioceptive inputs, e.g. vibration of the antagonist (Lövgreen, Cody and Schady, 1993a), have been shown to lead to misinterpretation of joint position. Damage to the cortical area 5 (Brodmann) also leads to a deficit of proprioception; posterior parietal lesions cause deficits in the comparing and interpreting corollary discharges and proprioceptive inputs (Stein, 1995), which lead to an inability to distinguish between muscular efforts and the weights of objects.

The aims of this experiment were:

firstly, to test the premise that patients with PD have an altered sense of weight discrimination (sense of effort) when compared to the control subjects and that patients with asymmetrical disease display more pronounced disturbance (Moore, 1987) during weight discrimination experiments with the more affected limb; and secondly, to test the correlation between age and discriminatory ability in healthy subjects.

Hypotheses.

1. PD patients will perform worse than the control subjects i.e. (a larger or more variable difference limen (DL)) in weight discrimination tasks.

2. PD patients with asymmetry in the upper limbs will display more errors in performance in weight discrimination tasks using the more severely affected upper limb as test side.
3. Age has no effect on the ability to discriminate sensation.

The background description to the psychophysical testing utilised in this chapter.

" Man's ability to discriminate sensations depends upon the ability to perceive the presence or absence of a given stimulus under certain conditions, and to detect changes in that stimulus if one or more of its dimensions are altered" (Corso, 1970).

This quotation relates to the threshold and the differential threshold in the following two experiments. Fechner (1860), in the last century introduced the classical theory of sensory discrimination which depends upon the concept of the differential threshold, or the Difference Limen (DL). When testing sensory thresholds some stimuli offered are greater and some lesser than a defined standard threshold. The values are presented to the participant in a large number of trials in a pre-arranged order.

The terminology and the "Best Pest" method of data collection (Lieberman and Pentland, 1982) will be described in this section; these details also relate to experiment 3. In the experiment, 40 trials were offered and their order was predetermined by a computer programme, the Best Pest (weight). In each trial the variable (test weight) is tested simultaneously against the threshold (standard weight). The protocol used by the author relates to the reference weight as the standard weight, which was applied to the contra-lateral limb to the test limb. The participant is asked to make a decision of whether the test weight is "heavier" or "lighter" than the reference weight. The results can be presented graphically (Fgures 14 and 15) as a psychometric function curve (Corso, 1970). These results form two curves, an ascending and a descending staircase. The upper differential threshold (UT) is the weight that needs to be added to the reference weight for the participant to make the correct responses 75% of the time , in saying the weight is heavier. The lower (differential) threshold is the weight that needs to be removed from the reference weight for the participant to make the correct response 75% of the times saying the test weight was lighter than the reference weight (Corso, 1970).

In the early part of the century the concept of the probability of a judgement was basic to the psychophysical methods of analysis which, in turn, relates to the random influences posed onto any decision making process. The perception, consisting of a physical stimulus and the interpretation of it by the pyschological functions of the CNS, enables man to make a judgement (Corso, 1970).

Some of the experimental nomenclature relating to the psychophysical data and description of statistical tests relied on psychophysical research methodology (Weber, 1834, cited by Watson et al ,1978 ;AppendixII).

Terminology used in the experiment:

a. The upper threshold (UT) is defined as the weight at which the subject responded "heavier" with a probability of 0.75 (Figure 17).

b. The lower threshold (LT) is defined as the weight at which the subject responded "lighter", with a probability of 0.75.

c. The point of subjective equality (PSE) which is defined as the test weight, when the subject responded "heavier" with a probability of 0.50.

d. The point of objective equality (POE) which is defined as the test weight being equal to the reference weight. (This value was defined for each experiment from reference to appropriate literature.)

e. The interval of uncertainty (IU) which extends between the upper and lower thresholds. This is calculated by subtracting the lower threshold from the upper threshold (IU=UT-LT).

f. The term difference limen (DL) is half the IU. (DL=IU divided by 2)

g. The Weber ratio (WR), used in the calculations. The WR is calculated by dividing the DL by the PSE

h. The just noticeable difference (JND);

i) the upper JND about the PSE corresponds to the difference between the UT and the PSE,

ii) the upper JND about the POE corresponds to the difference between the UT and the POE,

iii) the lower JND about the PSE corresponds to the difference between the LT and the PSE,

iv) the lower JND about the POE corresponds to the difference between the LT and the POE.

The data from these values can be displayed in tabular form or graphically. The shape of the normal distribution of the graph is described as an ogive curve (Figure14).

The background to the methodology of the Best Pest system of data collection.

The comparison method for decision making is indirect in the sense that thresholds appear only in the final statistical treatment of the data (Osgood, 1969). The general procedure in the classical problem of weight discrimination is that the subject judges the test weight as 'heavier' or 'lighter than the reference weight (Osgood, 1969). This protocol is used in the author's experiments 2 and 3 where the participant supplies a verbal response. By only allowing the decision of 'heavier' or 'lighter', then the third response of 'equal' is excluded, and this method of response is known as a two category comparison method.

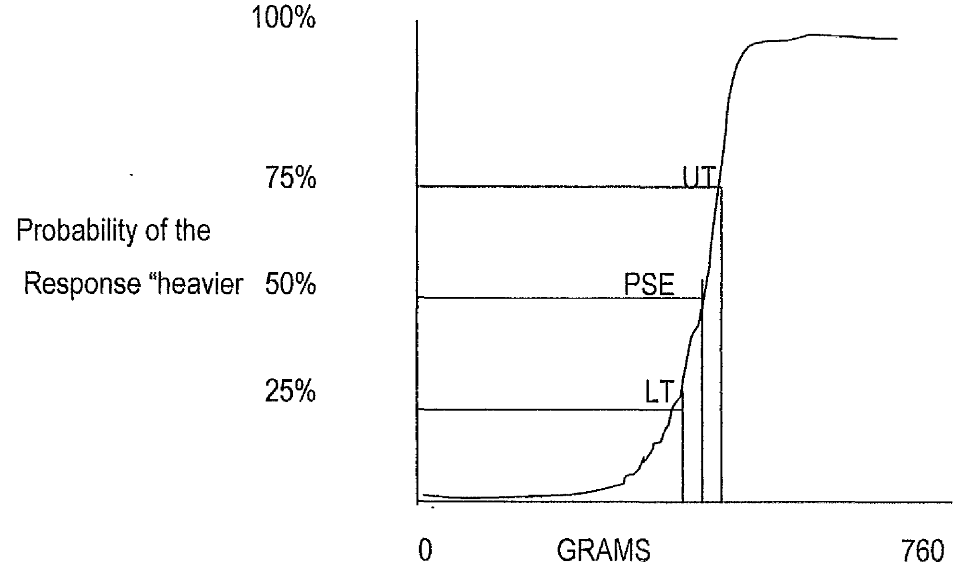
The Best Pest system for the measurement of pyscho-physical thresholds was written for the computer by Pentland (1980). This followed a prototype produced by Corwin, Kintz and Beaty (1979). The system by Pentland (1980) is more efficient and focuses on "sequential parameter estimation" (Lieberman and Pentland, 1982). The technique has similarities with other systems, but is faster and more accurate than other staircase procedures according to Lieberman and Pentland (1982).

A 'staircase' is named because it reflects the shape of a flight of steps, in that a series of weights whose incremental values are equal (like steps having an equal rise) were plotted in a sequential order, which would take on the appearance of a staircase. The reference weight is equivalent to the middle step in the flight, therefore there are as many increments above as there are below the reference point. During the testing procedure the terms ascending and descending staircase are used, the former relates to the weight that is from the lowest increment up to the reference weight i.e. the bottom step of the staircase to the middle step, and the latter the greatest weight or, like the top step down to the reference weight i.e. middle step respectively.

To determine a threshold for a psychometric function a staircase procedure can be utilised. The Best Pest is a staircase method, that determines the threshold accurately and as quickly as possible. The definition of the term threshold, is the level of an independent variable that determines a response for a particular probability (Lieberman and Pentland, 1982). Taylor and Creelman (1967) produced details based on earlier studies by psychologists, Dixon and Mood (1948), Cornsweet (1962) and Wetherill (1963) all relating to the minimum number of measurements required to produce the information. The Best Pest depends on information already gathered in previous trials, which then is utilised and leads into the programme's choice of the next trial. The Best Pest software establishes the next weight to be offered for the decision to be made during the trials, on the basis of information gathered as the trial is progressing.

The ogive curve shows the classical distribution of psychometric functions, based on the distribution of judgements predicted from the classical theory (Weber, 1834, cited by Watson et al, 1978). The data distribution is as shown in figure 16, and should follow a (sigmoid) cumulative normal distribution. The 75%, 50% and 25% probability lines (figure 14) are shown as the horizontal lines, reflecting the probability of giving the correct response, 75%, 50% and 25 % of the times respectively according to Weber (1834, cited by Watson et al, 1978) and Fechner (1860).

Figure 14.



The ogive curve, the general form of the psychophysical function is displayed, together with the threshold levels and the psychometric variables of LT- lower threshold, UT- upper threshpold and PSE- point of subjective equality are indicated.

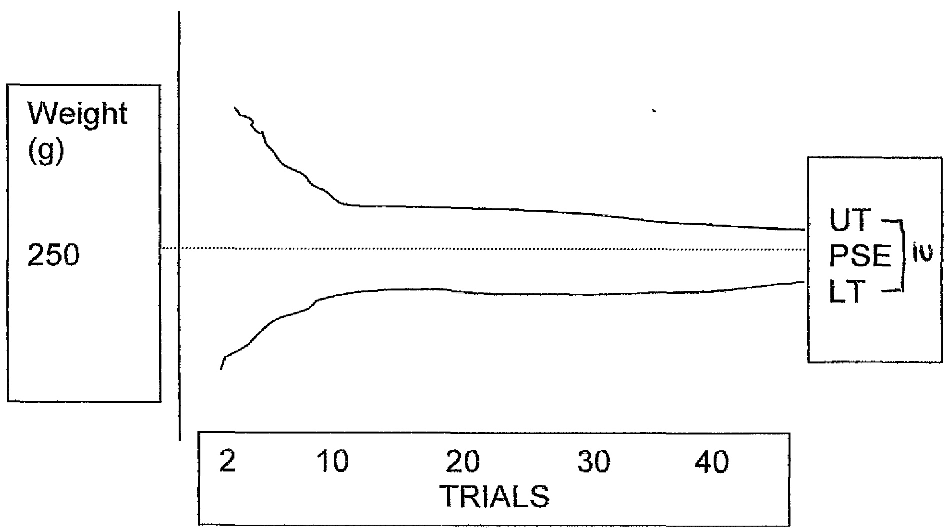


Figure 15. The figure shows the lines representing UT and LT converging towards the PSE as the trials progress

KEY: IU interval of uncertainty, UT upper threshold
LT lower threshold, PSE point of subjective equality.

Once the levels of the two staircases have stabilised, that of the descending staircase is an estimate of the UT, and that of the ascending staircase an estimate of the LT.

3:ii METHOD

The sample: a) the patients. The patient group comprised 10 patients with idiopathic PD. These patients, 2 females and 8 males, gave written informed consent prior to testing. They were selected on the following inclusion criteria. The patients had to be diagnosed by the consultant as having idiopathic PD and been stable on a medication regime, or in the case of the newly diagnosed patients not having been started on medication. The patients must not have had any other neurological abnormality or musculoskeletal defect that affected the upper limb function. Patients were tested (see previous experiment for details) for cognitive status (Folstein et al, 1975) by the Mini Mental Status Examination Exclusion criteria were specified as any accident or musculoskeletal injury affecting the upper limbs, or arthritic problems of the joints of the cervical spine and upper limbs. A patient presenting with another neurological condition would also be excluded.

The clinical details of these patients appear in Table 30, which shows the bradykinesia scores for these patients. The percentage values are expressed for the worse side, and indications of quality of movement are demonstrated (Table 31).

Table 30. Personal and Clinical details of the patients.

Patient	K	L	M	P	Q	R	S	V	W	Y
AGE	73	79	71	68	73	68	56	50	81	56
SEX	M	M	F	M	F	M	M	M	M	M
DOM	R	R	R	R	R	R	R	R	R	R
WORSE SIDE	R	L	R	L	R	R	R	L	L	R
H&Y	II	III	I	II	II	III	II	II	II	II
WRS L	4	11	6	7	7	6	3	8	11	9
WRS R	5	9	5	10	8	7	4	7	8	10
MMSE	30	30	30	29	30	29	30	29	29	27

The patients were given a code in letters for recognition, K-Y. DOM.-Dominant hand, H&Y-Hoehn &Yahr scale, WRS-Webster scores L ,left and R, right, MMSE-mini mental status examination.

It was noted (Table 31) that patients K and M had slower BLS scores for their clinically better sides. (The two clinical scales of BLS and the Webster are not measuring all the same features of movement, so there could be patients that give apparently different scores on one scale than on the other scale.) Clinical scores for bradykinesia, tremor and rigidity were measured using the Webster scale (Webster, 1968). Independent measures of bradykinesia were made using the Bradykinesia Laterality score (BLS). The Hoehn and Yahr score was also determined (Hoehn and Yahr, 1965) as a general measure of the stage of the disease. Patients with grades I to III were included. Local ethical approval was granted.

Table 31. Bradykinesia laterality scores.

	Worse side	Equal both sides
K	L is 36% SLOWER	
L	L is 25% SLOWER	
M	L is 25% SLOWER	
P	L is 16% SLOWER	
Q		YES but QD
R		YES
S		YES but QD
V	L is 8% SLOWER	
W	L is 10% SLOWER	
Y		YES

Key: QD- quality deteriorated.

The Controls.

The control group (n=9) was age matched (Table 32). The control group had a mean age of 63.4 years compared to the patient group of 67.5 years, not significantly different, t-test p=0.45. To identify if age had a bearing on the ability to discriminate weight, a larger range of healthy subjects was required for testing (n=25, Tables 32 and 33). They also had no neurological or musculoskeletal problems and were able to give informed written consent prior to testing. Their personal details are displayed in Tables 32 and 33; all subjects were right handed.

Table 32. Personal details of the control group.

Subject identification code (SID).	Sex	Age (years)
AC	M	76
AF	F	62
AG	F	49
AH	F	78
AJ	M	40
AK	M	65
AM	M	66
O	M	71
T	F	64

The experimental design.

The participant was seated in an arm chair with a pillow across the knees. The forearms were positioned in a supinated posture (Figure 16). A firm plastic wrist support (PWS) of pre-moulded plastic, was attached to each wrist 2 cm proximal to the ulnar styloid (a layer of foam was positioned between the skin and the weight holder for comfort).

Table 33. The "other healthy " subjects.

Subject identification code	Sex	Age (years)
AN	F	21
AO	F	19
B	F	21
C	M	24
D	F	31
F	M	24
H	M	27
A	M	53
AA	F	35
AD	F	74
AE	M	40
AL	M	49
G	F	35
E	F	35
J	F	49
Z	M	35

The PWS was fastened with velcro straps to secure it to the forearm. On the external surface of the PWS was a protruding extension shaft, which presented with a vertical projection for the weights to be positioned. The weights were circular metallic discs (accurate to +/- 0.3g). The actual weights to be lifted by the elbow was not easily available in the literature, as previous experiments had not related to single joint motion (Danziger and Botwinick, 1980; Flanagan, 1996), but weights been held in the hand, its control being different from the more proximal musculature (Lemon, 1993,1995). There were three sets of weights used which were in 30, 40 and 50 g increments up to 500g (Table 35). The weight of the PWS was equal for both sides, and allocated as a zero test weight.

Experimental arrangements.

The Best Pest software programme was utilised for the selection of the weight application. This programme had been designed for another set of experiments relating to joint angles and the software was therefore modified to be used for the weight discrimination tests (BP WEIGHT). Prior to the data collection the participants were randomly assigned to have the left arm as the test or reference arm; this was pre-set for the whole group prior to their attendance. The choice of weight sets also was randomised in advance. Clinical and personal details were taken for the participants and were recorded (Tables 30-33). The computer was loaded from the B P Weight programme of software and files names were recorded for the participants. The initial two trials represented the extremes of the range, from the highest to the lowest values. After these early sequences the computer organised a randomised sequence of ascending and descending trials, an example of the weights offered in one of these trials is presented in Figure 17. If the increment of 40 g was being tested then units of 40g on the ascending and descending staircases would be offered, each in turn by the computation programme, to be considered as heavier or lighter then the reference weight.

Experimental details:

1.The participant was asked to close his/her eyes. The test weight was placed on the test arm and at the same time the reference weight was placed on the reference arm.

2.The participant was then asked to lift the arms simultaneously through a few degrees of elbow flexion, to then keep the arms still and tell the experimenter if the weight on the test arm was heavier or lighter than the reference weight.

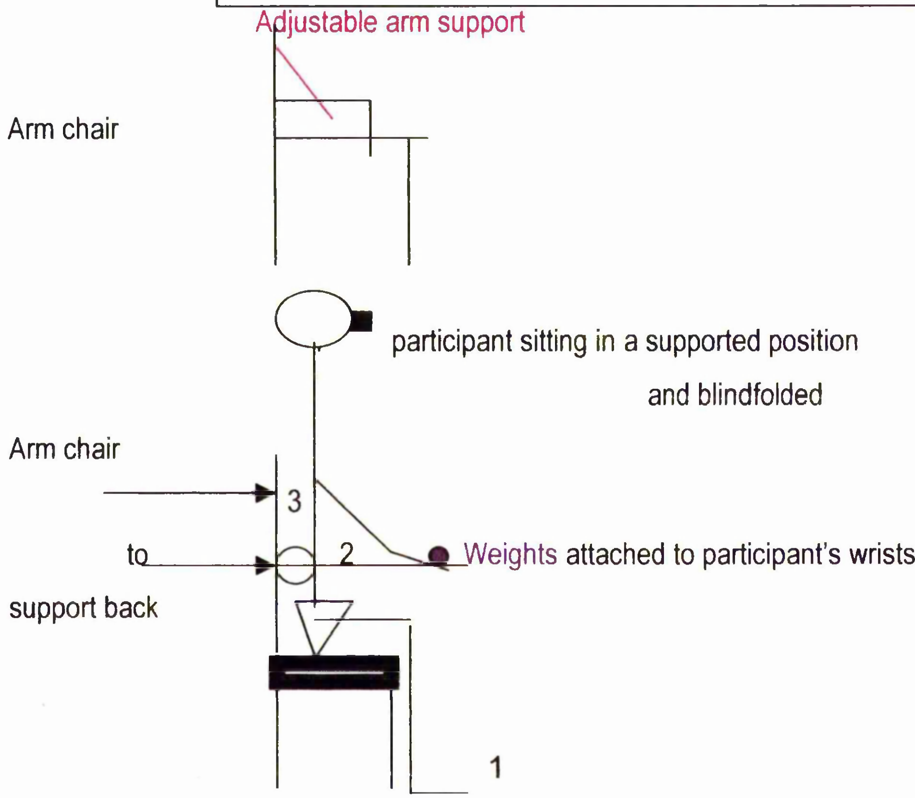
3. The verbal response from the participant was entered into the computer.

4.The weight was changed according to the selection by the computer and the same question was asked again. The data were stored by the computer for later analysis. The patient was allowed to open his/her eyes and asked if the wrist straps were still comfortable.

The whole sequence from 1 - 4 was repeated again with the other arm as the test arm, starting with a practice trial (three trials were given as a practice, to accommodate the patient to the change over). Figure 17 shows the classical arrangement of the two staircases, with the psychophysical parameters of upper and lower thresholds being illustrated as the two staircases, which show that at the upper end of the range the weight being heavier than the reference weight and similarly the lowest end of the staircase the weight is lighter.

The participant has to fulfil the mandatory requirement of correctly responding to the first two test weights or the test had to be aborted. If incorrect responses were made by the participant to the first few trials the programme requires the test to be discontinued or the results would be flawed. None of the older or middle-aged controls or the patients could satisfy these criteria so data in the 30 g trials are only shown for some of the younger subjects (except subject D who could not fulfil the requirements to continue the 30g tests). The criteria for the remaining 40 and 50 g trials was satisfied by all participants.

Figure 16. The scheme of the experimental arrangements for the equipment and participant.



The forearm is supinated. The proximal part of the forearm is supported on the chair arm, the distal aspect and the hand are free.

KEY:
1 Feet supported
2 Forearm and hand

Table 34. The abbreviations and formulae for calculating the variables.

IU- Interval of Uncertainty (g) [**IU = UT-LT**].
DL-Difference Limen (g) [**half the value of the IU**].
PSE-Point of Subjective Equality (g) [**PSE = UT- DL].**
WR- Weber ratio [**WR = DL divided by PSE**].

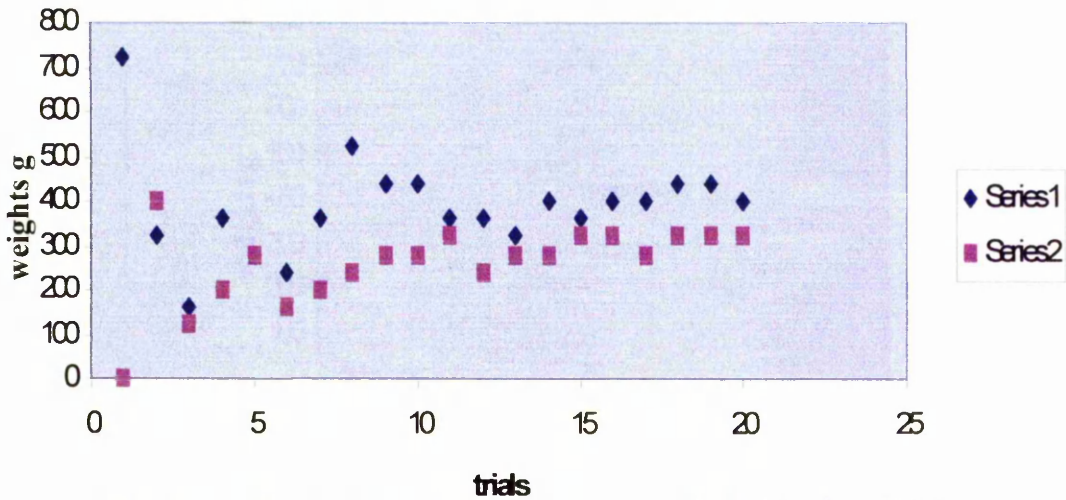


Figure 17. An example of the sequence of weights (g) offered during a trial. The descending and ascending staircases are shown as series 1 and 2 respectively.

Table 35.

50 GRAMS test weights g	40 GRAMS test weights g	30 GRAMS test weights g
500	490	490
450	450	460
400	410	430
350	370	400
300	330	370
250	290	340
200	**250**	310
150	210	280
100	170	**250**
50	130	220
0	90	190
	50	160
	10	130
		100
		70
		40
		10

Table 35.

This table indicates the ranges and reference weights used in experiment 2.

The results were prepared in the following way. The last three trials for each of the descending and ascending staircases were averaged. A set of data sheets was then completed to contain the mean results for all the measurable variables for all the individuals for each set of trials. A series of psychometric (Table 34) and basic descriptive statistical tests were then performed, tables and figures being prepared by the appropriate software (Excel 7 and Word 8). The theory behind these experiments assumes a normal distribution according to the descriptions by Weber.

3:iii RESULTS AND ANALYSIS.

The results were analysed in relation to the psychophysical variables (DL, PSE and the WR), and they were also displayed as a series of tables and graphical representations of the performance of the groups. The patient and control group results were considered first followed by the age-related aspects of the healthy subjects' performance.

Section 1. The control group and the patients will be considered first as two separate groups, followed by a between group comparison with respect to the three main variables, DL, PSE and WR.

(i) **The controls.** Difference Limen.

The most important variable was the difference limen (half the value of the interval of uncertainty).

Table 36. The mean DL (g), standard deviation (St. Dev.) and standard error (St.Error) values for the controls for test arm right (R) and left (L) at 40 and 50 g.

Control	L40g	L50g	R40g	R50g
AC	13.3	16.7	26.7	33.4
AF	40	33.6	0	25
AG	26.7	16.7	13.4	16.7
AH	23.3	16.7	23.4	41.5
AJ	6.7	108.4	6.7	41.5
AK	40	58.4	20	8.4
AM	33.3	16.4	0	8.4
O	20	33.4	40	16.7
T	33.6	33.3	20	50
MEAN	*26.3*	*37.1*	*16.7*	*26.8*
St. Dev	*11.6*	*30.1*	*13.1*	*15.4*
St.Error	*1.2*	*3.3*	*1.3*	*3.9*

Table 36 indicates the mean values for the DL of the control subjects, calculated (as are all subject mean values in this section) from the last three scores of the upper and lower thresholds on the ascending and descending staircases. Table 36 shows that the control group mean values of the DL for the left test side tended to be more than those of the right at the 40 and 50 g levels.

The DL values were not the same for the two weight levels, and there was no consistency even in order, on one side compared to the other across the weight levels. There was therefore no systematic effect of test side or weight interval.

The 40 and 50g intervals were close and both trials had the same reference value (POE) of 250 g; results are close for both sides and at both weight intervals.

The Point of Subjective Equality:

Table 37 showed there was a very similar PSE value for the two test sides and at each test weight. The noticeable fact was that the group mean PSE (Table 37) for the two test sides and at both test weights (for the left at 193.3 and 202.1 g, and for the right at 208.1 and 196.8 g) was similar to the POE (250 g).

Table 37. The mean PSE (g) standard deviation (St. Dev.) and standard error (St.Error)values for the controls for test arm right (R) and left (L) at 40 and 50 g.

control	**L40g**	**L50g**	**R40g**	**R50g**
AC	183.3	283.3	250.0	100.0
AF	143.3	216.9	130.0	91.6
AG	143.3	233.3	276.7	316.7
AH	193.3	183.3	240.0	291.5
AJ	310.0	175.0	309.9	124.8
AK	130.0	241.6	203.3	191.7
AM	83.3	99.7	183.3	241.7
O	296.6	316	210.0	216.7
T	256.9	183.3	70.0	50.0
MEAN	*193.3*	*202.1*	*208.1*	*196.8*
St. Dev	*78.7*	*64.1*	*73.9*	*94.0*
St.Error	*3.1*	*8.0*	*3.0*	9.7

The Weber Ratio:

The values for the WR (Table 38) tended to be higher at the 50 g trials than the 40 g. The test arms left and right showed values at 0.17 and 0.13 for the 40 g trials and, 0.18 and 0.29 for the 50 g trials respectively.

Table 38. The mean WR, standard deviation (St. Dev.) and standard error (St.Error) values for the controls for test arm right (R) and left (L) at 40 and 50 g.

control	L40g	L50g	R40g	R50g
AC	0.1	0.1	0.1	0.3
AF	0.3	0.2	0.0	0.3
AG	0.2	0.1	0.4	0.1
AH	0.1	0.1	0.1	0.5
AJ	0.02	0.6	0.02	0.3
AK	0.3	0.2	0.1	0.04
AM	0.4	0.2	0.0	0.03
O	0.1	0.1	0.2	0.07
T	0.1	0.2	0.3	1.0
MEAN	*0.17*	*0.18*	*0.13*	*0.29*
St. Dev	*0.12*	*0.17*	*0.14*	*0.31*
St.Error	*0.12*	*0.41*	*0.13*	*0.56*

The Patients. Patient Q during one trial had uncomfortable sensory disturbance in the right upper limb, and this trial had to be aborted (Table 39, right test arm at 50 g). In the testing sequence for this patient the aborted trial was the final one in the sequence. The data therefore were incomplete for this patient and in Tables 39-41 the column has a blank instead of a numerical value. The mean values for the patient group comparisons therefore related to n= 10 for test arm left at 40 g and 50 g, and test arm right at 40 g although for the test arm right at 50g trial n=9.

The Difference Limen:The mean group DL values for the patients (Table *39*) showed similar results for the group on the test side right of 47.0 and 42.8 for the 40 and 50 g respectively, and the test arm left had a similar value for the 40 g trials of 40.3, but a larger DL for the 50 g trials of 64.2. Table 39 showed no consistent effect of side or weight interval on the DL in the patient group.

The Point of Subjective Equality: The PSE values for the group mean scores (Table 40) tended to be higher on the right at both test weights and therefore nearer to the POE at 250g. The score for the test arm right at the 50 g reference weight is almost identical to the POE.

Table 39. The mean DL (g), standard deviation (St. Dev.) and standard error (St.Error) values for the patients for both test arms at 40 and 50g .

Patients	Left 40g	Left 50g	Right 40g	Right 50 g
K	140.0	33.4	73.4	58.4
L	46.7	16.7	173.4	26.7
M	53.2	83.3	20.0	33.4
P	13.4	58.4	46.7	33.3
Q	26.7	133.3	13.4	---
R	20.0	75.0	46.7	91.6
S	0.0	25.0	30.0	16.7
V	39.2	33.3	26.7	33.4
W	13.3	158.4	6.7	58.4
Y	50.0	25.0	33.3	33.4
MEAN	*40.3*	*64.2*	*47.0*	42.8
St.Dev	*39.3*	*48.8*	*48.4*	22.8
St.Error	*2.2*	*2.5*	*2.5*	*2.5*

Table 40. The mean PSE (g), standard deviation (St. Dev.) and standard error (St.Error) values for the patients for both test arms at 40 and 50g

Patients	Left 40g	Left 50g	Right 40g	Right 50 g
K	310.0	116.7	336.7	275.0
L	123.3	383.3	276.7	130.0
M	129.8	223.3	70.0	100.0
P	156.7	241.7	96.7	100.0
Q	143.3	233.3	156.7	---
R	70.0	158.3	403.3	391.6
S	90.0	175.0	240.0	166.7
V	157.2	183.3	183.3	216.7
W	143.3	275.0	250.0	391.6
Y	160.0	91.6	283.3	400.0
MEAN	*148.4*	*206.4*	*229.7*	*255.2*
St.Dev	*64.1*	*83.9*	*48.4*	*127.5*
St.Error	*2.8*	*3.3*	*4.1*	*4*

Weber Ratio.

The mean values for the WR are presented in Table 41, for the individual and group results.

The mean group results offered no obvious effect of weight interval or test side on the WR for the patients.

Table 41. The mean WR, standard deviation (St. Dev.) and standard error (St.Error) values for the patients for both test arms at 40 and 50g .

Patients	Left 40g	Left 50g	Right 40g	Right 50 g
K	0.45	0.28	0.21	0.21
L	0.37	0.04	0.62	0.21
M	0.4	0.35	0.28	0.33
P	0.08	0.24	0.48	0.33
Q	0.18	0.57	0.08	---
R	0.28	0.47	0.11	0.23
S	0	0.14	0.12	0.1
V	0.24	0.18	0.14	0.15
W	0.09	0.57	0.02	0.14
Y	0.31	0.27	0.11	0.08
MEAN	*0.24*	*0.31*	*0.22*	*0.20*
St.Dev	*0.15*	*0.18*	*0.19*	*0.1*
St.Error	*0.11*	*0.15*	*0.2*	*0.16*

The patients versus the controls.

Statistical tests were performed on pooled data between the controls and the patients, to test for differences between the effect of side and weight intervals.

Difference Limen.

The DL values for the 40 g trials for the PD group tended to be larger than the controls.

The DL values for the 50 g trials for the PD group tended to be larger than the controls.

Pooling the data (controls, n=36 and PD, n=39) for the DL values of the test arms (L+R) and the weight intervals (40 + 50 g) and using an unpaired t-test showed there was a significant influence of the effect of group at p=0.0041.

The DL's pooled for 40 and 50 g intervals, for the controls and PD patients had group mean values of 19.6 g and 41.0 g, and standard error of the mean at 3.3 g and 6.6 g, respectively.

i) The mean DL values of the PD group were significantly larger than the controls (p=0.0041).

ii) The mean DL standard deviation of the patients was larger than that of the controls.

iii) The statistical testing of the comparison of DL standard deviation values between the PD group and controls for the two individual weight increments separately (40 and 50g) was not performed to reduce multiple comparisons using dependent data.

Point of subjective equality. There is no obvious effect of group. The mean value of the PSE across the test sides and weight intervals equalled 200.1 g for the controls and for the PD group it equalled 210.0 g. The PSE was a little higher in value for the patients than the controls, and it tended to be nearer to the POE at 250g than the corresponding value of the controls, but the difference was not appreciable.

Weber ratio. On average there tended to be a somewhat higher WR for the PD patients who had a mean score of 0.24 compared to the controls' score of 0.17, on the left test side at 40 g and similarly on the 50 g increments the group scores were respectively of 0.31 and 0.18. The right test side for the WR value of the 40 g intervals for the patients was 0.22 and 0.29 for the controls. There was some tendency for the PD patients to have higher WR scores, but there was no significant difference between the groups.

Section 2. The effect of age on sensory discrimination.

Tables of the mean values the younger subjects who were able to fulfil the requirements for testing across all the three weight increments of 30g (Table 42), 40g (Table 43) and 50 g (Table 44) are displayed.

Table 42. The mean values of the dependent variables for the younger subjects for the 30 g weight increment, and for both test sides.

Variable	**mean**	**St. Dev**	**St. Error**
Test arm left. **DL(g)**	56.3	98.5	3.5
PSE (g)	241.3	98.5	3.5
WR	0.23	0.18	0.12
Test arm right. **DL (g)**	26.9	16.9	1.5
PSE (g)	224.4	83.1	9.5
WR	0.057	0.05	0.08

Table 43. The mean values of the dependent variables for the younger subjects for the 40 g weight increment, and for both test sides.

Variable	**mean**	**St. Dev**	**St. Error**
Test arm left. DL (g)	29.6	21.7	1.7
PSE (g)	195.2	42	2.3
WR	0.15	0.1	0.1
Test arm right. DL (g)	29.2	10	1.1
PSE (g)	204.2	85.9	3.3
WR	0.14	0.1	0.1

Table 44. The mean values of the dependent variables for the younger subjects for the 50 g weight increment, and for both test sides.

Variable	mean	St. Dev	St. Error
Left test arm.			
DL (g)	48.9	29.95	1.9
PSE(g)	251	47.2	2.4
WR	0.19	0.12	0.12
Right test arm.			
DL(g)	33.3	28.2	1.9
PSE(g)	250	57.3	2.7
WR	0.13	0.6	0.3

The Difference Limen.

The mean group values for the DL (Tables 42-44) of the younger subjects show that there is a more consistent level for the DL with the test arm right across the three weight intervals than the left. The mean values are 26.9, 29.2 and 33.3 g (for the 30, 40 and 50 g trials) for the right arm compared to the mean values of 56.3, 29.6 and 48.9 g for the left test arm respectively.

The Point of Subjective Equality.

The mean values (Tables 42 - 44) for the younger subjects show a variety of results from the lowest of 195.2 g for the left test arm at 40 gm, to the highest for the left test arm at 251 g for the 50 g trials, which approximates to the POE at 250 g. The test arm right has similar values with the lowest at 204.2 for the 30g trials to the highest of 250, equal to the POE for the 50 g trials. This shows an accurate matching of the PSE with the POE for both test arms at the 50 g trials.

The Weber Ratio.

The Weber ratios (Tables 42 - 44) for the younger group shows some inconsistency across the test arm and the weight increments. The largest ratio is produced with the left test arm for the 30 g trials at 0.23, compared to the lowest for the test arm right at 30 g trials of 0.057.

The group of 25 healthy subjects tested across the 40 and 50g trials will be considered next.

The effects of age (n=25) are considered across a span (19-78 years, mean age of 45.7 years) of approximately 60 years (Table 45). Apart from only some of the younger subjects being suitable to be tested at 30 g, age does not seem to have much effect in terms of performance (Table 45 and Figures 19 and 18).

Pearson's correlation coefficient reflected the following scores when age was plotted against DL values; test arm left 50g R squared =0.0241, test arm left 40g R squared = 0.0031, test arm right 50g R squared = 0.01948 and test arm right 4 0g R squared = 0.0002, thus showing no correlation at all of sensory discriminatory ability with age (Figures19 and 20).

Table 45. The healthy subjects' identification codes, ages, mean DL values (g) at both test weights (40 and 50g) and test arms left (L) and right (R).

Code	Subject's age	L50g DL	L40g DL	R50g DL	R40g DL
AN	**21**	0	33.4	50	26.7
AO	**19**	33.3	45	41.7	26.7
B	**21**	100	5	41.7	26.5
C	**24**	33.3	13.4	50	33
E	**35**	58.3	26.7	25	33.4
F	**24**	50	26.7	66.6	20
G	**35**	50	13.3	-25	46.7
H	**27**	66.7	73.3	16.7	33.2
A	**53**	75	53.3	91.5	26.7
AA	**35**	41.7	20	8.35	20
AD	**74**	16.7	26.7	33.4	53.35
AE	**40**	41.7	20	58.4	26.35
AN	**49**	11.7	46.7	50	6.7
D	**31**	75	20	8.4	13.4
J	**49**	75	33.3	100	18.3
Z	**35**	66.6	46	25	13.3
AC	**76**	16.7	13.3	33.4	26.7
AF	**62**	33.6	40	25	0
AG	**49**	16.7	26.7	16.7	13.4
AH	**78**	16.7	23.3	41.5	23.4
AJ	**40**	108.4	6.7	41.5	6.65
AK	**65**	58.35	40	8.4	20
AM	**66**	16.4	33.3	8.4	0
O	**71**	-33.4	20	16.7	40
T	**64**	33.3	33.6	50	20

The issue of dominance.

The participants were all right handed. The results were difficult to unravel as the heterogenicity in the patient group meant some patients had clinical scores that were worse in the right limb, some with the left and the remainder having symmetrical problems The severity of the motor signs also ranged between Hoehn and Yahr grades I to III. The control group(age-matched to the patients) displayed results for the mean DL which suggested that the dominant limb was better at the task for both the 40 and 50 g trials, than the non dominant limb (ie 16.7 and 26.8, compared to 26.3 and 37.1 respectively) but no significant difference was found (t-test).

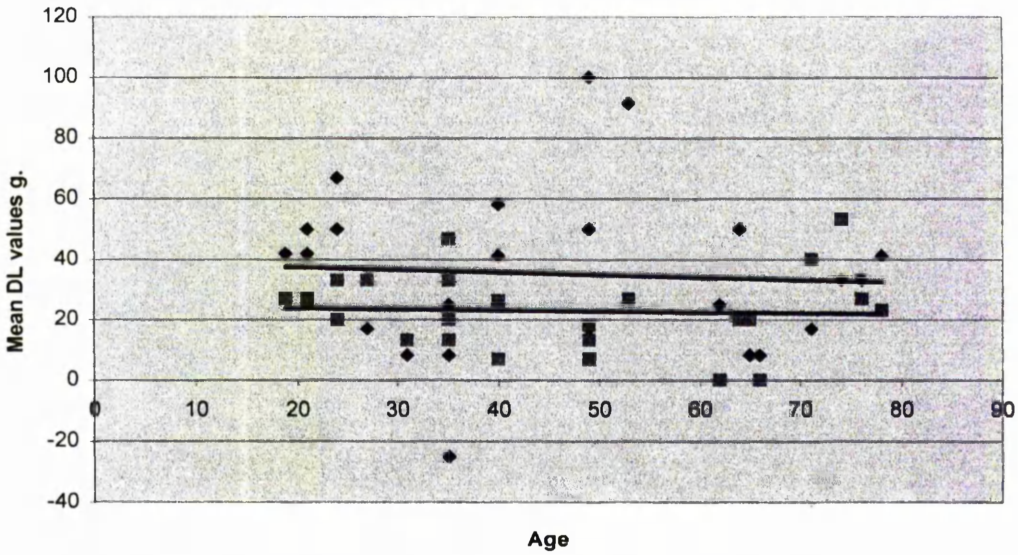


Figure 18. A figure showing the correlelation of the right test arm mean DL values at 50 g and 40g with age.The ascending staircase values are in ■ and the descending in ◆.

The upper trendline represents the correlation of right arm mean DL values against 50g and the lower against the 40g respectively.The trend lines for the healthy subjects visibly show no correlation.

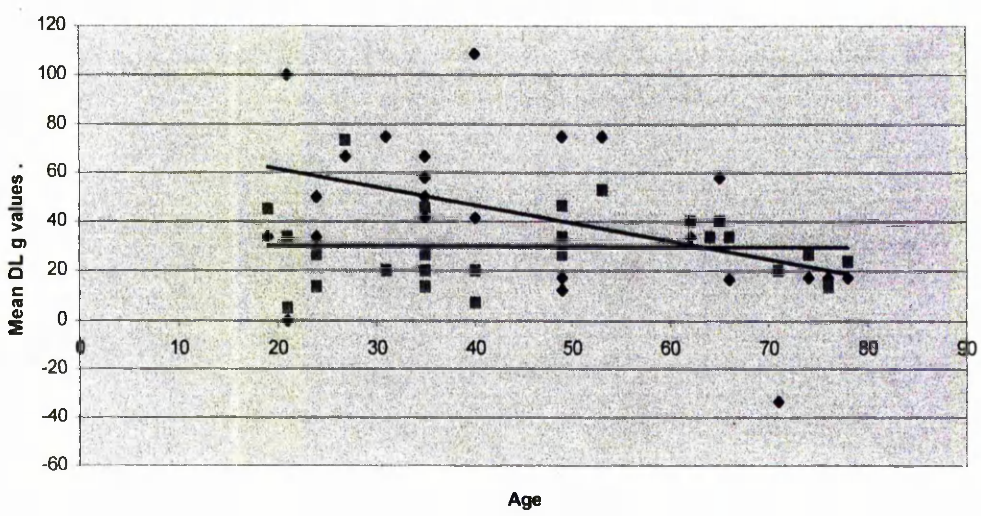


Figure 19. The figure shows the correlation of the healthy subject's left test arm, mean DL values at 50g and 40g with age.

The more horizontal trend line represents the 40g correlation and the sloping trendline the 50g correlation.

Section 3. The variability of the results (standard deviations about the DL, PSE and WR). The range of results was variable across test sides, groups and test weight intervals. The standard deviations reflect the variability, which can be seen in the preceding tables and figures in this section. The standard deviations of the DL scores for the patients and controls are displayed in Tables 36 and 39 respectively. The results show for the test arm right and left at 40 g, the patients are approximately three times more variable than the controls. The 50 g test weight trials show the patients test arm left scores to be marginally less variable than the controls, but the test arm right for the patients shows the results to be over 50 % more variable than the controls.There is no visible or statistical correlation of the DL values between age and weights trials for the healthy subjects' left test arms.

Table 46. The effect of dominance on better side performance for the patients.

Patient	Dominant side Mean DL (g)	Non-Dominant side Mean DL (g)	Dominance as best (B) / worse (W) performance
K	65.9	86.7	B
L	100.05	31.7	W
M	26.7	68.2	B
P	40.0	35.9	W
Q	(13.4)Blank	80.0	Non-comparable
R	69.1	47.5	W
S	23.4	12.5	W
V	30.05	36.3	B
W	32.5	85.9	B
Y	37.5	35.5	W

The patients demonstrated (Table 46) their ability to discriminate was not particularly affected by side in terms of dominance or clinically better or worse sides. As this was predominantly a bilateral matching task the result was not surprising.

The standard deviations of the PSE values, in Tables 37 and 40, reflect the fact that the patients scores range from 48.5 g to 127.5 g, whereas the controls are within a much smaller range of 64 g to 93.9g. This shows the patients as a group have more inter–individual variation in their responses.

Overall, the ability of the PD patients to discriminate bilateral differences in weights, as indicated by the DL values, was worse than that of the controls, and the effect of age was not a factor

<u>Discussion of the formulation of experiment 3.</u>

The results from experiment 2 led the author to consider the modifications that may be needed to reduce even more of the variables in experiment 2, that may have had a bearing on the of the data.

1. Right handed subjects and patients were recruited as before, but patients had to exhibit clinical signs of greater severity on the left side. This was to eliminate any compensatory effects that may confound the interaction of dominance and the side of worse clinical signs in the patients' data.

2. Weights were hung from a wrist strap not from a PWS. This new equipment was to reduce extraneous stimulation of the cutaneous receptors at higher weights due to torsional effects.

3. The range of weights offered needed to be increased to try and prevent the ceiling / flooring effects from occurring, to determine the discriminatory ability of the participant. The ceiling or flooring terms relate to the responses of the participant being incorrect at the extremes of range. For example when the extremes of the range are offered if the lightest weight in the trial is offered and the participant responds that this is heavier than the reference weight, this is called the floor effect. Therefore, the POE weight needs to be higher to allow for more increments above and below to test this poorer level of discrimination ability. The new POE weight was fixed at 360g instead of the previous value of 250g. This larger range would offer more selection for the participant to assess weights which were of greater magnitude of heaviness or lightness compared to the reference weight.

4. Counterbalancing of the order of testing was less complicated as only one set of weights would be being tested. This would reduce or eliminate any order effects.

5. Caffeine drinks were prohibited. This was to reduce the possible stimulant effect.

EXPERIMENT 3: Weight discrimination

3:i. Introduction

The main aim of this experiment was to compare the performance of PD patients to controls, and secondly to investigate if the PD patients with asymmetry in the upper limbs demonstrated disordered sense of effort in the more bradykinetic limb compared to the less affected limb (Moore,1987) during weight discrimination experiments. The sample group tested was a homogeneous group in that the clinical stages of the condition were as similar as possible, with tremor being absent or minimal, all participants having more pronounced problems on clinical rating scales with the left upper limb and exhibiting right handed dominance. If patients with asymmetric bradykinesia demonstrate an increased sense effort is this due to failure of the proprioceptive control of the afferent feedback or distortion of the corollary discharge mechanism?

The design of the experiment allows for the comparison of :

1) The two groups i.e. the controls versus PD patients in terms of

a) dominant versus dominant and the clinically better side,

b) non-dominant versus the non-dominant and clinically worse sides, respectively.

2) The PD patients better versus worse sides in terms of PD clinically better versus PD clinically worse sides. Therefore if the former is greater than the latter, it could be due to

a) dominance and / or

b) less severe clinical signs.

Of course, more tests and regrouping would be needed to establish the effects of clinical signs.

<u>Hypotheses.</u>

1. Confirmation of results of experiment 2.

PD patients will perform worse (i.e. larger DL, more variable) than the age matched controls in weights discrimination.

2. PD patients with asymmetry in the upper limbs will have a higher DL or show a greater sense of effort on the more severely affected side,

3. Subsidiary aims: To test for laterality (dominance) effects in controls (in PD it cannot be ascertained whether there is a difference between the worse clinical side and the non-dominant side).

To compare performance between experiment 2 and 3, where the task and equipment differed, and the generality of the findings.

To compare the results to previous literature and findings of PD patients and control subjects.

3:ii METHODS .

The sample: The patients.

The group comprised eleven patients with idiopathic PD. These patients, 3 females and 8 males, gave written informed consent prior to testing. They were selected on the following criteria. The patients had to be diagnosed by the consultant as having idiopathic PD and being stable on a medication regime, with right upper limb dominance and clinical features worse on the left hand side.

The patients must not have had any other neurological abnormality or musculoskeletal defect that affected the upper limb function. Patients were tested for dementia and cognitive status (Folstein et al, 1975) by the Mini Mental Status Examination and had to score between 24 and 30. Clinical scores for bradykinesia, tremor and rigidity were measured using the Webster scale (Webster, 1968) for each upper limb. Independent measures of bradykinesia were made using the Bradykinesia laterality score (BLS). The Hoehn and Yahr score (HY) was also determined as a general measure of the stage of the disease (Hoehn and Yahr, 1965) and patients with grades I and II were included. In the tables and graphs for this section the patients have identification codes as a letter P and a number, the controls have the letter C and a number (Figures 20 and 21).

The Webster Rating scales indicate values (Figures 20 and 21) for the 3 motor disorders of bradykinesia (Bra), tremor (Tre) and rigidity (Rig), with these totalled for each side (Tot). The dominance (Lat) of the patients is indicated, the age and sex, together with the duration (Dur) of the condition.

Figure 20.

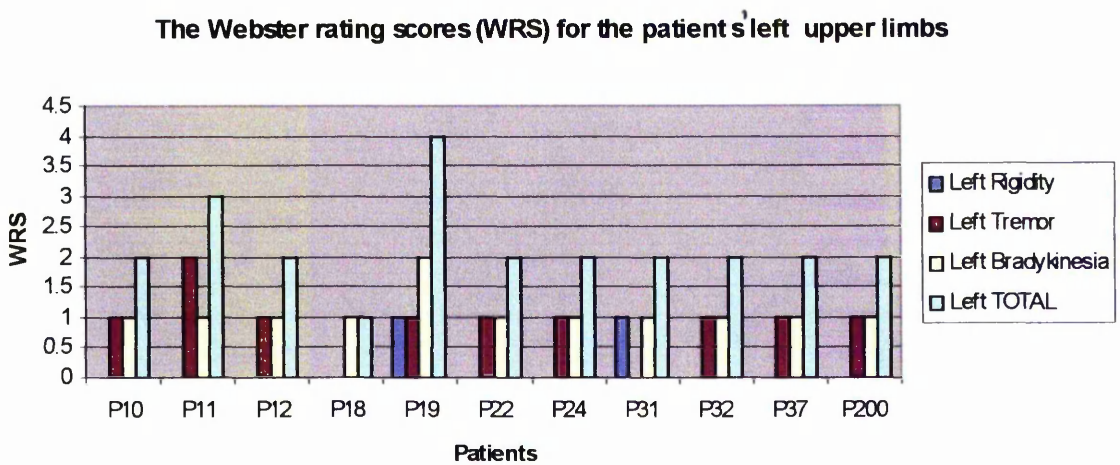


Figure 21.

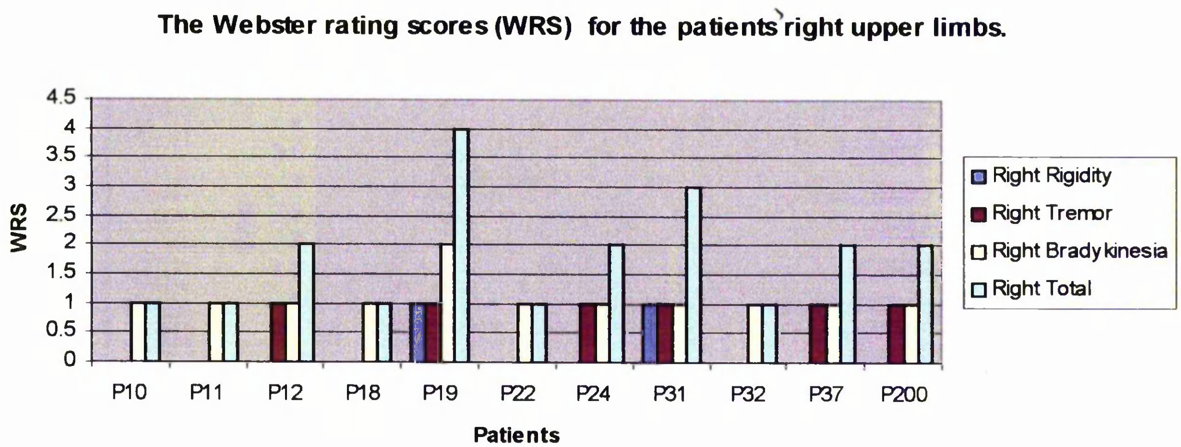


Table 47. The personal and clinical details of the patients

PARKINSONIAN PATIENTS							
SID	**sex**	**age**	**lat**	**MMSE**	**dur.yrs**	**BLS**	**H&Y**
P10	M	74	R	28	10	L	II
P11	F	70	R	29	10	L	II
P12	M	75	R	30	12	L	II
P18	M	56	R	30	6	L	I
P19	M	80	R	28	10	L	II
P22	M	79	R	30	16	L	II
P24	M	50	R	30	15	L	II
P31	M	71	R	30	4	L	II
P32	M	67	R	28	3	L	I
P37	F	44	R	29	4	L	II
P200	F	42	R	29	1	L	II

Key: BLS, L= LEFT IS SLOWER, THAN RIGHT UPPER LIMB.

The clinical details of these patients appear in Table 47 with the bradykinesia laterality scores in Table 48. The WRS are for the motor signs of the upper limbs, only. The BLS scores represent the speed of upper limb movements of the worse (left) side compared to that of the better (right) side, and are presented and expressed as a percentage reduction of the speed of the right upper limb. The patients' worse side was designated due to WRS scores and, if both of these sides were equal, then the BLS confirmed the worse side.

Table 48. The Bradykinesia Laterality (BLS) data.

Patients	20secs **Left** thumb	half-thumb	hand taps	index taps	totals	
P10	15	7.5	9	9	25.5	
P11	14	7	11	15	33	
P12	18	9	7	13	29	
P18	30	15	16	32	63	
P19	14	7	6	12	25	
P22	18	9	17	20	46	
P24	17	8.5	31	14	53.5	
P31	13	7.5	24	10	41.5	
P32	6	8	12	16	36	
P37	20	10	10	8	28	
P200	18	9	16	25	50	
Patients	**Right** thumb	half thumb	hand taps	index taps	totals	**BLS** **Left % slower than Right**
P10	16	8	10	8	26	**1**
P11	16	8	14	19	41	**19.5**
P12	18	9	9	14	32	**9.37**
P18	32	16	16	40	72	**14.2**
P19	16	8	8	17	33	**32**
P22	22	11	25	28	64	**39.1**
P24	19	9.5	31	15	55.5	**3.7**
P31	13	7.5	25	11	43.5	**4.8**
P32	18	9	15	20	44	**22.2**
P37	20	10	10	9	29	**3.5**
P200	19	9.5	16	27	52.5	**4.8**

The control subjects were age-matched (the mean of the patients' ages was 64.7 years compared to the mean of controls' of 57.3 years; a t-test showed this to be not significantly different, p=0.22) and where possible attempts were made to match the sex and socio-economic factors (patient's partners were tested). They also had to possess no neurological or musculo-skeletal problems and be able to give informed written consent prior to testing and to score within normal ranges on the MMSE.

The controls.

Table 49. The personal details of the control subjects.

Controls				
SID	**Sex**	**Age (years)**	**Laterality**	**MMSE**
C150	M	69	R	30
C151	F	49	R	30
C152	F	38	R	30
C153	F	53	R	30
C154	M	54	R	30
C155	M	61	R	30
C156	M	36	R	30
C157	M	45	R	30
C158	M	70	R	30
C60	F	70	R	29
C61	F	69	R	30
C66	F	73	R	30
MEAN	.	57.25		29.92
ST.DEV		13.25		0.289
ST.ERROR				0.24

The experimental arrangements.

The weights were contained in a series of plastic bottles which were attached to wrist straps. The test weights covered the range from a single container designated at zero test weight, through (a range of 40 g intervals) to the greatest test weight of 800 g. The reference weight was an identical container made up to the value of a 360g weight. This provided a greater range of increments for both staircases. The leather wrist straps were attached at the level of the radial styloid. These straps had a firm dependent ring secured to the inferior point of the strap (a layer of foam was positioned between the skin and the strap for comfort).

The participant was seated in a firm chair with arm rests (Figure 22). The forearms were positioned in a mid-prone posture with the thumbs uppermost. A marker was placed on the arm rest to allow for constant positioning of the olecranon at this point. Back rests were positioned and secured to support the vertical alignment of the humerus, allowing the elbow joint to be in 110 degrees of flexion at rest.

The Best Pest software programme was modified to become the Best Pest-Weight programme and was utilised for the selection sequence of the weight application. This programme had been designed for this experiment with a reference weight of 360 g as the test weight, providing a pseudo-random sequence of 40 trials. Twenty trials of the ascending and twenty of the descending staircase were scheduled, with increment of 40 g intervals. The subjects were given an explanation of the procedure. To address the issue of the practice effect, participants were randomly assigned to start the procedure with a particular upper limb, that one being designated the reference arm and the other the test arm, the value of the weight being changed according to the programme. The angle of elbow flexion required for the experiment was from 110 degrees to 80 degrees of flexion. To facilitate this without the participant's vision, two clamp stands were located adjacent to the chair arms and marked so the experimenter could align their two index fingers at the equivalent end stage of the movement, enabling the participant to move to this point in the range for each trial.

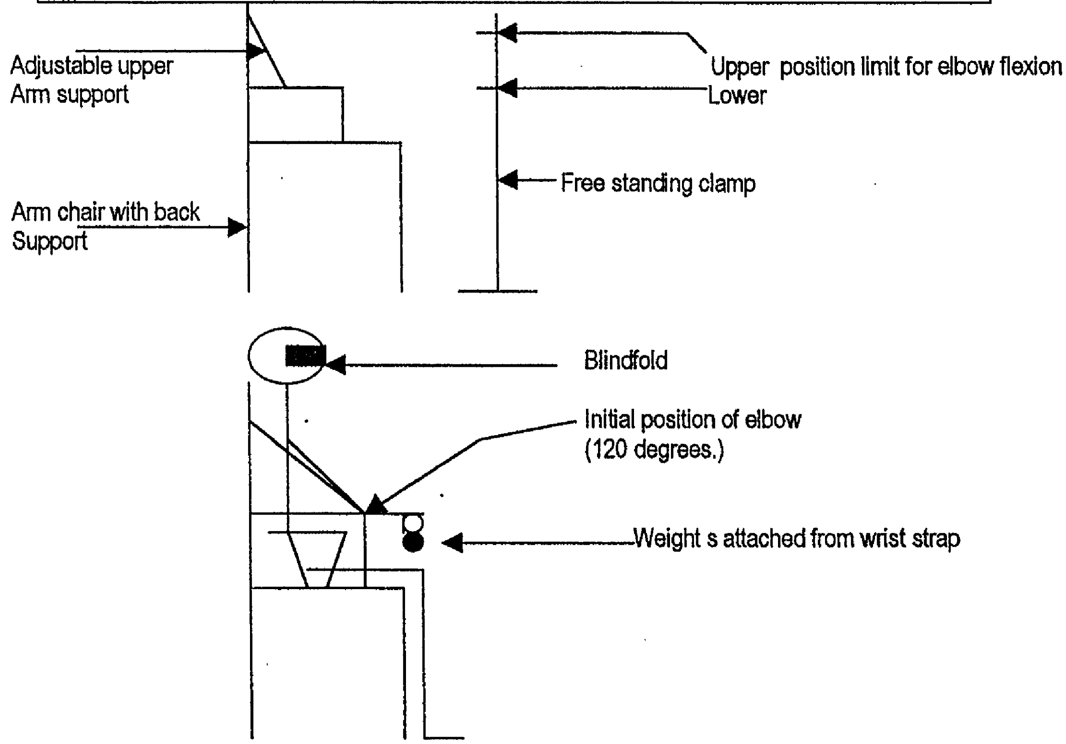
The subject was allowed a practice run with the wrist straps attached to experience the range of movement; the instruction to move slowly until the hands touched the experimenter's fingers was given, followed by the command to hold this position. To remind the participant on each trial which side the reference arm was, a gentle tap was applied to the participant's ipsi-lateral knee, prior to asking the question. At this point the participant was asked to state if the test arm felt heavier or lighter than the reference arm. Following the response, the participant was told to lower the arms and the arms came to rest with the weight supported, and the weights removed from the both arms. The response was typed into the computer and the next test weight was indicated. The reference weight and the new test weight were added to the wrist straps and the participant was asked to raise both arms slowly for the next trial.

This sequence was repeated 40 times. The second phase saw the reference arm change to become the test arm; a practice session of three trials was given to allow the participant to focus on the opposite side. Then, the process was repeated for a further 40 trials. When this was completed the weights were all put to one side and the participant was asked to repeat the movement and say which arm felt heavier than the other. The blindfold was removed .

Data and statistical analysis.

The data from the control group and the patients' group were subjected to descriptive and statistical analysis. The assumptions underlying the use of parametric inferential statistics were not significantly violated in respect of any of the sample distributions of analysed dependent variables. The sensory discriminatory data were analysed by descriptive statistics, and by using a 2 (group) x 2 (side) ANOVA.

Figure 22. The experimental arrangements for the equipment and patient positioning.



The forearm is semi pronated, the olecranon lies on the marked
Position, on the chair arm. The proximal part of the forearm is supportedon the chair arm, the distal aspect and the hand are free.
In the lower diagram the clamp has not been shown, for clarity of the set-up.
The standard clamp stand has two horizontal bars representing the starting level and the finishing, upper level. During the experiment the forearm moves, (elbow flexion) upwards, from the lower level to the upper marked level..

3:iii. Results and analysis.

The results are presented in four sections. The dependent variables of DL, PSE and WR are produced as tables, figures, and statistically analysed for the controls and the patients separately. Finally, the controls are compared to the patients.

The basis to all the statistical aspects of this chapter relates to the mean scores of the upper and lower threshold values. The upper and lower thresholds were converted to mean values (of the last three scores on the lower (ascending) threshold and the upper (descending) threshold respectively); the DL, PSE and WR values are calculated) as described in experiment 2.

Four patients, P11, P19, P32 on one side, and P200 on both sides, were found on examination of the individual plots to exhibit a "floor" effect (where the range of increments offered was not great enough for the patient to make an accurate decision). They were therefore excluded from the ANOVAs. Each subject must contribute data for "two sides" for the ANOVA. Therefore n=12 and n= 7 respectively for controls and patients.

i) The controls.

The results for the controls are presented first, as a base-line for the discrimination of the weights. The mean values of the data are presented in table format for the controls (Tables 50-52).

The Difference Limen:

The group mean value for the right test arm was 40.7 g compared to 39.7 g for the left; with a standard deviation value for the right of 20.03 g compared to 17.0 g for the left.

The group data for both sides pooled gave a mean value of the DL as 40.18 g, and a standard deviation of 18.15 g, with a standard error of 3.7 g.

In the control group, the DL did not therefore differ substantially between sides, revealing the group mean values to be close to 40g for both the dominant (right) and the non-dominant (left) test sides. The ANOVA indicated no significant main effect of side (p=0.382).

The Point of Subjective Equality.

Both the left and right mean values for the PSE were below the POE (360 g), at 239.9 g and 257.4g respectively (Table 51). This demonstrates that for both test sides, the controls under-estimated the reference weight of 360g. The group data for both sides pooled gave a mean value of the PSE as 248.6 g and a standard deviation of 113.6 g, with a standard error of 23.2 g. In the control group the PSE did not therefore differ significantly between sides, revealing that the dominant, right upper limb had no significantly better overall discriminatory ability than the non-dominant left side.

The details from the ANOVA for both the PSE and WR values are considered later in the chapter.

The Weber Ratio.

The WR value (Table 52) is calculated from the DL and PSE scores, and is a ratio of these two values;, therefore a high WR could reflect a high DL score, or a low PSE value, or both of these options. The author considers the relatively low PSE value to be the greatest contributing factor. The group mean value of the WR for the right was 0.17 compared to 0.24 for the left.

The group mean left test score for the standard deviation reflects approximately twice the size of the value for the right and emphasises the difference between sides in the WR of the controls.

Table 50. The mean DL (g) scores for the controls.

Controls	**The mean DL (g). Test arm left**	**The mean DL (g). Test arm right**
C 150	66.7	60.0
C151	26.7	26.7
C152	40	41.7
C153	53.3	20.0
C154	46.8	20.0
C155	18.4	19.7
C156	66.6	60.0
C157	46.6	40.1
C158	24.2	20.0
C60	20.0	73.4
C61	26.7	66.7
C66	40.0	40.0
Mean	*39.7*	*40.68*
St.Dev	*17.0*	*20.03*

Table 51. The mean PSE (gm) scores for the controls.

Controls	**The mean PSE (g) Test arm left**	**The mean PSE (g) Test arm right**
C 150	426.7	273.3
C151	66.6	239.9
C152	160.0	334.9
C153	373.3	406.6
C154	473.2	206.6
C155	194.9	207.3
C156	106.6	193.3
C157	166.6	333.3
C158	162.4	166.6
C60	42.3	273.3
C61	359.9	199.9
C66	346.6	253.3
Mean	*239.9*	*257.4*
St.Dev	*147.6*	*71.1*

Table 52. The mean WR scores for the controls.

Controls	The mean WR, Test arm left	The mean WR, Test arm right
C 150	0.16	0.22
C151	0.40	0.11
C152	0.25	0.13
C153	0.14	0.05
C154	0.10	0.09
C155	0.09	0.1
C156	0.63	0.31
C157	0.28	0.12
C158	0.15	0.12
C60	0.43	0.27
C61	0.07	0.33
C66	0.12	0.16
Mean	*0.24*	*0.17*
St.Dev	*0.17*	*0.09*

ii) The patients.

The patients' performance overall was worse than that of the controls. Tables 53 -55 display the mean values of the variables.

The Difference Limen.

The values for the patients DL scores were greater than the controls (65.7 and 49.5 for the patients' mean left and right test arms and 39.67 and 40.68 for the controls, respectively). Their ability to discriminate the weight was therefore poorer than the controls (Table 53 for the mean values of the DL).

Several patients, 6, had poorer performance on the worse (left) side and 1 was poorer on the better (right) side (Table 53). However, the patients' group mean scores for the worse limb compared to the better limb are 64.24 g to 41.82 g, showing that the clinically worse arm was actually performing the worst , but not significantly so. The group mean value for the worse side was 65.7 g compared to 49.5 g for the better side. The group data for both sides pooled gave a mean value of the DL as 57.62 g. and a standard deviation of 34.34 g, with a standard error of the mean at 9.18 g. In the patients' group the DL did not therefore differ substantially between sides (Table 53) revealing that the better, dominant, right upper limb had no better overall discriminatory ability than the worse, non-dominant left. The ANOVA showed no significant difference for the main effect of side for the DL ($p=0.382$).

The discriminatory thresholds of the dominant, clinically better side were similar to those of the non-dominant, clinically worse side.

Table 53. The mean DL (g) scores for the patients.

Patients	The mean DL(g) scores Worst Test arm	The mean DL(g) scores Better Test arm
P10	153.3	40
P12	63.3	40
P18	53.4	66.7
P22	63.3	26.5
P24	0	72.35
P31	53.4	66.65
P37	73.3	34.4
Mean	*65.7*	*49.5*
St. Dev.	*45.39*	*10.48*

The Point of Subjective Equality.

The patients' group mean PSE (Table 54) for the clinically worse test upper limb, somewhat surprisingly tended to more closely match the POE (360 g) than did that of the clinically better test side (Table 54). Both the mean of the patients' worse side and the better side values for the PSE were below the POE (360 g), at 258.o g and 268.7 g respectively. This demonstrates that for both test sides (although the better test side was slightly nearer the POE at 360 g than the worse side), the patients under-estimated the reference weight of 360g.

Table 54. The mean PSE (g) scores for the patients.

Patient	The mean PSE (g) Worse test arm	The mean PSE (g) Better test arm
P10	259.9	226.6
P12	163.3	306.6
P18	266.6	333.3
P22	523.3	159.5
P24	360	300.5
P31	79.9	359.9
P37	153.3	194.4
Mean	*258.0*	*268.7*
St. Dev.	*148.6*	*75.44*

The group mean values for the better side, 268.7g were compared to those for the worse side, 258.0g. The group data for both sides pooled gave a mean value of the PSE as 263.4 g, standard deviation of 112.02 g and standard error of the mean as 30.3 g. In the PD group the

PSE did not therefore differ substantially between sides, revealing that the better, dominant, right upper limb had no better overall discriminatory ability than the worse, non-dominant left. Four patients had poorer scores for their worse sides and three had poorer scores for their better sides. They were not the same individuals, consistently performing worse on a given side, compared to the DL scores (Tables 53 and 54).

The Weber ratio.

The relevant contributions to this ratio (Table 55) stem from the DL and PSE values. The author was surprised by the amount of under-estimation of the PSE score by the patients, and its effect of its contribution to the WR.

Table 55. The mean WR scores for the patients.

Patient	**The mean WR scores. Worse test arm**	**The mean WR scores. Better test arm**
P10	0.59	0.18
P12	0.39	0.13
P18	0.20	0.20
P22	0.12	0.17
P24	0	0.24
P31	0.67	0.19
P37	0.48	0.18
Mean	*0.35*	*0.18*
St. Dev.	*0.25*	*0.03*

The group data for both sides pooled gave a mean value of the WR as 0.27. The WR value is calculated from the DL and PSE scores and is a ratio of these two values; therefore it could reflect a high DL score, or a low PSE value, or both of these options.

iii) Comparison of performance of controls and patients.

The three dependent variables were 1) DL

2) PSE

3) WR.

The results are presented from the dependent variables each being subjected to a separate ANOVA which addressed:

(i) the main effects of

I) group,

II) side,

and (ii) the interaction between group and side.

The data for the ANOVAs were from the control group (n=12) and from seven out of the original eleven in the patient group (n=7). The results showed the way in which the patient group was affected by side was different from the way in which the controls were affected by side. The possible interaction of the group and side effects were tested by an ANOVA.

The Difference Limen.

The ANOVA indicated:

- A significant main effect of group. Thus, the values of the DL of patients exceeded those of the controls , [F(1,37)= 4.16; p=0.049].
- The effect of side was not significant [F(1,37)= 0.79; p=0.382]. Thus, across groups, the values of DL were not influenced by the side (left versus right, or clinically worse versus better) of the test arm.
- There was no significant group by side interaction [F(1,37)=1.01; p=0.321]. Thus the patients and the controls behaved similarly with respect to the side of testing.

The Point of Subjective Equality.

ANOVA indicated that neither the main effects of group [F(1,37)= 0.14; p=0.710], nor side [F(1,37) = 0.13; p= 0.722], were significant. Additionally, there was no significant group by side interaction [F(1,37)=0.01; p=0.931].

Thus, the PSE values of the patients and controls were comparable and were not systematically altered by the side of the test arm.

The Weber Ratio.

ANOVA indicated:

- A significant main effect of side [F (1,37)=5.10; p=0.030]. For the controls, the WR values of the left test side exceeded those of the right test side (mean values 0.24 and 0.17, respectively) whilst for the patients the WR values of the clinically worse test side exceeded those of the clinically better side (mean values of 0.35 and 0.18, respectively).
- There was no significant main effect of group [F(1,37)=1.63; p=0.211].
- There was no significant effect of group by side interaction [F(1,37)=0.90; p=0.348].

Section d. The standard deviation of the variables.

Figures 23 and 24 show the group mean standard deviation values for the two groups across the DL, PSE and WR and for both test arms. This indicates the variability of the means for the variables and the pooled test arms and the groups.

The mean SD values tended to be greater for the patients for the DL and PSE results, indicating more inter-subject variability. Across the WR standard deviations of both the left test arm for controls and the worse side for the patients have grater variability than do the dominant and better sides respectively

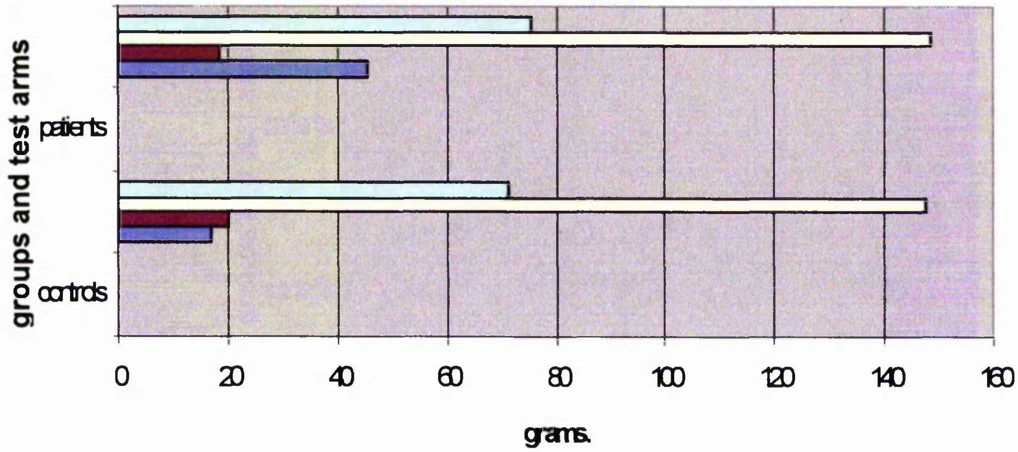


Figure 23. The figure shows the standard deviation mean values for the both groups and both test arms. The colours represent the following values-a) for the PSE scores –green, the better/right test arm; yellow the worse/left test arm, b) for the DL scores- red, the better/ right test arm, blue, the worse/left test arm.

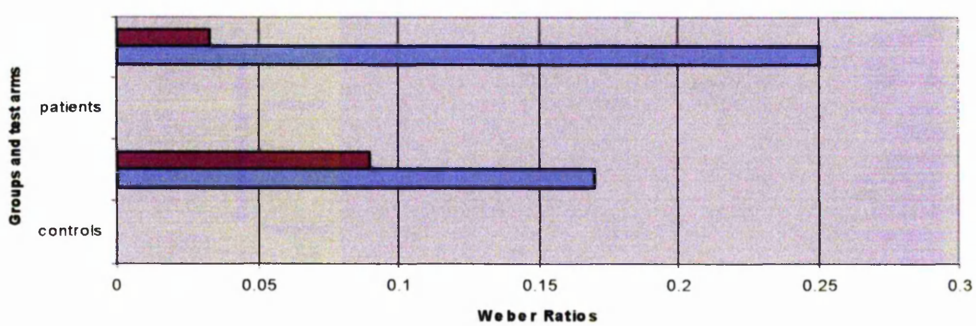


Figure 24: The figure displays the group mean standard deviation values for the WR scores. The red indicates the better/right test arm, blue the worse/left test arm for the controls/patients.

Discussion.

This discussion addresses in turn the respective findings from the three experiments and then common issues are collectively highlighted.

Experiment 1 has produced novel observations regarding the quantification in the elderly, neurologically-intact subjects of the ability bilaterally to match voluntary elbow flexion forces under isometric, static conditions.

The results from this experiment indicate that PD patients' performance is impaired in several respects. PD patients tended to be less accurate than the controls in bilateral force matching, with a group mean error index of approximately twice that of the healthy age-matched individuals. However, like the controls the PD patients produced significantly greater forces on the test side relative to the reference side ($p=0.03$).

Experiment 1 primarily investigated the sensation of contractile force. The task was almost a purely isometric one which probably utilises predominantly, though not exclusively, Golgi tendon organ activity as the feedback source. Obviously a laboratory-based experiment is far removed from everyday tasks, the reason for doing the experiment, and taking it out of a functional context was to produce a minimalist experiment. The advantages, by reducing the receptor activity from the cutaneous receptors and, thereby, leaving (primarily) the Golgi tendon organs as the predominant source of afferent input, outweigh the disadvantages of a laboratory- based experiment. An isometric task tends to reduce cutaneous receptors from also being involved since the distortion of the skin which occurs during movement is a major source of stimulation of the cutaneous receptors.

An interesting feature of the present results was that discrepancies between the forces generated on the two sides were commonplace. This was observed in both control and PD subjects. The test to reference ratios were invariably greater than 1, i.e. the reference forces were consistently 'overestimated', by a factor of 70% for the patients and 30% for the controls. There was no obvious effect of age or side of test arm (dominant or non-dominant). The task chosen for testing was in a laboratory situation. However, some activities may approximate to the situation e.g. carrying a tray with several glasses on, which involves holding the tray with both hands and balancing the tray to allow for the distribution of forces which may be different on both sides if the tray is unevenly loaded. The forces of contraction have to be precisely matched on both sides for such a task, in order to keep the tray level.

Why is the performance so poor at such an apparently a simple force matching task? There are several possibilities.

Having eliminated artifactual explanations relating to the matching of the calibration of the equipment on the two sides a series of neurophysiological reasons must be considered.

a) the force transducers on the two sides may have been incorrectly functioning or calibrated unequally. However, this could not be the case as both sides were involved in being the reference sides in turn. Which ever arm was the reference arm gave values to be higher on that side.

b) the display monitors may not have been properly matched or there may have been experimenter error in calculations. However, to counter these points the test reference ratios were always greater than 1 for both the right and left arms as test arms. Therefore, since the equipment was not switched form one side to the other (i.e. measured right versus left) any errors due to a mismatch in equipment should be: right versus left, not, test versus reference arm.

1. Neuro-physiological explanations:

a) somewhere in the circuitry of the CNS a mis-match between the motor signals to generate forces and the perception of this sensation of force generation were not equally matched. The result was that incorrect, and larger forces were generated. Ipsi-lateral and contra-lateral neuronal activities concerned with a sense of force matching are considered with the corollary discharges for the motor commands, signalling force production (De Domenico and McCloskey, 1985; Moore, 1987; Cody et al, 1990a; Martin and Jessel, 1991; Mink and Thach, 1991; Alexander et al, 1992; Matthews, 1992; Jones et al, 1992; Mills, 1995; Gordon et al, 1997). These bilateral comparisons may have been affected. The participants were asked to utilise proprioceptive input from an isometric contraction in one limb, and to try to generate the same feeling of force production with contra-lateral limb. The attempt to maintain the force with one limb whilst generating the same forces with the other limb involves a bilateral interpretation task (Ingvarsson et al, 1997). This type of action requires the CNS to process the sensory input from one side and to match the motor commands for the opposite side in terms of force production, for the other limb to generate the same 'feel' of a contraction.

b) the basal ganglia will compare the command signals for force production. Both the patients and controls, generated greater forces with the test side compared to the reference side. This led to the suggestion that the production of the test arm forces caused an over-estimation of the actual forces generated by the reference side, or that the feel of the force generation by the test side was under-estimated. These findings of greater errors in the matching of the test to reference limb forces are supported by Hallett and Khoshbin's study (1980).

c) dominance /non-dominance and better / worse clinical sides seemed to have no effect on the results for either arm as test arm, but for test arm to reference arm there is an effect.

d) issues relating to fatigue and strength are other 'neural' factors that could influence the results. The effect of fatigue on the reference side, was considered a minor issue as the reference force had to be sustained for a longer period of time than the test force, although the level of force was low (far less than the contractile maximum, at 5% and 10%) and unlikely to produce appreciable fatigue.

A sense of effort is a contributory factor in the experiment as a sense of contractile force. Force generation is dependent on the numbers of motor units recruited (Henneman, 1974; Gandevia and Rothwell, 1987; Fredericks and Saladin, 1996). Interpretation of this force may depend on the corollary discharges. If a contraction is sustained over a period, fatigue may start to set in and further recruitment of motor units is needed to sustain the original forces. The increase in neural drive to maintain this force activity on the action may be interpreted as an overall increased effort. It may explain the reason for the controls and PD patients over-estimating the reference force. The reference force had to be produced and maintained by the subject in advance of the test force. Each subject was working to his/her own capacity and the values were ratios of a percentage of the individuals' maximum force capacity. In this aspect the forces generated were unique to each participant. Were the patients too weak to carry out the testing procedures? This was not found to be the case as each individual was assessed for a maximum force contraction and then tested at 5% and 10% of that maximum. If any fatigue was setting in then in order to maintain the required force more motor units would have been recruited and this could have been interpreted as an increased effort that needed matching by the test side.

Timing of the activity meant that the muscles of the reference arm may have shown some fatigue. However, the size of forces as reference were small (5 and 10% of the individual's maximum), and the time for sustaining them was only short (several seconds at most) so probably this reason has little overall impact in the explanation of the results of this activity. Experiment 1 was performed at the participant's own time speed, as piloting had led to the finding that the patients needed more time than the controls to settle and generate the forces supported by Logigian et al, (1990), Lazarus and Stelmach (1992), and Jordan, Sagar and Cooper (1992). There may be another issue related to timing, in that people could compare the (overestimated) sensation of the first force and would, therefore, generate greater forces with the second limb.

e) attentional factors are a potential source of problem when addressing complex tasks. The subject's attention may have been unequally divided between the two sides so that (for example) the reference side always received more attention. The participants may have been focussing on the reference side more than the test side as they were trying to maintain the matching of the visual signal of the target force. This could lead to the reference side input being given greater weighting in the central comparator of bilateral judgement.

f) visual feedback may well be responsible for the results. There was a visual signal given as feedback on the reference side and this may have influenced the processing of the feel of the sense of force in the reference limb. There was absence of visual feedback for the test limb to confirm the test force, so proprioceptive guidance and corollary discharges only had to be interpreted to match the sensation of the reference force (i.e. proprioceptive and visual input with corollary discharges). The presence or absence of visual feedback may preferentially affect the attention to one side.

g) reflexes and their activity in the cord may have been unequally set for the side acting as test side, but there is no real evidence to support this. How could reflexes really affect the results? If the excitatory signals operate at a subconscious level lead to force generation then the person may not be consciously aware of force production. Descending commands from the cortex may be supplemented by reflexes originating from muscle receptors. If the contribution from the excitatory reflex inputs is not as great on both sides perhaps this is interpreted as needing greater force production to match the two sides. Perhaps reflexes in some way may reflect the dominance control in a limb, but there is no evidence from this in the experiment and this must be speculative. Signals of muscle force arise only as the force is generated and these afferents may alter the peripheral input to the motor neurone pools earlier on the reference side than the test side. Lazarus and Stelmach (1992) also showed control subjects had an initial problem generating an increased isometric force and to have difficulty in maintaining this force in the tasks of bilateral elbow flexor force matching.

h) memory disorders may also fit into the equation but the task however, was short and relied on a minimal memory component.

In fact any, or all of these mechanisms may be responsible for the over-estimation of force production, possibly by altering the balance of attention between the two limbs, on the reference side in experiment 1. The most likely explanation is the visual feedback and the associated alteration of attentional focus as factors that are consistently absent from the decision making process for each arm as test arm, which could explain why the ratio is consistently bias toward being greater than 1 for the test to reference ratio.

Previous related literature :No specific literature could be identified that revealed the identical methodological details as in experiment 1. Literature relating to bilateral tasks of force generation (Jordan et al, 1992; Kunesch et al, 1995) was similar in some aspects to the author's experiments. Decisions are made about bilateral tasking of the upper limbs and simultaneous activity is involved (De Domenico and McCloskey, 1985; Benecke et al, 1986; Lazarus and Stelmach,1992). Often the literature specifies joint movement perception from passive actions leading to movement (Paillard and Brouchon, 1968; Marks, 1997) and other literature from hand held force activities (Jenmalm and Johansson, 1997) which relates to gripping activities with different textures of objects and pinching tasks (Wing, 1987; Stelmach, Teasdale, Phillips and Worringham,1989; Jenmalm and Johansson, 1997; Ingvarsson et al, 1997; Gordon et al,1997) and object release (Gordon, 1997; Gordon et al, 1997). Many muscle groups are involved as compared to the single group of elbow flexors as detailed in the first experiment (Berardelli et al, 1986; Stelmach and Worringham, 1988; Lazarus and Stelmach, 1992; Sanes and Shadmehr, 1994; Gordon et al, 1997). The control of forces for the digit gripping tasks is under different control than are the elbow flexors (Lemon, 1993).

Overall, the author feels the absence of visual feedback, in part of the task of force matching, is the most likely factor contributing to the overestimation of the reference forces for both normal subjects and the PD patients. As the reference side had to be held longer with the presence of visual feedback, the participant's attention may have been focussed more towards this side than the test side (with no visual feedback) and therefore caused the overestimation of force on the reference side. There may be a relationship between visual feedback, sense of effort and attention.

In the PD patients however, there may be other explanations as well.

Several categories of explanation to address the issue of the force matching errors (error index) being greater, but not significantly so, for the PD patients (0.87) than the controls (0.44) explanations may include :

a) dependence on visual feedback is known to be given a high reliance by PD patients in making movement related decisions (Richards, Cote and Stern, 1993; Beneke et al, 1986). Attention focusing and visual reliance may have provided the patients with an inability correctly to assess the comparison of the feel of the force production by the two sides. These patients have difficulty interpreting sensations generated during movement without the additional information given by visual feedback, and this may have enabled the controls to perform with less inaccuracy. Visual feedback during part of the task and its absence in other parts is most certainly a greater problem for the PD patients than controls.

b) weakness of the patients may be an issue. Several controls produced greater forces than the patients. It is also known that tremor which is a factor that leads to weakness in the form of un-fused contractions was present in all 4 patients. However, the forces required of each subject were always scaled to the individuals' maximum and therefore this is not a convincing explanation.

c) the motor units, force production and force gradation are known to be affected in PD (Viallet , Massion, Massarino and Khali, 1987; Stelmach et al, 1989; Jordan et al, 1992; Phillips et al, 1994) therefore, these deficits may have a bearing on the sensory information generated and in its interpretation. The PD patients may have had difficulties in grading (Lovgreen and Cody, 1997) and reproducing a desired force (Sheridan et al, 1987). This was most probably a contributory factor in the patients' performance.

d) receptors, in particular the GTO's and their influence on the abnormal control of the proprioceptive reflexes, may contribute in the PD patients to their poor performance. In these patients the abnormal neural control of the lower motor neurone recruitment could address the feature together with potential problems in the peripheral receptor function (Fournier et al, 1983; Berardelli et al, 1986; Brodie, 1989a).

e) possibly these aspects may have minimally contributed to the performance in the patients. Slowness in action is well known in PD patients (Stelmach and Worringhaml, 1988; Stelmach et al, 1989; Yanagisawa, Fujimoto and Tamaru, 1989) and perception (Warson, Colebatch and McCloskey, 1984) of the reference force may have taken longer than in the controls. An increased sense of effort in the patients may have led to overestimation. Corollary discharges may be ineffectively generated or integrated in the PD patients (Rogers and Chan, 1988) so decision making is more difficult (Houk, Davies and Baiser,1995; Swinnen, Van-Langendonk, Verschuren , Peeters, Dom and De Weert 1997).

Of all the potential sources of problems, in the bilateral decisions of force generation, for the PD patients the author feels the dependence on visual reliance is the major factor to cause the errors , a view supported by Demirci, Grill, McShane and Hallett, (1997).

Experiments 2 and 3.

The experiments 1-3 differ from each other and from previous studies, in several respects. The tasks differ on the basis of the decision phase of the experiment relating to a static activity in experiment 1, and to a movement phase followed by a static contraction decision phase in experiments 2 and 3. These experiments all utilise isometric contractions. Experiments 2 and 3 are progressions from experiment 1, in that they include movement, but the decisions are made by the participant at an isometric phase. The experiments were designed to study if there was an extension of the evidence from the first experiment, showing patients to have difficulty in bilateral matching of forces and inter-limb activity (Beheshti, 1993; Stein, 1995; Swinnwen et al, 1997). Experiments 2 and 3 are essentially similar in approach and will be discussed together. These experiments have produced novel observations regarding the quantification in the elderly, neurologically-intact subjects of an ability to distinguish bilateral differences in the weights of objects lifted and supported by voluntary elbow flexor contraction. The task investigated a different sensation from experiment 1, though related in quality. The nature of the sensation investigated in these latter two experiments was the sensation of heaviness or weight. Again, the judgement was made under essentially static conditions i.e. several seconds after deliberate movement had ceased.

Methodological issues.

Generally experiment 2 resembles experiment 3 in terms of the Best Pest methodology, the sense of weight discrimination under investigation and the muscle groups tested.

i) The Best Pest is a well established methodology (Cornsweet, 1962; Osgood, 1969; Corwin et al, 1975) and it is widely used in sensory testing (Lieberman et al, 1982). It is accurate and reliable (Pentland, 1980; Lieberman and Pentland, 1982) being also relatively fast in facilitating sensory discrimination. The technique could have some drawbacks however, which addressed later in this section. The samples tested reflected both sexes as advocated by Ross and Roche (1987) and Brodie (1989a and b).

ii) Similarities of experiments 2 and 3 also included the estimation of individual thresholds, which were calculated from the mean of the last three values, for each of the ascending and descending staircases; this enabled a realistic figure of performance to be included for statistical analysis. In both cases a forced decision response (Kellogg, 1930) was required and no 'equal' decision could be made by the participant (each response had to be heavier or lighter, not the same).

iii) Both experiments 2 and 3 had 20 trials in each staircase. More trials in each staircase could produce increased reliability but this would have been sacrificed for the prolonged attention aspects of the task.

iv) Standardised instructions were read to each participant in both cases. The decision phase was the same time for each experiment.

v) Speed of both upper limbs was also tested for parity using the BLS, where differences between the limbs could be identified. These two scores led to identification of the patient's "worse" side. Some of these scores were however very close for the two limbs, and it may well be that the limb designated the slowest was not significantly slower than the other. This issue would need to be addressed if the study were repeated.

b) The differences between the two experiments relate to several issues:

i) The sample size of the patients in experiment 2 was ten and in the third experiment was eleven. Experiment 2 also contained a large number (n=25) of healthy individuals who were investigated for the effects of age on discriminatory ability (Watson et al, 1979; Danziger and Botwinick, 1980). The variability of medication regimes was reduced by all the participants being stable on their medication for at least two months. All were tested when the medication was effective as outlined by Cutson, Laub and Schenkeman (1995). Some patients, newly diagnosed patients, were on no medication at all, but movement abnormalities showed on the WRS and Hoehn and Yahr scores.

The age issue was considered as a potential problem as the patients were in the elderly range, and there have been changes in muscle tissue noted in the elderly (Rogers and Evans, 1993; Gordon and Patullo 1993). However, in experiments 2 and 3 control and patient groups were age-matched.

ii) The weight intervals in experiment 2 were 30, 40 and 50 g, whereas in experiment 3 the intervals were only one set of 40g. Weights of a lighter variety offer greater sensitivity in discrimination, but too light a weight would reduce the inclusion of many subjects (Botwinick, 1980).

iii) The reference weight was 250 g (Danziger et al, 1980) and 360g in experiments 2 and 3, respectively. The altering of the reference weight in experiment 3 led to a greater number of intervals and potentially aimed to increase the chance of the patient in being able to distinguish differences in weights, without the floor or ceiling effect occurring.

iv) The randomisation of the ordering effect was for both test arms and all weight intervals in the second experiment, and for the test side only, in the third experiment. Subjects were specifically selected to have right handed dominance and patients with clinical signs worse on the left side, in experiment 3. This was to potentially reduce the dilution of the effect of dominance and clinical signs cancelling each other out. If patients had been grouped with a mixture of different sides for dominance and clinical severity, the variables could not be controlled for, and the difference may have been cancelled in such a sample as the dominant worse and dominant better would have been included together, as well as non-dominant worse with non-dominant better sides being compared .

v) The weights were attached differently in the two experiments. Weight holders were attached to wrist straps in experiment 2 and via weight bottles hung on the straps in the later experiment. Issuing the weights was facilitated in the third experiment by having all increments prepared before the experiment. This reduced the time of the testing of 40g trials in experiment 3.

vi) The range of movement allowed before the decision phase, was strictly standardised in experiment 3.

Observations in controls.

i) There was no effect of side on DL values. The classical papers concerning sensory discrimination from the psychologists in the last century were from Weber (1834, translated into English in 1974) and Fechner (1860). Very few comparable studies to the author's, in terms of the anatomical area tested, Best Pest and similar methodologies could be found. Therefore, it is difficult to directly compare values (DL, PSE and WR) of results with the other studies. These earlier studies had predominantly considered bilaterally hand-held or thumb-held weights, not elbow flexor-held weights (Watson et al, 1979; Danziger and Botwinick, 1980; Gardener et al, 1983; Ross and Roche, 1987; Brodie, 1989a and b).

The issue of handedness was considered by Brodie (1989a and b). The DL values for subjects in Brodie's study (1989a and b) showed lower values for the hand controlled by the ipsi-lateral hemisphere to Broca's area. Ross and Roche (1987) considered the effect of dominance and sex on performance. They found the female gender had no preferential effect of dominance compared to the non-dominant hand as the test arm. The best performance although not significantly so in terms of discrimination was for the male group tested when the left arm was the test arm in left handed subjects. The reasons for this were given as greater specialisation of the hemisphere, and dominance in males.

The healthy subjects in the present study showed no demonstrable significant effects of age on DL, except that the 30g weight intervals were only perceived accurately by some, but not all of the group under 40 years of age. This was comparable to studies by Watson et al, (1979) who found older subjects took longer to make decisions but performed as well as younger subjects, and Botwinck (1980) where younger subjects (i.e. below 30) performed marginally (but significantly) better than older groups.

ii) There was no effect of side on PSE values. Previous literature did not identify these values in the text. It was however interesting to note that the pooled PSE values tended to be lower (239g and 257g) than the POE (250g and 360g, in experiments 2 and 3 respectively) which contrasted with experiment 1. (Experiment 1 did not use psychophysical (PSE) values per se, but the reference force could be considered comparable to the POE in the experimental rationale of experiments 2 and 3.) The reference weights were underestimated during all weight intervals in both experiments 2 and 3. If there were a decrease in the PSE, then the test arm would show an increased sense of heaviness/effort as the subject judges the test weight to be heavier than it actually is.

iii) The WR values showed a significant effect of side in experiment 3, the non-dominant side i.e. the left being worse than right. The Weber ratio is used in the experiments to test if there is parity across the different trial weights. In this context it is only going to relate to small differences, as the three sets of reference weights (30, 40, 50gm) are close. The WR values tended to be lower (but not significantly so) in the controls than in the patients.

iv) Age was not found to significantly correlate to DL values, over the wide range of ages tested.

Observations in patients

i) The DL values were greater than those of the controls, with no significant effect of side. The PD patients had significantly higher pooled DL values than the controls. The tendency for greater variability of DL was apparent (increased standard deviation values).

ii) The PSE values were comparable to the controls. The pooled values of PSE tended to be lower (210g and 268g) than the POE (250g and 360g, in experiments 2 and 3 respectively). There was no appreciable or significant difference here from the controls.

iii) There was a significant effect of side for the WR as the worse clinical side performed less well than the clinically better side (p=0.030). The WR values tended to be higher in the patients than in controls.

There are similarities and some differences of explanations between the three experiments as to why the patients' performance was worse than that of the controls.

i) Common features: In all three experiments judgements were made during an active contraction phase. These judgements were simultaneous and required minimal memory. In all experiments judgements were made under essentially static conditions of an isometric contraction, although movements associated with the lifting phase in experiments 2 and 3 may generate important contributory sensations. In all experiments a sense of effort arriving from the central neural corollary discharges, is likely to have contributed in the interpretation of a sensation. In all experiments bilateral judgements were required. In these experiments the dominance factor relates to elbow movement not manual function, so the dominance versus non-dominant limb may not be as applicable as in the case of sensory discrimination experiments with the hand.

The term "sensation of muscle force" is known to include isometric force sensation and the feeling of heaviness when an object is lifted: feelings arise from the shortening and lengthening of structures during contraction. Literature to support PD patients at the Hoehn and Yahr stage I is difficult to find, but experiments on unilaterally affected cerebellar patients have revealed that the weight lifted by the weaker arm always felt heavier in patients (Holmes, 1922 cited by Gandevia, 1987). If the peripheral signals related to the absolute muscular tension were directly involved in these judgements then no overestimation should occur, perhaps a similar mechanism may exist for the PD patients.

ii) Comparison of experiment 1 versus experiments 2 and 3: The precise balance of sensory receptors being triggered in the experiments is likely to have varied but the basic neural strategies for the comparison of the sensory inputs (and the corollary discharges) from the two sides are likely to have been similar.

In the first experiment the evidence indicates that PD patients have difficulty in matching bilateral forces and this is also supported by the second and third experiments (Benecke et al 1986; Beheshti, 1993).

The experiments 2 and 3 were designed to study if there was an extension of the evidence from the first experiment, showing patients to have difficulty in bilateral matching of forces and inter-limb activity (Beheshti, 1993; Stein, 1995; Swinnwen et al, 1997). As the findings from the experiments sustain the fact that patients have difficulty in bilateral matching of forces it is reasonable to assume that PD patients may have some disturbance in a sense of effort.

Experiments 2 and 3 include tasks of isometric contractions, with the presumption that the Golgi tendon organs are the primary sensorial organs firing in response to the forces generated in the task.

The complexity of the tasks.

The bilateral nature of the experiment required judgements to be made of both upper limbs and included activity and integration in both sides of the CNS to facilitate the decisions in the discriminating process (Gandevia, 1987; Stelmach et al, 1989; Chevalier and Deniau, 1990; Jones et al, 1992; Chen, 1997; Berlucci and Aglioti, 1997; Sheridan et al, 1987; Alexander et al, 1992). This level of complexity involves central comparison of two individual senses arising simultaneously for the right and left sides of the body. Therefore, the task is likely to have a greater complexity (Schell and Strick, 1984) and impose significant demands on the cognitive capabilities of the participant (i.e. attentional and decision-making aspects to the process).

"*Where does this muscle sense originate?* "(Matthews, 1992.)

In normal subjects before and after a muscle contraction there is a sequence of activity in the CNS leading to a sense of muscle having been activitated. The receptors and their afferent pathway to the cord will be considered first. The origin of the sensory pathway includes the receptor firing, the transmission of this effect into the CNS; the latter involves the relay of these signals to higher centres, predominantly through the brain stem to the thalamus, with the final transmission from the thalamus to the cortical receiving areas, SSA1 and SSA11, the latter contributing to perception.

Receptors

A role for the receptors' input to the perception of force production in a sense of effort is now considered. There may be several afferent sources of information arising from an active contraction which produces a static holding position of a joint. During an isometric contraction of muscle, the receptors most active are the Golgi tendon organs; the muscle spindles also contribute once the isometric position is achieved, though slightly differently from the isotonic stage (McCloskey et al, 1983). Some studies show that joint receptors fire through mid-range of movement (Proske, 1981; Proske, Schiable and Schmidt, 1988), although these receptors are known to be at their most active at the extremes of range. Joint receptors show no propensity for active or passive movements of a joint (Paillard and Brouchon, 1968). Cutaneous receptors are fairly quiescent during a static mid-range position of the limb, as they tend to fire more intensely when the skin is being deformed on rotary movement. Experiments 1, 2 and 3 all feature this mid-range position. Proprioceptor function has been studied in de-afferented patients (Fleury et al, 1995) and can be compensated for by vision up to an extent. Lack of visual signals rendered these patients incapable of weight discrimination in the absence of peripheral receptor function. Lack of cutaneous input alone has not been found to hinder the discrimination of weights (Worringham and Stelmach, 1988).

The central stages of the interpretation process.

Traditionally slow/pursuit movement control is thought to be mediated by a negative feedback system involving the comparison of the sensory signal with the motor command signal (Matthews, 1992). Ingvarsson et al, (1997) included the psychological and cognitive stages, where ipsi-lateral and contra-lateral neuronal activities concerned with a sense of weight discrimination are considered with the corollary discharges for the motor commands, signalling force production (De Domenico and McCloskey, 1985; Moore, 1987; Cody et al, 1990a; Martin and Jessel, 1991; Mink and Thach, 1991; Alexander et al, 1992; Matthews, 1992; Jones et al, 1992; Mills, 1995; Gordon et al, 1997). Memory and attentional issues are included in the decision making process, although there is only a minimal memory component; motivational issues may also feature but these are difficult to assess and as the sample volunteered perhaps it can be assumed that they were motivated.

The role of efference copies / corollary discharges

Matthews (1977) used the term "efference copies" of the motor discharges to describe the information thought to be passing to the sensory centres, supplying them with information of a motor command. The term corollary discharges is also used in the literature; related are also the terms 'sensation of innervation' and 'sense of effort' (McCloskey, 1978; Evarts, Fromm, Koller and Jennings, 1983; Sanes, and Shadmehr, 1995).

In the three experiments the role of corollary discharges is viewed as important by the author in allowing the comparison of sensory information leading to the issue of motor instructions and the comparison of these signals by the CNS.

iii) <u>The PD patients neurological deficits</u>

Patients with PD have no apparent restriction of conscious proprioception when tested clinically. Patients may be unaware of abnormal trunk postures although they will correct these on instruction, and in the asymmetrical stages of the condition are unaware of side-leaning more to one side than to the other (Markham, 1987). Some patients exhibit the effect of drifting of their upper limb position on pointing, when the eyes are closed (Chouza et al, 1986). There have only been a few experiments written in detail investigating joint position sense and muscle contraction, or the relationship between proprioception and abnormal motor control in PD patients. Schneider et al (1987) concluded that PD patients had proprioceptive deficits of control in their upper limbs. Moore (1987) argues that asymmetrically affected PD patients exhibit slower and smaller movements with the more severely affected upper limb, than do normal subjects performing voluntary contractions of the upper limbs. Gandevia and Rothwell (1987) proposed that kinaesthetic acuity may be of greater importance in a functional sense, when voluntary contraction is acting to control the limb position (Stelmach and Philips, 1991).

There are potentially confounding issues such as:

i) Are the patients intellectually impaired?

There was no evidence that the patients were intellectually impaired or demented in comparison to the age-matched controls. The higher centres were tested with a MMSE (Folstein et al, 1975). All participants had to score above the normal level of 24, so the suggestion of cognitive impairment in the PD group was not grounded (below 24 is the cut off for dementia). The exception in the scores was in two patients who had difficulty with the writing-part of the tasks, being unable to manipulate the pen to write. They were able to verbalise what should feature for those aspects and following discussion with the clinical psychologist, these results were accepted for the scoring as correct responses.

ii) Have the patients a poor memory?

The MMSE showed this was not the case. During testing the patients did not seem to require any repetition of instructions. The patients tested also had scores of I-III (the majority, in the first two stages) in the Hoehn and Yahr staging, not suggesting serious deterioration of the disease stage or cognitive function. All participants in the practice sessions clearly demonstrated an understanding of the required tasks.

iii) Was tremor a source of the problem?

Tremor may have had some perceivable effect on performance, but none of the patients had high clinical scores for tremor and resting tremor levels are usually diminished with activity (Brown et al, 1997). None of the patients demonstrated any discernible evidence of tremor on visual inspection of the beams on the oscilloscope screens in experiment 1.

iv) Was there a poor activation of generation of the force?

There may have been a slowness to activation as PD patients are known to have slow initial activation of motor programmes, but the timing of force generation was not being measured as a variable. Patients are known to be able to generate forces equivalent to a matched control if allowed to pace the movement to their own preferred speed (Stelmach et al, 1989). The reasons for this slowness of action may lie with a multitude of deficits from a background tremor leading to unfused contractions and a slowness at force generation of the required magnitude, an inability to process and integrate information, a difficulty in accessing motor programmes to generate movement instructions and/or a reduced motivational, attentional or cognitive level of activity which may be medication- linked.

v) The abnormal neural control of the lower motor neurone recruitment could also explain this poor performance, together with potential problems in the peripheral receptor function, central processing of proprioceptive input and or corollary discharges (Moore, 1987). Stelmach and Philips (1991) observed that functional disruption may be due to an age related decline, deficits in higher centres of cognitive processing, medication side effects, or difficulties in co-ordination of movements (where reliance is placed on feedback guidance or preparatory processes).

PD patients do exhibit some sensory problems, such as fleeting pains, prickling and burning or cold sensations. [One patient failed to complete the testing procedure in one of the author's experiments as he started to suffer from sensations of coldness shooting into his upper limb in the later stages of testing.] There is no hard evidence, however, to suggest that the peripheral pathways are at fault. More probably the cortex seems to be the likely place for the abnormality of information processing (Stein, 1995), as this region, Brodmann's areas 5 and 7, receives the proprioceptive information and movement from adjacent areas 1, 2, and 3. These regions receive inputs from the basal ganglia efferents, so it is possible that the discrepancies occur in these zones.

The presence of the pre-motor, motor and sensory signals can be integrated and evaluated as a sensation of activity or effort. If the PD comparator function of the basal ganglia is impaired (Meara, 1994), this may account for the motor dysfunction present in the control of movement as proprioceptive information is incorrectly interpreted. Support for impaired central processing is supplied by single unit recordings in the MTPT primates (Tremblay, Filion and Bedard, 1989; Filion and Tremblay, 1991). Central information processing may have deficits in any of the relay pathways and at the synaptic connections between the cord and the cortex (Carey and Burghardt, 1993). The PD patient has motor problems of bradykinesia, tremor and rigidity, thereby reflecting interruption to the quality of synchronous, volitional activity present in a healthy CNS.

Attentional factors may be involved. In experiment 1 the patients may have been focusing on the reference side more than the test side, as they were trying to maintain the matching of the visual signal of the target force.

In patients with an abnormal sense of effort, the question must first address the probability of the disturbance being due to information processing. The stages in information processing (Gandevia and Rothwell, 1987; Gordon et al, 1997) for bilateral, simultaneous, discrimination testing includes a peripheral aspect and a central aspect to the processing (Fleury et al, 1995; Demirci et al, 1997). The issue of possible disturbances in neural processing of the patients may be responsible for their inability to be as accurate as the controls in weight discrimination tasks. Studies by Moore (1987) showed PD patients to be incapable of perceiving marked bilateral differences in the movements of corresponding joints. He hypothesised that an impairment of either sensory input or corollary discharges was the cause. Goodwin, McCloskey and Matthews, (1972) employed bilateral matching tasks to investigate kinaesthesia, but were unable to offer the detail of how the brain carries out bilateral discriminatory judgements.

The probable causes of impairment of the discrimination of the relative weights, may show a deficit in the proprioceptive interpretation by the brain of the patient (Evarts et al, 1983). This may be due to an abnormality of control of motor movements in PD (Sanes and Shadmer, 1995) or in the comparison of these two sets of sensory signals (Cody et al, 1990a, b; Carey and Burghardt, 1996). Therefore, it seems as if there are sequential stages in the discrimination process and any, or all, of these may contribute to the performance of PD patients.

Other issues that may be addressed in future experiments:

The first relates to the choice of the control subjects. The recruitment of some controls may have been flawed, as some of the patient's partners were selected. If environmental agents had led to the onset of PD then the control may also have been affected by these same toxins; however, careful questioning ruled out any apparent neurological deficit in these controls. The recruitment of partners has many advantages, i.e. often matching of age, intelligence, social class and diet.

The use of an independent researcher could have been recruited to give the instructions to the participants if attempting to reduce experimenter bias. An attempt was made to control for this by having the instructions read out from a card for each participant.

A larger sample could have made the results more generalisable, thus giving more external validity to the testing. However the available data base was not so extensive as to locate greater numbers of patients within the set, strict inclusion/exclusion criteria.

The testing across larger ranges of weights and forces would give a more complete picture, but compliance, attention and medication issues become more complex over a protracted period of testing.

The use of more in-depth qualitative measures of testing cognition, memory and attention span could have been employed if psychology staff are available to support a research project. This may then negate the issues of intellectual function as contributory factors affecting the decision making process.

Concluding remarks.

(i) The hypotheses relating to patients' performance (relative to that of controls) concerning greater inaccuracy of bilateral force-matching (experiment 1) and discrimination of bilateral differences in weight/ heaviness (experiments 2 and 3) were upheld.

(ii) The hypotheses relating to the possible effects of dominance (versus non-dominance) or clinical severity (better versus worse) on accuracy of bilateral judgements were not upheld.

(iii) There was no evidence that parkinsonism was associated with an increased sense of effort.

CHAPTER 4.

Physiotherapy intervention; evaluation by single case system design.

This chapter addresses a methodology for establishing the issue of clinical effectiveness for physiotherapy, with four single case study designs being utilised. The neuroscientific basis for these interventions is then highlighted.

1. i Introduction.

Riddoch and Lennon (1994) reported an issue that had recently arisen in the medical press criticising physiotherapy research, citing an editorial in 'The Lancet', which stated that "physiotherapists have a poor record in initiating and responding to research, and numerous techniques are used with little or no scientific background". At the time of publication that editorial was valid in its criticism of the profession. The criticism was in response to comments from a review of thirty-five trials comparing physiotherapeutic treatments for low back pain, that there were no conclusive recommendations. Perhaps as Riddoch and Lennon (1994) noted, the methodologies utilised were inappropriate to the evaluation of practice. It was a general criticism, but the professional philosophy and the physiotherapy research base has started to establish itself in response to the demands of the National Health Service (NHS) and is seeking to identify the appropriate methodologies for research. The rationale for physiotherapeutic intervention in neurology has its origins in the neuroscience literature and clinical trials and partially in single case studies. This chapter unravels the basis for this intervention by the single case study, a design approach in research methodology common for many medically based professions.

Clinical effectivenesss

> "The extent to which specific clinical interventions, when deployed in the field for a particular patient or population, do what they are intended to do i.e. maintain and improve health and secure the greatest possible health gain from the available resources" (NHSE, HMSO, 1998).

This definition was laid out in the NHS document Promoting Clinical Effectiveness in the NHS. The focus of the paper was to promote the use of an evidence base in clinical services, leading to improvements in terms of financial and patient benefit. For physiotherapists and their patients this means the "conscientious and judicious use of current best evidence from clinical care research in the management of individual patients" (HMSO, 1998). The alternative forms of evidence not encompassed in this definition (Bjordal and Greve, 1998) include clinical expertise, clinical assessment, information gathering, previous professional knowledge and patients' preference (CSP, 1997; Bury and Mead, 1998).

These multiple sources of evidence can be used to support the healthcare professional and the interaction between him/her and the patient. Patients' empowerment is actively encouraged and this relies on the judicious use of valid best-practice, and its implications for the individual. Clinical effectiveness is concerned with producing health benefits, using the available evidence, in the context of the wider environmental and organisational aspects of the health care systems (CSP, 1997). The balancing of these many factors needs experience (and the judgement of Solomon !) in the current political climate to allow access to "effectiveness, appropriateness, accessibility, equity and responsiveness" (HMSO, 1998).

The NHS defines clinical effectiveness and stresses the need to balance the benefits of specific clinical interventions with the availability of resources (Hopkins, 1994). Physiotherapists have a professional code of practice and implicit in this is the responsibility and duty of care to patients. Without this evidence of effectiveness, derived from the high quality levels of research, the profession will be unable to demonstrate the extent to which its interventions provide benefits for patients.

The background to 'Single system design' research (Single Case Study).

Parkinson's disease patients are treated as individuals, having unique presentations in degrees of severity, with associated signs and symptoms. Studying behaviour change in the individual allows an intervention to be assessed for that individual, rather than comparing the group effects of an intervention on a sample of patients. Conclusions drawn from single case study research are applicable to that unique individual and cannot be extrapolated for use on the whole population. From case study research can develop the basic research hypotheses for future experimental randomised control trials (Robertson and Lee, 1994; Robertson, 1995; Barlow and Hersen, 1998).

There are limitations in group experimental approaches in the forms of ethical objections where a treatment intervention is withheld from the control group, although these rely on the premise that the intervention is effective in the first place. Despite the lack of logic in this, many ethical objections are raised on these grounds. The practical problems of collecting an homogenous sample of patients with PD are very difficult, as the presenting signs and symptoms are so variable. Averaging the results may obscure the clinical outcomes in group work. Single case studies offer another important contribution to science and form the initial evaluation in therapy research, if they are carried out in a rigorous manner, sufficiently sound to minimise or eliminate threats to the internal validity of the research (Riddoch and Lennon, 1994).

1:ii. Single case study design.

Four patients with Parkinson's disease are presented in this chapter as case studies. The physiotherapy chosen for these interventions has its knowledge-base in the neuroscience literature (these sources will be identified in the discussion section, after the individual case studies). A description of each patient and his/her associated problems has been identified by individual clinical assessment; in each case the methodological design was the same, but the data collection tool may be different. The results are analysed for each study and there is a combined discussion at the end of the four studies, from which conclusions are drawn and evaluation (Anderson, 1989) of the interventions (Kahn and Miller 1975) is performed.

Methodology.

Experimental design.

The case studies follow the A-B-A design, where the first A stands for a baseline measurement phase, B for the treatment /intervention phase, and the second A the final baseline measurement phase. This is the simplest of the case study designs. It is referred to as a withdrawal design as the intervention is given and then withdrawn and the patient is followed up with measurement after the treatment phase. The design allows for analysis of the effects of the introduction of the therapy intervention and its withdrawal. This is the nearest design to clinical practice, when a patient is referred for a course of treatment and then discharged, so that ethical issues about withdrawal are removed/reduced. Following the withdrawal of treatment in a clinical context, ethical aspects are addressed by giving the patient follow up advice and guidance, and in this research study these features were upheld.

In this situation a design of A-B-A-B sequence would be inappropriate, as patients often have medication and other fluctuations over a time span that would complicate the picture for analysis. Limitations to the interpretation of data may be compounded by limited measures during the baseline state.

Baseline measurements.

Baseline measurements are taken over an interval of time, that time being long enough to establish a baseline for the individual. The treatment intervention was applied and monitored, followed by the withdrawal phase for repeated measurements. These measurements must be clearly specified (Chesson, Macleod and Massey, 1996) and observable, as repeatability is needed after the intervention stage. The sample group comprised four patients, who were assessed for baseline measurements during the times they attended for other research measurements, in conjunction with the experiments detailed in chapter three. This removed the ethical issue of waiting for baseline measurements prior to treatment, as these patients were technically on a waiting list. Full clinical assessments and identification of their problems were documented and a specific problem based treatment intervention was produced.

The measurements taken over this time span must be performed in exactly repeatable conditions (Barlow and Hersen, 1988). There is no simple definition of how long the base line should be, although it needs to be long enough to show an established stability in the absence of a trend, allowing a stable pattern to emerge. A trend refers to the tendency for performance to increase or decrease consistently with time. The descriptive function from a base line offers information relating to the patient's problem, and secondly predicts the future performance if the intervention is not applied, i.e. if conditions continue as they are.

Validity.

The basis of research is to compare the relationships between variables. Drawing inferences about the effects of an independent variable or treatment intervention requires attention to a range of factors that may cloud the results (Kazdin, 1982). Validity is the extent to which a score measures what it is intended to measure (Barlow and Hersen, 1988).

Internal validity

Internal validity is strongest when it allows inferences to be drawn from the results which rule out alternative explanations other than the independent variable. Threats to internal validity can be minimised or ruled out by taking into account history and maturation, instrumentation, testing, statistical regression, selection bias, attrition and diffusion of treatment (Kazdin, 1982). Some reduction in the threats to internal validity can be organised if a case study includes continuous assessment before, during and after, treatment as was the case in the studies tested. Validity of the scales such as the Webster scale is well established, but this measure is not sensitive to the effect of a single physiotherapeutic intervention but a global measure of motor performance. The time/distance measure is used frequently in clinical practice and will give accurate timing of a distanced walked; however, it gives no detail of the quality of the gait and no level of how the subject felt during the activity. The Borg perceived exertional scale could have also been incorporated, a validated tool that could have shown the effect of the intervention in terms of effort required.

Balance was measured subjectively by asking the patient for their subjective comment. The balance performance measure can be used to assess balance in standing, but there were no acessible dynamic measurement tools available for the case studies to test functional balance during gait.

Social validation is addressed by the use of a perceived anxiety scale, which is a nominal scale, non-validated measure (Poppen, 1988; Ruuskanan and Ruppila, 1995) but is used frequently in clinical practice to ascertain a subjective comment as to how the patient rated he/she was feeling. The scale is a nominal rating scale and only valid to the time, place and circumstance of its use, just as the visual or verbal rating (pain) scales (VAS/VRS). The scale for the measurement relates to the patient's assessment of his/her impression of self perceived anxiety. The scale is 0 = no anxiety, 1 = mild anxiety, 2 =moderate anxiety, 3 =severe anxiety, 4 = extreme anxiety. The patient is tested before the treatment intervention.

The use of measurement tools must not be used too frequently or false readings may be produced as the practice effect may be incorporated and invalidate the results.

External validity.

As with internal validity, threats can be made relating to external validity that raise questions about the results. Often these external variables may limit generality of the findings and are dependent on such factors as the way in which the therapist gave the instruction, the age of the patient, the setting of the intervention and so on. The goal is the demonstrable general relation which exists beyond the unique circumstances of the experiment. Priorities of external to internal validity, usually weigh in favour of internal (Kazdin, 1982).

Changing one variable at a time is demonstrated in the case studies, as patients were only tested when medication levels had not recently been manipulated, and when this stable medication was at its most effective.

Reliability.

The feature of reliability is addressed by using clinically standardised and validated measurement tools and outcomes if they are available, training of the observer, and calibration of necessary equipment (Barlow and Hersen, 1988). Repeatability of the approaches, outcome measures and results from individual cases would then tested in another design such as randomised controls trials.

Measurement tools.

Case P199. The measurement tools were:

1) a distance / time measure (seconds /metres)

2) a clinical evaluation of function: the Webster scale (nominal numerical scale),

3) the carer's subjective comments on balance (qualitative comment).

Case P198. The measurement tools were:

1) the perceived anxiety scale (subjective, qualitative comment) used to measure the effect of treatment, and measured as numbers (nominal data) of episodes of fear lead to freezing, and to lack of speech.
2) an overall aim of continuing employment .

Case P32. The measurement tools were:

1) a measure of balance, on a subjective scale (qualitative comment).
2) the Webster scale (nominal scale).

Case P31. The measurement tools were:

1) a time /distance measure (seconds /meters).
2) the Webster scale (nominal scale).

The Sample group

The sample was of one of selection, all four patients having being diagnosed with Parkinson's disease and found to be within normal levels with no dementia according to the MMSE (Folstein et al, 1975). The patients were identified for therapy when they volunteered to take part in experiments, described in chapter 3. The four patients selected for this method of research will be described in terms of personal and clinical details, physiotherapy assessment, problem list and identified intervention. The measurement process will be described, and then the presentation and analysis of results for each patient will be displayed.

Data analysis.

Descriptive statistics were employed to display the data (Dixon and Mood, 1948; Chesson et al, 1986; Anderson, 1989; Flick and Uwe, 1998). A two standard-band deviation test (Ottenbacher, Hsu, Granger and Fielder, 1996) is utilised in some of the case studies. This is a statistical measure which is graphically displayed. The data from tests yielding interval and ratio data can be considered in this format. The data are plotted as a line graph. The mean value of the pre-intervention phase and the standard deviation of the pre-intervention phase are calculated. A band is drawn horizontally across the graph, representing a value of 1 standard deviation value above the mean, and a second line parallel to the first, and at 1 standard deviation below the mean, is positioned. Data falling outside this band (2 standard deviations wide) are said to be significant (Daly, Bourke and McGilvray, 1992).

The personal and common clinical details are shown in Tables 56 and 57. Specific individual variation of clinical features is presented in the introduction to each case study. All patients gave written informed consent. Table 57 shows the individual motor signs, (tremor, rigidity and bradykinesia), self-reported anxiety awareness for the patients and total WRS for the whole body.

The individual cases

Case P199. Physiotherapy clinical assessment :

This lady presented with some gross motor problems, of bradykinesia and tremor affecting predominantly her right side. She was also very apprehensive and had lost her confidence in going out of the house, identifying that walking was her main problem.

Balance in sitting was controlled by weight bearing to the left and her dynamic balance was compromised once the base of support was challenged. Her gait presented as the typically shuffling picture described in the texts.

Fine motor control was affected but her gross motor power was reduced in the right hand. Gross sensation was normal. The total Webster score was 7, the bradykinesia laterality score was 29% slower for the right hand, and the mini mental status score was 29.

TABLE 56. The personal and clinical details of the patients.

SID	SEX/ Age	Cog.	Dur	BLS	H&Y
P199	F/64	29	1	R	II
P198	M/54	30	5	L	II
P32	M/67	28	3	L	II
P31	M/71	30	5	L	II

Key to tables 56 and 57

The SID (subject identification codes) codes allocated to the sample group are in association with codes in chapter 3.

Dominant hand= right in all patients, Cog =score for mini mental status test,

Dur. = duration of the disease, in years

BLS = bradykinesia score, L=left is worse side, R =right is worse side

H&Y = Hoehn and Yahr score.

Table 57. The Webster Rating Scale (WRS).

SID	WRS, upper limb scores			Whole body score WRS
	Tremor.	Rigidity	Bradykinesia	
P199	L=1 R=1	nil	R=1	7
P198	R=1	L=1 R=1	L=1 R=3	8
P32	L=1 R=1	L=1 R=1	L=2 R=3	9
P31	R=1	L=1 R=1	L=1 R=1	8

Intervention for patient P199.

The intervention selected for this patient was:

1. a biomechanical approach to weight transference exercises (Handford, 1986),

2. mental planning (Van Leeuwen and Inglis, 1998) and preparation for walking, using timing for emphasis to initiate changes in direction, and to avoid obstacles when walking (Harrison and Jackson, 1994).

Table 58 The anxiety scores and freezing episodes, prior to intervention.

SID	Freezing Episodes	Anxiety Levels
P199	++++	***
P198	++	***
P32	nil	*
P31	nil	nil

Key for tables 58 and 59.

The WRS scores are given for the left upper limb are top in the column, and for the right upper limb, lower in the column. (If the score was zero, this is omitted.)
The total WRS scores includes the whole body score.
The total body scores also include such features as weakness of voice, skin condition etc. as well as the motor scores.
Anxiety is indicated by * signs (code in text , under measurement tools)
Freezing, (by the number of episodes) as + signs

The details of this intervention:

1. Weight transference was taught by the following exercises, each being repeated 6 times twice a day for three weeks:

A) standing with feet wide apart (initially holding on to a work surface) transferring the weight to the left foot and lifting the right foot off the floor, then repeated with the left leg being raised (Gilchrist, 1998).

B) standing with the right leg in front of the left (in stride standing) then rocking the weight forward onto the forward foot and then to the back foot. This was also repeated with the left foot forward.

C) the former two exercises were progressed, by then taking a step in the direction of weight transference (Edwards, 1996).

2. A strategy was taught to the patient for alleviating balance problems once the patient could perform the previous exercises (Payton and Nelson, 1996; Harrison and Jackson, 1994; Niewboer, Feys, De Weerdt and Dom, 1997; Larin, 1997; Van Leeuwen and Inglis, 1998). The patient was taught to transfer her weight to the contra-lateral limb when approaching an obstacle in her path. She did this by recognising the obstruction, then mentally recalling to side step and then to take a step forwards, thus preventing the shuffling at the obstacle.

Initially she needed guidance to plan to side step and this was done using a counting sequence, so that she could plan to side step on the countdown of five.

The measurement tools were a distance/time measure, the timed 10 metre walk test (Wright et al, 1998), a clinical evaluation of function, the Webster scale (Webster, 1968) and a self-perceived anxiety score (Poppen, 1988, Ruuskanan and Ruppila, 1995), together with a subjective impression from the carer as to his assessment of his wife's perceived level of anxiety.

Baseline A measurements of the 10 metre walk test, and Webster scores (WRS) for upper extremity swing (UES) and gait were taken over the first three weeks, together with a subjective / visual impression of balance by the carer. Phase B: the treatment intervention schedules were taught to the patient and these were refined and practised for a three week period. Measurements were taken during the intervention phase B, and again at the three week post- intervention phase, the second A baseline.

RESULTS.

During (B) the intervention phase the patient was progressing well with the gait re-education and commented that family and friends had noticed that she was walking better. The carer noted that the anxiety was reducing as she improved in her movements (Worm, 1988; Yekuteil, 1991; Yekuteil, Pinhasov, Shahar and Stroka 1991).

Table 59. The measurements of P199.

Week	(1, 2, 3) Pre-Int.V	(4, 5, 6,) INTERVENTION	(7, 8, 9,) Post- Int.V
Perceived Anxiety Levels by the patient	3	3	2
10 Metre Walk Test	(25,28,27) Seconds	(19, 18, 17,)	(20, 19, 19)
Subjective impression, by carer of balance	** ** **	* * *	** * *
	* denotes apprehension		

Key: The abbreviations " Pre-int.V and post-Int.V " relate to pre- and post intervention respectively. The perceived anxiety levels were on a scale of 0-4. These values are designated by the appropriate numbers of: 0 = no anxiety, patient completely relaxed, 1 = mild apprehension, 2 = moderate apprehension, 3 = considerable anxiety and 4 = severe anxiety. (The carer was asked for the information away from the patient's hearing.) The mean value for the timings during the pre- intervention phase of the 10 metre test was 26.7 seconds and the standard deviation value was 1.5 seconds.

The results show an increase in the walking speed (Williams et al, 1994; Willems and Vandervoort, 1996). This is demonstrated by the downward slope of the time-line on the graph, representing fewer seconds to cover the distance after the intervention period starting at week four (Figure 26).

Figures 25 and 26 show the objective measures of timing of the walk test.

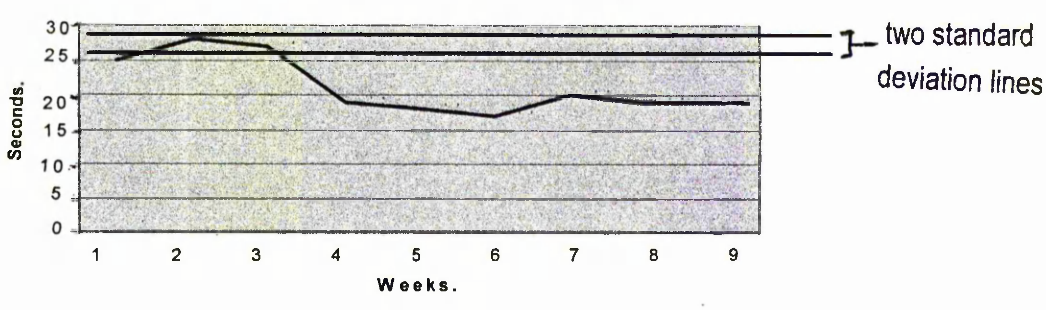


Figure 25. This figure shows the results for P199 of the timing of the walk test, with the two standard deviation lines forming the band.

2 St.Dev Band is calculated from the mean (26.7sec.) of the first three values in phase A (weeks 1-3), and a standard deviation value of 1.5 seconds.

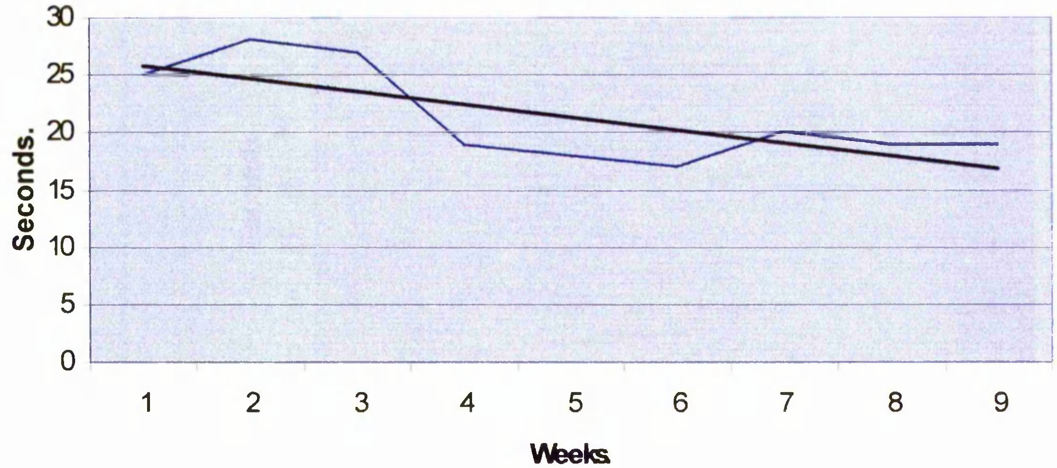


Figure 26. This shows timed walk values and its correlation with the weeks as a the linear trendline (the thick black line) plotted for the timed walk test (thin blue line) of P199 over the nine week period.

Objectively, in phase B, her gait was at a more normal pace: it had speeded up and was more rhythmical on observation. The shuffling seemed to have disappeared as long as she was not "tense" or in a confined space. When given the opportunity of a corridor or pavement to walk along she could then turn safely. This was possible by concentration and moving slowly with confidence. Balance has improved on backward and side-stepping (Panzer and Hallett, 1990).

Table 59 indicates the perceived levels of anxiety, and the timing of a 10 metre walk test in seconds; it demonstrates the change and contributes to the evidence of the effectiveness of the intervention. The 4th row represents a subjective impression of balance by the carer, where * indicates an improvement on the initial visit to the department, at less frequent times than other measures. This revealed statistical significance in the intervention and post-intervention phases. Maintenance of the faster walking speed is shown after the intervention, from weeks 7-9 (Tarantola, Nardone, Taccine and Schiepati, 1993). A two standard deviation band test was produced from the 10 metre walk test (Figure 25); these results were linked with a reduction in the patients' perceived anxiety levels (Ruuskanan and Ruppila,1995) and the carer's observations.

The results show the intervention and post-intervention results of the timed walks as being in

the statistically significant banding, by this type of analysis. The linear trendline in Figure 26 shows the trend in improvement in the Pearson correlation (R squared =0.5421) of speed with time after the intervention which was also being sustained, but not significantly so. Clinically, the increased time for the distance walked was an improvement with some carry over effect from the intervention.

Case 198

Physiotherapy Clinical assessment:

This gentleman was well controlled on minimal levels of medication. He held a high managerial position with a large multinational company, and was most concerned about the way stress affected his performance professionally. His manipulative skills were smooth and accurate, being able to hold a cup and saucer with no apparent problems; he was able to sign his name with considerable concentration. There was evidence of micrographia (Passingham, 1997) during the written part of the MMSE. There seemed to be no evidence of tremor until he performed the research task which included many repetitive elbow flexion movements. The trunk was exhibiting rigidity initially, but this quickly disappeared. His gait presented with a normal rhythm and good stride length, although some hesitation was noted when the corridor became congested, as he hesitated with the side stepping which was needed to negotiate the way. The speed of walking was normal for the conditions and sustainable. This patient had to give a presentation to a weekly business meeting and found tremendous difficulty both prior to the presentation and during it. The Webster rating scale measured 8. The bradykinesia laterality score was equal for both sides. The mini mental status score was 29.

The following problems were identified:

1. stress affecting him and his motor performance deteriorating as a result. He has tried to avoid stressful situations to help this problem.
2. occasional dragging of his left leg when walking distances (he enjoys walking in the hills, and this occurs after a couple of miles), often associated with pain in his instep and tightness of the toes in the left foot (the latter can be improved by stretching the toes).

3. a fear of balance inadequacy especially when descending stairs, if his view was impaired.
4. left shoulder ache and stiffness when medication was wearing off.
5. pain in his hips during lying on his side (in this position at nights). This disappears on moving off the bed.
6. dyspnoea when he was under stress, but never when he was out walking.
7. difficulty sometimes in cognitive activities when under pressure.

Intervention.

Physiotherapy intervention identified: Relaxation therapy (Harrison and Jackson, 1994; Turnbull, 1992). The aims for the intervention of relaxation therapy, to help control breathing and form a strategy for coping with a stressful situation, were discussed with the patient.

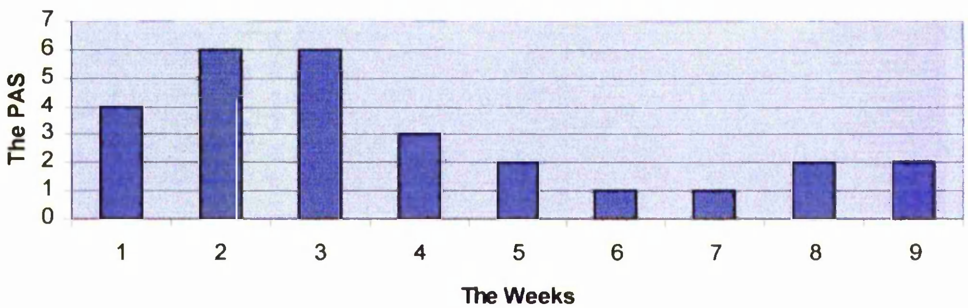
Relaxation therapy: pre-requisites to the therapy were a quiet room and a posture that was initially recumbent and fully supported. The patient was taught diaphragmatic breathing and this was performed at his own pace. The relaxation was taught by reciprocal inhibition, that is by focusing the mind on one small body segment, working peripherally to central areas and allowing each part in turn to "let go and feel heavy" It took half an hour to practice this initially and then, after a week, the patient could recognise any tension and use the method with breathing control to reduce the effects of tension.

The relaxation therapy was taught and practised by the patient, until he was able to employ the strategy at will. This took practice sessions of daily attempts for a week to achieve. He was taught how to utilise the approach (in an abbreviated form) prior to meetings which then acted as a strategy for reducing the anxiety and feelings of general freezing he had perceived previously. The patient was taught to monitor and evaluate his perceived stress levels (Poppen, 1988, Ruuskanan and Ruppila, 1995) and these were recorded as well as the number of freezing episodes (a freezing episode was defined as an interval when the patient was unable to move forward and continue with his speech).

Results.

The results are displayed in the form of Figures 27 (perceived anxiety levels) and 28 (freezing episodes). During and after the treatment intervention the actual numbers of freezing episodes (Figure 28) felt, and the patient's ability to minimise the severity of the anxiety also showed a positive response (Figure 27). The results also show a reduction in the freezing episodes overall, especially during the intervention, which was

Figure 27.



sustained after the intervention phase.

Figure 27 shows a bar chart of the nominal data scores of the perceived anxiety levels (PAS) of the patient, P198.The patient's perceived anxiety levels also showed a similar fall during and after the intervention as was also found by Payton and Nelson (1996).

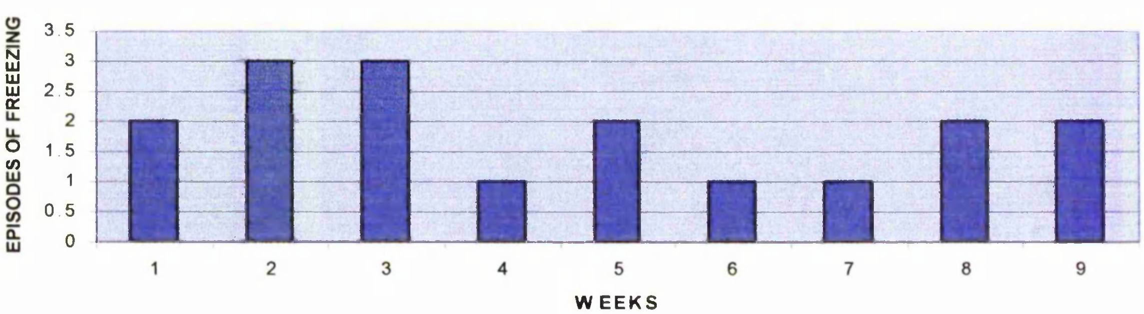


Figure 28 shows the numbers of freezing episodes for patient P198, from the baseline A measurements which were taken weekly at the end of weeks 1, 2 and 3, prior to the intervention of relaxation therapy; during the treatment phase, intervention B, at the end of weeks 4, 5 and 6, following the intervention; and through the second baseline A, at the end of weeks 7, 8 and 9.

The overall aim was to keep the patient in employment, and this objective was achieved, as his firm offered him an 18 months' contract to continue in his role and set up a new overseas branch of the company.

Case P32

Physiotherapy clinical assessment:

This elderly gentleman was a keen gardener in his spare time and found balance to be a problem. He was functionally independent with mobility, and his gait presented with a normal speed, but there was evidence of lack of trunk rotation and arm swing. His cognition was in a normal range at 28 on the mini mental status examination.. The Webster rating score (5) of the general movement features is indicated in Table 59. The bradykinesia laterality score revealed his left upper limb to be the slowest. He experienced the early stages of freezing as he described his feet as "sticking" to the floor on occasions.

The following problems were identified:

1. lack of trunk rotation and reduced arm swing.
2. difficulty with balance when he experienced a freezing incident.

Physiotherapy intervention identified:

1. trunk rotation facilitation, was followed by active rotation exercises (Handford, 1986; Rothwell, 1996; Bridgewater and Sharpe, 1997)
2. the need for a strategy to reduce the effects of freezing, such as sensory cues and mental planning (Payton and Nelson, 1996; Harrison and Jackson, 1994; Crammond, 1997).

Details of the intervention

1. Trunk rotation was facilitated with the patient in a side lying position, incorporating passive and rotational components of movement. One of the physiotherapist's hands was placed over the iliac crest and the other over the scapula region; passive rotation of the upper trunk was produced by gently pushing the scapula anteriorly and cephalically with the pelvis in the opposite direction posteriorly and caudally. At the end of each range slow, light over-pressure was applied. The activity was performed for 10 repetitions on each side (Hollis, 1989; Chan et al, 1993).

Rhythmical passive assistance to walking was provided by the therapist, standing behind the patient, with one hand on the anterior of the pectoral region and the other hand behind the opposite scapula. As the patient started to walk the therapist's hands, acting synchronously, pushed the advancing shoulder of the patient forwards and simultaneously pulled the opposite shoulder backwards. This facilitated rotation of the acting synchronously, pushed the advancing shoulder of the patient forwards and simultaneously pulled the opposite shoulder backwards. This facilitated rotation of the trunk on the pelvis, and a distance of 10 metres was covered (Hollis, 1989; Rothwell, 1996). Active trunk rotation movements were taught to the patient in an upright sitting position and these were repeated 10 times (Handford, 1986).

2. A strategy was taught to the patient for alleviating freezing episodes (Payton and Nelson, 1990; Harrison and Jackson, 1994; Niewboer et al, 1997; Larin, 1997; van Leeuwen and Inglis, 1998). The patient was taught to transfer his weight to the unaffected limb when an episode occurred. He did this initially by recognising the event; secondly by mentally recalling an unlocking prompt, after counting to 5; thirdly, leaning towards the unaffected side, and finally, lifting the 'freed' leg and taking a step as though he were climbing over an object (Bagley et al, 1991). The treatment intervention schedules lasted for a three week period. Baseline A measurements of the Webster scores (WRS) for gait were taken over three weeks, together with a subjective impression of reducing the effects of freezing episodes. Measurements were taken during the intervention phase B, and again at the three week post intervention phase, the second baseline A. The patient was unable to attend more frequently.

RESULTS.

Table 60 indicates the WRS scores and the subjective impression of difficulty with the freezing episodes is also indicated. The results show a very small change in the gait WRS scores with the intervention. There are virtually no validated clinical scores for measuring freezing in a way that would be of use as a clinical tool other than counting the number of episodes or assessing its effect on balance. There was a slight improvement in the WRS for arm swing during the treatment intervention. The value zero score indicates that arm swing has returned and was present in weeks 2, 5, 6 and 7. It is known from the Handford (1986) study, that reduced trunk rotation and lack of arm swing is visibly apparent in PD with slowness of gait

Table 60. WRS measurements for patient P32.

Weeks	1	3	4	6	7	8
WRS: gait	1	2	1	1	1	1
arm swing	1	1	1	0	0	1

Measures of Freezing

Weeks	1	3	4	6	7	8
Subjective impression of freezing episodes	1	2	1	1	1	1

Scores were for both sides, showing an improvement over time in return to arm swing and gait improvements i.e. less shuffling.

KEY to the freezing episodes: 1=mild reaction/no threat to balance;

2= longer problem in time/no threat to balance;

3= threat to balance;

4= balance lost.

Case P31.

Physiotherapy clinical assessment:

This retired gentleman had a keen interest in outdoor activities. He was functionally independent with a minimal resting tremor in his upper limbs. His gait presented with a reasonably slow speed, but there was also evidence of lack of trunk rotation and arm swinging, and the number of steps he used was large, although the step length on visual inspection seemed short. There was some evidence of bradykinesia on manipulative tasks, especially with button fastening, but he was able to achieve these activities. His cognition was in a normal range and he had a good understanding of the problems with which he presented.

The Webster rating score at week 1 was 9 for the general movement features indicated in Table 61. The bradykinesia laterality score revealed his left upper limb to be the slowest, and the mini mental status examination yielded a score of 30.

The following problems were identified:

1. Lack of trunk rotation and arm swing in gait.
2. Difficulty with short stride length and balance.

Physiotherapy Intervention.

1. Trunk rotation facilitation, followed by active rotation exercises (Handford, 1986; Rothwell, 1996; Bridgewater and Sharpe, 1997)
2. Weight transference training and stepping activities (Schenkman et al, 1989b; Payton and Nelson 1990; Harrison and Jackson, 1994).

Details of the intervention.

1. For details of trunk rotation techniques, please refer back to Case P32.
2. Weight transference was taught, for details of these techniques, please refer back to Case P199.

The treatment intervention schedules were facilitated by the therapist and practised by the patient for a three week period. Baseline A measurements of the 10 metre walk test, Webster scores (WRS) for upper extremity swing (UES) and Gait were taken over three weeks, together with a subjective/visual impression of balance. Measurements were taken during the intervention phase B, and again at the three week post-intervention phase, the second baseline A.

RESULTS

Tables 57 and 61 indicate the WRS scores and Figure 29 , the 10 metre walk test results respectively. The results show a reduction in the WRS scores with the intervention, in terms of improvement in arm swing and gait. Subjectively the other features of gait which improved were turning and length of the step. This meant that the observed number of steps over the distance reduced after the intervention and the improvement is shown in Figure 29.

The patient was somewhat reluctant to be overtly measured during his walk testing. The author believes this was because of to his concern that his walking problems were obviously not only in his imagination. The initial hesitancy shown reduced as he became less anxious about the intervention.

Table 61. Measurements for WRS scores of patient P31

Week number	Upper limb swing	Gait	Total WRS upper limb & gait.
1	2	1	3
2	2	2	4
3	2	1	3
4	1	1	2
5	1	0	1
6	0	0	0
7	1	0	1
8	1	1	2
9	1	1	2

Table 62. Measurements of the timing of 10 metre walk test in seconds, hesitation and balance incidents for patient P31.

Week	10 Metre Walk Test, in seconds	Gait hesitation *	Balance incident +
1	16	**	++
2	18	**	++
3	17	**	++
4	15	*	+
5	14	*	+
6	14	*	+
7	15	*	+
8	15	*	+
9	15	*	+

- Key: ** denotes hesitation in initiating gait, * a less pronounced hesitation,

Table 63. The collective assessment of the results.

Patient	Problems	Intervention	Clinical improvement *
P199	Reduced balance, Shuffling gait Anxiety	Weight Transference, Balance retraining, Mental planning	* SS- gait *
P198	Anxiety Panic/ freezing	Relaxation therapy, Strategy development, Mental planning	* *
P32	Reduced arm swing, Trunk rigidity Reduced Balance	Trunk rotation activities, Strategy development, Balance retraining,	* * *
P31	Trunk rigidity Reduced stride length/gait Poor balance	Trunk rotation activities, Weight transference exercises (Repetition and practice).	* * SS-gait *

KEY: The evaluation of physiotherapy:

*- clinically significant = improved function.

SS-gait =improvement in gait was statistically significant (according to the 2 standard band deviation test).

Figure 29 shows a two standard deviation band analysis of the 10 metre walk test results. The mean value of the pre-intervention phase was calculated, to be 17 seconds with a standard deviation of 1 second.

Figure 29. The two standard band deviation graph of P31's walk test.

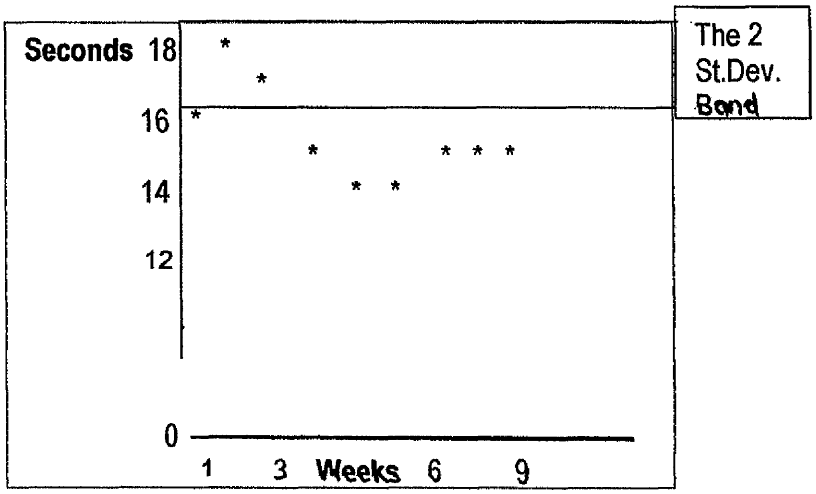


Figure 29 shows the two standard band and the Patient P31's results of the timed walk test over the nine weeks of testing. The mean value of the pre-intervention phase was calculated, to be 17 seconds with a standard deviation of 1 second. The intervention and post intervention values fell below this band, therefore the patient produced a statistically significant (p=0.005) result when the results of the ten metre walk test were subjected to a two standard deviation band test.

The patient maintained a 15 second timing post-intervention and this was associated with a reduced hesitancy and a less frequent problem with balance incidents; he also noticed that his confidence had improved and he felt his balance was much better after the treatment intervention and in the post intervention phase. Subjectively his gait (Potter et al, 1995) appeared more normal after treatment, and he was less hesitant. From observation, the trunk rotation (Bridgewater and Sharpe, 1997) and arm swing (Andou et al, 1993) that was apparent post-intervention, seemed to reduce his former balance problems in gait.

DISCUSSION

The interventions found to be statistically significant were therefore found to be:

Weight transference, balance retraining and mental practice. Table 63 shows the combined results for the evaluation of physiotherapy intervention. The problems for the patients are present in the left hand column, the appropriate treatment is indicated in the next column and the effects are documented as clinically and/or statistically significant (the former, relating to improved functional scores or patient's/carer's perception of improvement and the latter, relating to the 2 standard-band deviation test for significance).

The following section will address some of the issues raised in the single case study research. These issues will vary from the design and operational problems to ethical considerations, patient satisfaction and finally the discussion of individual cases. The theoretical framework that underpins physiotherapeutic intervention in relation to the literature will be considered, in a context that may show the bridge between physical intervention and behavioural changes.

Problems associated with the design.

Common problems associated with the design are the length of the base- line and, overall how many data points can be collected. The larger the number of data points, the more secure the researcher is in drawing conclusions about the effect of treatment not being produced by another variable. Evaluation of the data from the four cases was affected by some ethical and moral issues. These patients, some of whom were elderly, had to travel long distances to the centre and one patient had to minimise his time absent from work, so the author was unable to collect longer runs of data. Several other patients who were initially recruited for single case design studies completed aspects of the process of assessment baselines and treatment intervention, but could not attend for sufficient measures (n=8) during the intervention phase or the post-intervention phase, and had therefore to be excluded from this study. Some difficulty was also experienced in gaining enough data points, at the three phases of the process from the four cases presented, for any rigorous statistical analysis to be undertaken.

Assessing interventions and presenting performance.

Fundamental practice in case study design leads to ways of assessing interventions and presenting performance. The data evaluation phase allows one to draw conclusions about the specific intervention for that patient under those particular circumstances. The evaluation takes place at two levels (Anderson, 1989; Aufdemkampe, 1991) one by visually inspecting the graphic or tabulated display of the data (Barlow,and Hersen, 1988) and the second by using a therapeutic criterion, which refers to whether the effects are important and have clinical significance (Kazdin, 1982). Table 63 shows the interventions having clinical and/or statistical significance. The experimental criterion may show effects in a true sense but these may have no bearing on a patient's increased or improved performance at a functional level. Small changes may be important, and visual inspection may reveal this better than some statistical tests. For example, for a small number of data points the means might reflect no overall change even though a trend has been established.

Statistical considerations.

The following discussion of actual statistical tests and analysis could be followed for an increase in data points. The serial dependency factor may rule out conventional t and F tests to establish significant differences between the phases; behavioural change is multi-faceted and dependency cannot be ruled out. Time series analysis could be considered for detecting significant change in one level and trend to the next. This will compare baselines to the intervention phase. The trend indicates the rate of change from one phase to the next. This type of analysis would be suitable for drawing conclusions about treatment interventions if serial dependency were not an issue.

Ethical issues in single system research.

Ethical issues in single system research come under four headings: risk of harm, loss of therapeutic benefit, informed consent and compatibility with clinical practice (Sim, 1986). The single system tailors the treatment(s) and the outcome measure(s) specifically to the individual patient in terms of content, intensity and frequency to suit the patient. This should redress the balance in favour of the design compared to group research. Another benefit of this research is that minor changes will be found early and can be promptly dealt with. The regular data points can often signal early detrimental changes whereas group research may only measure pre and post intervention. The single study may give a poor response about a treatment to a group of patients, but it will give specific detail about its effects to that one individual patient.

There is always a withdrawal phase in the design; an argument could be opened here, but in clinical practice there are occasions when treatment is not consistent, due to the patient or therapist being off sick or on holiday, or whilst maintenance in the department is taking place which may necessitate changes in venue. Sometimes treatment is withdrawn to see what carry over effect is present.

Informed consent provides a safeguard to the patient, as long as the patient is a competent individual, to allow them to take part in giving the informed consent, basing the decision on adequate understanding of the process and its implications. There is a need for an evaluative and critical approach to therapy (Sim, 1998). Issues come forward such as the relationship between the therapist and patient, which may lead to less objectivity in measurement. Obtaining specific permission to carry out the study is worthy of careful thought.

Social validation of the intervention effects can be considered in terms of subjective evaluation, by the patient, carer or experimenter, or by social comparison methods. This approach has been utilised in case P199.

The individual cases. P199. The comparative approach before and after the treatment intervention, identifies if and how the patient is different after the treatment. The carer noted that the patient was progressing well with the gait re-education (Lord, Halligan and Wade, 1998) and subjectively commented on the apparent more rhythmical movement.

P198. The overall aim was to keep the patient in employment. This objective was achieved as his firm offered him an 18 months' contract to continue in his role and set up a new overseas branch of the company. The reduction in his perceived anxiety levels was of clinical significance. He now had an effective strategy for reducing the effects of his anxiety induced freezing. Patient compliance, his motivational drives being high, and the intellectual ability to take on empowerment were other factors supporting his improvement.

P32. Perhaps with these particular movement disorders, more sensitive measures are needed to show the subtle changes that occur; the patient was adamant that he felt he could cope with freezing and balance problems better after the treatment intervention. A strategy had been devised to use for his freezing episodes and he was able to maintain function and there was a carry over effect after treatment had been withdrawn. The post intervention period showed clinical significance of the effects of treatment. More measurements than in this case would have allowed for better testing of the data points, but one has to balance the equipoise of physiotherapist-clinician with that of physiotherapist-researcher (Sim, 1998). There were more planned measurements than were actually taken in the Case 32. Compliance, goal setting and empowerment were issues that needed to be given more weight in the evaluation of the results for patient P32. Perhaps these aspects of movement disorders need more sensitive measures to show subtle changes, although the patient was adamant that he felt he could cope better with the freezing and the balance problems after the treatment intervention. Long term follow up would identify if this feeling of functional improvement could be sustained, and the use of a functional scale would have been useful for the comparisons across time.

The main benefit in single system research may be that it can be closely tied to a particular patient's needs. Joint goal setting on the part of the physiotherapist and the patient seems to have a motivational effect, as this patient requested further treatment intervention at a later date.

P31. The patient noticed that his confidence had improved and he felt his balance was much better after the treatment intervention and in the post intervention phase. Subjectively, his gait appeared more normal after treatment and he was less hesitant. The trunk rotation and arm swing that were apparent post-intervention seemed to reduce his former balance problems in gait when observed. This patient offered his views that his motor performance was subjectively improved during the intervention phase (accepting that a 30% improvement happens even to patients who are undergoing placebo trials (Twomey, 1996)). He also noted a continued improvement at the post intervention stage. Objective measures showed he sustained the carry over effect. Statistically, the timed walk test showed no significant improvement, but his clinical improvement was in the level of reduced hesitancy and an improvement in his sense of confidence. An increased sense of well-being emerged, and this enabled him to leave the house and walk in the locality to do basic shopping, which he was previously afraid to do. This meant he could be more independent and go each morning for his newspaper and call in at his club to socialise once more. The evidence may lie in quality of life measures rather than objective measuring for some of these patients. He had not previously mentioned his reduction in social contact, this appeared only after the research intervention. This emphasises patient satisfaction issues.

The theoretical base to the interventions.

a) The approach utilised for patients P199 and P32 included mental practice and imagery, which have been proven to be beneficial to neurological patients if normal cognition is present (Van Leeuwen and Inglis, 1998). To facilitate independent motor activity after cerebrovascular accident, Van Leeuwen and Inglis (1998) have shown using brain imaging techniques, that the same areas of the cortex for motor planning and imagery of that movement are active. Crammond (1997) has discussed the identification of mental imagery activating descending motor pathways, and altering the transmission of signals to the cortical afferent pathways. Mental rehearsal of a previous act is possible, but only as it is experienced in practice . Motor imagery is a separate entity from creative imagery (Crammond, 1997). Therefore, patients have to previously experience the movement before they can utilise mental planning.

b) Athletes commonly utilise the motor planning features in preparation for activity. Mental practice has been extensively used in sport, motivation has also been found to enhance this practice to develop skills (Harrison and Jackson, 1994). Mental practice is the "symbolic motor movement" required for these functional tasks. Rehearsal of these tasks has been found to assist patients if practised in the strict way that is laid down, even when the patient is not yet able to deliver the sequences of movement in the real sense.

The capacity of the CNS to develop and undergo plasticity is well documented in head injured patients and the Bobath approach relies heavily on these features to regain normal movement control (Edwards,1996). Physiotherapists utilising sensory cues - visual, auditory and thought - can stimulate activity in the patient with damage to the basal ganglia, and mental practice appears to be an extension of this approach. Some cells in the SNpc can be activated for motor action by an appropriate cue, if the cue appears within a period of less than one second, between the waiting period between the cue and the required motor action (Kandel et al, 1991). The counting in of patient P199 for timing to change direction of her movements may be facilitated by this route.

c) Training by practice, and specific training techniques were experimentally shown to be significant in the study by Platz et al (1998). Subjects in this experiment were also tested with auditory cues and the authors commented on a lack of improvement in the task. It could be that the task became too complex as these patients are known to have difficulty producing complex patterns at one time (Lazarus and Stelmach, 1992). Practising (repetition) was found to lead to an increased speed of specifically trained movements, with no corresponding reduction in accuracy. This theory underlies the Carr and Shepherd (1992) approach to motor relearning, utilising repetition and careful instructions with feedback of performance (Kinsman,1990). Soliveri et al (1992) found PD patients able to learn with practice, although they needed more time to achieve the similar response levels to normals. Cues have been found to assist many patients with PD (Martin et al, 1967; Bagley et al, 1991; Niewboer et al, 1997). The use of cues as strategies enabled patients P199, P32 and P198 to improve their performance.

Motor learning concepts (Carr and Shepherd, 1992; Cohen, 1993; Larin, 1997) and theory are being brought into use, and the relevant aspects were applied to the patient in case study P199. The Platz et al (1998) study supports the therapist who keeps to clear, simple instructions when teaching the PD patient motor strategies. The aspects of retention and transfer of advice to functional situations were employed. The main features were clarity of practise of the goals and the context in which they were practised (Larin, 1997). Kamsma et al (1995) advocate compensational motor strategies for these patients. Gross motor skills become problematic in PD patients and the difficulties in the raising of the body from sitting to standing or turning are typical. Transfer of skills has to be compensated for and this approach has shown significant improvements. When intensive training of general exercise strength and reorganisation of functional training was carried out, there was found to be consistent improvement by video analysis, together with an increased results with rating scales and application to daily life scenarios (Carr and Shepherd, 1992; Kamsma et al, 1995). The clinical significance is thus demonstrated.

d) Trunk muscle training is supported by Bridgewater and Sharpe (1997) for recently diagnosed patients, whose torque values increased over the period of twelve weeks, although the clinical scales showed no changes. Possibly such scales are not sensitive enough to detect these specific changes where benefits were clinically significant, as the aerobic activity had improved. The chronic degenerating condition may be held on a plateau rather than show increases on the scales, as the control group showed no such changes. Changes in improvement of grip strength, gait speed, and motor co-ordination have been noted; some of these objective measures have been used in the case studies previously described.

e) Trunk rotation and facilitation, applied to patients P199 and P31, may have its underlying theory in the way the cells of the putamen function. Kandel et al (1991) report that half of the putamen cells are related purely to the direction of movement, and the others to the forces that are generated in these movements. Delong (1987) reveals that the putamen neurones in trained monkeys respond to simple motor acts. Passively-imposed loads (as the therapy technique would produce) are directionally sensitive and may be used by the putamen to influence on going movements. Rothwell (1995) links the transmission from passively activated deep pressure receptors, to inhibition on the contra-lateral side of the basal ganglia. (Environmental chemicals i.e. MPTP, can alter the receptive fields of these inputs, which may explain one way in which motor control under these conditions is affected). Most neurones from the motor loops from the putamen fire to adjust the next phase of the movement rather than to initiate a movement, and may update cortical programmes. Trunk rotation is visibly reduced in PD in slow walking (Handford, 1986), and the approach used to facilitate movement by the therapist's hands in a passive way produces an increase in the available rotation for the patient. Could there be a link between the facilitation techniques and the stimulation of deep receptors leading to reciprocal inhibition?

In the patient P31, with bilateral involvement and reduced arm swing, there may be a problem of contra-lateral neglect from the damaged dopaminergic pathways. Thus, cueing and mental planning may be able to trigger arm movements by routes other than the ganglia-thalamo-cortical route to stimulate motor activity. Pelvic rotation was an important aspect in the treatment of patients P199 and P31, and results from the study by Chan et al (1993), indicate that improvement in rotation led to step and stride length increases in gait, whilst walking speed in normals correlated to arm swing, with the elbow being flexed.

f) Balance retraining was a common feature identified in several patients. Patients P199, P32 and P31 all had balance problems. Panzer and Hallett, (1990) concluded that they found no evidence of postural instability being concurrent with normal ageing. The risk factors for falling include cognitive impairment, sedentary lifestyles, abnormal control of the musculo-skeletal system, some or all of which may be present in the PD patient. Danis et al (1988) and Weller et al (1992) consider the assessment of the risk of falls to be related to the base of support and its distance from the centre of gravity. The difficulty of foot separation and a large base of support was a feature of patient P199. This patient had a great fear of transferring weight to the opposite foot prior to the stance phase in gait, for the advancing limb to be allowed to lift off the floor following the push-off phase. There was no evidence to support (Williams et al, 1994) that a broader base with advancing age was the norm: conclusions suggest that in PD, poor foot separation when turning may be the cause of the falls. The risk of falls, and their consequent disastrous problems, is a major obstacle to these patients.

The control of balance and posture has many components and is individualistic (Berg et al, 1989; Duncan et al, 1992; Bohannon and Leary, 1995). The body has a natural antero-posterior and lateral sway coefficient. If this is maintained, balance is dynamically safe (Williams et al, 1994). For an individual patient the aim will be to assess the underlying problems. Studies reflect the findings of postural sway being increased in both standing balance (Panzer and Hallett, 1990; Bohannon and Leary, 1995), and sitting balance (Ashburn, 1996). Searching for a strategy to overcome the excess postural sway and maintain balance continues. Central integration of proprioceptive inputs with repetition of trials helps to improve balance and reduce postural sway (Patti et al, 1996).This theoretical basis was found to assist patient P32 in his treatment. Exercise groups showed an improvement in all measures of balance (Shumway-Cook et al, 1997), and the amount of exercise was variable for each patient. The tailoring of individual exercise programmes was supported as described the case studies. Muscle strength is reflected in gait speed and may be considered an outcome measure (Wade, 1994; Potter et al, 1995) together with other functional scales in assessment. Balance is a contributory factor to gait speed in the elderly (Bowes et al, 1992; Williams and Vandervoort, 1996) and, allowing for age, some patients seem to develop it as a strategy to compensate for other deficiencies, to prevent a de-stabilising movement. There are documented age related changes for side stepping in gait and patient P199 (Bowes et al, 1992; Gilchrist, 1998). These show similar features to the patient where quick and accurate side shifting was not possible and this may be a reason for the balance disturbance. The training and practice of this simple activity resulted in a significant improvement in function.

g) Patient satisfaction with rehabilitation services is enhanced when they are allowed to take responsibility in planning the goals of their treatment towards areas or degrees of independence and progress (Keith, 1998). Satisfaction is a multi-dimensional aspect that is difficult to measure. Patient and carer satisfaction is extremely important to rehabilitation as active involvement by the patient, and often the family, leads to an improvement in the patient's functioning. The greatest satisfaction levels revolve around the patient who receives adequate information and quality of care, humaneness in approach and practitioner competence (Keith, 1998).

Conclusions.

1. These findings reflect the need for larger national studies to identify, beyond doubt, the benefit of physiotherapeutic intervention across individuals with PD, and then to test the results in a randomised control trial. This will enable evidence based practice to be established.

2. Some of the interventions produced significant results for these patients. However the low (but acceptable) numbers of data points may generally threaten the validity of these results.

3.The findings of the single system design enable the conclusions to be drawn for that patient at a particular stage in the disease process but they are not generalisable to a large population. Single system design may be appropriate to the study population, as patients may be seen for treatment over a period of time. Suitable interventions can be assessed for these individuals (Jette, 1995), as opposed to group studies where the results tend to fall towards the average effects, and individual benefit may not be apparent for that one patient.

4. Suitable rating scales need developing to efficiently test the level of a patient's anxiety. Use of validated scales will enhance the results.

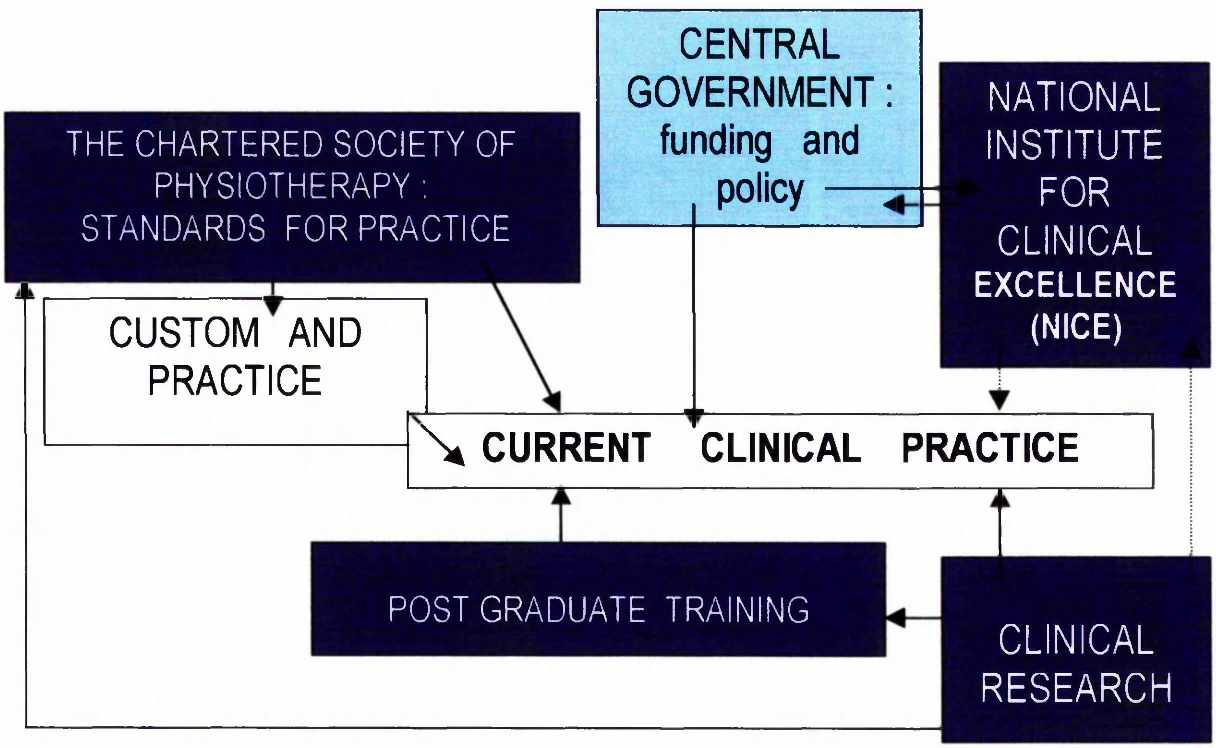
5. An average case load was identified for therapists in the Lövgreen et al (1998) study of 11 PD patients. This would preclude numbers available for larger group studies in the clinical field, therefore supporting single case design, n=1 research, in the field.

Further discussion is concluded in chapter 5, as implications for physiotherapy

"Patients and their families place trust in the health professionals. They need to be assured that their treatment is up-to-date and effective and is provided by those whose skills have kept pace with new thinking and new techniques" (HMSO, 1998).

There are many factors influencing physiotherapy practice for Parkinson's disease (Figure 30) and several of these such as governmental policy and central funding (broader issues) are outside the scope of this thesis. The final chapter presents a new theoretical framework addressing the implications for physiotherapy practice as identified in terms of the research observations from the thesis linking the relationship of these findings to evidence based health care (Figure 30 and Table 64) and clinical governance (Table 65). The implications of the research findings for developing a new framework will influence future physiotherapy practice. The chapter concludes with the author's plans as a pathway to the future.

Figure 30. **The influences on current practice.**



The dotted arrows represent future sources of influence which will be different from this and previous years. The blue boxes indicate potential points of changing future practice.

From the survey findings issues are highlighted (Table 64) (i) access and referral practice, (ii) treatment approaches and outcome measures, (iii) the need for post graduate training, and (iv)consensus from the Delphi concerning accepted and preferred practice. The experimental neuroscientific findings demonstrate poor performance in patients, with issues related to the bilateral force generation and sensory discrimination, with increased demands on attentional and visual aspects in performance. All the issues contribute towards the new theoretical framework via the routes of the National Institute for Clinical Excellence (N.I.C.E.) and postgraduate training (Figure 30).

From the thesis and its associated study have emerged several issues.

Issues (1-4) related to the neuroscience experiments are summarised from chapter 3.

1. Reinforcing the advice given to patients about functional strategies to compensate from the lack of effective proprioception. Patients may benefit more from visual cues to encourage/facilitate proprioceptive integration and to allow for the re-calibration of proprioception.
2. Implications for encouraging the "use of the good side" now may not be appropriate, as the bilateral decision process has been found to be defective.
3. A limiting factor to the so called " neurophysiological approaches" such as the Bobath technique may have to be rethought in its use for patients with basal ganglia lesions.
4. An attentional issue will need to be considered in any approach used in therapy sessions.

Issues related to postgraduate training (5), referral practice (6) and an eclectic approach (7) were identified from chapters 2 and 4.

5. The lack of certainty in the theoretical knowledge of therapists was identified together with managerial support for the therapists to train, as appropriate ways could be identified for this training.

6. Self referral by the patient at any stage of the disease was deemed to be the desired way for referral, as was early carer involvement. Both these parties were found to important in being involved with the professionals as goal setters in the patient's management.

7. Aspects of intervention detail, for example an eclectic approach, use of cues and rotation exercises, were identified in terms of physiotherapy treatment desired at all stages in the disease process, backed by home exercises and written information.

These issues and approaches therefore, are highlighted as recommendations for changing practice (Table 64). The pathway to facilitate this change is indicated in Figure 30, where new evidence can be disseminated at post graduate training events, conferences and by publication. Evidence can be collated into the production of guidelines for practice by N.I.C.E. and then utilised by the professionals. With the inception of the new Patients' Charter the intentions of the political machinery may be revealed. Policy invariably has political dimensions, decisions will not be based on evidence alone but will respond to funding allocations, the desire of politicians to curry favour with the electorate, and national social policy (Bury and Mead, 1998). It will be many years before this philosophy of evidence-based medicine can be soundly implanted into the NHS. Health outcomes in the NHS require resources to be used in reducing risk factors, and levels of disease, minimising impairment and complications of treatment, and in improving the quality of life for patients and carers. Sensori-motor interaction has given neuroscientists a "window" into CNS functioning. The proliferation of new ideas and technology over the last few years on the nature of proprioceptive feedback in natural behaviour will continue to be investigated. The results from the neuroscience research must be transferred to benefit the patients. Physiotherapeutic techniques and approaches utilise basic neuroscientific information.

The implications for practice, from the evidence found in the research undertaken by the author (and from the supporting literature) will enable a change in practice as evidenced based treatment. The literature studied alongside the experiments and case studies has also supported the results so a change in practice can be postulated and transferred to physiotherapeutic intervention.

Table 64. BASIS TO INFLUENCE A CURRENT PRACTICE FRAMEWORK FROM THIS THESIS.

Patient issues:

(i) early referral being advocated.

(ii) treatment approaches utilising sensory cues (visual, auditory and mental planning).

(iii) relaxation therapy being incorporated .

(iv) an eclectic approach favoured, rather than neurophysiological approaches.

(v) written advice and exercise details.

(vi) repetition and practice with feedback.

(vi) patient and carer involvement in planning goals.

Professional issues:

(vii) professional post graduate training being routinely established.
(viii) development of national guidelines for practice.

The professional issues of establishing post graduate study as continued professional development (CPD) will become mandatory by law during the year 2000 to maintain state registration. The demand from CPD at this level of training can be facilitated by clinical research (Figure 32 and Table 65). The production of guidelines for practice is now formally being taken by the N.I.C.E. committee and will form the basis of clinical governance.

The delivery of quality standards in the NHS was laid down in the White Paper (HMSO, 1998). Table 65 is modified from the White Paper (HMSO, 1998) and shows the flow from the required inputs, to the outcomes demanded by the Department of Health. "Clinical governance" is the term that now supersedes the well-used term of "quality " in the NHS. The emphasis is still on quality, but is wider-reaching as it now includes the financial element within the NHS. This framework sets the accountability of the NHS for constantly be upgrading and safe-guarding standards to provide high quality care for the patients (HMSO, 1998).

The ideas from clinical governance are summarised in Table 65. The underlying philosophy is that excellence in clinical care will flourish. Twenty five years ago the Cochrane report highlighted the thoughts that indicated the low degree to which medical practice was based on robust research which could demonstrate clinical effectiveness. A gap was identified. This situation has continued, but there is now a shift away from the consensus of tradition and a move towards an evidence base for healthcare. What exactly is the evidence? Clinicians may give weight to their own experience rather than the research of scientists who work on the basis of average responses (Grayson, 1997): the evidence base is only as powerful as the foundation it serves to justify.

Table 65. THE CLINICAL GOVERNANCE STRATEGY.

Input sources	**Requirements**	**Outcomes**
National Institute for Clinical Excellence Frameworks	Clear standards of service models **(EVIDENCE- BASED PRACTICE)**	Dependable local delivery
Patient and public involvement	Professional self regulation	Monitoring of standards
Staff input	Professional lifelong learning	**CLINICAL GOVERNANCE**

Concluding Remarks.

The literature searches, associated studies and experiments have highlighted a link between an evidence base in the neuroscience and some treatment approaches in physiotherapy for patients with Parkinson's disease. The research and skill acquisition must continue to provide the best service for these patients. Until a cure can be found for this disease physiotherapy is emerging as an appropriate addition to the pharmacological intervention for these patients, and their carers.

A pathway to the future.

The future clinical and research plans are now considered. This relates to the development and management of a centre of excellence for physiotherapy intervention in PD in the UK.

(i) Clinical implementation.

Clinically the implementation of standardised assessment formats and therapeutic interventions, such as exercise programmes will receive credence from the PEP evaluation study and highlight the best practice. From this will be defined the continuing research questions to be addressed for these patients' interventions. Clinical guidelines are currently being considered and it is planned to formulate these and submit them to N.I.C.E.

(ii) The research front.

On the research front there are two immediate leads which the author would like to follow. Firstly, the use of cues to facilitate movement control. Preliminary work on protocols and early piloting have been undertaken by the author in the implementation of auditory cues in the guidance of movement. In particular, techniques were developed for the assessment of the parameters of gait in patients who exhibit freezing problems with walking. The research will facilitate the continued identification of the theory of underlying physical and neuroscientific principles of treatment.

There is apparently an interesting gap found in the literature and in also clinical practice. This gap concerns respiratory care for the PD patients, as many have critical episodes with respiratory complications being cited as a major cause of death in these patients. An obvious and simple investigation could assess the benefits of physiotherapy in reducing the respiratory problems which are a secondary complication of this disease. Such respiratory problems result if untreated, in a flexed immobile thorax and severely-reduced lung volumes with minimal expansion, and weakness of expectoration contributing to the distress.

A centre of clinical excellence.

A specialist education centre for under-graduate and post-graduate and multidisciplinary team members is envisaged as being part of the remit to be proposed by the author. The establishing of a centre of clinical excellence in the region would allow the pooling of available expertise and the development of the appropriate services to cater for the rehabilitation of neurological patients. The centre would be a focal contact for clinicians as an evidence-based facility in the NHS. Culham (1998) highlights the concern that the links between researchers and clinicians need strengthening if the profession is to remain credible in healthcare provision.

BIBLIOGRAPHY.

Ada,L., Canning,C. (1990) Key Issues in Neurological Physiotherapy. Chap 1. Butterworth Heinemann. London.

Alexander,G.E., Crutcher,M.D. (1990) Functional architecture of basal ganglia circuits: Neural substrates of parallel processing. Trends Neurosci.vol:13:266.

Alexander,G.E., Delong,M., Crutcher, M.D. (1992) Do cortical and basal ganglionic motor areas use "motor programmes" to control movement? Behav. Brain Sci. vol:15:656-70

Anderson, A.J.B. (1989) Interpreting data. Chapman and Hall. London.

Andou,M., Kurosawa,K., Maruyama,H., Kosaka,K., Fujita,N., Yamanishi,T. (1993) Relationship between arm swing and walking function. Phys. Ther. Sci. vol:5:51-54.

Armstrong,D.M. (1988) The supraspinal control of mammalian locomotion. J. of Physiol. vol: 405: 1-37.

Association of Chartered Physiotherapists with a Special Interest in Elderly People. (1991) Physiotherapy and older people. Standards of Clinical Practice. Chartered Society of Physiotherapy. London.

Association of Chartered Physiotherapists Interested in Neurology. (1995) Standards of Physiotherapy Practice in Neurology. Chartered Society of Physiotherapy. London.

Aufdemkampe,G. (1991) Some comments on single case studies. Physio. Theory and Practice vol:7: 63-71

Bagley,S., Kelly,B., Tunnicliffe,N., Turnbull,G.I., Walker,J.M. (1991) The effect of visual cues on the gait of independently mobile Parkinson's disease patients. Physio. vol.77: 8-11.

Baker,M., Fardell,J., Jones,B. (1997) Disability and rehabilitation. Survey of education needs of health and social service professionals, open learning project. Sage Pub. London.

Barlow,D.H., Hersen, M. (1988) Single case experimental design. 2nd edit. Pergammon press. London.

Barnes,M.P. (1997) Standards in neurological rehabilitation. European federation of neurological societies task force. European J. of Neurol. vol.4: 325-331.

Baron,M.S., Vitek, J,L., DeLong M. (1996) Treatment of advanced Parkinson's disease by posterior GPi pallidotomy: results of a pilot study. Ann. of Neurol. vol. 40 : 355-366.

Barriball,K.L., Christian,S.L., While,A.E., Bergen,A. (1995) The telephone survey method: a discussion paper. J. of Adv. Nurs. vol:4: 115-121.

Basmajian,J.V. (1984) Therapeutic exercise. 5th.edit. Williams & Wilkins. London.

Bate,P. (1997) Motor control theories- insights for therapists. Physio. vol 83: : 11-14.

Beckley,D.J., Panzer,V.P., Remler,M.P., Ilog,L.B., Bloem,B.R. (1995) Clinical correlates of motor performance during paced postural tasks in Parkinson's disease. J. of Neurol. Sci. vol:35:133-138.

Beheshti,Z. (1993). Neurophysiological basis of rhythmic limb movements in humans. Physiotherapy. vol :79 : 31-35

Benecke,R., Rothwell,J.C., Dick,P.R., Day,B.L., Marsden,C.D. (1986) Performance in simultaneous movements in patients with Parkinson's disease. Brain. vol:109 :739-757.

Benecke,R., Rothwell,J.C., Dick,P.R., Day,B.L., Marsden,C.D. (1987) Disturbance of sequential movements in patients with Parkinson's disease. Brain. vol:110:361-379.

Berardelli A., Dick, J.P.R., Rothwell JC., Day B.L., Marsden C.D. (1986) Scaling of the size of the first agonist EMG burst during rapid wrist movements in patients with Parkinson's disease. J of Neurol. Neurosurg. and Psych. vol:49:1273-9.

Berg K.O., Wood-Dauphinee S., Williams J.I., Gayton D. (1989) Measuring balance in the elderly. Physio.Canada. vol: 41.304-311.

Berlucci, G., Aglioti. (1997) The body in the brain: neural bases of corporeal awareness. Trends Neurosci. vol:20: 560-564.

Binder, M,D., Kroin, J.S., Moore, G.P., Stauffer, E.K., Stuart, D,G. (1976) Correlation analysis of muscle spindle responses to a single motor unit contraction. J. of Physiol. vol:271: 337-349.

Bjordal, J.M., Greve, G. (1998) What may alter the conclusion of reviews? Phys.Ther.Rev. vol:3:121-132

Blin,O., Ferrandez,A.M., Pailhous,J., Serratrice,G. (1991) Dopa- sensitive and dopa-resistant gait parameters in Parkinson's disease. J. of Neurol. Sci. vol: 103: 51-54.

Bohannon, R.W., Leary,K.M. (1995). Standing balance and function over the course of acute rehabilitation. Arch Phys Med Rehabil. vol :76: 112-134.

Bousfield, C. (1997) A phenomenological investigation into the role of the clinical nurse specialist. J. Adv. Nurs. vol: 25: 245-256.

Bowes, S.G., O'Neil,C.J.A., Dobbs,R.J., Dobbs,S.M. (1994) Bradyphrenia and Parkinsonism. Age and Ageing. vol: 23:1-2.

Bowes, G., Charlett,A., Dobbs,J., Lubel,D.D., Mehta,R., O'Neill,C.J.A., Weller,C., Hughes,J., Dobbs,S.M. (1992) Gait in relation to ageing and ideopathic parkinsonism. Scand J. Rehab. Med vol:24:181-186.

Boyd, I.A., Roberts, T,D,M. (1953) Proprioceptive discharges from stretch receptors in the knee joint of the cat. J. of Physiol. vol:122: 38-58.

Bridgewater,K.J., Sharpe,M.H. (1997). Trunk muscle training and early Parkinson's disease. Physiotherapy Theory and Practice. vol: 13:139-153.

Brodie, E.E., (1989a) Manual asymmetry in weight discrimination; hand or spatial field advantage? Perception. vol: 18: 397-402.

Brodie, E.E., (1989b) Manual asymmetry in weight discrimination; hand preference or hemsipheric specialisation. Cortex. vol: 25: 417-23.

Brotchie,P., Iansek,R., Horne,M.K. (1991) Motor function of the monkey globus pallidus. Papers 1&2. Brain. vol: 114: 1667-1702.

Brown,P., Corcos, D.M., Rothwell,J.C. (1997) Does parkinsonian action tremor contribute to muscle weakness in Parkinson's disease? Brain. vol: 120: 401-408.

Burgess,P.R., Wei, J.Y. (1982) Signalling of kinaesthetic information by peripheral sensory receptors. Ann. Rev. Neurosci. vol: 5:171-87.

Burke,D., Hagbarth, K., Lofestedt, L., Wallin, B., G. (1976) Response of human muscle spindle endings to vibration during an isometric contraction. J. of Physiol. vol: 261: 695-711.

Burke,D., Hagbarth, K., Lofestedt, L. (1978) Muscle spindle responses, in man, to changes in load during accurate position maintainance. J. of Physiol. vol: 276: 159-164.

Bury, T., Mead, J. (1998) Evidence based healthcare. Butterworth Heinemann, Oxford.

Caligiuri,M.P, Heindel,W.C., Lohr,J.B. (1992) Sensorimotor disinhibition in Parkinson's disease: Effects of levodopa. Ann Neurol. vol: 31:53-58.

Carey,L.M., Oke,L.E., Maytas,T.A. (1996) Impaired limb position sense after stroke: A quantitative test for clinical use. Arch Phys Med Rehabil. vol: 77:45-51

Carey J.R., Burghardt T.P. (1993) Movement dysfunction following central nervous system lesion: A problem of neurologic or muscular impairment. Physical Therapy. vol: 73:538-547.

Carpenter,M.B. (1981) Anatomy of the corpus striatum and brainstem integrating systems. In

Brooks, V.B., (Ed) Handbook of physiology. Section 1, vol 2. p 947-994. Pub.FA Davies, California.

Carr,J.H., Shepherd,R.B. (1992) Foundations for physical therapy. Heinemann, London.

Chan,C.W.Y. (1986) Could Parkinsonian akinesia be attributable to a disturbance in the motor preparatory process? Brain research. vol: 386:183-196.

Chan,J., Lee,J., Neubert,C. (1993) Physiotherapy intervention in Parkinsonian gait. NZ Journal of Physio. vol: 5:21-27.

Chatterton,H., Lövgreen,B. (1999) Physiotherapy management of the elderly patient with Parkinson's disease. (Ed) Meara,J., The management of the elderly patient with Parkinson's disease. Cambridge Univ. Press. In Press.

Chen,T.C.H. (1997) Reciprocal inhibition in Parkinson's disease. Acta Neurol Scand. vol: 95:13-18.

Chesson,R., Macleod,M., Massie,S. (1996) Outcome measures used in therapy departments in Scotland. Physio. vol :82 : 25-31

Chevalier, G., Deniau,J.N. (1990) Disinhibition as a basic process in the expression of striatal function. Trends Neurosci. vol: 13:277-280.

Chouza, C., Scaramelli, A., Aljanati, R., de Medina, O., Coamano, J.L., Lorenzo, J., Romero, S. (1986) Sensorimotor disturbances in Parkinson's disease: index finger test. In Yahr, M.D., Bergamann, B., editor, Ad.Neurol. vol: 45. New York : Raven Press.

Clark,F., Burgess, P.R. (1986) Proprioception with proximal interphalangeal joint of the index finger. J. Neurophys. vol: 42: 877-888.

Cody,F,W,J., Lövgreen,B., Schady W. (1990a) Proprioceptive guidance of human voluntary wrist movements in normal subjects and cerebellar disorders. Neuroscience letters, Suppl.38: S.44.

Cody,F,W,J., Lövgreen,B., Schady W., Richardson,H. (1990b) Proprioceptive control of human voluntary wrist movements studied in healthy subjects and patients with cerebellar dysfunction.J of Physiol. vol:6: 429: 37P

Cody,F,W,J., Lövgreen,B., Schady W. (1991) Human visuomotor tracking in cerebellar dysfunction. Communication Physiological society. J of Physiol. vol: 6:C26.

Cody,F,W,J., Lövgreen,B., Schady W. (1993) Increased dependence upon visual information during visuomotor tracking in cerebellar disorders. Journal of Electroencephalography and Clinical Neurophysiology. vol: 89: 399-407.

Cody,F.W.J. (1995) Neural control of skilled human movement. (Ed) Studies in Physiology. Portland Press

Cohen,H. (1993) Neuroscience for rehabilitation. J.P.Lippincott. London.

Collen,F.M., Wade, D.T., Robb, G.F. (1991) The Rivermead mobility index. Clinical rehabilitation vol: 12:107-119

Collins, W. (1965) The New National Dictionary. William Collins and Sons Ltd. London and Glasgow.

Comella,C.I., Stebbins,G.T., Brown-Toms,N., Goetz,C.G. (1994) Physical therapy and Parkinson's disease: A controlled clinical study. Neurol. vol: 44:376-378.

Corcos,D.M., Chen,C.M., Quinn,N.P., McAuley,J., Rothwell,J.C. (1996) Relationship of strength to rate of force in Parkinson's disease. Ann of Neurol . vol: 39:79-88.

Corso,J.F. (1970) The experimental psychology of sensory behaviour. Holt, Rinehart and Winston. London.

Cornsweet, T.R. (1962) The staircase method in psychophysics. Am. J. of psychology. vol: 75: 485-491.

Corwin,T.R., Kintz,R.T., Beaty,W.J. (1979) Computer aided estimation of pschophysical thresholds by Wetherill tracking. Behaviour Research Methods & Instrumentation. vol: 11: 526-528.

Crammond,D.J. (1997) Motor imagery: never in your wildest dream. Trends in Neurosci. vol 20: 54-57

CSP (1997) Working party doc. Clinical Effectiveness Strategy. August. C.S.P. London.

Culham,E. (1998) Evidence based practice and professional credibility. (Editorial) Physiotherapy Theory and Practice. vol: 14: 65-67.

Cutson T., Laub K C., Schenkman M. (1995) Pharmacological and nonpharmocological interventions in the treatment of Parkinson's disease. Physical Therapy. vol: 75(5): 363-373.

Daly,E.L., Bourke,G.J., McGilvray. (1992) Interpretation and uses of medical statistics. Blackwell scientific .London

Danis,C.G., Krebs,D.E., Gill-Body, K.M., Sahrmann,S. (1988) Relationship between standing posture and stability. Physical Therapy. vol: 78, no. 5.

Danziger, W.L., Botwinick, J., (1980) Age and sex differences in sensitivity and response bias in a weight discrimination task. J. Gerontology. vol: 35: 388-394.

Day,B.L., Marsden,C.D. (1984) Patients with Parkinson's disease can employ a predictive motor strategy. J. of Neurol. Neurosurg. and Psych. vol: 47: 1299 -1306.

Day,B.L., Marsden,C.D., Obeso, J.A., Rothwell, J.C., Traub, M.M. (1981) Manual motor function in deafferented man. Physiological Society conference presentation. vol: 7: 23 - 4.

De Domenico,G., McCloskey,D.I. (1985) Accuracy of voluntary movements at the thumb and elbow joints. Exp.Brain Res.. vol: 65:471-478.

De Rijk,M.C., Tzourio,C., Breteler,M.M.B., Dartigues,J.F., Amaducci,L., Lopez-Pousa, S., Manubens-Bertran,J.M., Alperovitch,A., Rocca,W.A. (1997) Prevalence of Parkinsonism and Parkinson's disease in Europe: the Euro-Parkinson collaborative study. J. of Neurol. Neurosurg.and Psych. vol: 62:10-15.

Demirci,M., Grill,S., McShane,L., Hallett,M. (1997) A mismatch between kinesthetic and visual perception in Parkinson's disease. Ann Neurol. vol: 41:781-788.

Dick,J.P.R., Rothwell J.C., Day, B.L., Cantello, R., Buruma, O.,Gioux M. (1989) The Bereitschaftpotential is abnormal in Parkinson's disease. Brain vol: 112:233-44.

Dixon,W.J., Mood,A. (1948) A method for obtaining and analysing sensitivity data. J. of the American Statistical Association. vol: 43: 109-126.

Duncan,P.W., Weiner,D.K., Chandler,J., Studenski,S. (1990) Functional reach: A new clinical measure of balance. J. of Gerontol. vol 45(6): M192-197.

Duncan,P.W., Studenski,S., Chandler,J., Prescott,B. (1992) Functional reach: Predictive validity in a sample of elderly male veterans. J. of Gerontol. Vol: 47(3); M93-98.

Dunne,J.W., Hankey,G.J., Edis,H.E. (1987) Parkinsonism:Upturned walking stick as an aid to locomotion.Arch Phys Med Rehab. vol:68: 67-74.

Durward,B., Baer,G. (1995) Physiotherapy and neurology: Towards Research- based practice. Ed. Physio. vol 8:25-32.

Edstrom, L. (1970) Selective changes in sizes of red and white muscle fibres in upper motor neurone lesions and Parkinsonism. J. Neurol. Sci. vol: 11:537-550.

Edwards,S. (1996) Abnormal tone and movement as a result of neurological impairment; considerations for treatment. Neurological Physiotherapy. A problem solving approach. Ed. Edwards S. London. Churchill Livingstone.

English, I. (1993) Intuition as a function of the expert nurse. A critique of Benner's novice to expert model. J. of Adv. Nurs. vol: 18: 387-393.

Evarts,E.V., Fromm, C., Kroller, J., Jennings, V.A. (1983) Motor cortex control of finely graded forces.J. Neurophysiol. vol: 49: 1199-1215.

Evarts,E.V., Teravainen,H., Calne D,B. (1981) Reaction time in Parkinsosn's disease. Brain vol: 104: 167-186.

Fechner,G., (1860) In D.H.Howes and E.G. Boring (eds) Elements of Psychophysics, vol.1. H.E. Alder (trans) New York. Rinehart and Winston,1996.

Filion M., Tremblay, L. (1991) Abnormal spontaneous activity of globus pallidus neurons in monkeys with MTPT-induced parkinsonism. Brain Res. vol: 547:142-151

Flanagan,R.J, (1996) Judging hand held loads. Chap 20, Hand and Brain, Eds.Wing, A.M., Haggard, P., Flanagan, R,J., California Academic Press.USA.

Fleury,M., Bard,C., Paillard,J., Cole,J., Lajoie,Y., Lamarre,Y. (1995) Weight judgement- The discriminatory capacity of a deafferented subject. Brain. vol: 118:1149-1156.

Flowers,K.A. (1976) Visual closed and open loop characteristics of voluntary movement in patients with parkinsonism and intention tremor. Brain. vol: 99:263-310

Flowers,K.A. (1978) Lack of prediction in the anticipatory behaviour of parkinsonism. Brain. vol: 101:35-52.

Flick,D., Uwe. T. (1998) An introduction to qualitative research. Sage publications. London.

Folstein,M.F., Folstein,S.E., McHugh,P.R. (1975) Mini-mental state. A practical method for grading the cognitive state of patients for the clinician. J. Psychiat. Res. vol 12:189-198.

Fosnam, H. (1998) Boosting Research at the CSP. Frontline. Feb.18th p10.

Fournier, E., Katz, E., Pierrot-Deselligny, E. (1983) Descending control of reflex pathways in the production of voluntary isolated movements in man. Brain Research. vol: 288: 375-377.

Franklyn,S. (1986) User's guide to the physiotherapy assessment form for Parkinson's disease. Physiotherapy. vol:72:17-21.

Fredericks C.M., Saladin L.K. (1996) Pathophysiology of the motor systems. Pub. FA Davies, California.

Freeman,J.S., Cody,F.W,J., Schady,W. (1993) The influence of external timing cues upon the rhythms of voluntary movement in Parkinson's disease. J. of Neurol. Neurosurg. Psychiat., vol: 56:1078-1084.

Freeman,J.S., Cody,F,W,J., Schady,W. (1992) Abnormalities of human rhythmic movement in Parkinson's disease. J. Physiol. vol: 47:3: 12P.

Gandevia,S.C. (1987) Roles for voluntary motor commands in motor control. Trends in Neuro.Sci. vol: 10: 81-85.

Gandevia,S.C.,Rothwell, J.C., (1987) Knowledge of motor commands and recruitment of human motor neurones. Brain. vol: 110:1117-1130.

Gardener, RM., Salaz, V., Reyes, B., Brake, SJ., (1983) Sensitivity to proprioceptive feedback in obese subjects.Percept. motor skills. vol: 571:111-8

Gaudet,G., Goodman,R., Landry,M., Russel,G., Wall,J.C. (1990) Measure of step length and step width . Physiotherapy, Canada. vol :42: 34-38

Georgiou,N., Iansek,R., Bradshaw,J.L., Phillips,J.G., Mattingley,J.B., Bradshaw,J.A. (1993) An evaluation of the role of internal cues in the pathogenesis of parkinsonian hypokinesia. Brain. vol: 116:1575-1587.

Ghez,C. (1991) Muscles: Effectors of the motor systems. chap 36. Neural Science, Kandel , E.R., Schwartz, J.H., and Jessel ,T.M., (eds) Applegate and Lang, Norwalk CT.

Gibberd,F.B. (1986) The clinical findings and pathology in Parkinson's disease. Physio. vol 72, :17-19

Giladi,N., McMahon,D., Przedborski,S., Flaster,E., Guillory,S., Kostic,V., Fahn,S., (1992) Motor blocks in Parkinson's disease. Neurol. vol: 42:333-338

Gilchrist,L.A. (1998) Age related changes in the ability to side step during gait. Clin. Biomech. vol: 13(2):91-99.

Gladman J., Whynes D., Lincoln N. (1994) Cost based comparison of domiciliary and hospital-based stroke rehabilitation. Age and Ageing. vol: 23.241-245.

Goodwin,G.G., McCloskey, D.I., Matthews, P.B.C. (1972) Propriocecptive illusions by muscle vibration. Science. vol: 175:1382-1384.

Gordan,A.M. (1997) Object release in patients with Parkinson's disease. Neuroscience Letters vol: 232 :1-4.

Gordon,A.M., Ingvarsson,P.E., Forssberg,H. (1997) Anticipatory control of manipulative forces in Parkinson's disease. Exp. Neurol. vol: 145: 477-488.

Gordon,T., Patullo, M.C. (1993) Plasticity of muscle fibre and motor types. Exerc. Sport Sci. Rev. vol: 19:331-5

Granit,R. (1972) Constant errors in the execution and appreciation of movement. Brain vol: 95:

649-660.

Graybiel,A.M. (1990) Neurotransmitters and neuromodulators in the basal ganglia. Trends Neurosci. vol: 13: 244-253.

Grayson,L. (1997) Evidence-based Medicine. The British Library. Hampshire.

Greenfield,S., Kaplan,S., Ware, JE. (1995) Expanding patient involvement in care. Annals of Internal Medicine. vol: 102. 520-528.

Guth, L. (1981) Over view of motor unit structure and function. Symposium paper. Nov. Am. Academy Physical Medicine and rehabilitation.

Haggerty, L. (1996) What is content analysis? Medical Teacher. vol: 5:99-101.

Hallet,M., Khoshbin, S.A. (1980) Physiological mechanisms of bradykinesia. Brain. vol: 103:301-8

Halsband,U., Freund, H.J. (1990) Pre-motor cortex and conditional learning in man. Brain.vol:113: 207-222.

Handford,F. (1986) Parkinsonian gait. Physio. vol.72:16-19.

Handford,F. (1997) Movement Notes for Patients and carers. P.D.Society Publication.London.

Harrison,K., Jackson,J. (1994) Relationship between mental practice and motor performance. Brit.J. of Ther. and Rehab. vol: 1: 18-23.

Hasan,Z., Stuart, D.G. (1988) Animal solutions to problems of movement control. Ann. Rev. Neurosci.vol:11:199-223.

Henneman,E. (1974) Principles governing sensory input to the motor neurones.The neurosciences 3rd study programme. Ed.Schmidt, F,O., & Worden, F,G., pp281-291. M.I.T. Press. Cambridge USA.

Hicks,C.M. (1995) Research for Physiotherapists. Churchill Livingstone. Edinburgh

Higgs,J. (1992) Developing clinical reasoning competencies. Physio. vol:78: 575-581.

Higgs,J., Titchen A. (1998) Research and Knowlege. Physio. Feb. vol: 84: 72-80.

HMSO (1994) The health of the nation, Dept. of Health .Public health commissioned data. vol 1(2:1).

HMSO (1998) A first class service. Quality in the NHS. 13823 NHS 3P Sep.(OAK)

Hoehn,M.M., Yahr,M.D. (1967) Parkinsonionism: onset, progression and mortality. Neurol. vol :17 :17-23.

Hollis,M. (1989) Practical exercise therapy. 3rd Edit. Blackwell Scientific Publications. London.

Hopkins,I. (1994) Economic change and health service reform: likely impact on teaching, practice and research in neurology. J. of Neurol. Neurosurg. and Psych. vol:57:667-671.

Houk,J.C., Davies,J.L., Beiser,G.D. (1995) Models of information processing in the basal ganglia. MIT press, Cambridge U.S.A.

Ingvarsson,P.I., Gordon,A.M., Forsberg,H. (1997) Coordination of manipulative forces in Parkinson's disease. Exp.Neurol. vol:145: 489-501.

Jasper, M.A. (1994) Expert: discussion of the implications of the concept as used in Nursing. J. of Avd. Nurs. vol: 20: 769-776.

Jenkinson, C., Peto,V., Fitzpatrick,R., Greenhall,R., Hyman,N. (1995) Self-reported functioning and well-being in patients with Parkinson's disease: comparison of the short-form health survey (SF-36) and the Parkinson's disease questionnaire (PDQ-39). Age and Ageing. vol:24:505-509.

Jenmalm,P., Johansson,S. (1997) Visual and somatosensory information about object shape control manipulative fingertip forces. J. of Neurosci. vol:117:4486-4499.

Jette,A.M. (1995) Outcomes research: Shifting the dominant research paradigm in physical therapy. Physical Ther. vol :75.editorial.

Jones,D.L., Phillips,J.G., Bradshaw,J.L., Iansek,R., Bradshaw,J.A. (1992) Impairment in bilateral alternating movements in Parkinson's disease. J. of Neurol. Neurosurg. and Psych. vol:55:503-506.

Jones.D., Lövgreen ,B., Ashburn, A., Chandler, C.,Handforth, F., Kinnear,E., Plant,R. (1998) Consensus on best approach. Frontline p.4. Dec.2.

Jones,J., Hunter,D. (1995) Consensus methods for medical and health services research. B.M.J. vol. 331:34-36.

Jones,M. (1995) Clinical Research in the Health Professions. Ed. Higgs,J., Butterworth and Heineman. London.

Jordan,N., Sagar,H.J., Cooper,J.A. (1992). A component analysis of the generation and release of isometric forces in Parkinson's disease. J. of Neurol. Neurosurg. and Psych. vol: 11:572-576.

Kahn,L., Miller,A. (1975) Observational methods, rating scales, and interventions. J. Psych. Res. vol:12:189-198.

Kamsma,P.T., Brouwer,W.H., Lakke,J.P.W.F. (1995) Training of compensational strategies for impaired gross motor skills in Parkinson's disease. Physio. Theory and Practice. vol:11:209-229.

Kandel,E.R., Schwartz,J.H., Jessel,M.J. (1991) The principles of neural science. 3rd.edit.,Elselvier.London.

Kausar,R., Powell,G.E. (1996) Subjective burden on carers of patients with neurological problems such as consequence of precise objective symptoms (objective burden). Clin. Rehab. vol:10:159-165.

Kazdin,A.E. (1982) Single case research design. Oxford University press. London

Keith,R.A. (1998) Patient satisfaction and rehabilitation services. Arch. Phys. Med. Rehab. vol. 79: 1122-1127.

Kellogg,W,N., (1930) An experimental comparision of equality judgements in psychophysics. Arch. Psychol. vol:17: 49-56.

Ketelaars, C.A.J., Huda, H.A.S., Schlosser, M.A.G. (1997) Long term outcome of Pulmonary rehabilitation in patients with COPD. Chest. vol:112.:363-369

Kilbreath,S.L., Gandevia, S.C., (1991) Independence digit control: Failure to partition perceived heaviness of weights lifted by digits of the human hand. J. of Physiol. London. vol: 442: 537-556.

Kitzinger,J. (1995) Introducing focus groups. B.M.J. vol :311:23-27.

Kunesch,E., Schnitzler,A., Tyercha,C., Knecht,S., Stelmach,G. (1995) Altered force release control in Parkinson's disease. Behav.l Brain Res. vol:67: 43-49.

Lammare,Y., Joffrey,A.J. (1979) Experimental tremor in monkey; activity of the thalamic and pre-central cortical neurones. Adv. Neurol. vol:24:109-122.

Larin,H.M. (1997) Motor learning: A practical framework for paediatric physiotherapy. Physiotherapy Theory and Training. vol: 14:33-47.

Lazarus,J.C., Stelmach,G.E. (1992) Inter-limb coordination in Parkinson's disease. Movement Disorders. vol 7: 159- 170.

Lemon,R.N. (1993) Cortical control of the primate hand. The 1992 G.L. Brown Prize lecture. Exp. Physiol. vol:76: 159-200.

Lemon, R.N. (1995) Cortical Control of Skilled Movements. Ed Cody, F.W.J., Neural control of Skilled Human Movement.Chap1. Portland Press, London.

Lieberman, H.R., Pentland, A.P. (1982) Computer Technology: Microcomputer based estimation of psychophysical thresholds: The Best Pest. Behaviour Research Methods and Instrumentation.vol:14 :21-25.

Logigian, E., Hefter, H., Reiners,K., Freund,H. (1990) Does tremor pace repetitive voluntary motor behaviour in Parkinson's disease? Ann. Neurol. vol:30:172-179.

Lord, S.E., Halligan,P.W., Wade, D.T. (1998) Visual gait analysis: the development of a clinical assessment and scale. Clin. Rehab.vol:2:107-119.

Lövgreen, B., Cody, F.J.W., Schady, W. (1993) Abnormality of sensory guidance studied in patients with cerebellar dysfunction, studied using visuomotor tracking. Clin. Rehab.vol:6: 350-356.

Lövgreen B., Cody F.J.W. (1997) Bilateral matching of human isometric contractile force in health and Parkinson's disease. Proceedings Abstract, XXXIII International Congress of Physiological Sciences IUPS,St Petersburg.

McCloskey,D.I. (1978) Kinaesthetic sensibility. Physiological reviews vol:58: 763-820.

McCloskey,D.I., Cross, M.J., Horner,R., Potter,E.K. (1983) Sensory effects of pulling and vibrating exposed tendons in man. Brain. vol: 2:1-37.

McIntosh,G.C., Brown,S.H., Rice,R.R., Thaut,M.H. (1997) Rhythmic auditory-motor facilitation of gait patterns in patients with Parkinson's disease. J. of Neurol. Neurosurg. and Psych. vol:62:22-26.

McIntosh,R,D., O'Boyle,D. (1995) Effects of perturbation of delay in response contingent, auditory feedback on the endogenous timing of repetitive movements. Pub. proceedings Phys.Soc. J of Physiol. vol 9:C35.

Mackay-Lyons,M., Turnbull,G. (1995) Physical therapy in Parkinson's disease. Neurol. Vol: 45:205-236.

Markham, C.H. (1987) The "motor" vs. "sensory " enigma in Parkinson's disease. In, Scneider, J.S., Lidsky, T.I. Basal ganglia and behaviour: sensory aspects of motor functioning. Hans Huber Pub. Toronto

Marks, R. (1997) Peripheral mechanisms underlying the signaling of joint position. NZ J. of Physiotherapy. vol: 4:16-23.

Marsden,C.D. (1994) Parkinson's disease. J. of Neurol. Neurosurg. and Psych. vol:57: 672-681.

Marsden,C,D. (1980) The enigma of the basal ganglia and movement. Trends Neurosci.vol:3:284-87.

Marsden,C.D., Obeso,J.A. (1994) The functions of the basal ganglia and the paradox of stereotaxic surgery in Parkinson's disease. Brain. vol:17: 877-897.

Martin, J.H., Jessel T.M. (1991) Modality coding in the somatic sensory system. Kandel,E.R., Schartz,J.H., Jessel,M.J.,(eds) The principles of neural science. 3rd.edit.,Elselvier.London.

Martin,J.P. (1967) The basal ganglia and posture. J.B.Lippincott Co. Philadelphia.

Martin,K.E., Phillips,J.G., Iansek,R., Bradshaw,L. (1994) Inaccuracy and instability of sequential movements in Parkinson's disease. Brain Res. vol:102: 131-140.

Matthews, B.H.C. (1933) Nerve endings in mammalian muscle. J of Physiol. vol:78:1-53.

Matthews,P.B.C. (1972) Mammalian muscle receptors and their central actions. London, Arnold.

Matthews, P.B.C. (1977) Muscle afferents and kinaesthesia. British Medical Bulletin vol:33: 137-142.

Matthews P.B.C. (1987) Proprioceeptors and their contribution to somatosensory mapping: complex messages require complex processing. Can.J. Physiol. Pharmacol. Vol: 66: 430-438.

Matthews,P.B.C. (1992) Where does Sherrington's muscle sense originate? Muscles, joints, corollary discharges? Ann. Rev. of Neurosci. vol: 5: 189-218.

Meara,R.J. (1994) Review: The pathology of the motor signs in Parkinson's disease. Age and Ageing. vol:23:342-346.

Meara, R.J., Cody, F.W.J., (1992) Relationship betwen electromyographic activity and clinically-assessed rigidity studied at the wrist joint in Parkinson's disease. Brain. vol:115:1167-1180.

Mills K.R. (1995) Effects of motor system lesions on skilled manipulation. (Ed) Cody,F.W.J., Neural control of skilled human movement.(Ed)Studies in Physiology. Portland Press.London.

Miller, D.C. (1991) Hand book of research and design and social measurement. 5th.edit., Sage. London

Mink,J.W., Thach,W.T. (1991) Basal ganglia motor control, Parts 1, 2 & 3. J.Neurophysiol. vol:65. 273-351.

Moberg, E. (1983) The role of cutaneous afferents in position sense and motor functions of the hand. Brain. vol:106: 1-19.

Moore,A.P. (1987) Impared sensorimotor integration in Parkinsonian and dyskinesia: a role for corollary discharges? J. of Neurol. Neurosurg. and Psych.vol: 50: 544-552.

Morris,M.E., Iansek,R., Matyas,T.A., Summers,J.J. (1994) The pathogenesis of gait hypokinesia in Parkinson's disease. Brain. vol:117:1169-1181.

Morris,M.E., Matyas,T.A., Iansek,R., Summers,J.J. (1996) Temporal stability of gait in Parkinson's disease. Physical Ther. vol: 76: 34-41.

Morecraft R.J., Van Hoesen, G.W. (1996) Pathophysiology of the motor systems Chapter 7. (Ed) Fredericks C.M., Saladin L.K.,Pub. FA Davies, California.

Mountcastle V.E., Lynch,J.C., Georgopoulos, A. (1975) Posterior parietal association cortex of the monkey. J. of Neurophysiol. vol:38:871-908

Munn ,P., Drever,E. (1990) Using questionnaires in small scale research. A teachers' guide. Mac Donald Lindsay Pinder PLC. Edinburgh.

Mutch,W.J., Strudwick,A., Roy,S.R., Downie,A.W. (1986) Parkinson's disease: disability, review, and management. B.M.J. vol: 293:23-27

Niewboer,A., Feys,P., De Weerdt,W., Dom,R. (1997) Is using a cue the clue to the treatment of freezing in Parkinson's disease? Physiotherapy Research International. vol:2:125-134.

Neilsen, J., Kagamihara, Y., Crone, C., Hultborn, H. (1992) Central facilitation of Ia inhibition during tonic ankle dorsiflexion revealed after blockade of peripheral feedback. Exp. Brain Res. vol:88:651-656.

Nishizawa, S.(1991) Different pattern of hemisphere specialisation between identical kinaesthetic spatial and weight discrimination tasks. Neuropsychologica. Vol:29: 305-12.

Nutt,J.G., Marsden,C.D., Thompson, P.D. (1993) Human walking and higher level disorders, particularly in the elderly. Neurol. vol:43: 268-279

O'Boyle, D.J., Freeman,J,S., Cody,F.W.J. (1996) The accuracy of precision of timing of self-paced repetitive movements in subjects with Parkinson's disease. Brain.vol:119:51-70.

Obeso, J.A., Guridi,J. (1997) Editorial. J. of Neurol. Neurosurg. and Psych. vol:62:2-8

Oppenheim, A.N. (1992). Questionnaire design, interviewing and attitude measurement. Pub,New Ed. Printers. London

Osgood,C.E., (1969) Method and theory in experimental psychology. Oxford University Press. 6th Ed. New York.

Ottenbacher, K.J., Hsu,Y., Granger,C.V., Fielder,R.C. (1996) The reliability of the functional independence measure: A qualitative review. Arch Phys Med Rehabil, vol :77:24-28

Oxtoby, M. (1982) Parkinson's disease patients and their social needs. Parkinson's Disease Society. London.

Paillard,J., Brouchon, M. (1968) Active and passive movement in the calibration of positional sense. In Freedman, S.J., and Homeword, I.L., (Ed) The neuropsychology of spatially oriented behaviour, pp 37-55. Dorsev Press.

Panzer,V.P., Bandinelli,S., Hallett,M. (1994) Biomechanical assessment of quiet standing and changes associated with ageing. Arch Phys Med Rehab. vol: 76: 23-27.

Panzer,V.P., Hallett,M. (1990) Biomechanical assessment of upright stance in Parkinson's disease: a single-subject study. Clin. Biomech. vol:5:73-80.

Parkinson J. (1817) An essay on the shaking palsy. Parkinson's Disease Society Publication (reprint). London

Partridge,C., Johnston,M., Morris,L. (1996) Disability and health: perceptions of a sample of elderly people. Physiotherapy research international, vol:1 : 17-29.

Partridge,C. (1996) The patient as a decision maker. Physiotherapy Research International. 2.Editorial.

Passingham,R.E. (1997) Micrographia in Parkinson's disease: the effect of providing external cues. J. of Neurol. Neurosurg. and Psych.vol: 63: 429-433.

Payton,O.D., Nelson,C.E. (1996) A preliminary study of patients' perceptions of certain aspects of their physical therapy experience. Physio. Theory and Practice vol:12:27-38.

Pedersen,S.W., Backman,E., Oberg,B. (1991) Characteristics of tetanic muscle contraction in Parkinson's disease. Acta Neurol Scand. vol: 84:250-255.

Pentland,A.P. (1980) The Best Pest, a maximium-likelihood parameter estimation proceedure. Perception and Psychophysics.vol:28: 377-379.

Peto,V., Jenkinson,C., Fitzpatrick,R., Greenhall,R. (1995) The development and validation of a short measure of functioning and well being for individuals with Parkinson's disease. Quality of life research,vol: 4 .241-248.

Phillips,J.G., Martin,K.E., Bradshaw,J.L., Iansek,R. (1994) Could bradykinesia in Parkinson's disease simply be compensation? J. Neurol. vol:241: 439-447.

Phillips,J.G., Stelmach,G.E. (1996) Pathophysiology of the motor systems Chap.9.(Ed) Fredericks C.M., Saladin L.K.,pub. FA Davies, California.

Plant, R., Lövgreen, B., Ashburn, A., Handforth, F., Jones., D., Kinnear,E. (1999) Physiotherapy

Evaluation in Parkinson's disease (PEP) project UKInterim report. PDS, London.

Plant R. (1996). Objectivity in physiotherapy assessment. Editorial. British Journal of Therapy and Rehabilitation. vol:2

Plant, R., Ashburn, A., Lovgreen, B.,Jones, D., (1999) Physiotherapy and Parkinson's disease: Evaluating best practice. Physio.vol:86: p32.

Playfer,J.R. (1997) Parkinson's disease. The fellowship of postgraduate medicine. Postgrad Med J. vol:73:257- 264.

Poppen, R. (1988) Behavioral Relaxation, Training and assessment. Pergammon Press. Oxford.

Potter,J.M., Evans,A.L., Duncan,G. (1995) Gait speed and activities of daily living function in geriatric patients. Arch Phys Med Rehabil. vol :76:11-14 .

Prochazka, A. (1996) Exercise: regulation and integration of multiple systems. Ed Rowell L,B., Shepherd, J.T., chap. 3. Proprioceptive feedback and movement regulation. p89-127. American Physiology Society, New York.

Proske,U. (1981) Golgi tendon organ during voluntary contraction. International Review of Physiology. vol:25. 127-171.

Proske,U., Schiable, H.G., and Schmidt, R.F. (1988) Joint receptor discharges at the cat elbow. Experimental Brain Research, vol:72: 219-224.

Protas,E.J., Stanley,R.K., Jankovic,J. (1996) Exercise and Parkinson's disease. Physical and rehabilitation medicine; vol:8:253-266.

Richards,M., Cote,L.J., Stern,Y. (1993) The relationship between visuospatial ability and perceptual motor function in Parkinson's disease. J. of Neurol. Neurosurg. and Psych. vol:56:400-406.

Rickards,C., Cody,F.W.J. (1995) Bilateral asymmetry of vibration induced errors of human wrist movements in patients with Parkinson's disease. Pub. Conf. Proceedings abstract, J. Physiol. Phys.Soc. vol: 9:C36.

Riddoch,J., Lennon, S. (1994) Single subject Experimental design: One way forward? Physio. vol: 80 :27-29.

Robertson,V.J. (1995) A quantitative analysis of research in physiotherapy. Phys. Ther. vol: 75: 313-321.

Robertson,V.J., Lee,V.L. (1994) Some misconceptions about Single subject designs in physiotherapy. Physio. vol: 80 :12-15.

Rogers, M.A., Evans W. J. (1993) Changes in Skeletal muscle with ageing: Effects of exercise training. Exerc.Sport Sci. Rev. vol:21:65-69.

Rogers,M.W., Chan,C.W.Y. (1988) Motor planning is impaired in Parkinson's disease. Brain Res. vol:438 :271-276.

Roskell,C., Cross,V. (1998) Attention Limitation and Learning in Physiotherapy. Physio.vol: 84 : 118-125.

Ross, H.E., and Murray, D,J., (1978) The sense of touch. (English translation of De Tacu (1834 Weber,E.H.). J. Exp. Psych. Society, pp41-58. Academic Press, London.

Ross,H.E., Roche,P., (1987) Sex, handedness and weight discrimination. Neuropsychologica. vol:25): 841-4.

Ross,H.E., Schwartz,E., Emmerson,P., (1986) The nature of sensorimotor adaptation to altered G-levels: evidence from mass discrimination. Aviat.Space Environment Med. vol:58: 148-52.

Ross,H.E.,Brodie, E.E., Benson,A,J., (1986) Mass discrimination in weightlessness and re-adaptation to earth's gravity. Exp. Brain Res. vol:64:358-66.

Rothwell,J. (1994) Control of human voluntary movement.1st.edit., Chapman & Hall.London

Rothwell,J. (1995) (Ed) Cody ,F.W.J., Neural control of skilled human movement. Studies in Physiology. Portland Press. London

Rothwell,J. (1996) Control of human voluntary movement. 2nd. edit., Chapman & Hall.London.

Royal College of Physicians Prince of Wales advisory group on disability (1992) A charter for disabled people using hospitals. Academic press. London.

Ruch,T.C., Fulton,J.F., (1960) Medical physiology and biophysics. 18th Ed. W.B.Saunders Co. London.

Ruuskanan,J.M., Ruppila, I. (1995) Physical activity and psychological well being among people between 65-84 years. Age and Ageing. vol:24:292-6

Ryan,N.P., Wade,J.C., Nice, A., Shenefelt,H., Shepard,K. (1996) Physical therapists' perceptions of family involvement in the rehabilitation process. Physio. Res.Int. vol:1:159-178.

Savage,C.W., (1970) The measurement of sensation: A critique of perceptual psychophysics. University of California Press. Berkeley

Sanes, J.N., Shadmehr,R. (1995) Sense of muscular effort and somaesthetic afferent information in humans. Can. J. Physiol. Pharmacol. vol:73:223-233.

Schenkman,M., Cutson,T.M., Kuchibhalta,M., Chandler,J., Pieper,C. (1997) Reliability of impairment and physical performance measures for persons with Parkinson's disease. Phys. Ther. vol:77: 4-7.

Schenkman,M., Butler,R.B. (1989) A model for multisystem evaluation treatment of individuals with Parkinson's disease. Phys. Ther. vol: 69:25-39.

Schenkman,M., Donovan,J., Tsubota,J., Kluss,M., Stebbins,P., Butler,R.B. (1989) Management of individuals with Parkinson's disease: Rationale and case studies. Phys. Ther. vol: 69 :18-26.

Schell, G.R., Strick, P.L. (1984) The origin of thalamic inputs to the arcuate premotor and supplementary motor area. J Neurosci., vol:4: 539-560

Schneider, J.S., Diamond, S.G., Markham, C,H. (1987) Sensory and motor problems in arms and hands. J. of Neurol. vol:37:951-956.

Sharpe,M.H., Miles,T.S. (1992) Position sense at the elbow after fatiguing contractions. Exp Brain Res. vol: 94: 179-182.

Sheridan,M.R., Flowers, K.A., Huller,J. (1987) Programming and execution of movement in Parkinson's disease. Brain. vol: 110:1247-1271

Shumway-Cook,A., Gruber,W., Baldwin,M., Liao,S. (1997) The effect of multidimensional exercises on balance, mobility,and falls risk in community-dwelling older adults. Phys. Ther. vol 77 : 7-11.

Sim, J. (1998) Respect for autonomy: issues in neurological rehabilitation. Clin. Rehab. vol:3: 4-10.

Sim, J. (1986) Informed consent: ethical implications for physiotherapy. Physio. vol: 72:584-587.

Skeil,D.A. (1995) Individual and staff professional development in a multidisciplinary team: some needs and solutions. Clin. rehab.vol:9:28-33.

Soliveri,P., Brown,R.G., Jahanshahi,M., Caraceni,T.,Marsden, C.D. (1997) Learning manual pursuit tracking skills in patients with Parkinson's disease. Brain vol:120: 1325-1337.

Soliveri,P., Brown,R.G., Jahanshani,M., Marsden,C.D. (1992) Effect of practice on performance of a skilled motor task in patients with Parkinson's disease. J. of Neurol. Neurosurg. and Psych. vol:55:454-460.

Stallibrass,C. (1997) An evaluation of the Alexander Technique for the management of disability in Parkinson's disease - a preliminary study. Clin. Rehab. vol:11:8-12.

Stein, R.B. (1974) Peripheral control of movement. Physiological reviews. vol :54 : 215-243

Stein.J.F. (1995) The posterior Parietal cortex, the cerebellum and the visual guidance of movement. Cody, F.W.J., (Ed) Neural Control of Skilled Human Movements. Portland press. London.

Stelmach,G.E., Phillips,J.G. (1991) Movement disorders - Limb movement and the basal ganglia. Phys. Ther. vol :71 :8-11

Stelmach, G.E.,Phillips,J.G. (1992) Physical therapy management in Parkinson's disease.Turnbull,G.I.,(ed) Physical therapy management of Parkinson's disease. Churchill Livingstone, New York

Stelmach,G.E., Teasdale,N., Phillips, J., Worringham,C.J. (1989) Force production characteristics in Parkinson's disease. Exp Brain Res. vol:76:165-172.

Stelmach, G,E., Worringham C,J. (1988) The preparation and production of isometric force in Parkinson's disease. Neuropsychologia. vol.26: 93-103.

Swinnwen ,S.P., Van-Langendonk, L.,Verschueren,S., Peeters G., Dom R., De Weert W. (1997) Interlimb coordination deficits in patients with Parkinson's disease. Mov.Disord. vol:12(6):958-68.

Tarantola,J., Nardone,A., Taccini,E., Schiepati,M. (1997) Human stance improves with the repetition of the task: effect of foot position and visual condition. Neuroscience letters vol:228 :75-78.

Taylor,A.E., Saint-Cyr,J.A., Lang,A.E. (1987) Parkinson's disease. Cognitive changes in relation to treatment response. Brain.vol:110:35-51.

Taylor, J.L., McCloskey,D.L. (1990) Ability to detect angular displacements of the fingers made at an inmperceptibly slow speed. Brain.vol:113:157-166.

Taylor,J.L., McCloskey,D.I. (1988) Pointing. Behav. brain Res. vol: 29:1-5.

Taylor, M.M., Creelman,C.D. (1967) Efficient estimates on probable functions. J of the Acoustical Society of America. vol:25 (Series B)1-48.

Teasdale, N., Phillips, J., Stelmach,G,E. (1990) Temporal movement control in patients with Parkinson's disease. J Neurol. Neurosurg. Psych. vol:53:862-868.

Torstenson,R., Hartvig,P., Langstrom,B., Westerberg,G., Tedroff,J. (1997) Differential effects of levo-dopa on dopaminergic function in early and advanced Parkinson's disease. Ann Neurol. vol:41:334-340.

Tremblay, L., Filion, M., Bedard, P.J. (1989) Responses of pallidal neurones to striatal stimulation

Turnbull,G.I. (1992) (Ed) Physical therapy management of Parkinson's disease., chap 3. Churchill Livingstone. New York

Tutty, LM. Rothey,MA., Grimell, RMJ. (1996) Qualitative Research for Social workers. Allyn and Bacon, Boston.

Twomey, L. (1996) Editorial- Research, more essential than ever. Physio. Res.i Int. vol:1.Editorial.

Umphred,D.A. (1990) Neurological rehabilitation. 2nd.edit., C.V.Mosby Company. London.

Van Leeuwen,R., Inglis, T. (1998) Mental practice and imagery. Phys.Ther.Reviews vol:3:47-52

Vallbo,A.B., Hulliger,M., Nordh. (1980) Do muscle afferents monitor joint position in man? Brain Res. vol:204, 209-213.

Viallet,F., Massion,J., Massarino,R., Khalil,R. (1987) Performance of a bimanual load-lifting task by Parkinsonian patients. J. of Neurol. Neurosci. and Psych. vol:50:1274-1283.

Wade,D.T. (1994) Measurement in neurological rehabilitation. Oxford medical publications. London.

Wade,D.T. (1998) (Editorial) Clin. Rehab.vol:12:363-368.

Waddington, P.J. (1989) Practical exercise therapy. Chapters 23, 27. Hollis,M., (ed) 3rd Edit. Blackwell Scientific Publications.

Walker, E,M. (1996) Questionnaire design in practice. Brit. J. of Ther. and Rehab. vol.3.No.4, 229-233.

Warabi, T., Noda H., Yanagiaswa, N., Tashiro, K.,Shindo,R. (1986) Changes in sensoriomotor functions associated with Parkinson's disease. Brain vol:109: 1209-1224.

Warson,J.D.G., Colebatch,J.G., McCloskey,D.I. (1984) Effects of externally imposed elastic loads on the ability to estimate position and force. Behav. Brain Res.vol:13 267-271.

Wascher,E., Verleger,R., Vieregge,P., Koch,S., Kompf, D. (1997) Responses to cued signals in Parkinson's disease distinguishing between disorders of cognition and of activation. Brain. vol:120, 1355-1375.

Watson, C.S., Turpentoff,C.M., Kelly, W.J., Botwinick,J., (1979) Age differences in resolving power and decision strategies in a weight discrimination task. J. of Geront. vol:34:547-52.

Weber,E.H. (1834) The sense of touch.(English translation of De Tacu (1978) by Watson,C.S., Turpenhoff, C.M., Kelly, W.J., Botwinick, J., (1979) Age differences in resolving power and decision strategies in a weight discrimination task. J. Geront. vol:34:547-52.

Webster,D.D. (1968) Critical analysis of the disability in Parkinson's disease. Modern Treatment; vol:5:257-282.

Weiner,D.K., Bongiorni, D.R., Studenski, S.A., Duncan, P.W., Kochersberger, G.G. (1993) Does functional reach improve with rehabilitation? Arch Phys Med Rehabil .vol: 74 :22-27.

Weiner,D.K., Duncan,P.W., Chandler,J., Studenski,S. (1992) Functional reach: A marker of physical frailty. J.A.G.S. vol: 40:31-38.

Weiner,W.J., Singer,C. (1989) Parkinson's disease and non-pharmacologic treatment programmes. J.A.G.S.vol:37:359-363.

Weisendanger ,M., Miles,T.S. (1982) Ascending pathway of low threshold muscle afferents to the cerebral cortex and its possible use in motor control. Physiological reviews vol: 62:423-53.

Weller,C., Humphrey,S.J., Kirollos,C., Bowes,S.G., Charlett,A., Dobbs,S.M., Dobbs,R.J. (1992) Gait on a shoestring: Falls and foot separation in Parkinsonism. Age and Ageing.vol: 21:242-244.

Weller,C., Nicholson,P.W., Dobbs,S.M., Bowes,S.G., Purkiss,A., Dobbs,R.J. (1992) Reduced axial rotation in the spouses of sufferers from clinical idiopathic Parkinsonism. Age and Ageing.vol: 21:189-194.

Weissenborn, S. (1993) The effect of using a two step verbal cue to a visual target above eye level on the Parkinsonian gait: A case study. Physio.vol: 79.:26-31.

Westling,G., Johansson, R.S., (1984) Factors influencing force control during precision grip in humans. Exp. Brain Res., vol:53: 277-284.

Wetherill,G. (1963) Sequential estimation of quantal response curves. Journal of the Royal Statistical Society. vol:25:1-48.

Wierzbicka,M.M., Weigner,A.W., Logigian,E.L., Young, R.R. (1991) Abnormal most-rapid isometric contractions in patients with Parkinson's disease. J. of Neurol. Neurosurg. and Psych. vol:54:210-216.

Williams, L.R.T., Caswell,P., Wagner,I., Walmsley,A., Handcock, P.J. (1994) Regulation of standing posture. NZ Journal of Physio. vol: 22 :27-31.

Willis,J. (1997) Project Parkinson's. Therapy weekly, November 27th, p4.

Williams, P.E. (1990) Use of intermittent stretch in the prevention of serial sarcomere loss in immobilized muscle. Annals of Rheum. Dis. vol: 49:316

Willems, D. Vandervoort A.A. (1996) Balance as a contributing factor to gait speed in the elderly. Physio. Canada. vol:48.:179-184.

Wing, A.M. (1987) A comparison of the rate of pinch grip force increases and decreases in Parkinsonian bradykinesia. Neuropsychologia, vol. 3 1988. Penguin Press.London.

Woodworth, R.S., (1938) Experimental psychology. Holt, Rinehart and Winston. New York

World Health Organisation. (1979) Formulating strategies for the health for all by the year 2000. pp11,17.WHO Geneva.

Woolacott M.H., Shumway-Cook A. (1990) Changes in postural control across the life span - A systems approach. Phys. Ther. vol:70.799-807.

Worm G.M. (1988) Recovery of motion in Parkinson's disease (letter). Archives of Phys. Med. Rehab. vol:69:463-464.

Worringham C.J., Stelmack. (1990) Practice effects on the programming of discrete movement in Parkinson's disease. J of Neurol. Neurosurg. and Psych.vol: 53: 702-704.

Wright,J., Cross,J., Lamb,S. (1998) Physiotherapy Outcome measures for Rehabilitation of Elderly People. Physio. vol :84: 216-221.

Yanagisawa,N., Fujimoto,S., Tamaru,F. (1989) Bradykinesia in Parkinson's disease: Disorders of onset and execution of fast movement. Eur Neurol:vol:29 (suppl.1); 19-28.

Yekutiel,M.P. (1991) A clinical trial in the reeducation of movement in patients with Parkinson's disease. Parkinson's Disease Society N.P.F. report 3rd. quarter.London.

Yekutiel,M., Pinhasov,A., Shahar,G., Stroka,H. (1991) A clinical trial of the re-education of movement in patients with Parkinson's disease. Clin. Rehab. vol:5:207-214.

Ype, PT., Wiebo H., Bruwoer H., Johannes P.W.F.L. (1995) Training of compensational strategies for impaired gross motor skills in Parkinson's disease. Physiotherapy Theory and Practice. vol:11. 209-229.

Zarit, SH., Zarit JM. (1996) Families under stress:Interventions for caregivers of senile dementia patients.Psycho Ther Res Prac.vol:19: 461-71.

Zauser,R. (1996) Subjective burden on carers of patients with neurological problems as a consequence of precise objective symptoms. Clinical rehabilitation.vol:10:159-165.

Zia,S., Cody,F.W.J. (1995) Evidence of impairment of human joint position sense in Parkinson's disease. Conf.proceedings abstract .J. Physiol, (London); 494P:68P

Zia,S. (1998) Proprioception in Human Basal Ganglia Dysfunction. PhD Thesis - Unpublished. John Rylands Library, University of Manchester.

APPENDICES

Appendix I. This appendix relates to chapter 2 and contains the list of statements generated from the literature by the PEP group (page 215). The statements were used to form the basis of the Delphi study. The Delphi questionnaire is presented after the statements (pages 216-224).

Appendix II. This appendix contains the mathematical basis for the psychometric studies in chapter 3.

APPENDIX I LITERATURE-BASED PARTNER-GENERATED STATEMENTS

Referral

- Confirmation of the diagnosis of Parkinson's disease (or other associated syndromes) leads to automatic referral for physiotherapy
- Physiotherapy review of the patient is available through all stages of the disease
- Written guidelines are supplied to the patient (and carer) for self referral back to physiotherapy
- A common recording system is in place from referral which maximises the effects of physiotherapy

Physiotherapy

- Patients with a movement difficulty have access to a physiotherapist
- Movement difficulty is assessed using a standardised assessment at the beginning and end of a course of treatment
- Physiotherapists are able to refer patients on to other professionals for problems identified which are outside the remit of physiotherapy
- A system to communicate the findings of physiotherapy assessments to other involved professionals is in place/exists
- The aim of physiotherapy in Parkinson's disease is to reduce disability through addressing movement difficulty and associated musculoskeletal problems affecting function
- Physiotherapy treatment is directed towards the secondary impairments of Parkinson's disease eg joint stiffness, abnormal gait, as opposed to the primary impairments of tremor, rigidity, bradykinesia and postural instability
- Physiotherapy treatment approaches are based on the known neurophysiology of Parkinson's disease
- Physiotherapists should teach patients to use conscious control of movement, visual and verbal cues to help overcome their movement problems
- The frequency of treatment and length of treatment course is based on the outcome of goals for treatment jointly agreed between patient and physiotherapist
- Physiotherapists review patients regularly using a standardised protocol as part of a long-term strategy of targeted input
- Physiotherapy intervention is successful if short-term goals are achieved and if in the long-term the patient's function is maximised and maintained for as long as possible

Teams

- Physiotherapy care for individuals with Parkinson'sisease is located in a multi-disciplinary team context
- Care and rehabilitation for individuals with Parkinson disease is under the control of a designated care manager
- Physiotherapy care for individuals with Parkinson disease is ideally based within a community context
- Ease of referral to other health and social care professionals is essential for the efficient use of services by individuals with Parkinson's disease

Outcomes

- Patients and carers have access to information about Parkinson's disease and available services
- Carers have the opportunity to be trained in procedures that will facilitate the management of the patient
- Physiotherapists ensure their knowledge is up-to-date on the management of people with Parkinson's disease
- Patients have access to a professional who can assess psychological status

PHYSIOTHERAPY IN PARKINSON'S DISEASE
DETAILS SHEET

Please answer the following questions:

1. Year of qualification as a physiotherapist — 19......
2. Current physiotherapy grade (e.g. Superintendent III) —
3. Current clinical area (e.g. Care of the Elderly) —
4. How many years have you been treating patients with Parkinson's disease? — .... years
5. Approximately how many patients with Parkinson's disease do you treat each month? —
6. Where do you treat patients with Parkinson's disease? (e.g. Day Hospital, community, neurology ward etc.) —
7. Do you run a Parkinson's disease clinic or group?
   YES/NO (please delete as appropriate)

   If YES, please give brief details, including numbers, other professionals involved etc. Please continue on a separate sheet and/or attach any documentation you may have about this aspect of your service.

8. Have you attended any specialist courses on the treatment of Parkinson's disease?
   YES/NO (please delete as appropriate)

   If YES, please give brief details of courses.

9. Please use the box below to tell us anything else about yourself and your service. Feel free to write over the page, use extra sheets or send us printed details.

PHYSIOTHERAPY IN PARKINSON'S DISEASE
INSTRUCTIONS SHEET

The following questionnaire is in two parts. **In Part I** you will be presented with a series of statements in four sections:

1. **CONTEXT** - WHERE and HOW physiotherapy is delivered in Parkinson's disease,
2. **REASONS** - WHY physiotherapy is delivered in Parkinson's disease,
3. **ACTIONS** - WHAT physiotherapy comprises in Parkinson's disease,
4. **EFFECTS** - OUTCOMES of physiotherapy in Parkinson's disease.

For each statement in the **CONTEXT** section, please indicate, on a scale of 1 to 9,

- whether it HAPPENS or DOESN'T HAPPEN in your current practice
  1 = happens all the time, 5 = happens about half of the time, 9 = doesn't happen at all
- whether it is DESIRABLE or UNDESIRABLE that it should happen in an ideal world
  1 = highly desirable, 5 = equivocal (neither clearly desirable nor undesirable),
  9 = highly undesirable.

For example:

HAPPENS 1 2 3 4 5 6 [7] 8 9 DOESN'T HAPPEN

DESIRABLE 1 [2] 3 4 5 6 7 8 9 UNDESIRABLE

Here a physiotherapist has indicated that the statement applies to their practice only about a quarter of the time, but in an ideal world it is very desirable that it should apply.

For each statement in the **REASONS, ACTIONS AND EFFECTS** sections, please indicate, on a scale of 1 to 9, whether you AGREE or DISAGREE with the statement. 1 = strongly agree, 5 = equivocal (neither agree nor disagree), 9 = strongly disagree.

In Part II of the questionnaire you will be presented with three case studies of early, middle and late stage Parkinson's disease. For each statement, again divided into **CONTEXT, REASONS, ACTIONS AND EFFECTS** sections, please indicate, on a scale of 1 to 9, whether you AGREE or DISAGREE with the statement. 1 = strongly agree, 5 = equivocal (neither agree nor disagree), 9 = strongly disagree.

Please make a response to **ALL** the individual statements in Parts I and II of the questionnaire. Please feel free to use **ALL** of the numbers on the scale.

Completion time for this questionnaire is approximately 30 minutes.

At the end of the questionnaire is a **COMMENTS SHEET**. The research team would welcome your feedback on any aspect of this exercise. If you want to comment on a specific statement, use the statement code, eg C7, followed by your comment.

PART I - PHYSIOTHERAPY IN PARKINSON'S DISEASE

	STATEMENT	RATING (PLEASE CIRCLE)
	CONTEXT	For each statement in the **CONTEXT** section, please indicate, on a scale of 1 to 9, • whether it HAPPENS or DOESN'T HAPPEN in your current practice 1 = happens all the time, 5 = happens about half of the time, 9 = doesn't happen at all • whether it is DESIRABLE or UNDESIRABLE that it should happen in an ideal world 1 = highly desirable, 5 = equivocal (neither clearly desirable nor undesirable), 9 = highly undesirable.
	Physiotherapy intervention is maximised if:	
C1	physiotherapy takes place in the community or, if hospital-based, it links closely into the community	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C2	physiotherapy forms part of a co-ordinated multi-disciplinary team input	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C3	a key worker system is in place	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C4	the findings of physiotherapy assessment and the outcomes of treatment are routinely communicated to other involved professionals	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C5	a standardised assessment form is used to identify problems and monitor changes	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C6	there is a long-term management programme in place to monitor each patient over time	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C7	physiotherapy is initiated on diagnosis	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C8	individual treatment sessions are supplemented by group work	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable
C9	all possible opportunities are taken to involve carers in treatment sessions	Happens 1 2 3 4 5 6 7 8 9 Doesn't happen Desirable 1 2 3 4 5 6 7 8 9 Undesirable

	REASONS	For each statement in the **REASONS, ACTIONS AND EFFECTS** sections, please indicate, on a scale of 1 to 9, whether you AGREE or DISAGREE with the statement. 1 = strongly agree, 5 = equivocal (neither agree nor disagree), 9 = strongly disagree.
	The purpose of physiotherapy is to:	
R1	re-educate motor control to enhance quality of movement	Agree 1 2 3 4 5 6 7 8 9 Disagree
R2	maximise mobility and functional independence	Agree 1 2 3 4 5 6 7 8 9 Disagree
R3	reduce the onset of secondary musculoskeletal, respiratory and cardiovascular complications	Agree 1 2 3 4 5 6 7 8 9 Disagree
R4	assess movement and function to enable targeted treatment and on-going monitoring	Agree 1 2 3 4 5 6 7 8 9 Disagree
R5	educate patients and carers about the physical management of the condition	Agree 1 2 3 4 5 6 7 8 9 Disagree
R6	provide support for self-management by individuals and carers over the disease course	Agree 1 2 3 4 5 6 7 8 9 Disagree
R7	maximise general fitness	Agree 1 2 3 4 5 6 7 8 9 Disagree
	ACTIONS	
	Physiotherapy is best undertaken within a theoretical framework which uses:	
A1	techniques drawn mainly from learning approaches (e.g. conductive education, Carr and Shepherd, psychomotor learning, cueing)	Agree 1 2 3 4 5 6 7 8 9 Disagree
A2	techniques drawn mainly from neurophysiological approaches (e.g. Bobath, proprioceptive neuromuscular facilitation),	Agree 1 2 3 4 5 6 7 8 9 Disagree
A3	techniques drawn mainly from biomechanical approaches (based on mechanical and kinesiological principles)	Agree 1 2 3 4 5 6 7 8 9 Disagree
A4	techniques drawn selectively from all available approaches	Agree 1 2 3 4 5 6 7 8 9 Disagree

	EFFECTS	
	The outcomes of physiotherapy should be assessed in relation to its effect on:	
E1	the specified aims of treatment	Agree 1 2 3 4 5 6 7 8 9 Disagree
E2	the primary movement disorder (e.g. rigidity, bradykinesia, postural stability)	Agree 1 2 3 4 5 6 7 8 9 Disagree
E3	the secondary complications (e.g. relating to musculo-skeletal, respiratory and cardiovascular systems)	Agree 1 2 3 4 5 6 7 8 9 Disagree
E4	functional ability (e.g. gait disturbance, transfers, bed mobility)	Agree 1 2 3 4 5 6 7 8 9 Disagree
E5	quality of life (e.g. role, social integration)	Agree 1 2 3 4 5 6 7 8 9 Disagree
E6	cost-effectiveness (e.g. reducing acute admissions)	Agree 1 2 3 4 5 6 7 8 9 Disagree
E7	subjective well-being (e.g. depression, anxiety)	Agree 1 2 3 4 5 6 7 8 9 Disagree

PART II - PHYSIOTHERAPY RELATED TO STAGE OF PARKINSON'S DISEASE

EARLY STAGE

Mrs Brown, aged 55, was diagnosed as having Parkinson's disease 6 months ago after a year of experiencing slight tremor, loss of fine dexterity, increasing slowness when walking and problems when turning round. Her consultant started her on a drug regime on diagnosis which successfully controls most of her symptoms. At a recent medical review she reported concern about her unsteady walking and was referred to the physiotherapy department. Mrs Brown is working part-time in a job that involves driving and delivery work, both of which are becoming difficult. She has not told her employer of her diagnosis. Her husband is uncomfortable discussing the diagnosis and its implications for the future.

	STATEMENT	RATING (PLEASE CIRCLE)
	CONTEXT	
	In this case a successful context for physiotherapy would involve:	
V1C1	community-based treatment	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1C2	individual treatment sessions	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1C3	carer involvement in treatment sessions	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1C4	multi-disciplinary team working	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1C5	on-going review	Agree 1 2 3 4 5 6 7 8 9 Disagree
	REASONS	
	In this case success would involve:	
V1R1	improved quality of movement	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1R2	improved functional ability	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1R3	prevention of secondary complications	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1R4	increased self-management skills	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1R5	on-going advice, information and support	Agree 1 2 3 4 5 6 7 8 9 Disagree
	ACTIONS	
	In this case success would be achieved through the use of:	
V1A1	cognitive, verbal and visual cueing	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1A2	exercise therapy (stretching, mobilising etc.)	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1A3	normal movement facilitation	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1A4	conductive education	Agree 1 2 3 4 5 6 7 8 9 Disagree
	EFFECTS	
	In this case success would be measured by:	
V1E1	simple measures of gait (eg speed, step length)	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1E2	Parkinson's disease symptom rating scale	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1E3	activities of daily living scale	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1E4	achievement of treatment goals	Agree 1 2 3 4 5 6 7 8 9 Disagree
V1E5	depression scale	Agree 1 2 3 4 5 6 7 8 9 Disagree

MIDDLE STAGE

Mr Smith is a 70 year old widower who has had Parkinson's disease for 7 years. He has been on drug treatment since diagnosis but this is currently under review due to the onset of hallucinations. He is beginning to experience episodes of 'freezing' during walking, especially when out in crowds and going through doorways. Mr Smith is independent in activities of daily living, although the degree of difficulty he experiences is dependent on the efficacy of his medication which declines before his next dose is due. He doesn't have a bath unless his daughter, who lives locally , is in the house. Meals are taking longer to eat and his daughter has reported that her father is loosing weight. She takes him shopping but car transfers are becoming a problem. Mr Smith is experiencing urinary frequency at night which is complicated by reduced ability to turn and to get in and out of bed. He also has a history of chronic obstructive airways disease. He feels he should move from his house as he is increasingly breathless and fearful on stairs.

	STATEMENT	RATING (PLEASE CIRCLE)
	CONTEXT	
	In this case a successful context for physiotherapy would involve:	
V2C1	community-based treatment	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2C2	individual treatment sessions	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2C3	carer involvement in treatment sessions	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2C4	multi-disciplinary team working	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2C5	on-going review	Agree 1 2 3 4 5 6 7 8 9 Disagree
	REASONS	
	In this case success would involve:	
V2R1	improved quality of movement	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2R2	improved functional ability	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2R3	prevention of secondary complications	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2R4	increased self-management skills	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2R5	on-going advice, information and support	Agree 1 2 3 4 5 6 7 8 9 Disagree
	ACTIONS	
	In this case success would be achieved through the use of:	
V2A1	cognitive, verbal and visual cueing	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2A2	exercise therapy (stretching, mobilising etc.)	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2A3	normal movement facilitation	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2A4	conductive education	Agree 1 2 3 4 5 6 7 8 9 Disagree
	EFFECTS	
	In this case success would be measured by:	
V2E1	simple measures of gait (eg speed, step length)	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2E2	Parkinson's disease symptom rating scale	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2E3	activities of daily living scale	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2E4	achievement of treatment goals	Agree 1 2 3 4 5 6 7 8 9 Disagree
V2E5	depression scale	Agree 1 2 3 4 5 6 7 8 9 Disagree

LATE STAGE

Mr & Mrs Jones have been married for 50 years and have just moved into sheltered accommodation. Mr Jones has had Parkinson's disease for 16 years, and also has a history of arthritis and cardiovascular disease. He uses a wheeled zimmer to walk but needs some supervision. His posture is markedly flexed and his gait slow and shuffling. He is falling more, and during his last fall he knocked his wife over injuring her. A recliner-riser chair and pneumatic bath seat assist with transfers. His wife needs to position him in bed at night and reposition him repeatedly as he has a tendency to wander. Mr Jones wears incontinence pads at night. Mrs Jones, who has a history of asthma and depression, is finding if difficult to cope with her increasingly confused and dependent husband. He attends a Day Centre one day a week.

	STATEMENT	RATING (PLEASE CIRCLE)
	CONTEXT	
	In this case a successful context for physiotherapy would involve:	
V3C1	community-based treatment	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3C2	individual treatment sessions	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3C3	carer involvement in treatment sessions	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3C4	multi-disciplinary team working	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3C5	on-going review	Agree 1 2 3 4 5 6 7 8 9 Disagree
	REASONS	
	In this case success would involve:	
V3R1	improved quality of movement	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3R2	improved functional ability	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3R3	prevention of further complications	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3R4	increased self-management skills	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3R5	on-going advice, information and support	Agree 1 2 3 4 5 6 7 8 9 Disagree
	ACTIONS	
	In this case success would be achieved through the use of:	
V3A1	cognitive, verbal and visual cueing	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3A2	exercise therapy (stretching, mobilising etc.)	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3A3	normal movement facilitation	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3A4	conductive education	Agree 1 2 3 4 5 6 7 8 9 Disagree
	EFFECTS	
	In this case success would be measured by:	
V3E1	simple measures of gait (eg speed, step length)	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3E2	Parkinson's disease symptom rating scale	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3E3	activities of daily living scale	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3E4	achievement of treatment goals	Agree 1 2 3 4 5 6 7 8 9 Disagree
V3E5	depression scale	Agree 1 2 3 4 5 6 7 8 9 Disagree

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE. NOW PLEASE PLACE IT IN THE ENVELOPE PROVIDED AND RETURN TO:

Appendix II

Sensory psychophysics:

Fechner was primarily interested in measuring the mental activities by considering the underlying physical events (Corso, 1970). The major link with Fechner's mathematical reasoning involved the concept of threshold or Limen; the minimal amount of energy or change of energy that could be detected by an individual.

The psychometric function.

The intensity of a stimulus depends on the strength of that stimulus. A sensory threshold is the lowest stimulus that a person can perceive and can be derived from a mathematical calculation. When a person is offered a range of stimuli of a progressively greater intensity, the results of the person's recognition of receiving the stimuli can be plotted as the percentage of times the detection is noted. The relation is termed the psychometric function.

The threshold.

By convention the threshold is defined as the stimulus intensity detected by half of the trials. The threshold is not a static feature and can be modified by many factors, for example when the body is subjected to excitement, medication, time, and other physically stressful events (Kandel et al, 1991).

"Weber's" Law.

Weber in 1834 considered this aspect of discrimination and stimulus intensity, and formulated what is now referred to as ***"Weber's" Law:***

$$\Delta S = K \times S$$

Where ΔS= the minimal difference in strength between a reference stimulus S and a second stimulus that can just be perceived, and K is a constant (Stevens, p35, 1966; Kandel et al, 1991).

The minimal difference is referred to as the "just noticeable difference".

The differential threshold is regarded as a law of relativity in psychology; what must "be added to produce a detectable difference is relative to what is already there" (Stevens, p35, 1966).

Weber proposed the principle that the ratio, between the stimulus and the increment, (that which must be added to) is dependent with intensity: Weber noticed that the smallest discernible difference between two weights is a constant fraction of the weights themselves.

The Weber fraction for weights is stated as approximately equal to 1/30th, meaning 31 grams are discernible from 30 grams, and 62 grams from 60 grams (Ruch and Fulton, 1960).
The *Weber fraction* is usually written as,

$$\Delta I / I = C$$

in which delta **/I** means a just noticeable difference.
In 1860 Fechner extended this law to describe the relationship between the stimulus intensity and the stimulus intensity perceived by the subject: the perceived magnitude of the stimulus can be plotted against the stimulus intensity, as a power function of different exponential values (Osgood, 1953).

The Weber-Fechner law was produced when Fechner tried to derive the relationship between the stimulus and the intensity by mathematical means. He made the assumption that discriminible increments are equal units of sensation, he was able to produce the formula:
Sensation = K log **I** + C
where K is the constant value.
There has been much criticism of Weber's law and of Fechner's equation. The former had less generality than it originally prescribed and the latter only applies to a limited range of intensities of the sensory modalities (Ruch and Fulton, 1960). However, it would appear that in general terms Fechner has described "a fundamental feature of sense organs behaviour; this being that over a certain range of intensities the frequency of discharge is a linear function of the logarithm of the stimulus" (Stevens, p306, 1960).