

**A QUALITATIVE AND QUANTITATIVE STUDY OF THE NATURE OF
DEVELOPMENTAL COORDINATION DISORDER**

By

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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ABSTRACT

Aims

The aim was to examine the theoretical and clinical plausibility of subtypes of movement difficulty, and explore the impact subtypes and/or additional factors would have on motor development.

Background

Developmental Coordination Disorder (DCD) is a chronic, often permanent condition evident from early childhood, characterised by difficulties performing a range of movement tasks that are not explainable by neurological or psychological impairments. The aetiology of the condition is unknown and various theories of motor development and impairment have been used to try and explain the variability in expression, prompting hypotheses over whether homogeneous subgroups can be identified that are consistent across populations and with distinct pathways, the identification of which would increase our understanding of the condition.

Hypotheses

- i & ii) Distinguishable subtypes of perceptual and motor performance in children with DCD are comparable to those obtained in previous studies with group membership consistent across theoretical models.
- iii – v) Subtypes contribute differentially to maturation and treatment response whilst additional factors will also be seen to influence movement skill acquisition.

Design and method

A mixed experimental design was used. The first study tested for the presence of specific components of motor behaviour; their interaction and influence on motor performance. A second study involved a subset of children in a cross-over intervention programme of 20 weekly therapy sessions with a 6 monthly review of movement skills and developmental progress, over a period of 2 years. Data analysis

considered whether distinct subtypes were consistent across theoretical perspectives and, whether these or other factors influenced maturation or treatment response.

Results

Factor and cluster analysis identified five subtypes, differentiating children on perceptual and motor performance, similar to previous sub-typing studies. A majority of children benefited from participation in group intervention. Progress was unrelated to degree of initial motor impairment or subtype although those with perceptual and severe movement problems were more likely to have persistent difficulties.

Conclusions

Five subtypes of DCD were identified which were not found to influence progress or response to treatment, for a smaller subset. Different theoretical perspectives did not predict similar group membership confounding nosological classification. An alternative approach to modelling coordination difficulties is recommended.

Abbreviations

ABD	Atypical Brain Development
ADHD	Attention Deficit Hyperactivity Disorder
AMPS	Assessment of Motor and Process Skills
APA	American Psychiatric Association
AS	Asperger Syndrome
ASD	Autistic Spectrum Disorder
ATNR	Asymmetric Tonic Neck Reflex
BOTMP	Bruininks Oseretsky Test of Motor Proficiency
BPVS (ss)	British Picture Vocabulary Scale (standard scores)
C-MABC	Checklist of the Movement Assessment Battery for Children
COMPS	Clinical Observations of Motor and Postural Skills
CO-OP	Cognitive Orientation to daily Occupational Performance
COPM	Canadian Occupational Performance Measure
COT	College of Occupational Therapists
CSQ	Coordination Skills Questionnaire
DAMP	Deficits in Attention, Motor Control and Perception
DCD	Developmental Coordination Disorder
DCDQ	Developmental Coordination Disorder Questionnaire
DSM	Diagnostic and Statistical Manual of Mental Disorders
ESRC	European Social Research Council
ETCH	Evaluation Tool of Children's Handwriting
FA	Factor Analysis
GM	General Medical Condition
ICD	International Classification of Diseases
IQ	Intellectual Quotient
KIN	Kinesthesia
KMO	Kaiser Meyer Olkin Statistic
K-S	Kolmogorov-Smirnov statistical test
KST	Kinesthetic Sensitivity Test

LCS	Leeds Consensus Statement
MABC	Movement Assessment Battery for Children
MABCTI	Movement Assessment Battery for Children Total Impairment Score
MAND	McCarron Assessment of Neuromuscular Development
MAT	Matrix Analogies Test
MBD	Minimal Brain Dysfunction
MFVPT	Motor Free Visual Perception Test
MLD	Mild-Moderate Learning Disability
NAPOT	National Association of Paediatric Occupational Therapists
nonREPGT	Non-Representational Gesture Test (subtest)
NTT	Neuromotor Task Training
NVLD	Nonverbal Learning Disability
PCT	Primary Care Trust
PDD	Pervasive Developmental Disorder
PONS	Profile of Neuropsychiatric Symptoms
RCT	Random Controlled Trial
REPGT	Representational Gesture Test (subtest)
RFR	Rapid Forearm Rotation
SD	Standard Deviation
SDQ	Strengths and Difficulties Questionnaire
SI	Sensory Integration Theory
SIT	Sensory Integrative Therapy
SIPT	Sensory Integration and Praxis Tests
SLI	Speech and Language Impairment
SDDMF	Specific Developmental Disorder of Motor Function
SDQ	Strengths and Difficulties Questionnaire
SPSS	Statistical Package for Social Sciences
VMI	Developmental Test of Visual Motor Integration
WAEC	Widmore Adult Education Centre
WHO	World Health Organisation
WORD	Wechsler Objective Reading Dimensions

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CHAPTER 1 INTRODUCTION

The ability to execute a range of tasks involving movement and coordination is integral to participation in many of the activities that are valued in modern societies. A number of children in the course of their development fail to acquire proficiency in movement skills, in the absence of identifiable pathology, limiting participation in daily tasks. These children are often described as having a 'Developmental Coordination Disorder'.

Developmental Coordination Disorder (DCD) is a chronic, often permanent condition characterised by impairment of motor skills resulting in poor functional performance (American Psychiatric Association, APA, 1994). These difficulties cannot be attributed to a general medical condition or Pervasive Developmental Disorder nor explained by intellectual impairment. The prevalence of DCD is estimated at 5% to 6% amongst school-aged children (Landgren et al., 1996, Henderson & Barnett, 1998).

DCD is considered to be made up of a heterogeneous group of children experiencing difficulties in either gross or fine motor skills, irrespective of any co-morbidity, which differentially influence function and performance and by deduction, therapeutic requirements (Polatajko, 1999). The possibility of more specific delineations of subtypes amongst this heterogeneous group has been raised in the literature with inconclusive results particularly with respect to the clinical relevance of any such subtype, either when describing perceptual-motor subtypes or when considering the association of movement difficulties with additional developmental disorders (Hoare, 1994; Macnab, Miller & Polatajko, 2001; Miyahara, 1994, Visser, 2003, Wright & Sugden, 1996). Furthermore, Macnab et al. (2001) demonstrated the influence of testing procedures on subsequent cluster profiles with the consequence that the subgroups identified in these few studies may have varied as different theoretical models, and associated evaluation procedures, were used for the identification of co-ordination impairments.

Longitudinal studies show a higher risk of persistent movement difficulties through adolescence as well as demonstrating concomitant social and emotional problems and/or poor academic achievement (Cantell, Smyth & Ahonen, 1994; 2003; Geuze & Borger, 1993; Gillberg & Gillberg, 1989; Hellgren et al, 1993; Hellgren et al, 1994; Henderson & Hall 1982; Losse et al, 1991; Schoemaker & Kalverboer, 1994; Sugden & Chambers, 1998). Cousins and Smyth (2003; 2005) identified a number of tasks that continued to be difficult for adults who had past and/or present coordination difficulties. The complexity and inter-relationship of motor impairments with learning, social and emotional problems is highlighted by the significantly higher risk of negative employment, social and/or emotional outcomes in adults in Sweden and the United Kingdom linked to co-ordination difficulties in childhood (Rasmussen & Gillberg, 2000; Sigurdsson, van Os & Fombonne, 2002).

Over the past two decades an increased interest in children with movement difficulties, particularly DCD, has resulted in a significant number of children being referred to remedial services (COT & NAPOT, 2003; Miyahara et al., 1998; Rintala et al., 1998; Rosblad & Gard, 1998). However, recent surveys of occupational therapy services in the UK for children with DCD have indicated excessive waiting times with inadequate provision in many instances (COT & NAPOT, 2003). These surveys show approximately 40%-60% of therapist caseloads to consist of children identified as having a co-ordination disorder (COT & NAPOT, 2003; Dunford & Kelly, 2001; Dunford, Street & Sibert, 2004; Green & Archer, 2000; Hackett, 2002). Furthermore, long waiting times for initial appointments have been linked to excessive time taken to complete some assessments, with perfunctory tests being utilized in the absence of clear links between the theories underpinning movement disorders, assessment techniques and treatment approaches (Green et al., 2002a; Green et al., 2005; Hardwick & Jessop, 2004). Hackett (2002) also highlighted the difficulties encountered by managers of services when there is a lack of empirical evidence regarding the efficiency and effectiveness of interventions, particularly in relation to children with DCD. It was felt that service provision in the UK would be improved by having a better understanding of the nature of DCD. The current project focuses on

some important questions, notably: What constitutes the key features?; How can they be identified?; How do these inter-relate?, and; What additional factors impact on outcome?

The notion that children with DCD need individualised therapeutic support has been given credence by the fact that few studies implementing a standard treatment to these children have been able to show progress in a majority — beyond that which would be estimated by normal maturational rate. Confusion surrounding the defining criteria and subsequent assessment of DCD has further contributed to the failure to identify globally successful treatments for these children (Geuze et al., 2001). Partly as a consequence of the overall heterogeneity in the presentation of DCD, various treatment programmes have been developed which either address the underlying motor, sensory or perceptual processes or focus on specific skill acquisition (Sugden & Chambers, 1998). Comparability between studies of treatment efficacy is restricted by differences in provision of services and treatment regimes (Pless & Carlsson, 2000). And moreover, most of the treatment studies have some limitations regarding sample selection and definition, reliability and appropriateness of measurement tools and blindness or lack of control group. Although Sugden and Chambers (1998) suggest that most treatments for children with predominant motor problems work, at least in the short term, few studies have looked at sustained benefits and outcome over a longer period. To some extent, the identification of the presence of coordination difficulties and educating those involved with the child, will help to ameliorate the pressures on the child to succeed in tasks at home and school. What is not known is whether a specific treatment approach would be more effective for a certain ‘type’ of co-ordination difficulty. The need for a comparison of the outcome of well-defined subgroups of children with DCD is also recommended by Pless and Carlsson (2000) and Stephenson (2005).

The research over the past four decades illustrates the pervasive difficulties children with co-ordination problems experience and emphasises the need to understand the nature of coordination disorders in order to provide effective treatments that reduce

the impact of the disorder on later function. Of particular interest here, is whether this rather large, mixed group of children, who present to clinical services with significant difficulties executing motor tasks, can be subdivided into more specific subtypes either by type or severity of co-ordination impairment and/or behavioural features. Additionally, focus is placed on whether there is a differential effect, if any, of subgroup(s) on natural and/or intervened outcome.

A long-standing involvement in clinical and research work had highlighted a number of very important clinical issues towards which the comprehensive data collected from a clinical group, in combination with additional research input, could further our understanding of movement difficulties of children and their remediation. The analyses undertaken in this project were designed to inform clinical practice by identifying the most salient measures regarding the child's motor and developmental status, in order to reduce the use of perfunctory assessments and assure more appropriate remedial programmes can be implemented in a judicious period.

1.1 Purpose – aims and objectives

This study aimed to examine the theoretical and clinical plausibility of subtypes of movement difficulty by determining:

- i) whether distinct subtypes can be identified within a recognised heterogeneous group and,
- ii) whether these subtypes influence outcome with and without treatment.

The aims and objectives of the project are addressed by considering the following questions:

- i) Are there distinguishable subtypes of perceptual and motor performance in a group of children with Developmental Coordination Disorder in the UK and, if so, how do these compare with published studies from Australia and Canada?
- ii) How well do different theoretical models, used to identify subtypes, predict original group membership?

- iii) How do these subtypes influence outcome, with and without treatment?
- iv) What impact do additional factors associated with motor development have on movement skill and treatment response?
- v) How do emotional and behavioural characteristics of children influence the acquisition of motor skills?

This study follows on and yet is distinguishable from four previous cluster analyses undertaken on children with co-ordination disorder (Hoare 1994; Macnab, Miller & Polatajko, 2001; Miyahara 1994; Wright & Sugden, 1996). The objectives of this project differ from these previous studies in that: i) the perceptual and movement profiles of the same group of children are analysed from different theoretical perspectives to determine whether group allocation remains similar despite differing assessment procedures; ii) additional information known to influence child development and in particular motor skills is included, and; iii) a subset of these children is taken to contrast treatment and maturational outcome by subtype as well as key developmental factors.

This study expands on the work undertaken in a screening project in Bromley investigating alternative methods for identifying DCD (Green et al., 2005). The foundation study had been set up to screen referrals, contrasting parent and teacher opinion of the extent of movement difficulties, to enable those children at risk of having DCD to be seen promptly. The process of identification of DCD included various types of assessments from the different theoretical frames of reference (eg. developmental, perceptual-motor, sensory integrative and motor learning) enabling the classifications of movement type (subtypes) from each theoretical perspective to be contrasted. The profiles of motor performance of the children from the screening programme, who were identified with DCD (who had been referred to clinical services), are analysed in detail to determine whether homogeneous 'sub-types' can be distinguished.

The clinical relevance of subtypes was explored by examining whether general group treatment accelerates motor development differentially between subtypes. An additional study, consisting of a subset from the original cohort, was undertaken to consider which children would benefit most from an Occupational Therapy group intervention. A child-centred approach was adopted to consider the functional impact of DCD in different environmental contexts with measures employed to address progress across settings (Coster, 1998). Post hoc analyses examined factors most likely to indicate the need for treatment and/or contribute to treatment responses.

In addition, a number of studies have suggested that children in population studies differ from those seen in clinical studies, compromising the relevance of these earlier results to clinical settings where children with co-ordination difficulties are seen most frequently (COT & NAPOT, 2003; McConaughy & Achenbach, 1994). The current study takes advantage of the availability of children referred to a clinical service due to problems performing motor tasks within their daily routines. Many of these children had participated in a screening programme aimed at reducing a waiting list for occupational therapy assessment (Green et al., 2005). Hence, this study utilises a convenience sample believed to be representative of clinical services in the United Kingdom (COT & NAPOT, 2003).

To explore the questions posed by the aims and objectives, a review, analysis and synthesis of the literature concerning movement problems and other specific learning difficulties were undertaken, using the Cochrane Library, CINAHL, MEDLINE, PsychFile and manual analysis of the reference lists of relevant papers, chapters and articles. Particular focus was placed on obtaining information regarding the development of motor skills (potential for distinguishable subtypes), research studies addressing the theoretical premise of motor problems and scientific evidence for distinctive 'types' of movement difficulties, as well as intervention studies addressing the motor difficulties of children.

1.2 The structure of the thesis

The thesis begins by providing an overview of Developmental Coordination Disorder, describing historical perspectives of movement disorders as well as detailing more typical features, presentation and outcome as currently understood.

A synopsis of the more common theories of movement skill development is set out to provide frames of reference for understanding movement impairments. These different views offer partially opposing mechanisms for conceptualizing and categorizing movement difficulties, with subsequent variations in the techniques used to identify and potentially remediate co-ordination impairments. These different approaches are discussed to form a background to the main substance of this thesis — an analysis of the similarities and differences between these theories and the impact that categorisation of children from one or another perspective may have on outcome.

The methodology is then described, with additional detail provided of less common or recently developed measures used to analyse motor skill and/or outcome. Results are reported in a descriptive and quantitative manner. Particular attention is given to the determination of more discrete if not homogenous subtypes, in either quality or degree of deficit, from the key theoretical approaches and how these contrast. The next sections report on overall outcome (maturation and intervention) with respect to the extent of the motor difficulty as documented at the initial assessment, as well as by subtype and the key variables hypothesised to have an impact on motor development. The relevance of the identified subtypes for distinguishing characteristics of children and predicting outcome is explored.

The discussion debates the impact of categorisation of movement difficulties, pulling together the results of this study with a critique of the theories and approaches currently employed in research and clinical practice. Concluding suggestions are given for a unifying model for understanding the heterogeneous nature of DCD and associated problems.

CHAPTER 2 OVERVIEW OF DEVELOPMENTAL COORDINATION DISORDER

2.1 Historical Perspective of Co-ordination Difficulties

Over the past century, clumsiness within developmental disorders has been described by various generic terms such as ‘Congenital Maladroitness’ (Collier, cited from 1920s), Clumsy Child Syndrome (Gordon & McInlay, 1980; Gubbay, 1975), Minimal Brain Damage/Dysfunction (Whitmore & Bax, 1999) and/or Developmental Dyspraxia. It is also considered within the concept of Sensory Integrative Dysfunction (Ayres, Mailloux & Wendler, 1987). Missiuna and Polatajko (1995) went on to show that these various terms are not necessarily interchangeable with the specificity of coordination difficulties as a ‘pure’ condition called into question by others. Rutter (1982) and later, Whitmore and Bax (1999) cogently argued against the notion of co-ordination and other developmental disorders as specific and/or definable disorders in view of the lack of a diagnostic distinction between measurable symptoms either in aetiology or performance/behaviour components. In all, by 1998 Henderson and Barnett had identified up to 16 diagnostic terms to describe children with coordination difficulties.

The current recognition of clumsiness as a substantial and primary impairment for some children was not formally acknowledged until its relatively recent inclusion within the Diagnostic and Statistical Manual of the American Psychiatric Association in 1987 under Developmental Coordination Disorder (DCD; APA, 1987, DSM-III), and by the World Health Organisation in the International Classification of Diseases in 1992 under Specific Developmental Disorder of Motor Function (SDDMF; WHO, 1992, ICD-10). The term DCD, virtually synonymous with the ICD-10 classification of SDDMF, will be used here to avoid assumptions regarding the specificity of the disorder and the latter’s emphasis on movement per se rather than the notion of coordinated movements in interaction with the environment.

An international meeting of invited researchers/clinicians in the field of motor impairment was held at The London (Ontario) Consensus in 1994. This group attempted to reach consensus on diagnostic criteria for children who exhibited excessive clumsiness and agreed that the term DCD should be used as the key word on all publications (Polatajko & Fox, 1995). (Refer to Appendix 1 for a comparison of these criteria). DCD was defined as a chronic, often permanent condition characterised by impairment of motor skills producing poor functional performance, the degree of which cannot be explained by the child's age, intellect or other neurological or psychiatric disorders. The London Consensus further described this group as differing in movement from their peers in areas which include: fine and/or gross motor skills; age equivalence in motor performance; quality of movement; functional performance at home, play and school, and; the amount of effort and/or difficulty experienced with novel motor based tasks. Secondary characteristics were also identified for consideration within the diagnosis, namely reduced self esteem, social acceptance and/or coping strategies. Core symptoms including the number of dysfunctional domains and the degree of difficulty in any one area were not quantified in the London Consensus report, nor have they been defined further in subsequent meetings of this research group other than to state that motor performance is substantially below that of their peers and affects functional performance. Debates continue regarding the appropriateness of specific terms and defining symptoms however, there is general agreement that researchers and clinicians should be working towards nosological refinement.

To this end, a recent series of seminars sponsored by the United Kingdom's Economic and Social Research Council (ESRC) and the Dyscovery Centre, Wales, drew together experts from around the world to discuss the criteria for diagnosis of DCD and subsequent assessment and interventions, concluding with the publication of the Leeds Consensus Statement (LCS, 2006). This group agreed to adopt the DSM-IV-TR (APA, 2000) as a useful basis for the diagnosis of DCD with a number of provisos (See Appendix 1 for DSM-IV and DSM-IV-TR criteria). As such, recommendations for refinement of the four criteria set by the APA include the following:

- **Criterion A.** “Performance in daily activities that require motor coordination is substantially below that expected given the person’s chronological age and measured intelligence.” (APA, DSM-IV-TR, 2000, p. 58).
 - An individually administered, standardised test of general motor competence should be used to identify children falling below the 5th percentile (those falling between the 5th and 15th percentiles should be considered at risk).
- **Criterion B.** “The disturbance in criterion A significantly interferes with academic achievement or activities of daily living.” (APA, DSM-IV-TR, 2000, p. 58).
 - The assessment should reflect culturally relevant developmental norms to include consideration of self-care, play, leisure and schoolwork (including handwriting, PE and tool use) along with the view of the child, parents, teachers and relevant others.
- **Criterion C.** “The disturbance is not due to a general medical condition (e.g., cerebral palsy, hemiplegia or muscular dystrophy) and does not meet criteria for a Pervasive Developmental Disorder.” (APA, DSM-IV-TR, 2000, p. 58).
 - Conventional neurological examination should be conducted to rule out major neurological conditions *but* should not exclude the possibility of dual diagnoses with other neurodevelopmental disorders such as attention deficit hyperactivity disorder (ADHD), autistic spectrum disorder (ASD)/pervasive developmental disorder (PDD) and/or developmental dyslexia.
- **Criterion D.** “If mental retardation is present, the motor difficulties are in excess of those usually associated with it.” (APA, DSM-IV-TR, 2000, p. 58).
 - Assessment should ideally include a measure of IQ to establish intellectual ability, however, where not possible relevant data from school performance, national tests and teacher opinion are acceptable. Children with measured or presumed IQ below 70 should not be given a diagnosis of DCD.

These refinements point towards greater concordance in defining the core symptoms of DCD as those of movement difficulties which influence participation in daily activities. Recognising recent evidence to suggest that DCD, although a unique and

separate neurodevelopmental disorder, may frequently co-occur with other neurodevelopmental disorders, it becomes more difficult to establish whether concurrent social, emotional and/or behavioural problems are primary (co-occurring) or secondary (consequential) — let alone what contribution these factors might make to overall outcome.

The expanding interest in problems related to motor co-ordination over the last century and subsequent increase in the numbers of children referred for remedial therapy has created the need to define cut-off points for Criteria A and B as recently recommended by the Leeds consensus (LCS, 2006) — more specifically, the nature/quality and degree of ‘clumsiness’ that distinguishes ordinary attributes from potential detrimental traits that require intervention (Green & Archer, 2000; COT & NAPOT, 2003; Miyahara, et al, 1998; Rintala et al, 1998; Rosblad & Gard, 1998). A relatively recent audit of an inner-city service (part of which was within the catchment area of the current study) suggested that approximately 60% of referrals to a paediatric occupational therapy service were due to concerns over co-ordination and motor skills (Green & Archer, 2000). This concurs with the more recent survey of services for children with co-ordination impairments undertaken by the College of Occupational Therapists (COT) and National Association of Paediatric Occupational Therapists (NAPOT) in the UK, which illustrates the prevalence of the condition and impact on services with increased referrals contributing to long waiting lists (COT & NAPOT, 2003). These surveys suggest that there are a considerable number of children who may benefit from some level of professional support, but what is not known, are which children with motor co-ordination difficulties require what type of intervention and to what extent. Are there qualitatively or quantitatively distinct features, current or historical, which indicate the need to intervene in a particular manner?

In considering the possibility that a relationship exists between presentation and outcome, many of those children referred to therapy services may also have had a history of peri-natal difficulties including pre-maturity. Neonatal difficulties have been found to be powerful predictors of persistent minor neurological dysfunction and

subsequent perceptual and motor difficulties (Foulder-Hughes & Cooke, 2003; Francis-Williams & Davies, 1974; Gillberg & Gillberg, 1989; Hadders-Algra & Lindahl, 1999; Jongmans et al., 1996; Sullivan & McGrath, 2003). In a large prospective study in the USA, Nichols and Chen (1981) found more than 350 significant associations between potential antecedent variables and the three major symptoms of Minimal Brain Dysfunction. However, no particular constellation of factors predisposed a child to movement difficulties as opposed to problems in learning or attention/activity (Nichols & Chen, 1981). An alternate view of the typology of DCD has been proposed by Kaplan and colleagues (1998; 2001; 2006) with the suggestion that co-morbidities should be considered the rule rather than the exception in this group of children with the consequence that those with attention or learning problems should also be tested for motor impairments and vice versa. This is consistent with the sentiments of the Leeds consensus group (LCS, 2006). Although a direct relationship between learning (reading), behavioural, social and emotional difficulties and patterns of motor performance has not as yet been demonstrated, a number of studies have documented the frequent co-existence of these developmental problems (Green, Baird & Sugden, 2006; See Appendix 2 and Green & Baird, 2005 for a review). The continuing debate as to whether pre-maturity or co-morbidity would rule out a diagnosis of DCD under Criterion C and/or D or whether these should be considered as making up distinctive subtypes is exemplified by the consensus of the Leeds' group which did not pass comment on the aetiological aspects of movement difficulties (APA, 1994; Barnett, Kooistra & Henderson, 1998; LCS, 2006; Geuze, et al., 2001; Gillberg & Gillberg, 1989; Jongmans, et al., 1998; Kaplan et al., 1998; Visser, 2003). A differentiation of outcome in children with varying degrees of attention and perceptual problems (Deficits in Attention, Motor Control and Perception; DAMP) provides some support for the postulate that children with coordination deficits may be made up of distinctive subtypes either in: type (quality) or severity of coordination deficit; aetiology and history, and/or; overlap with other conditions, and that these subgroups may require different intervention strategies (Landgen et al., 1996; Rasmussen & Gillberg, 2000).

Qualitative differences in the performance of motor skills have been considered from various theoretical models used to explain the movement difficulties of children. Sensory integration theory (SI) is built upon a model which clusters children according to a relative profile of strengths and problems across perceptual and movement tasks. The principle behind this approach, which is one of the most frequent practiced in the USA, Canada and UK, is that there are differences in the underlying mechanisms of sensory processing contributing to different types of movement problems that would then warrant a differential approach in intervention (Ayres, 1971; Ayres, 1989; Howard, 2002; Kelly, 2004; Mandich et al., 2001a). On the other hand, Wilson and McKenzie (1998) undertook a meta-analysis of research into the information-processing difficulties of children with DCD; the most frequent problems evident being those of visuospatial processing (and, to a lesser extent, problems with inter-modal and kinaesthetic perception). These results are more consistent with the approach taken by Rourke (1989) who defined a syndrome of 'nonverbal learning disabilities' (NVLD) which clustered children with movement difficulties together with conditions involving deficits in right hemispheric functions, lending emphasis to cognitive models of motor impairment. Weintraub and Mesulam (1983) had provided earlier evidence of right hemispheric (visuospatial) deficits concurring with motor performance problems although Denkla (1983) argued that the descriptions of these children were also consistent with a diagnosis of Asperger Syndrome. The past decade has provided a number of studies exploring inter-modal perceptual analysis (matching across modalities) and intra-modal perceptual analysis (matching within a modality eg. visual to visual or proprioceptive to proprioceptive) that suggest that children with DCD may have greater difficulty with tasks involving cross-modal comparisons, particularly that of visual to proprioceptive and/or potentially inter-hemispheric communication (MonWilliams, Pascal, & Wann, 1994; MonWilliams, Wann, & Pascal, 1999). These results are somewhat in contrast to the hypotheses put forward by Weintraub and Mesulam (1983) and Rourke (1989) emphasising problems of visual 'gestalt'. Although research to date has predominately focused on distinct perceptual or motor processes of DCD, more recent ecological models such as Dynamical Systems theory, seek to explain underlying

mechanisms from a very different perspective in which there is a reciprocity (coupling) of perception and action connected to the context and environment of the task rather than distinct perceptual processes (Wade, Johnson & Mally, 2005).

Despite differences in terminology and symptomatology there is clearly a considerable group of children whose difficulties in performing motor tasks exceed expectations based on their general motor and intellectual development (Henderson & Henderson, 2002). The complexity of the impairments experienced by children with DCD has however always been clear to parents and clinicians. Recognition that symptoms of many developmental disorders overlap — to varying degrees in different individuals, and that these may change over time — further confounds the ability to define diagnostic distinctions. The ability to determine prevalence and aetiology, although difficult, remains important in defining the boundaries between talent deficit and developmental deviance (Hall, 1988). This thesis considers whether theoretical distinctions, and hence possible discrepancies in terminology, account for the differing presentations of these children or whether there are more substantive subtypes of coordination impairment that would warrant differential interventions. Issues surrounding the overlap of motor with other developmental disorders are also of importance within this paper.

2.2 Presentation and features

Although confusion surrounds the nosological issues defining movement difficulties, the descriptions of the children over the past few decades have remained fairly consistent — with parents articulating the complexity of the difficulties their children experience. Over the years, parent and teacher reports include comments such as ‘unable to copy work from a blackboard’, ‘writing looks like a spider’, ‘never selected for the football team’, ‘messy eater’, ‘has never been able to ride a bike’, etc. Stephenson, McKay and Chesson (1991) documented the frequency of parental concerns about their child’s difficulties in specific areas. Writing (94%),

throwing/catching ball (90%), and using cutlery (87%) were the most predominate with comments regarding skills in running, jumping, hopping, riding a bike, tying laces, pencil control and drawing all mentioned over 50% of the time. Stephenson's more recent (2005) study goes on to describe the impact that movement difficulties may have on a broader aspect of family life. The children themselves have been known to comment "My body doesn't do what I tell it to do" and "I try my hardest and my teacher still thinks I'm lazy". Clinical descriptions of these children include difficulties with manipulating tools, poor visual-spatial skills affecting drawing and writing, poor postural control and balance and poor bilateral coordination. Discrepancies between verbal capability and motor output/productivity are also alluded to by teachers and psychologists. Pless, Persson, Sundelin and Carlsson (2001a) explored parental descriptions of young children with DCD which highlighted the impact on parenting of, not only the motor behaviours of their children, but the problems of coping with the emotional and communication needs of these children.

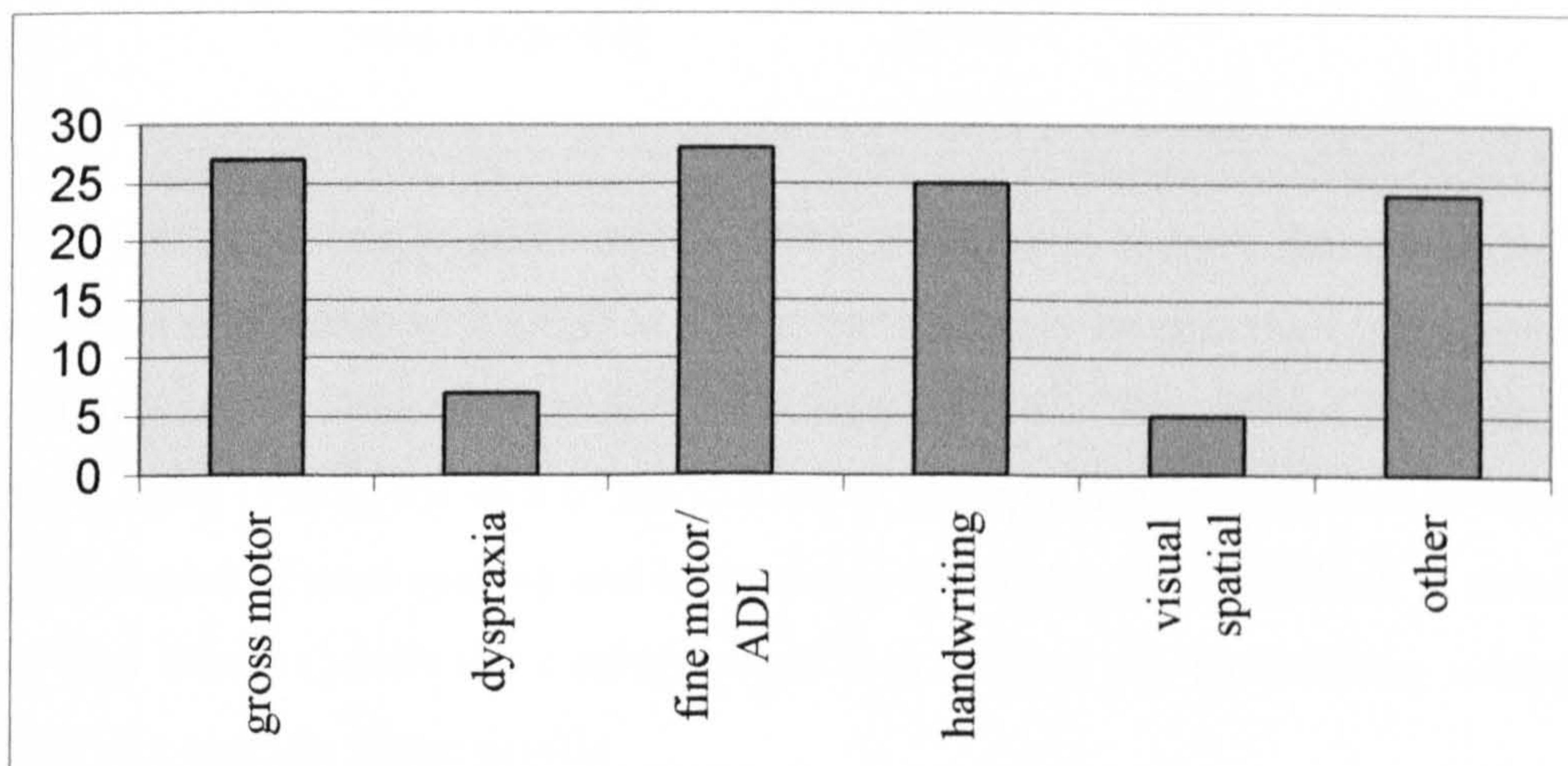
More specific criteria for the identification of these children have listed poor fine and/or gross motor skills along with frustration and difficulties when learning new motor skills, along with documentation of the extent to which these problems influence functional performance at home, play and school (Polatajko & Fox, 1995; Willoughby & Polatjko, 1995). The skills a child needs, to be consistent with more typical development, may be somewhat different from the expectations placed on some children to compete or excel against peers, as opposed to being described as 'without talent' (Hall, 1988). It is essential therefore to ensure that the identification of a significant co-ordination impairment is independent of heightened expectation. However, child and family-centred practice, as advocated by the NHS framework and Children's Bill (HMSO, 2004), recommends the evaluation of any difficulties with reference to the context and culture in which skills need to be performed; therefore the identification of a failure to meet an expected level of performance within a particular context could be considered as an appropriate concern for investigation. Thus, gaining parental opinion is vital to the determination of extent of any difficulty and the impact on a child's daily life. To place the current study in

context, the referrals to a community Occupational Therapy service (on which the current study is based) over a two-year period (n=141) were reviewed. The source of referrals for these children is set out in Table 2.1. Analysis of the referee's concerns for a child is illustrated in Figure 2.1. Direct referral from parents was restricted to this service and therefore the parental concerns were noted from the referrals of doctors where they were specifically mentioned. Figure 2.1 illustrates the reporting of difficulties executing motor skills which warranted referral to an Occupational Therapy service. The most frequent reasons provided on referral forms outlined problems in balance and ball skills (gross motor), use of cutlery, scissors and ability to execute constructional tasks (fine motor) as well as poor handwriting. The percentage of these which specifically mention poor handwriting is outlined for a smaller subgroup (Figure 2.2).

Table 2.1 Source of Referral (n = 141)

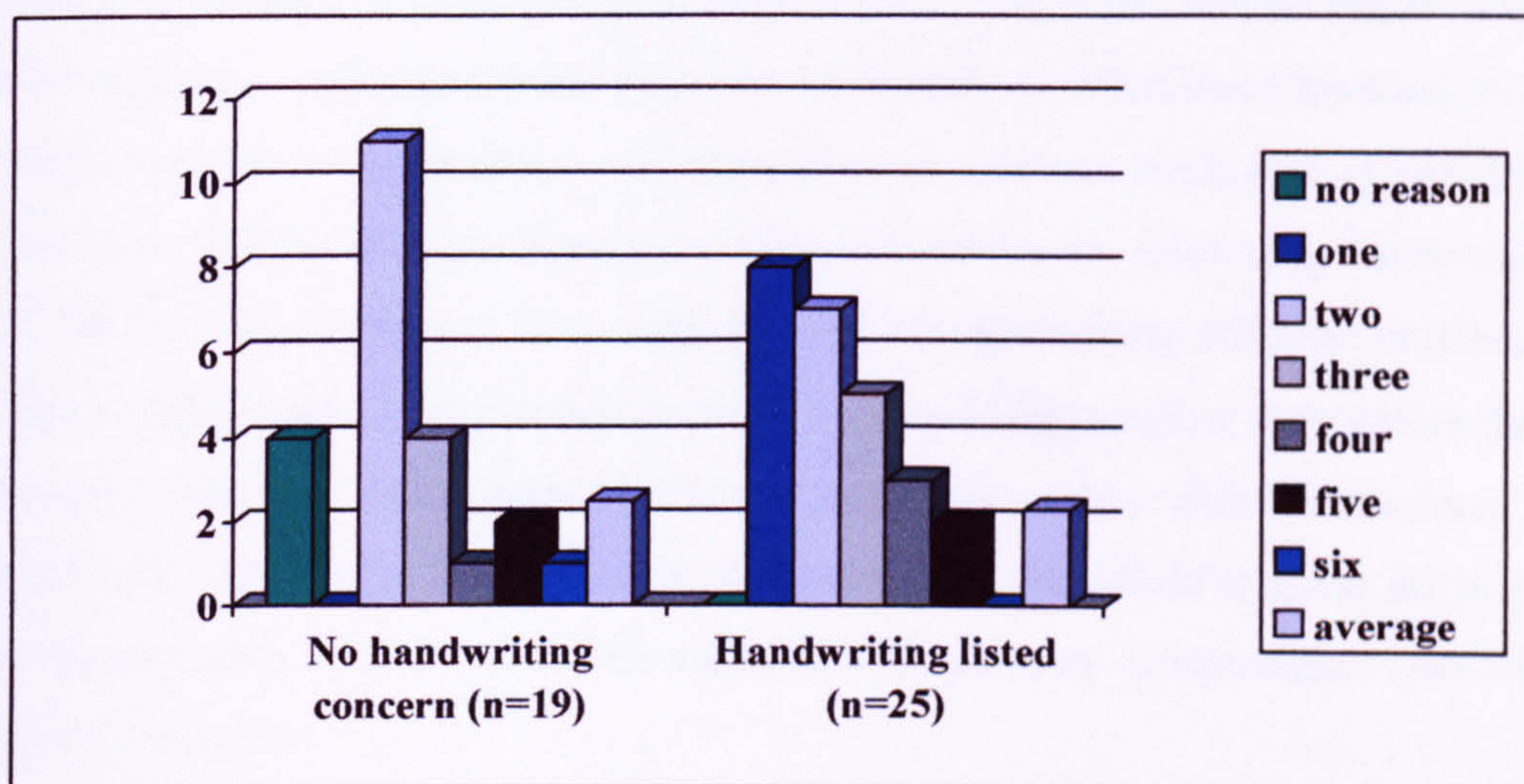
Referral Source	Number (Percentage)
Health – Medical	66 (46.8)
Health – Therapy	19 (16.5)
School – Teacher	39 (27.7)
Psychology – Educational/Clinical	15 (10.6)
Other	2 (1.4)

Figure 2.1 Numbers of Parents/Referees mentioning specific concerns (n=141)



In a smaller subset of these children who were subsequently identified with DCD and opted to participate in the treatment study it is notable that in approximately one third of those referrals which mentioned poor handwriting, this was the only reason given for referral to Occupational Therapy (8 out of 25). Whereas in more than half of those referrals which did not mention handwriting as a problem, at least two reasons for referral were articulated. (See Figure 2.2 for an illustration of the number of referral reasons provided for children). This raises a number of questions as to whether children with more pronounced handwriting problems form a more distinct subgroup of DCD or whether children with discrepantly poor handwriting in addition to other motor problems are more likely to have co-existing difficulties with literacy or indeed other developmental conditions influencing learning.

Figure 2.2 Numbers of referral reasons: contrasting those listing handwriting as a concern to those that did not (n=44)



Malloy-Miller, Polatajko and Anstett (1995) go further to suggest that there may be subgroups of children with DCD or equivalent who may be classified into groups according to their error patterns in handwriting. In the Malloy-Miller, Polatajko and Anstett study (1995), the lack of association of perceptual-motor abilities to visual-spatial factors of poor spacing and letter size in writing makes it difficult to determine how they would classify these subtypes and thus whether any handwriting subtype is linked to a specific motor profile.

Furthermore, it is not known whether children identified via different sources eg. medical versus educational, have fundamental differences in the profile of their strengths and weaknesses. An analysis of the differences between parents and teachers with respect to their concerns regarding the motor difficulties of children found parents to be fairly accurate in their estimation of the impact of a child's motor problems on daily performance (Green et al., 2005). The conclusions from this paper are somewhat ambiguous in view of the skewed sample (a large majority of children with co-ordination difficulties) that differed from those on which both the parent and teacher questionnaires were developed. Therefore, it may be presumed that parents are in touch with the extent of their child's functional difficulties although any association with more specific motor problems is more obscure, as Pless et al. found (2001a). Teachers on the other hand, found it more difficult to identify the child with motor problems within the classroom, with frequent comments that they (teachers) had had little opportunity to observe the child perform the range of motor activities included in the teacher questionnaire. Junaid et al. (2000) had similar results with poor sensitivity of the Movement Assessment Battery for Children Checklist (MABC-C) when completed by teachers. An alternative perspective has been suggested by Netelenbos (2005), which is to consider that, as teachers are observing functional activities in daily situations, they could therefore be identifying different children whose problems performing tasks are more impaired in situ rather than within the laboratory context. This opinion would not necessarily marry with the results of Green et al. (2005) who found parents' judgements of their child's motor skills in the home/community environment to be valid but that teachers' concordance with clinical diagnosis was low.

An additional note on this point (source of referral), concerns the issue of identification of poor motor skills when intellectual capability is in the average or above range. A recent study in the South London borough of Croydon, showed that only 15% of children with intelligent quotients (IQs) less than 70 had a statement of special educational needs or attended a school for moderate learning difficulties (Simonoff et al., 2006). The worryingly high estimates of between 5.8% to 10.6%

(dependent on the intellectual measure used) of children with IQs <70 in the UK from this study, would suggest that attendance at a mainstream educational facility is no guarantee of average or above intellect and a number of these children may be mistakenly identified with DCD if intellectual assessments are not undertaken.

Of interest however, in the current study, are whether there are distinguishable differences in these children on clinical assessment to constitute specific sub-types and how specific features may contribute to outcome.

2.3 Longitudinal perspective and natural outcome

Longitudinal studies provide evidence — not only of the continuing persistence of clumsiness — but of longer lasting sequelae which may persist into adolescence and adulthood despite an apparent resolution of the 'motor' decrement (Cantell, Smyth & Ahonen, 1994; Cantell, Smyth & Ahonen, 2003; Geuze & Borger, 1993; Henderson & Hall, 1982; Losse et al., 1991; Shoemaker & Kalverboer, 1994; Rasmussen & Gillberg, 2000; Sigurdsson, van Os & Fombonne, 2002; Skinner & Piek, 2001; Soorani-Lunsing et al., 1994). This would suggest more than just a 'developmental lag' but rather differential deficits which may be compounded by social and emotional factors.

There have been few studies following children who have been identified with DCD into adulthood. Cousins and Smyth (2005) report on two studies of adult groups who had histories of clumsiness or accident 'proneness', the research of Shelley and Riestler in 1972 and Porter and Corlett in 1989. These studies intimate a potential persistence in problems learning new motor tasks (slowness in mastery) but that the basic skills to master tasks of daily living were essentially accomplished. Problems in performing tasks were usually only evident when these adults were placed in circumstances requiring a high degree of motor competence. Cousins and Smyth (2003) have endeavoured to trace developmental pathways of children with DCD. In a retrospective study, 19 adults who had either had a diagnosis of DCD or self-

reporting histories suggestive of developmental coordination difficulties, were assessed on a number of motor tasks equivalent in type to the Movement Assessment Battery for Children (MABC, Henderson & Sugden, 1992). They were found to perform more poorly across all the tasks in comparison to a control group of age and gender matched recruits. Analysis of the self-report questionnaires of skills and competencies from these subjects and a wider pool of 45 adults reporting motor difficulties in childhood, suggests that some everyday tasks, especially the ability to drive a car, illustrate a continuing functional impact into adulthood.

Prospective studies undertaken in Sweden and reported by Rasmussen and Gillberg (2000) followed children with developmental motor impairments to the age of 22 (the motor difficulties were assumed to be commensurate with DCD but the studies were originally instigated to explore the incidence of minimal brain dysfunction [MBD] and variations in tests and measurements confound interpretation). These and earlier results emphasise the potential neuropsychiatric co-morbidity associated with movement difficulties. An increased risk of negative psychiatric outcome at age 16 years amongst children with Deficits in Attention, Motor control and Perception (DAMP) was found in a study by Hellgren, Gillberg, Bagenholm and Gillberg (1994) with the greatest risk being amongst those children having predominant deficits in motor coordination (a risk of 47% of their sample with DAMP, n=56; 62% of those with the most severe DAMP and 67% of those with motor perceptual deficits, compared to a 4% risk amongst their comparable control group n=45). At age 22, 58% of the index group compared to 13% of the controls (from the original cohort of children with and without motor impairments) were considered to have a poor outcome determined by functional and independent living measures to include employment, reliance on benefits, criminal convictions or diagnosis of psychiatric or personality disorder (Rasmussen & Gillberg, 2000). Albeit the work of Gillberg's team in Sweden constituted a small study within a contained community, more recent publication of the work of Sigurdsson, van Os and Fombonne (2002) following a population of British born children also provides evidence of longer term psychiatric risk amongst individuals who have experienced co-ordination difficulties as children.

Skinner and Piek's study (2001) provides further testimony of a relationship between perceived motor competence, poor motor skill and anxiety in adolescence. These studies give rise to questions regarding the psycho-social influences on potential motor subtypes with respect to the longer term outcome of these children and that these features may in themselves constitute 'sub-type' characteristics. And indeed, Henderson and Hall (1982) intimated this with their identification of different subgroups of children with co-ordination problems, finding a small group in whom the motor problems occurred in isolation (5/16), a small group in whom the motor impairment was accompanied with lower intellectual testing and reduced academic attainment along with social immaturity (5/16) and an additional group who showed wide ranging performance on neurodevelopmental and motor testing (6/16). Cantell, Smyth and Ahonen (2003) have also shown a persistence of, not only lowered perceptions of athletic competence, but also of diminished scholastic/educational achievement in older adolescents with DCD. Along a similar vein, Wright and Sugden (1996) identified children with DCD from amongst a non-clinically referred group who experienced a number of additional behaviours such as distractibility, lack of persistence and disorganisation. More recently, Chambers (2000) found a high incidence of associated behaviours amongst younger children identified with motor difficulties. More detailed discussion of the relationship of DCD to other developmental conditions is included in section 4.2.2. Of interest to the current study is whether these associated behaviours warrant distinction in view of their association with motor difficulties at an earlier age — in other words, do these co-morbidities contribute differently to outcome and response to intervention when associated with DCD?

CHAPTER 3 THEORIES OF MOVEMENT SKILL DEVELOPMENT

This chapter begins by exploring the main theories of motor development and later, discusses how these are applied to children with motor impairment. Providing a theoretical framework for understanding how children acquire motor skills is a prerequisite for developing interventions that can be successful in the remediation of problems. Furthermore, the Leeds consensus group concluded the need for more theoretical underpinning to define the condition (DCD) and in particular, to draw upon the literature in motor control, learning and development (LCS, 2006)

3.1 Motor development

Traditional theorists align the development of motor skills with the maturation of the child's neurological system (Forssberg, 1998). This framework defines a structured perspective in which skills are thought to develop in progressive stages. The emphasis is hierarchical in nature whereby graded levels of control at a neural level appear behaviourally, in a predictable and sequential fashion. More recently, alternative explanations for the acquisition of motor skills have emerged. Ecological approaches predominately focus on the dynamic interaction of the infant with the environment. These theorists, whether maturational or ecological, have tended to study specific aspects of movement control such as balance (and recovery of balance following perturbation) or reach and grasp patterns. Much has been made of differences in motor control, motor learning and motor planning when explaining movement problems — yet whether these are true or philological distinctions have yet to be determined. Some differentiation of the clinical and theoretical concepts of motor control, motor learning and motor planning is required so as to tease out the relationship and boundaries between motor disorders such as cerebral palsy and co-ordination impairments in which there are disorders of skilled movement without obvious motor disability. To ensure some consistency in terminology the following conceptions, which are commonly (traditionally) held by therapists and clinical practitioners, are provided for these terms:

- ***Motor control*** is considered to be more directly linked to the neurological mechanisms by which an individual regulates his or her motor actions when performing a task. Problems in motor control are more commonly associated with overt neurological insult such as cerebral vascular damage and cerebral palsy and reflect asynchrony of motor actions such as dyskinesia (problems in force and direction of movement), dystonia (problems in muscle tone) and tremor/ataxia (errors, in rate, force, range and regularity of movements) (Shumway-Cook & Woollacott, 1995). The study of motor control tends to focus on measuring the processes underpinning movement performance at one snapshot/episode in time.
- ***Motor learning*** on the other hand is more concerned with the process and rate by which skills are acquired as a result of practice or experience. Motor learning is often considered to be dependent upon cognitive processes especially: the ability to identify a goal of action, the rate of learning and the ability to store, retrieve and recombine strategies from memory (Goodgold-Edwards & Cermak, 1990; Schmidt & Lee, 2005). Studies of motor learning therefore focus on identifying relatively permanent changes in skill after practice or experience. Difficulties in motor learning may sometimes be attributable to more general learning difficulties and may thus be associated with deficits in learning other skills such as reading and mathematics.
- ***Motor planning*** is not felt to be synonymous with either motor control or motor learning, but derives more from information processing theories. Although it utilises both, motor planning (frequently referred to as *praxis*) should be distinguished from the motor functions of tone, strength, fluency and precision as well as aspects of learning and task comprehension (Njiokiktjien, et al., 2000; O'Hare, Gorzkowska & Elton, 1999). Praxis is the neurological process by which cognition directs motor action to enable adaptive interaction with the physical world and from a developmental perspective is considered a precursor to the acquisition of skilled, non-habitual movements (Ayres, 1985). Thus it is not a problem in stored and automatic motor programmes such as walking, rolling or creeping. Nor is the primary problem in 'dyspraxia' thought to be solely in the execution aspect of motor performance. Praxis refers more specifically to

intermediary information which bridges the idea of a plan of action (utilising concepts of how the body can move and use objects in the physical environment) and motor execution. Studies of 'praxis' in children are confounded by the historical association with 'apraxia' encountered as a consequence of brain damage. In practice, distinguishing between deficits of movement planning and deficits of movement execution eludes clinicians. Variations in the definitions of dyspraxia further confound our understanding of 'pre-movement plans' with some researchers opting for *gesture* as a measure of *praxis* (Henderson & Barnett, 1998).

Theorists and researchers may make different assumptions regarding the distinctions, if any, between these terms. For example, the mastery of redundant degrees of freedom for motor control (timing and force regulation) may be conceptualised as a motor learning or motor control problem depending on how rigidly definitions are ascribed. In contrast, studies of motor control in differing environmental contexts may explore the rate of acquisition of a skill (eg. recovery of balance after perturbation) as a motor learning problem. Current frames of reference for understanding motor development differentially emphasise theories of motor control and motor learning and therefore lead to different schools of thought on why and how problems arise. Consequently, despite describing similar overt characteristics of children, different mechanisms may be used to identify potential difficulties, with alternative interventions devised to assist the child in overcoming any problems in acquiring movement skill. These theoretical perspectives of motor development will be discussed in the next section before contrasting respective 'deficit' models.

3.1.1 *Maturational Theories*

3.1.1.1 Neuro-motor

Earlier concepts of co-ordination described it as the accuracy of judging distance, force, speed and direction of muscle movement that is required to execute planned and voluntary actions (O'Hare & Brown, 1988). This definition is consistent with neural models for describing movement control. The neural control of movement

is most frequently conceptualised on three levels. The highest level is concerned with strategy — represented by the motor association areas of the neocortex and basal ganglia — as the executive of the forebrain identifying the goal of the movement and the best movement strategy for the task (Bear, Connors & Paradiso, 1996). The middle level is concerned with tactics — represented by the motor cortex and cerebellum — acting as the artist and musician supporting spatiotemporal sequences of muscle contractions required to smoothly and accurately achieve the strategic goal. The lowest level which executes the action — represented by the brain stem and spinal cord — provides for the automated functions activating motor neuron and interneuron pools to make any necessary adjustments, particularly of posture (Bear, Connors & Paradiso, 1996).

Neural-developmentalists use descriptive models to describe stages illustrating the acquisition of measurable motor skills, particularly postural control and locomotion, which are assumed to reflect underlying neurological and structural changes. Theories of (neuro)motor development were heralded in the early 20th century by individuals such as Gesell (1928, 1945) and McGraw (1948) who provided rich details of the sequence and order of motor milestones. These ‘nativistic’ constructs implied that changes in neural growth and subsequent use were pre-programmed (hard-wired) into the system so that new behaviours emerge over time and with maturation (Goldfield & Wolff, 2004; Ulrich, 1997). In a revision of the description of the cycle of development (published posthumously), Gesell described the child as: “the product of the nervous system” (Gesell, Ilg & Ames, 1977, p.11). In later years, Gesell continued to emphasise the principle of ‘Growth Gradients’, progressive stages or degrees of maturity that a child passes through towards higher levels of behaviour, with these primarily being dependent upon the maturity of the child’s nervous system (Gesell, Ilg & Ames, 1977, p 17). Of interest however, are some qualifying comments; such as statements attesting to the individuality of each child and consequent uniqueness or unevenness of patterns of growth influenced by environmental as well as temperamental factors (Gesell, Ilg & Ames, 1977, p 14.). Furthermore, Gesell and his colleagues started to

describe the process of change between 'Growth Gradients' as alternating stages of equilibrium and disequilibrium (Gesell, Ilg & Ames, 1977).

Needless to say, and despite some evidence to the contrary, the importance of acquiring 'developmental milestones' in an ordered and sequential manner has formed the foundation for a number of assessments and interventions for the motor 'disordered' and driven much of the research into areas of motor development such as static balance, sway and locomotion (Gesell, 1945; Griffiths 1967; Gesell, Ilg, Ames, 1977; Thelen & Smith, 1994). More recently, Jeannerod has also proposed that early reaching behaviour was related to the maturation of appropriate pathways in the brain (Jeannerod, 1997). Many practitioners and researchers continue to use these milestones to describe their subjects and achievements (eg. creeping, crawling, walking with support, walking, reaching) with little attention to the purpose of such actions and overall productivity of behaviour. These measurable attainments are frequently used to define the success or failure of a child without any analysis of the processes underlying their observable emergence (Ulrich, 1997). While a certain degree of neural organisation and growth may be evident alongside improved skill, it is not known which direction this occurs; i.e. Improvements in motor performance following neural maturation could equally be the converse equation.

There is continuing debate surrounding the role of early reflexes, particularly postural/tonic neck reflexes, their presence and role (demise or integration), and the development of mature patterns of movement. Reflexes may be divided into two main categories: persistent and disappearing. However, there is some argument over cut-offs defining pathology for both of these categories. For example: the startle reflex which is persistent throughout life, may be pathological if extreme and/or evident in situations in which it would not normally be provoked, but no latency or response decrement has been determined by age, and; discrepant views exist over the extent to which the asymmetrical tonic reflex (ATNR) may be incorporated (diminished) when reaching away from the body centre with head

turning (Levitt, 2004). Touwen (1979) in particular, has focussed much attention on the importance of 'soft signs' — presence of persistent and more predominant reflex activity than is typical for age — as evidence of minor neurological delay/dysfunction relating to poor co-ordination and movement.

Fellick et al. (2001) explored the role of 'neurological soft signs' as predictive of developmental problems of cognition, co-ordination and behaviour and found, despite significant correlations, that the sensitivity and positive predictive values of persistent problems performing these neurological 'soft signs' tasks (above the 90th centile) to predict which children were likely to have impairment in other areas, were quite low. These indicators of 'neural' maturation have been emphasised by others as important predictors of later developmental trajectories and continue to be used by paediatricians and neurologists in the school medical examination despite the equivocal relationship of these 'soft signs' to co-ordination problems (Rutter, 1982; Bax & Whitmore, 1987).

Although primarily concerned with children with identifiable developmental motor disorders such as cerebral palsy, by emphasising the importance of achieving motor milestones, developmental constructs support an understanding of the emergence of motor patterns and consequent function.

3.1.1.2 Cognitive

In a similar vein, cognitive theories have been used, in part, to explain motor development. One of the most famous of researchers of relatively recent times, Piaget, provided in-depth descriptions and observations (many of which are derived from observations of his own children) of the stages through which children progressed (Piaget, 1952). Beginning from sensory-motor interactions with the environment, the infant was described as developing perceptual understanding for symbolic representation prior to having the mental capacity for concrete operational thinking and then abstract logical thought in later childhood (Piaget, 1952).

Development of schemes, spatial concepts (movement in space) and object concept,

were described as progressing through a series of six stages moving from ego-centric reasoning to a broader construction of the reality of time and space. Piaget thus considered that the rudiments of movement and visual-motor interactions are in place early in infancy and are then elaborated with learning and experience in an invariant sequence (Johnson, 2004). Piaget linked the notion of discreet cognitive sequences with observed progress in motor development, with the implication that motor sequences emerged from a similar sequential process (Ulrich, 1997). In part, arising from this conceptual framework, are information processing theories which link the performance of movement skills with the cognitive processing of sensory/perceptual information (Wilson, 2005). From this perspective, improved efficiency in various components hypothesised to underpin motor skill — such as memory processes associated with rehearsal, associative memory and mental imagery (memory) — contribute to improved reaction times and skills in movement execution (Wilson, Maruff & Lum, 2003). As with the neural-maturational approach described previously, many educationalists, practitioners and researchers continue to use these sequences to identify ‘atypical’ progress with little attention to the individuality and variability of attainments or aspects of transition between stages.

Nativists consider some types of intelligence and movement ability to be innate. Motor development is thus considered in terms of unfolding brain-behaviour relations which are moderated by experience (Wilson, 2005). Specific cognitive and maturational constraints are thought to enhance or limit the expression of goal-directed movement behaviour. Evidence for this process has been provided by various studies showing improvement in visually guided movements and visual spatial targeting (mental rotation tasks) following mental rather than physical rehearsal, an approach adopted in neurological rehabilitation where mental rehearsal or virtual reality may aid recovery of motor function for individuals with acquired or congenital movement disorders (You et al., 2005). The ability to mentally represent movement has been linked to performance in tests of kinesthetic acuity in young adolescents and adults but not in younger children (Livesey, 2002).

From these perspectives, movement skill is seen to emerge predominately as a consequence of (neural) maturation enabling increasing complexity of information processing and movement production. Information processing is thought to be required to interpret sensory input, in a sequential and simultaneous manner, with the transformation of input information required before output systems can respond. Components involved in information processing include various attention systems (e.g. selective, flexibility, sustained, etc.), memory, capacity (amount of information handled) and feedback mechanisms, with movement skill acquisition occurring as a consequence of improvements in these underpinning systems. Development from these viewpoints would come about by improvements in these components. However, children's developmental pathways (whether motor or cognitive) do not appear to be as homogeneous as Piaget's theory would predict — children do not apply the same cognitive strategies across all tasks, situations and conceptual domains — with the subsequent deconstruction of the notion of discreet developmental stages (Hetherington & Parke, 1986; Thelen & Smith, 1994).

3.1.2 Ecological models

In contrast to the more deterministic approach taken by maturational models of motor development, the latter quarter of the 20th Century showed a shift towards a phenomenological approach to explain the individuality and variability of skill expression under differing environmental and task constraints.

3.1.2.1 Perception in Action

More recently, the importance of considering environmental factors and the impact of 'context' on function have altered the perspective of theorists (Geuze, et al., 2001). Many researchers have moved from the purity of laboratory studies of motor control to consider the principle of productive, or rather functional, movement behaviour. Definitions of motor co-ordination have shifted from descriptors of motor control (sitting and standing balance) to a broader remit incorporating the ability to combine movements for a meaningful and productive

purpose – frequently including the manipulation and use of objects. Gibson (1986) in particular, argued for the value of stimulation obtained during activities — perception in action (that is, stimulation which is actively sought by the individual) versus that imposed by the environment — as an instrumental process by which motor development occurs (Anderson et al., 2004). Gibson’s seminal work suggested that the environment affords (invites and yields) opportunities for the detection of information that is specific to the individual and the context in which action occurs (Michaels & Carello, 1981). These ‘affordances’ (environment:person specific couplings of perceptual information and action) are thought to be achieved through coordinated structures mediating the multiple degrees of freedom that are dependent on body scaled ratios (Turvey & Fitzpatrick, 1993). Turvey and Fitzpatrick (1993, p 1185-1188) provide 13 hypotheses toward an understanding of the development of perception-action capabilities which consider the processes of movement pattern formation (analogous to chaos with feedback) and which describe a “weak coupling of cyclic processes at different time scales” to incorporate the affordances and constraints of internal and external factors. The principle of ‘coordinative structures’, which Bernstein describes as groups of muscles and joints which act as functional units, may be used to explain how infants learn to convert the multiple degrees of freedom (variability) into a controllable system by forming synergies for movement production in response to perceptual stimuli (Bernstein, 1967; Tuvey & Fitzpatrick, 1993). The importance of skills that are achieved through active perception of tasks and contexts, and which conversely may also impose constraints on skill acquisition, has been supported by Bertenthal et al., (1997), Goodale et al., (1996) and others who found that ‘visuo-motor co-ordination involves the direct mapping of perceptual information onto specific motor response loci that do not show transfer to other actions’ (Anderson et al., 2004, p 61.). Pozzo et al. (2006) found a similar strength of perception-action coupling in studies which illustrated the role of internal models, containing specific kinematic details of vertical arm movements, in enabling more accurate motion estimation.

Although, in this context, Gibsonian theory is also somewhat nativistic with its emphasis on genetic pre-attunement in which evolution contributes to “many skills apparent in some rudimentary form before becoming fully functional or manifesting themselves in new contexts” (Anderson et al., 2004, p59.). This leads, not only, to the question of whether specificity of practice/experience dictates motor development but also within/under what context or environmental constraint, skills might be elicited. Clinical experience would suggest that many of those assessments which have sprung from Gibson’s work, predominately those of visual perception and visual motor integration, could be probing foundation skills that have yet to transfer to meaningful tasks, with the implication that changing the context might alter the skill. In keeping with this philosophy of direct perception, Gibson argued that perception was inseparable from conjoined animal and environmental systems which ‘afforded’ salience and relevance for detection that was specific to the individual and context (Michaels & Carello, 1982). Therefore the practice of assessing hypothesised sensory or perceptual components of tasks removes the essential context in which the skills need to be deployed. The legacy of Gibson has been to shift the emphasis from the measurable stages of neuro-developmental maturation to the process of why and how.

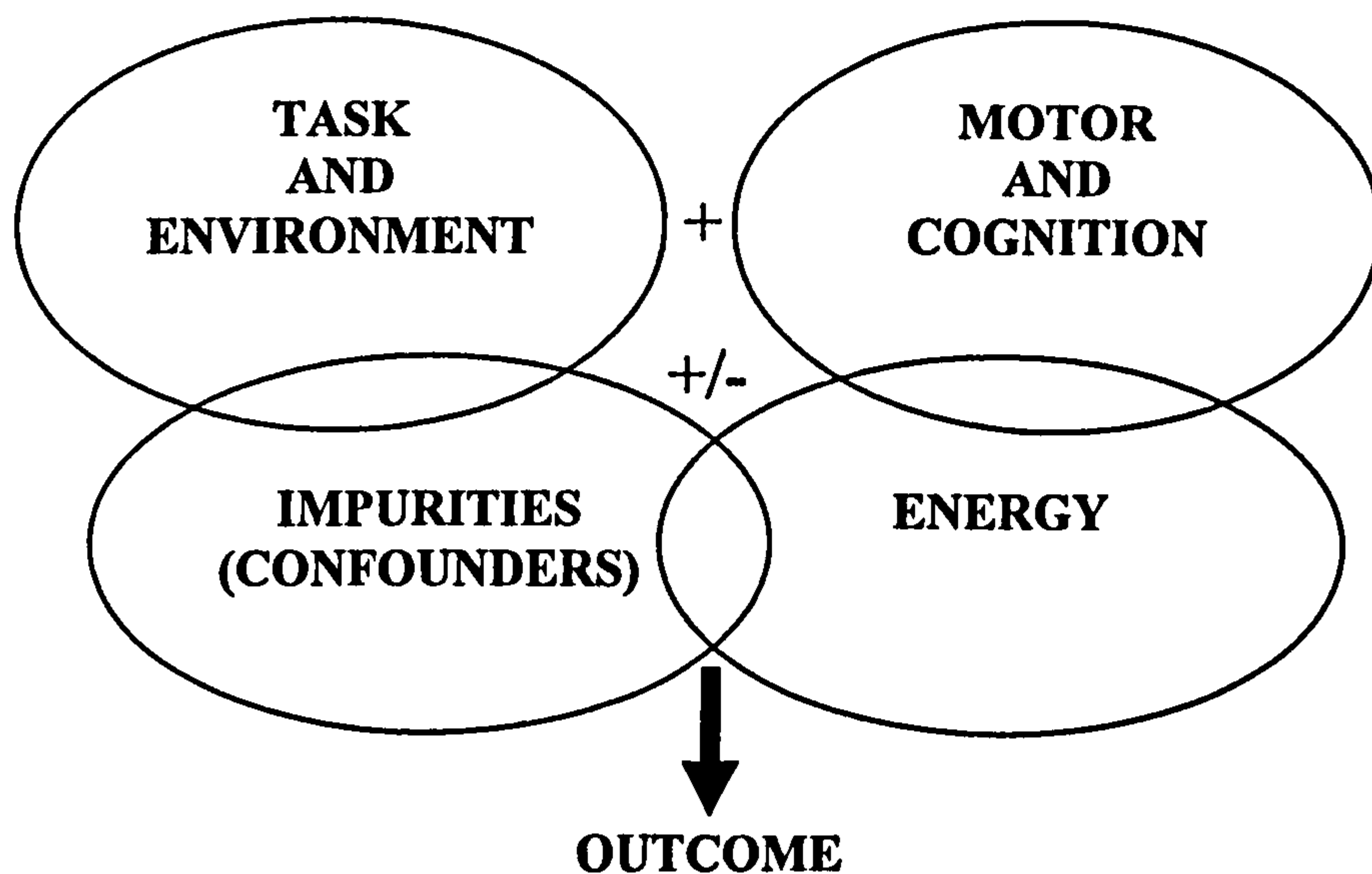
3.1.2.2 Dynamical Systems Approach

In contrast to previous, and partially, reductionist theories, a Russian neurologist, Bernstein (1967), was one of the first to suggest that there was unlikely to be a systematic relationship between concepts of the mind, concepts of the brain and behaviour. He introduced the principle of ‘degrees of freedom’ and cooperativity (Goldfield & Wolff, 2004). A dynamic interaction between systems arises with a more precise mix of mechanisms and processes proposed to be linked to “the specific task at hand and the individual’s expertise in that task” and which can be manipulated and seen to be independent of neurological/anatomical maturation (Thelen & Smith, 1994, p. 37). Thus what is known already, coupled with how that

knowledge is organised and interconnected, determines how experience can be retrieved, attended to and strategically used.

This somewhat more phenomenological model has emerged in part due to the futility of reductionism and as well as the irrationality of attempts to explain atypical development through constraints of structural, maturational models (Thelen & Smith, 1994). More current (dynamical) views consider developmental processes as non-linear functions in which the environment, context and individual capabilities influence outcome. Figure 3.1 illustrates the circular and dynamic interaction between the requirements of the task and environment when coupled with the motor and cognitive capabilities of the child; these may be influenced (positively or negatively) by the internal and external state/energy/motivational components and any constraints outside the control of the individual or typicality of the task. Key tenets of a dynamical systems approach include constructs of variability, stability and rhythmicity. From this perspective, developmental change is described as a dynamic series of differing states of stability, instability and phase-shifts with particular patterns emerging under certain constraints (Thelen, 1995, p.84).

Figure 3.1 Representation of non-linear interaction of task, environment and individual



Systems are therefore predicted to lose stability during a phase shift. The principle of rhythmicity, with attractors and control parameters, emerges in a manner similar to that defined by resonance theory and wave functions, until the most stable pattern of movement eventually occurs (Chang, 1981). A common behaviour system may have multiple stable and quasi-stable states that support self-organisation. Variability is thus an index of the strength of the behavioural attractor that provokes rhythmicity and allows for developmental progress. Performance is determined by the context (space, task and time) and not necessarily pre-defined developmental determinants. “Development occurs by the continual dynamic match between the organism and information about the task and supporting environment” (Thelen & Smith, 1994, p. 88). Through a series of elegant experiments, Thelen & Smith (1994) have illustrated this dynamic interchange of individual, task and environment by changing the context and perturbations and measuring the recovery to optimal performance. Although Thelen’s research predominately focussed on the motor skills of balance and reaching in young infants, cognitive development is considered along the same lines in which an understanding of objects and people is subject to the “same dynamic processes whereby complex, heterogeneous elements self-organise to produce coherence in time and space” (Thelen & Smith, 1994 p. 183). Analysing movement and/or cognitive development as dynamical rather than a deterministic process has shifted the nature of research to how change occurs rather than measurement of the consequences of change. This provides an important basis for considering how to facilitate skill in a delayed or disordered system.

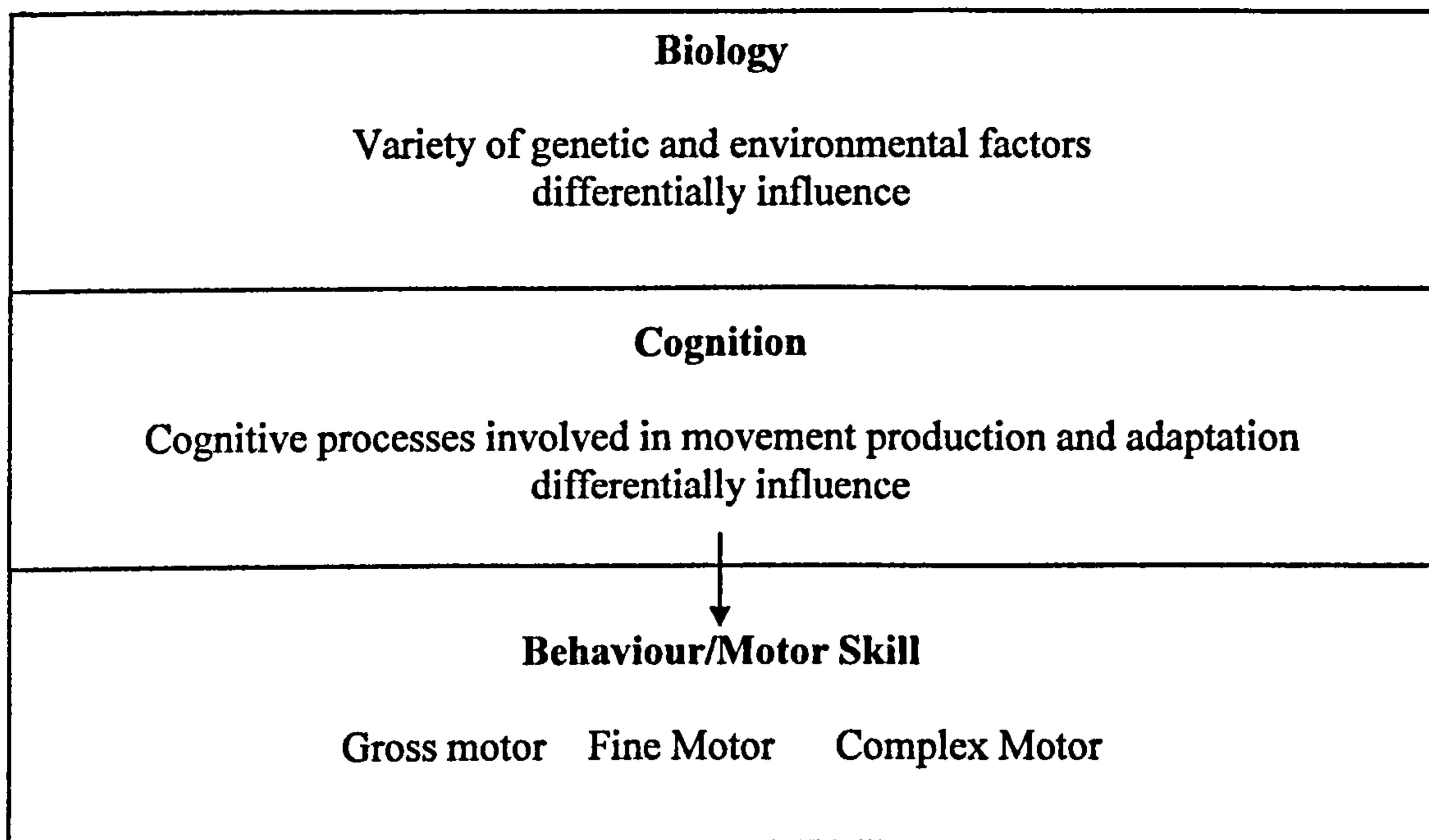
3.1.3 Summary of perspectives of movement skill development

Studies exploring the acquisition of movement skill have essentially taken two main courses: a linear developmental perspective that ascribes the presence of new motor skills to partially deterministic, structural and maturational changes in the nervous system; and, a non-linear dynamical perspective in which systems interact and are dependent on individual capability along with the context of both the task and

environment that may constrain or facilitate action. Developmental theorists consider the overall maturation of the nervous system and neuro-motor capability as of paramount importance for the selective recruitment of muscles for strength and power in tasks requiring postural stability and balance (including hopping and jumping). Whilst emphasising the importance of achieving motor milestones, developmental constructs support an understanding of when motor patterns and function emerge in typical environments. In contrast, Thelen and Smith (1994) construct a theory of development based on the work of Bernstein and Gibson, that stresses the importance of how skills are acquired, and which involves the interaction of the organism with the environment. Their investigations explore behaviour without preconceptions and systematic laws attempting to link concepts of the mind, brain and behaviour. Rather, their studies have elaborated on Gibson's theory, showing the inter-dependence between environment, task and individual (motor, cognitive and energy/impurities). In Dynamical Systems Theory, "Pattern formation, co-ordination or category acquisition" refer to organisms' exhibition of preferred rhythms/periodicities, which are stable across a range of vectors with the capability of systems to reorganise to a new stable state and subsequent skill acquisition (Thelen & Smith, 2002, p.183).

Thus the development of skilled movement may result as a combination of cognition, experience, and the capabilities of the musculo-skeletal and neuro-motor systems (to some extent biologically if not genetically predetermined). In the interim of having a theoretical construct that links the aetiology of motor development with output when movement problems occur, Morton (2004) provides a model for conceptualising developmental disorders (see Figure 3.2). This model allows a number of theories to be represented in the absence of unequivocal evidence substantiating any specific approach. It is conceivable that there are disproportionate contributions from various subsystems (illustrated by biological and cognitive systems in Figure 3.2), insufficient in themselves to warrant a diagnosis of more overt disorders of movement, learning or behaviour (e.g. cerebral palsy, moderate learning difficulties or executive function disorder respectively) yet, which could result in an impairment of co-ordination, perhaps distinguishable as specific subtypes due to hypothesised aetiology.

Figure 3.2 Causal Model for Movement Disorders adapted from Morton (2004, p.76)



3.2 Perspectives of Developmental Coordination Disorder

Throughout recent decades, children with co-ordination difficulties have been described with a variety of presentations that refute a simple diagnostic model of 'clumsiness' (Hoare, 1994; Polatajko, 1999; Wright & Sugden, 1996). A decisive theory of motor control, motor learning and/or motor planning - let alone motor co-ordination — which conforms with both neurological (possible aetiological) and behavioural (observable output) models, has yet to be articulated. Thus, there remains a lack of clarity regarding identification of the problems some children experience in executing motor tasks. Professionals vary in the approaches taken for analysis, interpretation and subsequent remediation of specific motor difficulties. These often reflect their preferred theoretical premise for understanding motor impairment. Evidence based approaches can be divided roughly into four main groups which come predominately from theories of motor control, motor learning and motor planning. These approaches differentially emphasise the processes underpinning co-ordination

or task attainment thereby focussing assessment on the issues conceived of being primary contributors to movement difficulties.

Maturational and developmental theorists have either emphasised the sensory-perceptual components of movement or neuropsychological aspects of information processing arising from within the individual. Explanations for movement difficulties arising from dynamical systems models have given more credence to environmental factors and task:person:environment interfaces influencing performance. These theoretical perspectives will be discussed in turn, to illustrate current practice in the identification and remediation of co-ordination difficulties.

3.2.1 Maturational models

The majority of studies of co-ordination difficulties in the first half of the 20th Century predominately came from maturational models describing problems achieving developmental attainments of sitting, walking, reaching, grasping in infancy to running, jumping, hopping, and complex manipulation of objects in childhood. Continuing into the beginning of the 21 Century, many paediatricians use the Griffiths Mental Developmental Scales to measure the rate of development of young children from birth to eight years of age (Griffiths, 1967). Developmental scales such as the Hawaii Early Learning Profile (Furuno et al., 1985) and Denver Developmental Screening Test (Frankenburg, et al., 1975) are favoured by therapists, along with standardised assessments such as the Bayley Scales of Infant Development (Bayley, 1969, 1993), Miller Assessment for Preschoolers (Miller, 1988) and Peabody Developmental Motor Scales (Folio & Fewell, 1983), as mechanisms for identifying children at risk of potential developmental difficulties including poor co-ordination (Burton & Miller, 1998). See Appendix 3 for a list of common clinical assessments used for identifying perceptual and motor disorders. All of these assessments, whether descriptive scales or standardised tests, owe much to the work of Gesell (1945) and McGraw (1945) and the neuromaturational theory they embraced (Burton & Miller, 1998). Thus, key indicators of 'dysfunction' were based on the premises that a) early

reflexive responses of the lower brain centres are gradually inhibited by higher cerebral functions, and; b) the appearance of early movement milestones occurs in a predictable sequence.

Building on this philosophy, Touwen (1979) developed an examination of children that emphasised immaturities in neuro-developmental status, evidenced by the persistence of immature reflexes and under-developed skill in performing more complex motor tasks such as walking along a straight line. This notion of 'delayed maturation' in DCD has been explored through studies of the development of postural control by Hadders-Algra, Brogen & Forssberg (1998) and Bottos et al. (1989) with Wann, MonWilliams and Rushton (1998) looking more specifically at comparisons of skill between children with DCD and non-clumsy children. Interestingly the latter found that the children with DCD were separated into two groups – those who had postural control problems and those without. More recently, Hadders-Algra (2002) has built on Edelman's *Neuronal Group Selection Theory (NGST)* and the principles of Touwen's assessment to identify children at risk of minor neurological dysfunction and subsequent problems in development and participation in daily activities.

Many clinicians choose to use developmental assessments for the measurement of skill acquisition (Rodger, 1994). This may reflect the comparative ease of measuring standardised skill attainments as opposed to the measurement of underlying hypothesised processes. The clinical utility of such measures may also support test selection by clinicians. Thus, these approaches use observable behaviours as markers for dysfunction that is thought to be due to delays or deficits in neural maturation. Arising from these maturational approaches to understanding developmental anomalies, other researchers have investigated the hypothesised links between sensory and perceptual processing and motor skill.

3.2.2 Information processing models

Information processing models for understanding perception and action have predominately taken a more traditional view of perceptual processing, rather than Gibson's 'direct perception' construct (see section 3.1.2.1), to describe anomalies of perceptual and/or motor control mechanisms thought to underpin DCD. Perception is thus conceptualized as an indirect process of discrete sensory events that requires 'processing' by higher cortical levels to provide meaning (Michaels & Carello, 1981). Deficits are then measured as functions of the individual rather than an interaction between person, task and environment. The following section describes some of the current frameworks used by clinicians for understanding coordination disorders.

3.2.2.1 Sensory Perceptual models

At a clinical level, different models have arisen to explain the role of the nervous system in motor development, most notably, Sensory Integration (SI) theory and other process oriented models such as that of kinesthetic processing proposed by Laszlo and Bairstow (1985 a,b). In these systems or process models, emphases are placed on the roles sensory input and/or feedback have in providing information to the central nervous system (CNS) for interpretation and consequent selection of appropriate movement strategy. Movement strategy selection is considered to be dependent both on the state of the internal and external environments and memory of similar movements (Bernhart et al., 2003). Problems in movement production are hypothesised to be due to hierarchical mismanagement as a consequence of lower order errors e.g. higher (cortical) centres of motor control are unable to plan and execute appropriate motor actions due to inefficient feedforward or feedback from lower (sensory/perceptual) CNS systems.

Theoretical explanations are provided linking lower order functions with higher order and subsequent output problems, such as the ability to sustain volitional movements against gravity, most commonly assessed through analysis of postures of prone extension and supine flexion. This is hypothesised to be due to poor

vestibular processing from SI theorists or delayed reflex integration from those propounding a more neuro-motor maturational approach (B.Wilson et al., 1994). To date however, it is unclear how these functions relate to a population of children with DCD as these items are not good at detecting problems of co-ordination (Fellick et al., 2001).

Many researchers have investigated the sensory and perceptual skills of purported 'clumsy' children and defects in visual, tactile, kinaesthetic (proprioceptive) and/or vestibular functions have been proposed as contributing to their motor co-ordination difficulties (Fisher, Mixon & Herman, 1986; Laszlo & Bairstow, 1985a; Missiuna, 1994; Mon Williams, Pascal & Wann, 1994; Mon Williams, Wann & Pascal, 1999; Smyth & Mason, 1998; Wilson & McKenzie, 1998). As a consequence of this evidence, various assessment batteries and treatment programmes have been developed which focus on suspected sensory, perceptual or motor processes underpinning specific skill acquisition (Sugden & Chambers, 1998; Sugden & Wright, 1998; Sugden & Wright, 2001; Wilson, 2005).

The sensory basis of movement and pre-movement readiness has been explored particularly in relation to postural stability (displacement detection and sway responses) and anticipatory control of grip force (Ayres, 1972a&b; Bairstow & Laszlo, 1981; Forssberg, 1998; Goodin, Aminoff & Ortiz, 1993; Jung-Potter et al., 2002; Wing, 1996). Wing's (1996) as well as Hill, Bishop and Nimmo-Smith's (1998) studies emphasised the kinematics of movement, inter-joint coupling and sensory feedback required for skilled actions to occur. Ayres' work from the 1960s-1990s considered the importance of organising sensory information, primarily in the brain stem areas, to support learning, motor performance and adaptive behaviour. The over-generalisation of the behaviours attributed to poor sensory processing and over-emphasis on specific brain areas contributing to measurable performance decrements, have limited the expansion of SI theory to some extent, however the importance of this approach in changing the direction of therapeutic interventions in the arena of children with problems in adaptive

behaviour, cannot be negated.

Wilson and McKenzie (1998) undertook a meta-analysis of research findings between 1974 and 1996, to explore predominate (traditional) information processing characteristics of children with DCD. Although the 'DCD' groups were poorer across all measures of information processing and in particular visuo-spatial processing, it is unclear how many of the children included in the studies would meet current criteria for DCD (for example: 37/50 of the studies used clumsiness as a feature for sample selection although the compatibility across motor measures determining presence or extent of clumsiness was not established nor were potential 'co-morbid' conditions controlled for which may have influenced findings, such as ADHD or dyslexia). In addition, a number of the studies included in the meta-analysis reported on the same groups of children in different published papers. Needless to say, many of the studies included in the meta-analysis provide some evidence for problems of: visual perceptual processing, complex visuo-spatial functions, kinaesthetic perception and/or cross-modal perception, amongst children with movement difficulties.

a) *Visual Processing.* The importance of vision and the visual control of movement has been described in the literature on motor control (Shumway-Cook & Woollacott, 1995). Researchers have suggested that children with DCD may rely more heavily on vision and visual perceptual analysis to monitor their movements than typically developing children (Deconinck et al., 2006; Missiuna, 1994; Missiuna, Rivard & Bartlett, 2003; Mon-Williams, Wann & Pascal, 1994; Rösblad & von Hofsten, 1994; van der Meulen et al., 1991). The most common factor that demonstrated a significant effect size in the 50 studies investigated by Wilson and McKenzie (1988) and which showed the greatest deficiency, was that of visual-spatial processing (with or without a motor component), providing some support for the hypothesis that children with DCD (or who appear clumsy) have difficulties processing visual information, especially visual-spatial aspects.

b) *Kinesthetic/Proprioceptive Processing*. Laszlo and Bairstow's work (1985 a,b) focussed attention on the role of body movement perception (proprioception and kinaesthesia). Research interest in the role of kinesthesia and proprioception (referring to the conscious and unconscious processing of joint and muscle movement sensations) in children with DCD continues. Hoare and Larkin (1991) and Smyth and Mason (1998) found kinesthesia to be a complex function and, although predictive of performance on some motor items, it was the complexity of the task (the multi-dimensional nature of perceptual, cognitive and motor functions) which most influenced performance.

c) *Vestibular Processing*. Although the SI literature provides theoretical support for vestibular dysfunction in children with learning disabilities (including 'clumsy' children), much of this research is confounded by simultaneous visual input (Fisher, Mixon & Herman, 1986; Polatajko, 1985). Wann et al., (1998) investigated visual-proprioceptive-vestibular functions through research using the 'swinging room' with mixed results. Their very small sample size warrants caution in interpretation, but provides additional support for the argument that the child with DCD may rely more heavily on visual information to maintain posture (Deconinck et al., 2006). Mon-Williams et al. (1999), Piek and Coleman-Carman (1995) and Lord and Hulme (1987) reiterated the theory regarding potential deficits in the integration of perceptual information across modalities in their conclusions regarding the relatively poorer proprioceptive functions of children with DCD.

Many therapists utilise the evidence from these studies when incorporating perceptual motor approaches into clinical practice with these children (Davidson & Williams, 2000). However, the expected strength of a relationship between perceptual skills and underlying cause of DCD that would support an information processing approach as a basis for understanding co-ordination difficulties, has not been established (Schoemaker, et al., 2001).

3.2.2.2 Sensory Integration

As SI intervention is one of the most frequently used approaches used by therapists to treat DCD, this approach will be described in more detail (Mandich, et al. 2001a). From the SI perspective, emphasis is placed on the somatosensory and vestibular based functions including discriminatory (degree of accuracy) and modulatory (degree of response) components, when analysing movement problems. Studies in this area have shown a relationship of sensory processing to postural mechanisms, fine motor control and complex motor planning (Ayres, 1971; Case-Smith, 1994; Clark & Pierce, 1988; Smyth & Mason, 1997). Of particular importance within the theoretical construct of SI theory is the emphasis on motor-planning and subsequent inclusion of test items involving visual-motor imitation, including both constructional and postural imitation (Ayres, 1985; Mulligan, 2003a). More recently, O'Hare et al. (1999), Njikiktjien et al. (2000) and Poole (2000) have attempted to chart the development of praxis in children through studies of gesture. Studies of gesture production in infants have also been used to explore the development of innate representation and the acquisition of theories about people and things (Meltzoff, 2004). Green et al. (2002b) explored motor skills alongside representational development by contrasting the performance of children with Asperger's Syndrome (AS) to those with DCD, and showed no clear differences in the pattern or quality of movement between these groups. Other studies have shown children with DCD to have poorer gesture production, both transitive and intransitive, than typically developing control children (Dewey, 1993; Hill, 1998; Hill, Bishop and Nimmo-Smith, 1998; Zoia et al., 2002). However the relationship of gesture to motor skill is not clear from these papers; for example, Lennox, Cermak and Koomar (1988) suggested closer links between gesture comprehension and language rather than praxis and Green et al. (2002b) found the correlation of motor impairment to gesture production confined to the AS rather than DCD children.

Although SI is one of the most researched theory and treatment approaches in the therapy literature, much of the work has not used stringent diagnostic criteria in

subject recruitment when focussing on populations of children with ‘learning disabilities’¹, nor controlled for pervasive developmental disorders or intellectual capability. As such it is difficult to generalise many of the results of studies from this perspective, which refer to children with a mix of academic, communication and/or behavioural problems, to children with DCD (Polatajko et al., 1991).

3.2.2.3 Cognitive information processing

Cognitive central processes have also been proposed by Van Dellen and Geuze (1988) and Pennington (1991) as possibly contributing to the slow and inaccurate performance of clumsy children. The poor memory of a task, involving encoding and decoding, along with competent sensori-motor integration has been implicated in the impaired reproduction of modelled movements of children with DCD (Skorji & McKenzie, 1997). It remains inconclusive whether these children have difficulties in their rate of learning or in utilisation of adequate rehearsal strategies (Dwyer & McKenzie, 1994; Missiuna, 1994). Although, Dwyer and McKenzie (1994) did not find deficits in the immediate recall of visual stimuli in DCD groups, these children were markedly less accurate in reproduction following a 15 second delay. These authors concluded that there may have been a difference in visual-rehearsal strategies between the two groups (which may also relate to ‘motor learning’ capability). Cases in which a marked discrepancy between verbal and performance tests on the Wechsler Intelligence Scale for Children (WISC) that is associated with severe clumsiness, without defects in the pyramidal, extrapyramidal, or cerebellar pathways controlling voluntary movements, have also been described (Gubbay, 1975; Walton, Ellis & Court, 1962). However, there is scant evidence to substantiate the predominance of this cognitive profile in children with DCD. If one were to follow the trend in other developmental conditions there seems to be little support for the emphasis on cognitive processes involving a Verbal:Performance IQ discrepancy identifying a child at risk of DCD. Rather, attention should be placed on underachievement not unequal achievement in one or more learning or behavioural abilities (Bishop, 1998, p146; Dyck et al., 2004).

3.2.3 *Dynamical Systems*

The recency of Thelen's work precludes detailed analysis of research exploring the difficulties in skilled movement production in children with otherwise normal motor development. Although Gesell and colleagues had begun to consider the transitions between 'Growth Gradients' in their theoretical descriptions of development, this process was not explored experimentally (Gesell, 1945; Gesell, Ilg & Ames, 1977). Hadders-Algra's attempts to describe the aetiology of movement difficulties marries neural maturational with dynamical systems theories by extolling Edelman's model of neuronal group selection in which neuronal groups are established by evolution but movement and experience determine functional integrity (Hadders-Algra, 2000).

Motor learning theories potentially bridge the gap between deterministic and dynamical ecological models as explored in the work of Sugden and Chambers (1998, 2003) and Mandich et al. (2001b), whereby repeated experience of skilled performance through practice enabled the more likely replication of improved skill under differing circumstances. Definitions of motor co-ordination difficulties which emphasise the 'failure to learn' voluntary motor activities despite adequate sensory-motor and volitional components suggest a more predominate cognitive deficit contributing to motor delay. Motor learning, as conceptualised by clinicians, emerges from perception-cognition-action processes which involve the search for a task solution that is dependent on the interaction between the individual, task and environment (Shumway-Cook & Woollacott, 1995). Adam's 'Closed-loop theory' and Schmidt's 'Schema-theory' provide a framework for how memory of perceptual traces or schematic representations allows for the capacity to repeat successful strategies for movement production, respectively, emphasising the strength of the perceptual trace or knowledge of results for recall and learning; although neither theory has been supported by experimental evidence (Schmidt & Lee, 2005). Bernstein (1967) was one of the first to emphasise the importance of strategy selection when solving motor problems. Fitts and Posner (1967) described three main stages involved in skill learning: cognitive, associative and autonomous. The first, cognitive

(verbal) stage, is concerned with consciously understanding the nature of the task, developing strategies that can be used to carry out the task and reviewing the outcome. The second, associative stage, involves a period of practice and refinement until the third autonomous stage is established, which allows the performer to focus on other aspects of the skill or task (Fitts & Posner, 1967). Problems in movement production may occur as a consequence of inappropriate strategy selection and consequent inadequate practice of successful outcomes for refinement of skill. As yet, there is little evidence to suggest that strategy selection differs between DCD and non-motor impaired children, however outcomes of intervention studies based on this model are promising (Polatajko et al., 2001a).

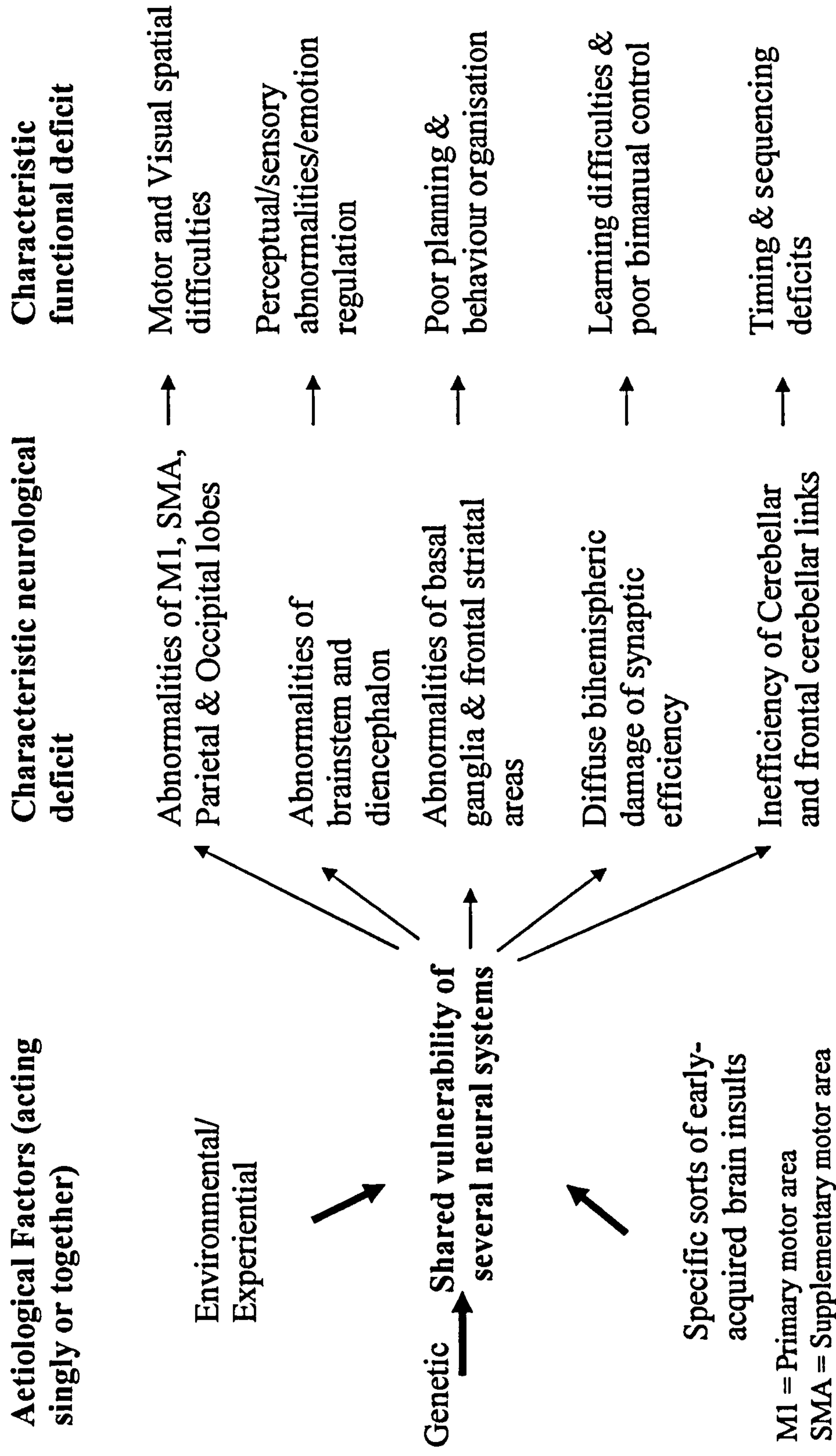
3.2.4 Summary of perspectives of Developmental Coordination Disorder

The principle of multiple primary deficits, first described by Goodman (1989) to describe the variety of presentation of children with Autism Spectrum Disorders, may well be the most appropriate means of capturing the 'heterogeneous' nature of DCD, from aetiological as well as behavioural perspectives. Figure 3.3 provides an alternative model of causality from that provided by Morton (2004) and illustrated in figure 3.2, by emphasising the various neurological elements underpinning cognitive and behavioural functions.

Chasms exist between the differing perspectives of motor development, depending on the relative bias of what sensory or perceptual theoretical construct is used to account for the movement difficulties of children. The theoretical and practical divisions of researchers and clinicians exploring the motor problems of children with DCD result in a differential weight given in assessment to the various components of movement skill or aspects of skilled motor performance. Consequently, subgroups of children with movement difficulties may emerge that can be delineated within and between theoretical lines — maturational models versus systems models — possibly evidenced through discrepancies between fine motor and gross motor deficits or visual-spatial versus proprioceptive-kinesthetic problems or postural stability versus adaptation.

Figure 3.3 Multiple Primary Deficits in DCD*

*adapted from Goodman (1989) to reflect movement difficulties rather than social impairment



3.3 Interventions for Developmental Coordination Disorder

Confusion surrounding the defining criteria and subsequent assessment of DCD seems to have contributed to the failure to identify globally successful treatments for these children. As a consequence of the heterogeneity in the presentation of DCD, various treatment programmes have been developed which either address the underlying motor, sensory, perceptual processes or focus on specific skills acquisition (Gentile, 1992; Sugden & Chambers, 1998; Wilson, 2005). Schoemaker, Hijlkema and Kalverboer (1994) found few programmes, either theoretically or in technical application, that were designed specifically to treat primary motor co-ordination difficulties. Comparability between studies of treatment efficacy is also restricted by differences in provision of services and treatment regimes. Most of the treatment studies have limitations regarding sample selection and definition, reliability and appropriateness of measurement tools, blindness of the assessors or lack of control group. Although Sugden and Chambers (1998) suggest that most treatments work — at least in the short term — few studies have looked at sustained benefits of treatment for children with predominant motor problems that are not associated with learning problems or co-morbid conditions.

Considering co-ordination deficits from the theoretical perspectives discussed earlier may enable us to approach the individuality and variety of presenting features, and thus target intervention with a degree of clinical reasoning. In view of the lack of substantive evidence supporting any particular treatment approach or regime, only a brief review of the main studies supporting interventions for DCD will be given here.

3.3.1 Information/process oriented (Bottom-up) models

The main theoretical and treatment approaches that have undergone the most empirical scrutiny show both Occupational Therapy and Physiotherapy using either Sensory Integrative Therapy (SIT), and/or Perceptual Motor Approaches (PMA) to be of benefit to children with co-ordination deficits when provided for a minimum of 24

hours of individual therapy. Within SIT, developed for children with specific learning disabilities, the emphasis in treatment is not on the introduction of sensory stimuli (sensory stimulation) but upon the organisation of sensory information for adaptive behaviour whereby sensory experience should be actively sought by the child rather than applied by a therapist. A meta-analysis by Vargas and Camilli (1999) and a review of the evidence by Mulligan (2003a, 2003b) found many of the studies investigating SIT compared to children receiving no treatment or an alternative treatment lacked validity and reliability. The most common errors included; lack of information on inter-rater reliability, not using blinding procedures and not controlling for subject variables such as age or intellect. It is also impossible to infer the extent of the Hawthorne Effect (the non-specific effects of intervention such as special attention or changes in routine – see section 5.9.1 for critique of the Hawthorne Effect) on testing of motor proficiency in view of the lack of a sufficient number of studies that use a contrast intervention group.

Interventions which focus on the sensory-cognitive interface, referred to commonly as PMA, have been developed by Kephart (1964), Frostig (1968), Laszlo and Bairstow (1985a) and others. These approaches place greater emphasis on visual-spatial, visual memory, visual-motor and kinaesthetic functions through experiential modification of perceptual experiences. PMA therapies incorporate a greater degree of practice of pre-determined activities to teach specific skills. Schoemaker et al. (1994) describe a physiotherapy programme comparable in many ways to the PMA of Kephart (1960). The majority of the treatment group (n=18) progressed from deviant to borderline or normal following 24 sessions over 3 months. Although there is little substantiated evidence to suggest that perceptual training necessarily improves motor performance over time (Hoare & Larkin, 1991; Polatajko et al., 1995; Sims, et al., 1996 a, b), an anecdote of Schoemaker et al.'s 1994 study suggests that their children did at least maintain their post-treatment level at a 3 year follow-up. A more recent study by Shoemaker and her colleagues reflects a shift to a task oriented approach in therapy (Jongmans et al., 2003; Niemeijer et al., 2003).

The extent of improvement achieved by Laszlo and Bairstow following Kinesthetic Sensitivity Training has not been replicated over a longer period (Sims et al., 1996a). Furthermore, Sims et al. (1996a) suggested that the experience of practice may have influenced perceived competence by contributing to a child's motivation and approach to a task, which in turn could improve actual performance. Although there is marginal evidence that SIT may achieve a more long-lasting and generalised effect than PMA for children with learning disabilities, direct comparison between studies is limited by methodological differences (Humphries, Snider & McDougall, 1993; Humphries, et al., 1990; Kaplan, et al., 1993; B.Wilson & Kaplan, 1994).

A recent meta-analysis by Pless and Carlsson (2000) regarding treatment efficacy on DCD is somewhat inconclusive in view of the inconsistencies of the sample selection between studies. Despite this, their study shows some evidence for the implementation of intervention that utilises a specific skills approach, within a group or home setting, and when it is undertaken 3 to 5 times per week (although the duration of sessions varies). In a separate study, Pless, Carlsson, Sundelin and Persson (2000) found that 10 sessions of group motor skills intervention, plus the inclusion of a counselling service to parents, was insufficient to support change in the more severely affected child. This is consistent with the study of Davidson and Williams (2000) who found their subjects did not sustain progress one year after 10 individual sessions of SIT plus parental advice, although the analysis of their data has been criticised (Green, 2001).

Peter Wilson and colleagues (2002; 2003; 2004; J.Williams et al., 2006) have explored potential deficits in the internal representation of movement through studies of gesture production and visually guided movements. They have developed a specific training programme in visual imagery in an attempt to ameliorate any representational as well as movement skill deficit. The initial promising results should be viewed cautiously in view of confounding factors regarding limitations of sample selection and the lack of control of potential concomitant attention disorders. Furthermore some of the

differences identified in Wilson's Australian children have not been replicated by other groups (Lust et al., 2006). However, other studies of the favourable response of children with motor disorders to virtual reality therapy provide credence to visual imagery as a mechanism for intervention in co-ordination disorders (You et al., 2005).

The meta analysis of Pless and Carlsson (2000), exploring treatment effects for DCD, suggested that intervention for DCD or equivalent condition was most likely to be effective when a 'specific skills theoretical approach' was adopted and provided some evidence that individualized approaches (within group or individual treatment programmes) may prove more effective which gives further credence to the notion of heterogeneity. It remains unclear what exactly they meant by a 'specific skills theoretical approach' and whether – despite some differences in presentation – sufficient numbers of children have a similar basis to their co-ordination difficulties to be considered a specific 'subtype' to warrant these children's inclusion in a group versus individual intervention package. Due to variations in treatment regimes, procedures of implementation and sample selection, it is not possible to know what interaction between these variables may have influenced outcome. Within these studies there is also some suggestion that a proportion of the subjects make limited or no progress despite intensive therapy. Pless and Carlsson (2000) and Stephenson (2005) both recommended that future intervention studies for DCD include analysis of the potential impact of subtype on outcome.

3.3.2 Ecological/skills based training (Top-down) models

Recently, cognitive behavioural approaches to address the 'learning' of new, functional skills have also emerged in the literature and evidence suggests positive benefits which may generalise to more adaptive behaviour (Henderson and Sugden, 1992; Martini and Polatajko, 1998; Miller et al., 2001; Polatajko et al., 2001a; Polatajko & Mandich, 2004; Schoemaker, Hijlkema & Kalverboer, 1994; Sugden and Chambers, 2003; Wilson, 2005). Henderson and Sugden (1992) developed a training

scheme which emphasises the learning/cognitive nature of poor motor performance. Sugden and Chambers (2003) have expanded this work in their recent studies comparing the efficacy of teacher and parent based programmes. The evidence to date suggests that a tripartite approach to intervention for children with DCD should include: identification of the presence of co-ordination difficulties; provision of support for parents to understand their child's movement difficulties; and, education of those involved with the child, is potentially as effective as direct treatment (by specialists) in ameliorating the ability of the child to achieve in tasks at home and school.

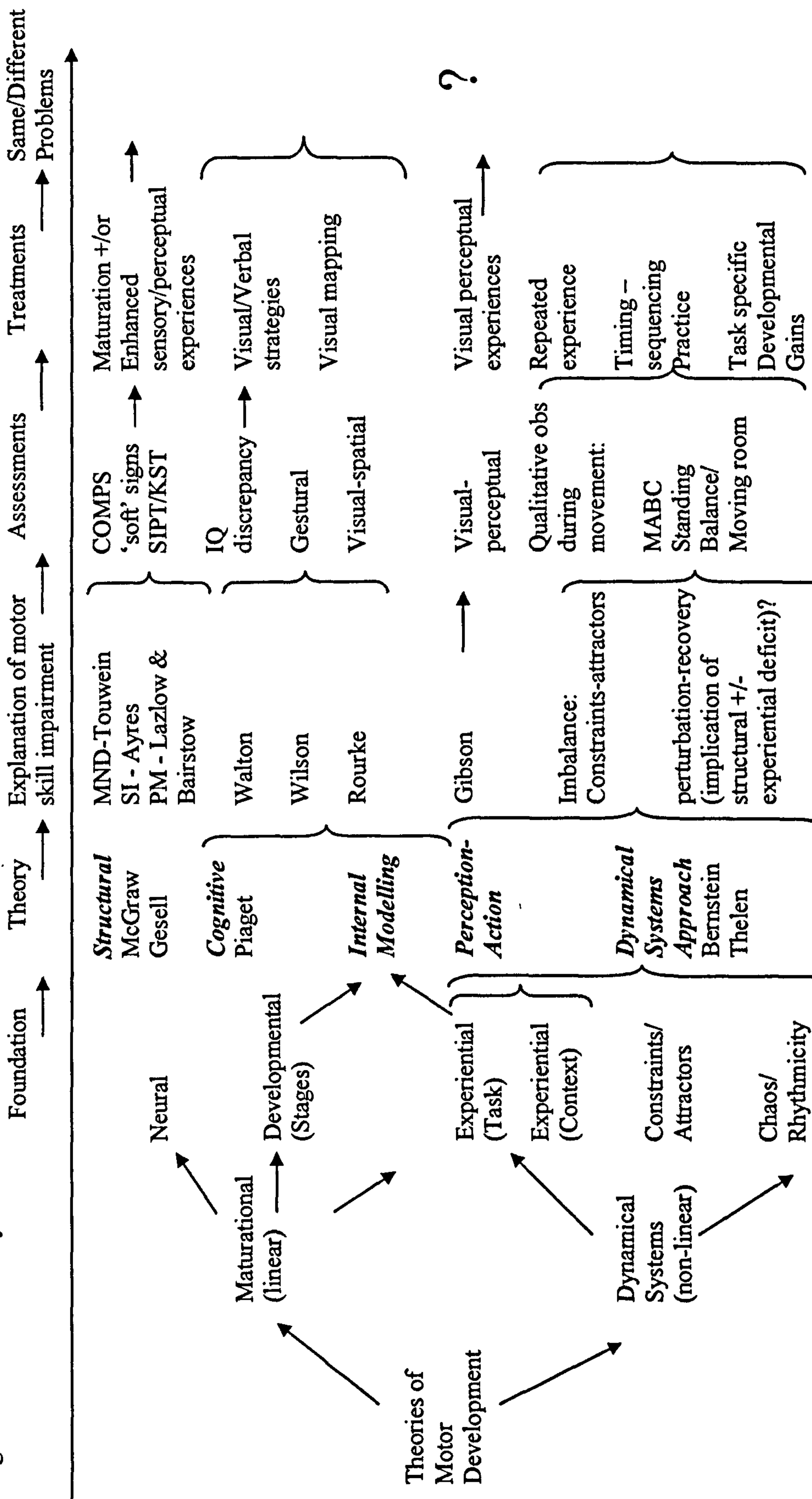
The Cognitive Orientation to daily Occupational Performance (CO-OP), described as 'Verbal Self-Guidance' comprises a systematic application of cognitive behaviour techniques (Polatajko, et al., 2001a; Polatajko, et al., 2001b). The child is taught to follow a process of analysing a task before selecting a strategy. Results to date, albeit with small numbers of children, show significant improvements in communication, socialisation and daily living skills yet little improvement in motor performance (Martini & Polatajko, 1998; Polatajko et al., 2001a; Wilcox & Polatajko, 1993). A defining element of DCD is that motor difficulties have a 'functional impact', thus despite not seeming to directly remediate the 'motor deficit', the CO-OP approach may be doing more to tackle one of the other 'core' features of DCD, ie. performance outcome. Consequently, although poor co-ordination may still be present following treatment, the remaining motor difficulties could then be placed within the normal distribution of 'clumsiness' or 'non-sporty' without conferring a label of 'disorder'. This may be due to the reduction in the effects these difficulties are having on daily functioning. These results would suggest that this approach is at least as effective and possibly more efficacious than traditional techniques when contrasting the 24-72 hours undertaken in the studies of Humphries et al. (1993) and Kaplan et al. (1993) with the 12 one hour sessions of CO-OP (Polatajko et al., 2001b). Longitudinal studies of CO-OP are required.

Cognitive models using verbal mediation either from the therapist or self-instruction

have also been used by Dutch researchers exploring task-oriented interventions (Jongmans et al., 2003; Niemeijer, et al., 2003). The Neuromotor Task Training (NTT) has a lot of similarities with the techniques recommended by Henderson and Sugden (1992) and adopted in the CO-OP approach. NTT roughly consists of three stages: giving instruction, providing or asking feedback and sharing knowledge with the emphasis shifted to practice following instruction and feedback. Initial results look promising although again only a small group of children with or at risk of DCD (n=23) have been investigated with limited follow-up.

There is as yet little understanding of the development of motor co-ordination that defines the interaction between motivation, perceptual processes, cognition and movement skill to an extent that these processes are incorporated into a remediation approach. Piek, Baynam and Barrett (2006) have provided the most convincing evidence to date of the importance of distinguishing types of motor impairment showing differential effects of fine, gross or complex motor problems, particularly between males and females, on participation and engagement in social and motor activities. Figure 3.4 provides the story line for the current project, illustrating a speculative overlap of the different theoretical foundations to motor development, explanations for motor skill impairment, assessments/test procedures devised to test out these theories and some of the various treatments that have been developed to date. In the first instance, a more detailed understanding of differing movement skills (potential homogeneous subtypes) and their progress over time, may help elucidate a theoretical premise that matches the clinical presentation of these children.

Figure 3.4 The Story Line



KEY: COMPS = Clinical Observations of Motor and Postural Skills; IQ = Intelligence Quotient; KST = Kinesthetic Sensitivity Test; MABC = Movement Assessment Battery for Children; MND = Minor Neurological Dysfunction; PM = Perceptual Motor; SI/SIPT = Sensory Integration/SI & Praxis Tests

CHAPTER 4 SUBTYPES OF CO-ORDINATION DISORDERS

Following on from the previous chapter which outlined some of the theories underpinning our current understanding of DCD, the first part of this chapter explores the theoretical grounds for distinct subtypes within DCD and the second part discusses the evidence for these theoretical distinctions. Of importance in this study is the potential differential impact that categorisation of children from one or another perspective may have on predictions for outcome with or without intervention.

4.1 Theoretical evidence for distinctions between types of co-ordination deficits

The heterogeneity within DCD, as evidenced through the numerous descriptions of these children, has led some to consider whether more homogeneous subtypes are formed by unifying characteristics of movement and/or perceptual ability (Dewey & Kaplan, 1994; Hoare, 1994; Macnab et al., 2001; Miyahara, 1994; Polatajko, 1999; Wright & Sugden, 1996). Others have focussed attention on the frequent co-occurrence of DCD with other developmental disorders and whether particular associations are significant such as for example, DCD with ADHD being substantially different either in aetiology or outcome from DCD with dyslexia or AS (Dewey, 2002; Visser, 2003). Research in other areas of development has also suggested that an association with movement difficulties may predict more negative or differing pathways of development and outcome (Gillberg, Gillberg & Groth, 1989; Heath, Toste & Missiuna, 2005; Hellgren et al., 1993, 1994; Kadesjö & Gillberg, 1999; Rasmussen and Gillberg, 2000; Sigurdsson, van Os & Fombonne, 2002). Gernsbacher and Goldsmith (2000) have considered the possibility of a 'dyspraxic' subtype within Autistic Spectrum disorders, suggesting differences in aetiology, neuroanatomy and consequent behavioural profile. It remains to be seen whether distinct outcomes can be attributed to specific associations of developmental conditions or rather a function of increasing deficit with each additional co-occurring condition (Heath, Toste & Missiuna, 2005; Kooistra et al., 2005).

Many therapists take considerable time in undertaking a range of tests during an assessment to identify not only whether a motor problem is evident but also to articulate the child's particular profile of movement quality, skill or perceptual ability in order to draw up individualised recommendations for intervention. This detailed, and somewhat phenomenological, approach to assessment has been given support through studies of the differential impact of fine and gross motor ability on self perception and consequent psychosocial needs of the individual (Piek, Bayman & Barrett, 2006). However, the length of time of assessments and individual treatment programming has been shown to have negative effects on service provision with many therapy services in the UK having excessive waiting times for initial assessments or treatment packages (Dunford & Kelly, 2001; Dunford, Street & Sibert, 2004; Green et al., 2005; COT & NAPOT; 2003). This is somewhat concerning in view of research which suggests that a differential diagnostic outcome may result from variations in test selection rather than specific differences in the presentation of the children (Crawford, Wilson & Dewey, 2001). Despite a relative dearth of studies exploring short and long-term outcomes of intervention, there is some suggestion that a proportion of children with DCD may make progress without intervention whilst others make limited or no progress despite intensive therapy (Pless & Carlsson, 2000; Sugden & Chambers, 2003; Sugden & Chambers, 2005). The theoretical and practical significance of potential subtypes of DCD—either by nature of movement profile or association with additional developmental disorders—is of fundamental importance to this study.

4.1.1 Explanations for 'sub-typing' within DCD from theoretical understandings of motor learning, execution and behaviour.

Chapter 3 describes developmental constructs that support an understanding of the emergence of motor patterns. Developmental approaches emphasise the importance of achieving motor milestones and hence will identify children at risk of movement difficulties when these targets are not met. Distinctions between children which may give rise to more defining subtypes are often made on either the extent of movement

difficulty (e.g. the degree to which a child's performance is below that expected for his/her age) or whether fine motor problems are in excess of gross motor (static and dynamic balance) and/or complex motor skills or vice versa (Piek, Bayman & Barrett, 2006). The intimation from a series of Finnish studies, suggests that children with more borderline motor difficulties (e.g. those whose degree of motor impairment was categorised as intermediate as opposed to 'stable clumsy' in comparison to a control group) may have fewer problems long term and to all intents and purposes were considered to have caught up with their peers by age 15 and 17 years (Cantell et al., 1994; Cantell, Smyth & Ahonen, 2003).

Approaches which place emphasis on hypothesised sensory or perceptual processing components of movement are exemplified in the treatment paradigms described by Ayres, *Sensory Integrative Therapy* (SIT, 1971, 1972a; Bundy, Lane & Murray, 2002; Fisher, Murray & Bundy, 1991) and Bairstow and Laszlo (1981). SI theory attempts to distinguish between the differing contributions of sensory information to task breakdown. The majority of Ayres' research work was directed towards understanding the various constellations of problems as indicative of specific 'neural' dysfunction (Ayres, 1971; 1972 a, b; 1985; 1989). To this end she developed a number of specialised assessments such as the Southern California Sensory Integration Tests (SCSIT, Ayres, 1972b) and the Sensory Integration and Praxis Tests (SIPT, Ayres, 1989). The theoretical model outlined by Ayres suggests that poor processing of vestibular and proprioceptive stimuli may give rise to problems of postural-ocular control and bilateral integration and sequencing. Difficulties processing tactile and proprioceptive stimuli were thought to contribute to somatosensory deficits and 'somatodyspraxia' (Ayres, 1985; Ayres, Mailloux & Wendler 1987). Praxis in this context referred to the ability of a child to plan and execute novel or unfamiliar motor actions (Ayres, 1989). More recent categorisation of types of SI dysfunction under a heading of Sensory Integration and Praxis Deficit includes two main subtypes: *Bilateral integration and sequencing deficits* (BIS) associated with poor coordination of the two sides of the body reflecting impaired processing of vestibular and proprioceptive sensations; and, *Somatodypraxia*, characterised by poor planning

related to poor tactile and proprioceptive processing as well as a *generalised SI dysfunction* (Bundy, Lane & Murray, 2002). BIS has also been considered to be a more mild form of practic disorder (Mulligan, 2003a).

Although Laszlo and Bairstow's work (1985 a,b) focussed attention on the role of body movement perception (proprioception and kinaesthesia), there is no indication from their work whether there are subgroups of children with DCD who have kinaesthetic difficulties versus those without, rather, children with movement difficulties have problems with body movement perception generally.

Some of the most convincing evidence for distinctions of 'perceptual-motor' problems underpinning DCD comes from the work of Wilson and McKenzie's (1989) meta-analysis of research into the information-processing difficulties of these children. The most frequently occurring problems were seen in visuospatial processing and to a lesser extent problems with cross-modal and kinaesthetic perception. Weintraub and Mesulam's (1983) and Rourke's (1989) work epitomise the relationship between visual spatial skills and coordination. Rourke (1989) attributes the difficulties of children with 'Non-verbal learning disabilities' (NVLD) to right hemispheric functions, thus making a neurological association with visual perceptual processing. Weintraub and Mesulam (1983) had earlier provided evidence of right hemispheric deficits co-occurring with clumsiness although Denckla (1983) argued that the children described represented those with Asperger Syndrome (AS). The distinction between the boundaries of the movement difficulties of AS and those of DCD remains blurred if not indistinguishable (Green et al., 2002b; LCS, 2006).

Wilson and colleagues have explored the visual spatial and visual imagery deficits in DCD through a number of studies of gesture, but rather than distinguish between children with DCD with visual spatial problems and those without, they tended to contrast the children with DCD as a group to those without movement difficulties (Maruff et al., 1999; P.Wilson et al., 1997; 2002; 2004). These studies did however, highlight the difficulties children with DCD have in visualising movement (their

imagined movements did not conform to Fitt's law as did those of control children) and visual spatial analysis. Furthermore the influence of mental practice (movement visualisation) on the acquisition and retention of motor skills has been seen to be beneficial in children with and without DCD (Jarus & Ratzon, 2000; Wilson, Thomas & Maruff, 2002).

There is considerable interest in understanding the role of imitation and gesture not only to movement planning and organisation but also in building up representations of people and objects. Studies exploring attention control and gesture have intimated at a frontal lobe dysfunction in ADHD (Benson, 1991; Chaminade, Meltzoff & Decety, 2002). Chaminade, Meltzoff and Decety (2002) identified differential cerebral activation during imitation tasks that required the formation of a goal versus production of the means, using positron emission tomography (PET). Right dorsolateral prefrontal cortex was more active during goal formation — consistent with the 'executive function' role of this area — compared to the medial prefrontal region which was more active during imitation of the means — compatible with this area's role in understanding others' intentions (Chaminade, Meltzoff & Decety, 2002). The enhanced premotor area activation evident when required to generate the means if only the goal is demonstrated, suggests that goal directed action may be more cognitively demanding when the method of production (the means) is not provided. These researchers later distinguished between imitation deficits involving poor body schema to be associated with the left inferior parietal lobe whereas problems executing gestures demanding greater visuospatial analysis were associated with right parietal lobe with a commonality of the ventromedial prefrontal cortex (Chaminade, Meltzoff & Decety, 2005). Gernsbacher and Goldsmith (2000) and Hughes (1996) however, provide some support for an executive function hypothesis rather than a more predominate visual-spatial decrement, associating problems of motor planning (including spatial organisation of movement) and autistic spectrum disorders. More recently, evidence suggests deficits in the action observation-execution matching system, the 'mirror neurons', in children with ASD (Lepage & Théoret, 2006; J.H.G. Williams et al., 2006). These mirror neurons have been identified in

humans in the precentral gyrus, the posterior inferior frontal gyrus and the rostral part of the inferior parietal lobule, and attenuation of these areas occurs in children under 11 years old (Lepage & Théoret, 2006; Rizzolatti & Craighero, 2004). Nakamura et al. (2004) attempt to distinguish between the differing neural systems of vision: the dorsal stream (associated with aspects of social recognition and includes the mirror neuron system) and the ventral stream (associated with object/shape recognition) in studies of hand sign recognition. This would suggest that children with social problems may have greater difficulty reproducing hand signs that are socially meaningful as opposed to imitation or gesture production of actions of objects.

If frontal/prefrontal dysfunction theories underpin (part of) the neuropathology of ADHD and ASD, it may well be conceivable that children with ADHD or ASD with DCD would have additional deficits in motor planning and behaviour organisation as a consequence of inefficiency of frontal/prefrontal systems that support visually prompted actions. This would imply a different profile of gesture ability and visual spatial skills of those children with DCD when co-occurring ADHD or ASD from the profiles of a purer group of DCD children. Sergeant, Piek and Oosterlaan (2006) set out a theoretical model of executive functions, the cognitive-energetic model, to provide some understanding of the neuropsychological deficits that are linked to both ADHD and DCD but which remains untested with clinical populations.

Alternatively, the studies of Nicolson et al. (1999) and O'Hare and Khalid (2002) have implicated the cerebellum when executing sequences of movement. Nicolson and Fawcett (1995) have hypothesised that cerebellar abnormalities not only led to problems with time estimation (sequencing deficits), but contribute to the phonological problems associated with dyslexia. Difficulties with temporal-spatial aspects of movement control have not only been associated with the verbal sequencing difficulties of children with speech and language impairment (SLI) but also with problems that some children experience when learning limb action sequences and performing gestures and temporal control of gaze and hand movements (Dewey et al., 1988; O'Hare & Khalid, 2002; Wilmut, Wann & Brown, 2006). Similar to the

previous question regarding differences in gesture ability and visual spatial skills, it remains conjecture as to whether a particular subtype of movement difficulty is associated with sequential processing problems that also affect language or literacy. The corollary of this is that children with DCD with a verbal:performance IQ discrepancy in favour of verbal skills would look different from those whose performance skills excel their verbal capability. An equally captivating hypothesis is that right-handed children are different from left-handed children with DCD. However, Bishop (1980) suggested that it is not so much the left-handedness which causes any problems, but rather, the greater association of sinistrality with poor use of the non-dominant hand. Although some might argue that there is a more specific association between left-handedness, dyslexia and also immune factors, it has yet to be shown that there is a specific causal factor that links these variables (Tonnessen et al. 1992; Morton, 2004).

An argument that inherent characteristics of the child, such as inner 'resilience', may distinguish children and contribute to different developmental trajectories and outcomes is supported by the work of Snyder and colleagues (2002; Snyder et al., 1997; Snyder, et al., 2002). 'Hope Theory' as set out by Snyder, is defined as the 'perceived capability to derive pathways to desired goals and motivate oneself via agency thinking to use those pathways' (2002, p249). Children with high hope are more likely to embrace self talk phrases such as, "I can do this and therefore I will" versus "I can't do this and therefore I won't", comments which contribute to perceptions about the success (or lack thereof) and motivational incentives to pursue personal goals (Snyder, 2002). Margalit considers the internal and external risk and protective factors that affect children's resilience and how these may contribute to 'differing developmental paths of adaptation among children with learning disabilities' (Margalit, 2003, p86). There is some discrepancy in the literature regarding the relationship of a child's automatic thoughts and maternal resourcefulness to the child's resourcefulness however, Margalit has illustrated the influence of 'resilience' in enabling some dyslexic students to persist in their attempts to overcome difficulties when others stop trying despite less apparent manifestation of the extent of their

reading difficulties (Cornah, et al., 2003; Lackaye et al, 2006; Zauszniewski, et al., 2002). On a similar vein but using a different theoretical construct, Davis (1997) developed the *Family Grid* to explore the relationship of parent to child and vice versa through contrasting expectant and real perceptions of skills and aspirations. The *Family Grid* is based on *Personal Construct Theory* in which it is thought a 'person anticipates events by construing their replications' (Bannister & Fransella, 1986, p8; Kelly, 1955; 1991). Thus discrepancies in real versus ideal perceptions are thought to contribute to difficulties in use of coping strategies and adaptation, evidenced in studies of adolescent mental health (Davis, 1997). It is interesting to note how these studies reiterate the work of Nichols and Chen (1981) and illustrate, not only the complexity of children's motor development, but also the influence of multiple internal and external (risk and supportive) factors on outcome. Alternatively, Hadders-Algra and Lindhahl (1999) have suggested that our inability to identify specific risk factors is perhaps more indicative of our lack of knowledge about minor developmental abnormalities of the brain and relationship to learning problems.

4.1.2 Summary of the theoretical constructs for the presence of distinct subtypes of co-ordination disorders

The variety of characteristics of children with DCD that could be considered as cohesive or unifying features provides some weight to the argument that there may be distinctive subgroups within this more globally heterogeneous population. The number of theories attempting to explain the co-ordination difficulties of children suggests that these differing hypotheses, developed to explain the variation in presentation of these children, give rise to a range of suppositions regarding potential homogeneous subtypes. What is unclear, is whether these theories are referring to the same groups of children with differences in procedural analysis and nomenclature rather than true nosological distinctions. In practice, the lack of agreement regarding the nature of DCD and potential influence of subtypes on outcome is reflected by therapists' preference to incorporate an eclectic approach in both assessment and intervention, even when dealing with a more specific problem such as handwriting

(Feder, Majnemer & Synnes, 2000; Mandich et al.2001a; Wallen & Walker, 1995). This may result in number of redundant procedures which may confound the overall interpretation of the child's difficulties and impact on recommendations for intervention.

4.2 Empirical evidence for subtypes of co-ordination deficits

4.2.1 Studies of subtypes of Developmental Coordination Disorder

A few researchers have explored the question of 'subtypes' within DCD along the lines of perceptual and motor performance. Hoare (1994) identified five patterns of dysfunction amongst children identified with DCD: 1) below average dynamic balance and kinesthetic acuity; 2) visual perceptual competencies with poor kinesthetic acuity; 3) visual motor deficits; 4) poor static balance and visual perceptual/visual motor functions, and; 5) poor static and dynamic balance. These subtypes were derived from testing six perceptuo-motor tasks including the Kinaesthetic Sensitivity Test (Laszlo & Bairstow, 1985b), Motor Free Visual Perception Test (Colarusso & Hamill, 1972), Visual Motor Integration (Beery, 1967), Purdue Pegboard (Tiffin, 1968), Static Balance derived from the standardized tests and running 50 metres as quickly as possible (Hoare, 1994). Again using cluster analysis, Macnab, Miller and Polatajko (2001) explored the subtype theory further using a similar protocol to Hoare's (1994) study and contrasted the clusters. Although identifying groupings similar to Hoare (1994), Macnab et al.'s (2001) study highlighted the impact that different measures have on cluster structures and therefore intimates at the differences which would arise by approaching the 'sub-typing' question from a different theoretical perspective.

The sub-typing study of Wright and Sugden (1996) explored a slightly different tangent by considering the interaction of the environment on the motor capabilities of children with DCD. These researchers also found a group who demonstrated a relatively even profile of skills irrespective of whether they were moving around the

environment or not, a group who had particular difficulty adapting to externally imposed challenges such as required for catching balls, a group who showed better manual dexterity ability ('fast hands') in a stable environment and a fourth group which demonstrated some variability in skill with significant problems moving their hands at speed yet showing competence in catching. These results suggest some separation of skills in fine motor tasks, frequently undertaken at a stable table surface, versus more dynamic gross motor activities involving movements in response to environmental changes. This is consistent with Piek, Baynam, and Barrett's (2006) more recent study suggesting a differentiation of the ability of children with DCD by problems of fine motor, gross motor and complex motor skills.

Applying a developmental rather than performance or process model, Jongmans (1994), explored the profiles of motor ability/impairment of children born prematurely. When those children with more generalized motor difficulties (possible motor disorders) were excluded, the five remaining profiles broadly match the clusters identified in the studies of Hoare (1994) and MacNab et al. (2001). Using performance rather than process terminology, those clusters reported by Wright and Sugden (1996) show similar variations of motor performance to both the process model subtypes' of Hoare (1994) and Macnab et al. (2001) as well as the developmental model of Jongmans (1994).

Following these same principles of analysis yet focusing on outcome (utilising a performance model), Miyahara (1994) explored the gross motor difficulties of children with learning disabilities in which four clusters emerged, one of which included no gross motor problems, the remainder included: 1) children who were poor in all gross motor tests of the Bruininks Oseretsky Test of Motor Proficiency (BOTMP); 2) poor in all gross motor items except balance; and, 3) good in all gross motor items except balance. When contrasting the studies of Hoare (1994), Jongmans (1994), MacNab et al, (2001), Miyahara (1994) and Wright and Sugden (1996) somewhat different evaluation procedures were used and it is therefore unclear the extent to which the

factors identified were test dependent in all of these studies or represent clearly distinguishable subgroups across the populations.

Although not incorporating 'sub-typing' or cluster analysis per se, Hadders-Algra (2002) found two distinct forms of minor neurological dysfunction amongst children with coordination difficulties which were dependent on the complexity (numbers of symptoms) of neurological involvement in their population study investigating the relationship between pre-and prenatal events and neurological, cognitive and behavioural development. Pless et al. (2000; 2001b) also found the complexity of motor difficulties to have an impact on outcome with younger children with more profound difficulties (<5 percentile ranking on the Movement Assessment Battery for Children, MABC) requiring more specific therapeutic interventions than those children with a more mild presentation. Of interest in contrasting these two studies with those of children born prematurely, is the principle of aetiology. Although Kaplan et al. (1998; 2001; 2006) argue for use of the term 'Atypical Brain Development' (ABD) to encompass the breadth of problems and interrelationship between developmental disabilities, the implication from this term is that there is a common causality between expressed symptoms due to some pre, peri, neo or post natal incident disrupting 'typical' development. Whereas it is this very 'atypical' adaptation to early cerebral insults, such as cortical reorganisation and maintenance of cortical-spinal projections within a specific time window in early infancy, that is associated with improved functional outcome in cerebral palsy (Smith, 2004).

The prototypes of SI dysfunction identified by factor and cluster analyses of the SIPT suggest distinctions of sensory-perceptual profiles as: Low average bilateral integration and sequencing (low average scores on standing and walking balance, bilateral motor coordination, oral praxis, sequencing praxis and graphesthesia subtests of the SIPT); Low average sensory integration and praxis (low average range on all SIPT tests); Generalised sensory integration dysfunction (characterised by below average scores on all SIPT subtests); and, Visuo and Somatodyspraxia (low scores on

design copying, finger identification, postural praxis/imitation, sequencing praxis/imitation, bilateral motor coordination, standing and walking balance, motor accuracy and kinaesthesia subtests). Two further profiles or clusters are identified via the SIPT; that of Dyspraxia on Verbal command – linked to language disorders, and that of High Average Sensory Integration – constituting no problems (Ayres, 1989). These clusters were derived from a large population of children with and without learning disabilities which may or may not have included those with motor in-coordination. Furthermore, there are only a few subsections in this battery dedicated to the execution of a motor skill: Motor Accuracy and Standing and Walking Balance and the constructional tasks of Design Copying and Constructional Praxis.

Comparison of these hypothesised dyspraxic subtypes with studies specifically investigating coordination are restricted (Murray, Cermak & O'Brien, 1989). In 1998, Mulligan attempted a confirmatory factor analysis of these hypothesised constructs and although found a reasonable fit for the five-factors most frequently reported by Ayres, a four-factor model was more satisfactory. Both Mulligan (1998), in her confirmatory factor analysis, and Lai et al. (1996) suggest that SI dysfunction is a more global construct providing a uni-dimensional interpretation of dyspraxic subtypes in which with BIS represents a more mild form of practic disorders (Mulligan, 2003a).

Of note in the two studies of Hoare (1994) and Macnab et al. (2001) was the presence of a group of children who performed well on measures of static balance which is consistent with a subtype of children with learning disabilities and motor problems who performed well on the balance subtest of the BOTMP (Miyahara, 1994). Wann et al. (1998) and Dewey and Kaplan (1994) also provide some support for a subtype of children with DCD who display relatively good performance on tests of balance. The majority of the subtyping studies also found a group of children with DCD and/or learning disabilities who had significant difficulties across all areas of motor and perceptual ability (Ayres, 1989; Dewey & Kaplan, 1994; Hoare, 1994; Macnab et al., 2001; Wright & Sugden, 1996). It remains unclear how the various profiles of perceptual or motor skills identified in these studies relate to the extent of movement

and learning problems and what association may exist with other developmental disorders.

4.2.2 Singular or Specific – Can subtypes be associated with other developmental conditions?

The extent to which secondary features may be ‘defining’ or ‘essential’ is poorly articulated in both major diagnostic tomes- DSM IV (APA, 1994) and ICD 10 (WHO, 1992) let alone at what point - any additional feature would exclude a diagnosis. Indeed, the Leeds Consensus recommend documenting the additional behavioural disorders but not to exclude a diagnosis of DCD unless it is evident that it is the behaviour rather than movement problems which impedes performance, for example: bumping into things due to inattention to environmental obstacles (LCS, 2006). It is therefore unclear the extent to which associated features, co-morbid developmental conditions and/or other external factors such as social support structures and inherent personality characteristics, serve to mitigate or exacerbate deficits on testing or response to treatment. Nor is it evident whether the association of DCD with a particular co-morbidity would constitute a separate ‘subtype’.

Research on children with ‘Minimal Brain Dysfunction’ (MBD) in the 1960s and 1970s suggested that a large number of these children presented with minor neurological signs which included clumsiness and poor co-ordination (Clements & Peters, 1962; Nichols & Chen, 1981). Clements and Peters (1962) estimated that 85% of children with MBD had a mixed presentation with learning problems, poor attention/ hyperactivity and/or minor neurological signs co-occurring more commonly than any individual symptom cluster in isolation.

Despite this earlier evidence to suggest a higher prevalence of a complex presentation, definitions of developmental disorders moved away from such generalised

terminology as MBD. This shift of conceptual focus to the 'discrepancy notion' led to the description of a number of specific developmental impairments identified by observed discrepancies between skills and estimated ability. Developmental disorders such as Speech and Language Impairment (SLI), specific reading, spelling and maths disorders, as well as individual and distinct psychiatric diagnoses such as Attention Deficit Hyperactivity Disorder (ADHD) and Pervasive Developmental Disorder (PDD) emerged in the Diagnostic and Statistics Manuals and International Diagnostic Classification of Diseases with several revisions (DSM-III, APA, 1987; DSM-IV, APA, 1994; ICD-10, WHO, 1992). Concentrating research on these 'pure' disorders was felt to aid understanding of these conditions by providing more details of underlying, key features. Needless to say, the majority of these studies have been confounded by the high co-occurrence of at least two 'specific' developmental disorders. More recent cross-sectional and longitudinal research studies are again recognising that symptoms of many developmental disorders overlap, albeit to varying degrees in different individuals, and may change over time (Green & Baird, 2005).

From the clinical perspective, parents and clinicians have always had a clear picture of the complexity of impairments suffered by children with DCD. To some extent, this complex mix may contribute to the variations in presentation to different services in which children with learning difficulties in conjunction with motor difficulties may appear in either educational or community paediatric settings whereas children with co-existing emotional and behavioural difficulties may be seen more frequently in child and adolescent mental health services (CAMHS). These discrepancies in presentation to services will influence the results of research studies drawing from these respective populations (Cantwell, 1996; McConaughy & Achenbach, 1994).

The past decade has shown an increase in the number of studies attesting to the frequency of co-morbidity amongst children with co-ordination difficulties (Green, Sugden & Baird, 2006; Kadesjo & Gillberg, 1999; Kaplan et al, 1998; 2001; 2006; O'Hare & Khalid, 2002; Silver & Hagin, 1990; Sugden & Wann, 1987). In a series of

studies, Kaplan and her colleagues (1998 onwards) have investigated the overlap between reading (dyslexia), attention and motor deficits. They found sufficient evidence showing the presence of at least two out of three of these problems should be considered the norm rather than the exception and have recommended the use of the more general descriptive term of ABD to describe these children rather than multiple, yet more specific, combinations of labels (eg. to include Dyslexia, Dyspraxia, Dyscalculia and Dysgraphia). A return to the use of an 'umbrella' term may however suffer the same fate as MBD in which the ambiguity of the label does not help address the specific profile of children. Furthermore, arbitrary links between conditions may be assumed and confound the association by potentially attributing a contributory status versus an associative one.

Reviewing the work of Piek and Dyck (2004), there is some foundation to their argument that sensory-motor deficits linked to children with DCD and autistic spectrum disorders but not those of children with ADHD may differentiate the problems of children with these developmental disorders (Cummins, Piek & Dyck, 2005). These authors however failed to distinguish between the more formally recognised subtypes within Autistic Spectrum Disorders (ASD) in which those with more classical Autism have been identified with visual-spatial strengths whilst those with Asperger's Syndrome are renowned for their poor performance in visual-spatial tasks as well as poor gross and fine motor skills (Klin et al., 1995). Consequently this generalisation of ASD as a uniform condition with respect to sensory-motor skills, confounds any comparisons that can be made between children with ASD and those with DCD.

Cummins, Piek and Dyck (2005) take this argument further in their more recent paper in which they attempted to control for visuo-spatial skills in contrasting the relationship between motor coordination, emotion recognition and social behaviour. They conclude that children with motor coordination problems show specific deficits in empathy related to recognition of facial emotion cues (not vocal cues) and that

motor problems were a significant predictor of social problems. Unfortunately, these authors did not undertake any differential diagnostic procedures to identify whether any of their motor impaired group (n=39) or control group (n=39) may have met criteria for a childhood social, emotional or behaviour disorder. They preclude the possibility of co-morbidity by stipulating that all children were in good health and were attending mainstream schools although an unspecified number were found to fall within a diagnostic range on the Childhood Behaviour Checklist. Needless to say the questions that arise from their work illustrate the need to understand the relationship between motor deficits and social-emotional factors in order to develop appropriate interventions.

Pitcher, Piek and Hay (2003) approached the issue of co-morbidity from a different perspective. These authors consider the differentiation of attention deficit disorder subtypes (predominately inattentive, hyperactive/impulsive or combined subtype) by accompanying motor deficit. Their findings suggest a stronger link between motor ability and inattention across all motor tasks on the MABC (Henderson & Sugden, 1992) however, fine motor skills could not be attributed directly to inattention and distractibility. The possibility of a relationship between motor performance and executive function skills, particularly response inhibition, has been given further support suggestive of a distinction between the movement problems associated with and without a co-morbid diagnosis of ADHD (Livesey, et al., 2006).

Visser (2003) returned to the notion of an 'automatisation deficit' associated with the traditional view of more generalised sensorimotor deficits encapsulated by the concept of MBD and evidenced in some studies of dyslexia (Fawcett & Nicholson, 1992) and raised the question of subtypes of DCD with respect to associated co-morbidity. The strong argument Visser (2003) presents for the 'automatisation deficit' paradigm is supported in his paper through the frequent co-occurrence of dyslexia, ADHD and DCD and concomitant problems performing a dual task condition as well as the hypothesised consideration of deficient cerebellar processing in these children. Perhaps, this particular constellation of developmental problems could be considered

to make up a more distinct subtype of DCD although it remains unclear whether this leads to a significantly different developmental trajectory that is greater than the effects of multiple disorders.

In their report of a large prospective population study of children, Nichols and Chen (1981) were unable to identify specific predictors for clumsiness (partly measured through presence of neurological signs) nor did pre-maturity emerge as a major factor predicting later motor difficulties. They subsequently concluded that there was no clear profile of antecedents or combinations of deficits and consequences (Keogh & Sugden, 1985).

Consequent to the Nichols and Chen study (1981), a number of investigations of children born pre-maturely and/or of low birth weight have demonstrated an increased risk of perceptuo-motor difficulties in the primary school years. Further to Jongman's work in 1993 which identified subtypes in the pattern of motor co-ordination difficulties amongst 6 year old children who had been born prematurely (see above), Hadders-Algra's (2002) hints at supportive evidence of neurological subtypes in a follow-up peri-natal study whereby children with poor co-ordination *and* minor neurological signs differ from those without this combined subtype and recommended shifting the focus of intervention for some of these children.

In considering the possibility of a relationship between presentation and outcome, many of those children referred to therapy services may also have had a history of perinatal difficulties including pre-maturity. Neonatal difficulties have been found to be powerful predictors of persistent minor neurological dysfunction and subsequent perceptual and motor difficulties (Foulder-Hughes & Cooke, 2003; Gillberg & Gillberg, 1989; Hadders-Algra & Lindahl, 1999; Jongmans, et al, 1998; Henderson & Barnett, 1998; Sullivan & McGrath, 2003). There is continuing debate as to whether prematurity would also rule out a diagnosis of DCD under Criterion C or whether this factor should be considered as making up a distinctive subtype when there is no

evidence of neurological disorder (APA, 1994; Barnett, Kooistra & Henderson, 1998; LCS, 2006; Geuze, et al., 2001; Jongmans, et al., 1998). Or rather, should Pasamanick and colleagues' (1956, 1966) view of a 'continuum of reproductive casualty' be reconsidered to account for a continuum of developmental difficulties/gradient of injury rather than discrete categorical differences?

Longitudinal studies reported in section 2.3 have highlighted other problems from which these children or young persons may be at risk and which may have greater impact in the longer term. For example, learning, behaviour, social and emotional outcomes are adversely affected in many adolescents and young adults who have had or continue to suffer from DCD (see Green & Baird 2005 for a summary). The differentiation of outcome in children with varying degrees of the contributing factors of DAMP or following treatment provides some support for the postulate that children with coordination deficits are made up of distinctive subtypes either in: type (quality) or severity of coordination deficit; aetiology/history, and/or; overlap with other conditions, and that these subgroups may require different intervention strategies.

4.2.3 Summary of empirical evidence for subtypes within developmental conditions

Despite differences in terminology and symptomatology there is clearly a considerable group of children who have significant difficulties in performing motor tasks (Henderson & Henderson, 2002). This paper considers whether theoretical distinctions, and hence discrepancies in terminology, account for the differing presentations of these children and/or whether there are substantive subtypes of coordination impairment that would warrant differential interventions. The potential influence on motor performance and outcome of some of the additional characteristics commonly associated with DCD is also considered. Issues surrounding the overlap of DCD with other developmental disorders are also of importance within this paper.

CHAPTER 5 METHODOLOGY

This study endeavoured to validate whether subtypes of DCD from different theoretical perspectives are clinically meaningful and thus relate to differences in outcome. A mixed experimental design was used to test for the presence of specific components of motor behaviour in a controlled clinical environment and the interaction of these factors in influencing motor performance. A second study tracked maturation over time, with and without intervention, of a smaller subset of these children identified with movement problems. This information is used to contrast the differing perspectives to understanding DCD.

5.1 Questions

- 5.1.1 Are there distinguishable subtypes of perceptual and motor performance in a group of children with Developmental Coordination Disorder who had been referred to an occupational therapy department in the UK and, if so, are these consistent with previously published subtyping studies in Australia and Canada?
- 5.1.2 How well do different theoretical models, used to identify subtypes, predict original group membership?
- 5.1.3 How do these subtypes influence outcome, with and without treatment?
- 5.1.4 What impact do additional factors associated with motor development have on movement skill and treatment response?
- 5.1.5 How do emotional and behavioural characteristics of children influence the acquisition of motor skills?

5.2 Design

A two-part study was used, incorporating qualitative and quantitative analyses, to investigate the presentation and outcome of children with DCD. Particular attention was given to any evidence for subtypes and the impact that these and other developmental factors may have had on the adaptive capability of these children.

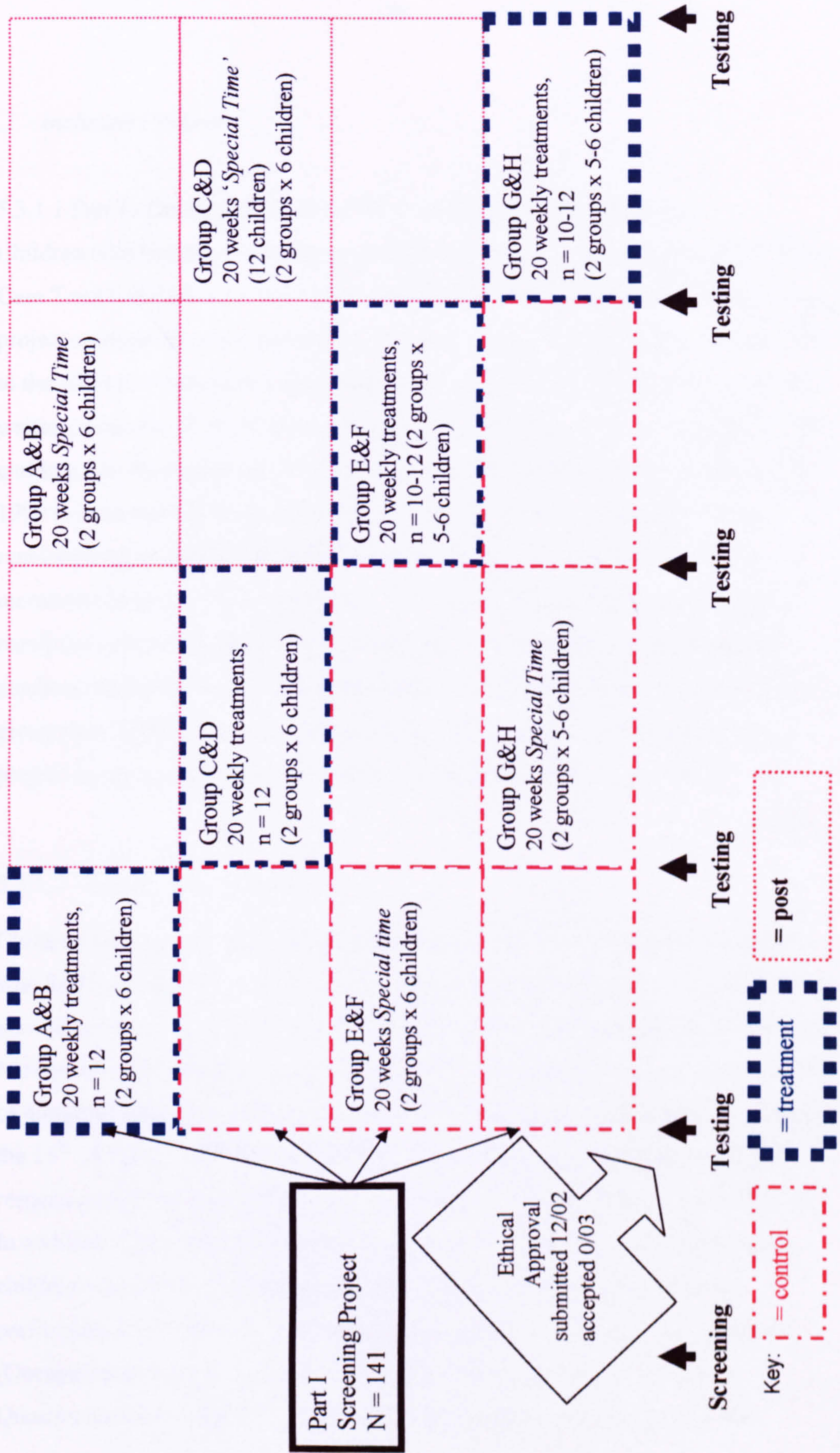
Part I provided detailed analyses of the profiles of the motor performance of children who were referred to a community occupational therapy service due to concerns regarding poor co-ordination and who subsequently underwent extensive clinical assessment. The identification of DCD included different types of assessments from the main theoretical frames of reference (eg. developmental, perceptual-motor, sensory integrative and motor learning). The subtypes identified from these theoretical bases were contrasted to ascertain the effects of terminology and theoretical perspective on possible subtype presentation. Additionally, information regarding birth history, co-morbidities, socio-economic background and emotional and behavioural characteristics of the children was also gathered and was considered with respect to the presentation and categorisation of children.

Part II was designed in line with the recommendations of Pless and Carlsson (2000) who highlighted the need for research on well-defined subgroups of children with DCD (see section 3.3), and thus involved a parallel study to consider which 'type' of child could benefit most from a specific Occupational Therapy group intervention. The clinical relevance of subtypes was explored by examining whether general group treatment accelerates motor development differentially between subtypes. Post hoc analyses examined factors most likely to indicate the need for treatment and/or contributed to treatment responses. Figure 5.1 illustrates the time line and major structural dimensions of the project.

5.3 Subjects

A convenience sample was obtained that incorporated children who had been involved in a screening study in which a large amount of data was collected on their condition. [Section 5.3.1.1 below provides details of the screening project.] In addition, in view of their advancing age and pending moves to secondary school, it was felt imperative to utilize this cohort (for Part II) before they were lost to other services or geographic areas. Ethical approval was sought to contact families/carers of children (age 5 years or over) who had participated in a screening programme and were identified with having or at risk of having a Developmental Coordination Disorder (Green et al., 2005). Part I of this study involved detailed analysis of the data collected during the screening project (n=141). Part II consisted of an intervention study on a smaller subset of these children identified with co-ordination difficulties (n=43/141), who consented with their families to undertake: pre-treatment baseline testing; provision of 20 one hour weekly group occupational therapy intervention; and, retesting at each 20 week cross-over period between treated groups and control groups (6-monthly periods). All children in control/cross-over groups were offered current occupational therapy protocols of self-help home programmes whilst awaiting participation in the group intervention. In addition, parents were asked to give their children 'special time' (focussed attention on the child's chosen task) over a designated period to control for the Hawthorne Effect – to ensure that results are specific to the treatment in the study rather than 'any' special attention obtained through participation in the intervention groups. Section 5.9.1 describes the theoretical dimensions of the Hawthorne Effect and 'Special Time' programme.

Figure 5.1 Study Design



5.3.1 Inclusion Criteria

5.3.1.1 Part I - Detailed analyses of the profiles of motor performance

Children who had participated in a predictive screening project in Bromley Primary Care Trust had their data included for analysis in Part I of this study. The screening project contrasted parent and teacher opinion of the extent of a child's motor skills to the clinical measurement of the degree of motor difficulty, in an aim to reduce waiting times for those children most at risk of significant motor impairment. The children had been referred to the local occupational therapy service from March 1999 to February 2003 due to concerns regarding motor coordination which required a more detailed professional examination. These subjects had been recruited consecutively from the top of the waiting list as determined by date of receipt of referral. Referrals were from a variety of sources including parents, teachers, therapists and psychologists although medical doctors formed the major group (See Table 2.1, p.22). (Green et al.'s, 2005 publication on the screening project incorporates only those children referred through to May 2002).

5.3.1.2 Part II – Intervention Study

Children between the ages of 6 and 10-6 years at the time of clinical assessment who had been identified as having or at risk of having DCD were invited to participate in Part II, the intervention study (n=78). For the diagnosis of DCD, the Movement ABC (Henderson & Sugden, 1992) was used as a standardised measure of motor capability in gross and fine motor skills, setting a criterion of on or below the 15th, 5th or 2nd percentile to qualify as either borderline, definite or severe, respectively, for a substantial motor impairment, meeting criterion A of DSM-IV. In addition, Criterion B of the DSM-IV was met through the inclusion of those children whose motor difficulties interfere with daily tasks and or school performance as measured by clinical assessment, parental and/or school report (Occupational therapy assessment, Developmental Coordination Disorder Questionnaire and Movement ABC Checklist respectively). In view of the

confusion surrounding Criterion C — the issues of: co-morbidities in DCD; constituents of an explanatory medical condition; and the variations in the diagnostic labelling of children with Attention Deficit Hyperactivity Disorder, Pervasive Developmental Disorders and Learning Disabilities — those children who had additional diagnostic labels but would otherwise have met criteria for DCD were included, providing they did not meet the exclusion criteria set out below. The presence and nature of co-morbidities was documented for each child. In the absence of a paradigm for Criterion D, with respect to the relationship between cognitive development and motor skills, children whose IQ was predicted to be within the normal range (British Picture Vocabulary Scale [BPVS] standard score ≥ 70) and who were attending mainstream school at the time of assessment were included in the project. This is consistent with the recommendations of the Leeds Consensus Statement (LCS, 2006).

5.3.2 Exclusion Criteria

To support comparison with other intervention studies for children with DCD, children whose intellectual quotient was estimated to fall below 70 on comparable tests of verbal reasoning (BPVS < 70) were excluded in line with the recommendations of Geuze et al. (2001). Non-verbal scales of intelligence were used for selection criteria as it was anticipated that many children with DCD would have visual-perceptual difficulties and thus could be expected to perform more poorly on these tests (Wilson & McKenzie, 1998). Information regarding non-verbal visual processing was collected and used in the data analysis.

Children who participated in the screening programme who were over 10-6 years at the time of original clinical assessment and/or whose Movement ABC scores placed them above the 15th percentile were not included in Part II, the treatment phase, due to difficulties anticipated in attendance of secondary school pupils over the extended period of the study. In addition, children in whom the presence of behaviours, such as

aggression or violence, for which group treatment would not be recommended, and those with marked difficulty staying on task during the clinical assessment as recorded by clinical judgment (usually accompanied by incomplete data collection) were also excluded from the intervention study. These behaviours were quantified using the Strengths and Difficulties Questionnaire (SDQ, Goodman, 1997).

5.3.3 Sample Size

5.3.3.1 Part I Sample size - Detailed analyses of the profiles of motor performance

This convenience sample consisted of 141 children taken in chronological order from the referrals to the Occupational Therapy service for poor fine or gross motor skills and who had participated in screening project undertaken in Bromley, Kent. Sample size for the screening programme had been determined by estimating the confidence interval (CI) for positive prediction values. A sample of 100 children was identified as sufficient for this study based on a 95% CI and estimated 80% positive predictive value (B. Wilson et al., 2000). A total of 141 children were seen as part of this study in anticipation of data loss and/or failure to return questionnaires. The teacher and parent questionnaire data of the first 100 children were reported on in a publication of this screening programme (Green et al., 2005). The decision to report on only part of the total cohort was made when it became apparent that the teacher reports from children seen in the latter half of the Summer term of 2002 would not be returned. As the children were due to move into new classes with different teachers in the Autumn term, the teacher questionnaires would be out of sync with parent and clinical assessment and any new teacher would have insufficient experience of the child to complete the questionnaires accurately. Ethical approval was sought to analyse the data from the entire sample participating in the screening programme – including the group reported on in the 2005 publication as well as the children for whom it had not been possible to obtain teacher report of motor skills.

Within the full cohort (n=141), two children were found to have Down Syndrome and were excluded prior to further analysis. A total of 120 children were identified as having no significant learning difficulties (BPVS Standard Scores ≥ 70). From this sample, 62 children were found to have DCD or be at risk of DCD (51.7%) with a further 38 (31.7%) falling into a 'co-morbid' group due to the presence of ADHD (n=5), Pervasive Developmental Delay (PDD) (n=7, although 2 further children were diagnosed subsequently), Speech and Language Impairment (n=9) and other identified medical conditions such as Epilepsy (n= 13) in addition to coordination difficulties making a total of 100 out of 120 children (83.3%) with motor difficulties. Also, although not classified as a co-morbid medical condition, 10 children were identified with Dyslexia or Specific Learning Difficulties (SpLD). However 66 children were receiving additional support at school, 13 of whom had full Statements of Special Educational Needs for difficulties across a range of academic subjects. Data were available for analysis from a total of 100 children who qualified for movement difficulties (with and without additional developmental conditions that were not exclusory under criteria set in 5.3.2).

In order to ascertain whether distinct subtypes exist in DCD, the statistical procedures of factor analysis and cluster analysis were employed. A large enough sample size, dependent on both the number of measures used and numbers of clusters anticipated, is required in order to undertake these analyses. As factor analysis is dependent on analysis of the variance and co-variance (difference and similarity) of the different variables, a sufficiently large sample is required for minimal acceptable reliability (see also section 5.10.1). It is commonly recommended that factor analytical studies contain at least 10-15 subjects per variable (Field, 2000a, 2000b). From Chapter 4, it was hypothesised, from a developmental/sensory perceptual frame of reference, that 5 to 6 key (measurable) variables may underpin the movement difficulties seen in DCD thus requiring a sample of between 60 and 90 children to explore the relationship of these variables. Previous factor and cluster analyses of DCD have been run on samples of 60 to 100

children, with the study by Macnab et al. (2001) having 62 subjects, the one by Hoare (1994) having 80 and that of Wright and Sugden (1996) having 69. It is unclear from these studies whether children with ADHD and other medical conditions had been excluded and therefore how 'pure' these other DCD samples were. The study by Miyahara (1994) contained 147 children with learning disabilities, not necessarily with movement difficulties, who were selected from a school rather than clinical population. Therefore, the Bromley screening programme is felt to have identified sufficient numbers of children with coordination deficits in the absence of more moderate to severe learning difficulties (100/120) to be comparable to the cluster analysis studies of Macnab et al. (2000), Miyahara (1994) and Hoare (1994).

5.3.3.2 Part II Sample size – Intervention study

Analysis was undertaken of the treatment effect size of previous intervention studies involving individual treatments for children with coordination disorders which utilised either the Bruininks Oseretsky Test of Motor Proficiency (BOTMP, Bruininks, 1978), the Test of Motor Impairment (TOMI, Stott, Moyes and Henderson, 1972) or the Movement Assessment Battery for Children (MABC, the TOMI revision, Henderson and Sugden, 1992). This reflected an average effect size of .65. (See Table 5.1).

Table 5.1 Effect sizes of earlier treatment studies of motor coordination

Study	Measure	Effect Size	Sample size
Humphries et al., 1990	BOTMP	.86	20
Shoemaker et al., 1994	TOMI	.86	35
Miller et al., 2001	BOTMP	.35(average)	20
Polatajko et al., 2001a	MABC	.55	14

Determination of power; dependent on a 90% probability of correctly rejecting the null hypothesis (of treatment effect); setting delta at 3.25 (90%) and effect size (d) of .65, identified a sample size of 50 subjects (Howell, 1995). Adjusting this equation for an 80% probability of correctly rejecting the null hypothesis, with an effect size (d) of .65, a recommended minimum sample size contains 37 subjects (Howell, 1995).

$$N = 2 \left(\frac{\delta}{d} \right)^2$$

$\delta = 3.25$ (90%)

$\delta = 2.8$ (80%)

There were 78 children identified with/or at risk of DCD from this sample who were below 10-6 years of age at the initial assessment date and who did not meet exclusion criteria as stipulated above (boys = 65, girls = 13). All of these children were invited to participate in Part II of the study. Inviting 78 children from a convenience sample to participate in Part II of the study accommodated an uptake of 60% and a 10-22% attrition rate over a two year period. Furthermore, with each child acting as their own control, the sample size is effectively doubled.

5.4 Ethical Issues

Some of this cohort of children had been on an operative waiting list for up to 2 years and circumstances may have changed since original referral and the identification of DCD through the screening programme. The delays experienced since referral may have a differential effect on families for reasons which cannot be identified by this study but may result in differences in the perceived need for therapeutic intervention, subsequent uptake to the intervention study and attendance. There may also have been a bias against the participation of families who found the scheduling of the intervention programme and review process difficult to commit to. Some flexibility in intervention scheduling was undertaken to accommodate one older child, whose allocated block of intervention coincided with his first term in secondary school, and he requested an alternative period for intervention. This boy was 'swapped' with another whose school commitments during his designated block would have conflicted

with attendance. Similarly, in the younger group, one child's treatment block was swapped with another to accommodate family commitments. It was not felt that either of these changes jeopardised the principle of randomisation to treatment groups and 'blindness' of test procedures. As this study was designed to run concurrent with established clinical services, children in the control groups had been offered existing Occupational Therapy services of self-help home programmes, at the time of their initial assessment. All children and families had the option to opt out of the project at any time without jeopardising their receipt of existing services. The impact of such a programme on the therapy protocols could only be made following completion of the programme.

Relatively few intervention studies for children with DCD are reported in the literature and these do not indicate negative or contra-indicatory factors involved in participation. It may however, be contested that participation in 72 hours of intervention with little positive gain constituted wasting of time and resources and potential 'negligence' in the provision of an inadequate therapy (B. Wilson et al., 1992). Contra-indications may also occur if providing treatment for a child whose self esteem is undermined by attendance at therapy sessions. However, the risks of negative effects from not receiving intervention prior to age 16 years have been documented (Hellgren et al., 1994).

A number of variables such as socio-economic background, intelligence, extent of motor deficit and attention problems, are also known to contribute to day to day as well as overall performance and may influence progress in treatment (Caulfield et al., 1998). Many of these factors were present amongst the group of children as a whole. The extent to which these factors influence treatment/outcome for children with DCD is unknown and explored as part of this study. Therefore it was felt that making a priori decisions as to which factors should be randomized or controlled could bias treatment group allocation and outcome.

Ethical consideration to the length of time children had been on a waiting list prior to assessment and receipt of intervention in this study was acknowledged and documented. The proposed intervention programme was in addition to the existing review and advice (self-help) programme available from the service and which had been offered to all children. Furthermore, participation in Part II of this study did not compromise access to existing services. Thus it was not felt appropriate to control for this variable (waiting time) in group allocation. Therefore computerised stratified randomisation to treatment and control groups was undertaken controlling for age, dividing children by into age bands 6-8 or 9-10 years (Altman, 1991; see Figure 5.1).

The split nature of the intervention study allowed for the profiling of the average maturational rate for this particular group of children. Parents of children needed to make a commitment to bring their child to the intervention programme and refrain from taking their child to additional physiotherapy, occupational therapy and alternative therapies for the remediation of motor difficulties during this period. The participation in any current therapy programme was documented every six months to ascertain any change in regime. Although the intensity and duration of this programme may have introduced bias, with the families of children who displayed more significant motor or behavioural difficulties undertaking a commitment to treatment (DeGangi et al., 1996), it was hoped that the data collected regarding the extent of motor impairment and co-morbidities allowed for analysis of these factors. The extent of motor difficulty and known additional diagnoses of children participating in the treatment study were contrasted with those who did not (3 families returning the consent form indicated that they would have liked to have participated but had moved out of the area). Attrition rate was not anticipated at the onset but was conservatively estimated at 15% based on the typical uptake for clinical services locally. To control for the Hawthorne affect, the parents of each group of children were asked to engage in 'special' time with their children for a 20 week period. The extent of participation in gross motor, fine motor and relatively non-motor activities was documented during these sessions.

5.5 Procedure

5.5.1 Part I – Data collection for analysis of profiles of motor performance

All research undertaken in a clinical setting is subject to review and approval from a medical ethics committee. Ethical approval had been obtained for the original screening project from the local (Bromley) Medical Research Ethics Committee to contact families/carers of children (age 5 years or over) who had been referred to the local Paediatric Occupational Therapy Department of Bromley Primary Care NHS Trust. Details of the procedures used in the screening study, including consent process, are described in Green et al. (2005). A request to use the anonymised data from the screening study was made in a new submission detailing the new study, Part I and Part II, to the local (Bromley) Medical Local Research Ethics Committee (LREC, See Appendix 4 for correspondence with LREC and ethical approval letters). A summary of the process by which data were collected for the children is provided here.

Letters outlining the screening project (a project to ascertain the effectiveness of questionnaires for identifying children at risk of DCD) had been sent to families along with a parent questionnaire, the Developmental Coordination Disorder Questionnaire (DCDQ). Parents returned this questionnaire along with a consent form to have their child's data from a subsequent clinic appointment, be used anonymously in analyses contrasting parent and teacher opinion of the child's motor difficulties with clinical assessment. The consent forms also requested permission to contact the child's teacher with a request for them to complete a teacher questionnaire of the child's movement capabilities (the Checklist of the Movement Assessment Battery for Children). All letters to families and schools were sent with stamped addressed envelopes to encourage return of the questionnaires. There were no funding incentives to participation, rather, the benefit to families was the possibility of an earlier assessment and report of their child's difficulties. The screening project was undertaken within a clinical service and therefore confidentiality was maintained as per departmental procedures. For research purposes, children were allocated a subject

number for data recording and analyses. All families were informed that they could opt out of the screening programme without jeopardising their place on the waiting list. The screening project was undertaken over a period of two and a quarter years and was a collaborative project with the authors of the DCDQ. The parent and teacher questionnaires, from the first 100 children, have been reported on in Green et al. (2005).

Clinical assessment of possible movement difficulties was undertaken at the Phoenix Children's Resource Centre in Bromley, except in the case of three children, one of whom was assessed at his school and two who were assessed at the regional child development centre. This assessment involved a number of standardised tests as well as structured observations and interview of parents to ascertain medical and educational history. All tests were undertaken according to standardised procedures described in test manuals. Test sequence was maintained as follows unless alterations were required to maintain the interest of the child: British Picture Vocabulary Scale, Matrix Analogies Test, VMI and supplementary tests, Handwriting sample, Movement ABC manual dexterity items, Gesture Test, Movement ABC Ball Skills and Static and Dynamic Balance items, Clinical Observations of Posture and Motor Skills, Assessment of Motor and Process Skills analysis of donning shoes and socks and the Self Esteem Measure (for older children). Testing was undertaken by relevantly qualified senior therapists, the majority of which were undertaken by the author, all of whom were blinded to the questionnaire responses of parents and teachers. The measures used in these assessments are described in section 5.6. The senior therapist prepared a report with recommendations of home and school activities to promote skill development in line with clinical practice in Bromley at that time.

5.5.2 Part II – Treatment Effectiveness

Subjects were recruited for Part II, the intervention study, at the end of the screening programme undertaken within Bromley. Ethical approval was obtained from the local Medical Research Ethics Committee to contact families of children aged 10 years and

6 months or younger who were identified with movement difficulties consistent with a diagnosis of DCD (or at risk of DCD) during the screening study. Letters and consent forms outlining the intervention study (including information on the programme of assessments and intervention as well as anticipated commitment for a 2 year study) were sent to both parents and children requiring a signature of both a parent and the child. (See Appendix 5 for copies of letters, information leaflets and consent form). Children were invited to join 'The Detective Club' to problem solve difficulties in performing different tasks. Families were informed that they could opt out of the study at any time without jeopardising their care from the Bromley Paediatric Occupational Therapy Department. Included in this initial package of information were three questionnaires for parental completion: the DCDQ, the Strengths and Difficulties Questionnaire and the Profile of Neuropsychiatric Symptoms. The DCDQ was used to provide an updated parental opinion of their child's motor skills (some children had been seen up to 2 and ½ years previously in the screening programme). The latter two questionnaires were included to obtain information on factors which may contribute to outcome as well as indicate the presence of aggressive or violent behaviours which would be contra-indicative for inclusion in a movement skills group (see exclusion criteria in section 5.3.2). All consent forms and questionnaires were sent with stamped self-addressed envelopes to encourage return without hardship or inconvenience to families. The intervention programme is described in the next section.

5.5.3 Part II – Intervention programme (pre, post and follow-up testing).

See Figure 5.1 for an illustration of the process. A cross-over design was used to incorporate a 20 week block of weekly group intervention, a six week period to measure progress and a 20 week period of either no treatment or participation in the 'Special Times' programme (to monitor the Hawthorne effect). Table 5.2 illustrates the testing protocol undertaken at each point over the period of the study.

Table 5.2 Tests/assessments undertaken at each stage of the study

Screening assessments	Pre-Intervention Study Test Point 1	During Project Test Points 2-4	Final Assessment Test Point 5
C-MABC	MABC	MABC	MABC
DCDQ	ETCH sample	ETCH sample	ETCH sample
MABC	CSQ	CSQ	CSQ
VMI	BOTMP subtests	BOTMP subtests	BOTMP subtests
Dressing (AMPS)	DCDQ	DCDQ	DCDQ
Gesture Test	SDQ	PONS	PONS
COMPS			SDQ
MAT			Family Grid
BPVS			HOPE Scale
Self-Esteem			WORD
	(medical, social and educational history form)	(medical, social and educational history form)	(medical, social or educational history form)

See section 5.6 for details of assessments and pages xiii-xiv for key to abbreviations

Children consenting to participate in the intervention programme were given a number for stratified randomisation into a treatment group of 6 to 8 children according to age bands for treatment (6-8 years and 9-10.6 years). Randomisation was undertaken using random sample selection function of the Statistical Package for Social Sciences (SPSS, SPSS Inc, 1999). Controlling for age in treatment groups was felt necessary in order to ensure that interest in the tasks undertaken during the sessions would be age appropriate and also that skill levels (even at this lower end of skill) were not too disparate. Stratifying the randomisation to groups in such a way, would also allow for some analysis of the differential manifestation of coordination difficulties at different ages identified by Hellgren et al. (1994), Hadders-Algra (2002) and Gillberg and Gillberg (1989). During their allocated treatment block, children attended a one-hour group, weekly over a 20 week period following the Cognitive Orientation to Occupational Performance (CO-OP, see section 5.9). Each group was led by one senior therapist assisted by a more junior therapist (trained in the CO-OP approach).

An Occupational Therapy Technician was available to assist setting up and dismantling the session. The senior therapist, who led all the sessions for the two years, was appointed on an honorary contract by Bromley Primary Care Trust (PCT) following submission of the financial benefits of the project by the author. A grant from the DCD Study Group (set up by the author on the profits of CO-OP training programmes run nationally) was used to finance part of this therapist's salary to ensure some independence of the intervention project and continuity throughout the study. This independence was felt to be important in the event that financial pressures on the NHS PCT could have resulted in early closure of the programme.

The intervention sessions were held in a local adult education centre, the Widmore Centre, located in the centre of Bromley with easy access to public transport and parking facilities. The removal of 'therapy' from the context of intervention was felt to be an important component of the project. In addition, the author had identified the availability of the venue at convenient times for the groups and that the cost for the hire of halls within the Widmore Centre was favourable in contrast to the cleaning costs required to make a room available at the Phoenix Centre.

At the end of each 20 week block, children were reassessed at the Phoenix Centre on all the follow-up measures. Children attended in groups of 4 to 6 which were not necessarily the same as their designated treatment group. Children were matched for review testing by year age to ensure the appropriate age bands of the MABC were undertaken as well as enable some harmony of skill so that 10 year olds were not paired with 6 year olds. Attempts to maintain a random controlled trial (RCT) were undertaken in which children were randomly assigned to an appropriate age group and the testers who recorded scores were blinded to each child's intervention group allocation. [Either the author administered the tests with students of psychology, occupational therapy or physiotherapy recording the scores, or a senior therapist who was blinded to each child's treatment status, undertook the assessments.]. Any anomalous assessments (e.g. individual versus group) were tagged to ascertain any discrepancy in test scores. However, over the course of the two ½ years a number of

children became friendly with each other and discussed their treatment or previous assessments during the course of the testing which may have provided clues to the assessors as to whether they had received intervention or not (but were not necessarily aware of when this had been).

During the 2 year period, and in part as a result of feedback from therapists leading the intervention sessions and in view of more recently published literature, it was felt that some additional measures should be incorporated into the final analysis. A submission was made to the local (Bromley) medical ethics committee for an amendment to the study protocol to incorporate these additional tests. Approval was granted following clarification that the amendments were in line with the new UK regulations governing standard operating procedures for research ethics committees that came into force on 1st May 2004. (See Appendix 4).

5.5.4 Study timetable

See figure 5.1 for illustration of timetable. The screening programme was undertaken over a period of 2 ¼ years from November 2000 to February 2003. The intervention study was commenced in February 2003 with monitoring assessments undertaken every 6 months, lasting 2 ¼ years, to incorporate as many final follow-up assessments as possible.

5.5.5 Venues

All testing was undertaken according to instructions set out in respective manuals. These were for the most part undertaken at the Phoenix Centre, Bromley. In view of the limited availability of a large space (gym) within the Phoenix Centre and in anticipation of the difficulties which some families may have in reaching the children's centre and the influence this may have on attendance and subsequent outcome of therapy, an alternative venue for the treatment sessions was used for the intervention programme (Green & Archer, 2000). The Widmore Adult Education Centre (WAEC) was identified as a treatment venue and corresponded with child

centred practice to remove the 'therapy' from therapy! A room suitable for undertaking both gross and fine motor activities and accommodating 6 children with 3 adults was identified at the WAEC with space for parents to join/observe groups at scheduled times. Bromley PCT agreed to subsidise the hire of these rooms twice a week following financial submission from the author.

5.6 Assessment measures – Part I

A number of assessments were undertaken at the child's initial appointment:

5.6.1 The *Developmental Coordination Disorder Questionnaire (DCDQ)* is a 17 item survey completed by parents which discriminates between children with and without motor problems across environmental domains (B.Wilson, Dewey & Campbell, 1998). Previous factor analysis in community and clinical samples revealed four factors contributing to the motor difficulties: Control During Movement, Fine Motor/Handwriting, Gross Motor/Planning and General Coordination. A total score is computed and cut-off scores for determination of the risk for DCD are currently based on Canadian norms of children between the ages of 8-14 ½ years. Reliability and validity are sound, identifying children with DCD 86% of the time and those without DCD 71% of the time, with high internal consistency of the items (B.Wilson et al., 2000).

In the more select population referred to the Bromley Paediatric Occupational Therapy Department for the screening study, sensitivity of the DCDQ was found to be high (93%) although there was low specificity (19%). The positive predictive value was 75% (95% Confidence Interval, CI: 64 – 83%) and the negative predictive value was 50% although with a wide confidence interval (95% CI 20 – 80%). The poor ability of the DCDQ to identify children without motor difficulties may have been in part due to the skew of the sample in which there was a high proportion of children identified with movement difficulties (72.4%). There is a large risk of introducing a Type II error (rejecting an assessment that is accurate) when the group of children who did not

have movement difficulties is so small in comparison to those who do (Goodman, 1997). Correlations of the DCDQ total score with the M-ABC were significant in the screening study ($r=.298$, $p<.005$, $n=97$) with parents seemingly reliable in their report of the level of their child's skills in daily tasks. Following the results of the screening programme, it was felt worthwhile to continue to use the DCDQ as a means of obtaining parental opinion on their child's functional limitations in motor performance (Green et al., 2005).

5.6.2 *The Movement Assessment Battery for Children (M-ABC, Henderson & Sugden, 1992).* This test, of the extent of possible motor impairment, comprises 8 items divided into three subsections; manual dexterity, ball skills, and static and dynamic balance. Scoring ranges from 0-5 with 5 indicating the highest level of impairment. A total impairment score is obtained from the sum of subsections and then converted to percentile ranks. A raw score of 0-9.5 is considered normal, a score of 10-13.5 (15-5%ile) is considered borderline, and scores of ≥ 14 (<5%ile) are indicative of very definite motor difficulties. Scores of 17.5 and above place the child more than two standard deviations below that of a normative group. This test age bands correspond to developmental attainments whereby children undertake different items dependent on age. Good reliability and validity have been established (Henderson & Sugden, 1992; Croce, Horvat & McCarthy, 2001). A recent study by Croce, Horvat and McCarthy (2001) contrasting the M-ABC with the Bruininks-Oseretsky Test of Motor Proficiency support the validity of the M-ABC test for assessing the motor ability of children age 5 to 12 years.

5.6.3 *Developmental Test of Visual-Motor Integration and Supplementary Tests (VMI, Beery, 1997).* This tests the ability of the child to copy 2-D graphic representations consistent with theories of visual-spatial problems in DCD. Scores are attributed according to accuracy and spatial orientation. Raw scores are converted to standard scores which represent a mean of 100 and a standard deviation of 15. Standard error scores vary depending on the age of the child and data is transformed to obtain a percentile rank and age equivalence. Scaled scores below 25 place a child at

risk of having some difficulty (integrating visual information with eye-hand control) and scores below 10 indicate significant difficulties. This test has been correlated with the development of academic skills reflecting visual spatial processing especially maths. Good reliability and validity is reported (Beery, 1997).

5.6.4 Dressing Skills (Assessment of Motor and Process Skills, AMPS, Fisher, 1994)

The AMPS scoring criteria was used to analyse performance in functional tasks consistent with Criterion B. Children were asked to don their socks and shoes and were scored on observation of the various motor and cognitive items of the scale. The AMPS provides qualitative information on the degree to which motor difficulties impede performance in addition to the way in which a child approaches and undertakes a task. There are currently no norms available in personal care tasks of children. The AMPS is a four point criterion referenced scale which allows for clinical judgment as to whether the child's performance is markedly deficient, poor, questionable or adequate and may therefore further clarify the data obtained from specific motor skills testing and support diagnosis of Criterion B of the DSM-IV classification of DCD. There is good reliability using RASCH analysis for adults performing daily living tasks (Fisher, 1993).

5.6.5 The Gesture Test (Cermak, Coster & Drake, 1980, adapted by Green, 1997)

considers more qualitative aspects of movement hypothesised to relate to motor planning and imitation. Recent interest in gestural representation has also highlighted the importance of mime and imitation in illustrating aspects of a child's representational capabilities related to social communication (Meltzoff, 2004). The test is made up of two components, each comprising 10 items. The first requires the subject to mime the use of specified tools (representational or transitive actions). The second requires the imitation of non-meaningful actions (non-representational or intransitive actions). In the representational subtest, the 10 tasks are performed to verbal command, e.g. 'Show me how you would comb your hair with a comb'. Before the command is given, each (real, three-dimensional) tool is presented for the subject

to identify. It is then removed from sight during the response, to eliminate the opportunity to use or handle the object. There is no specification as to which field of vision the object is presented but all attempts were to place this centrally on an open palm to avoid illustrating the correct way to hold the item. In the non-representational subtest, the subject is required to imitate hand and arm positions demonstrated by the examiner 'as if looking in a mirror'. All actions/gestures are scored on a four-point scale as follows; a score of 1 is given when the sequence of movement is unrecognisable, scores of 2 or 3 are awarded when the action/gesture is recognisable but spatial or temporal accuracy is imperfect (a score of 2 may also indicate use of body as object in the representational subtest and scores of 3 are restricted to two spatial/temporal errors). A score of 4 is given for a correct representation. A change in response/relocation of posture during the action results in a half point being either added to or subtracted from the response score. Scores for each subtest therefore range from 10-40 with higher scores representing better performance. No norms are available on the current version of this test although previous studies have indicated that non-motor impaired children over the age of 5 years are able to execute these items with very few spatial errors (Njikiktjen et al., 2000). Using Spearman rank correlation Green (1997), found significant inter-rater agreement for the total scores was .95, and for the two components, .85 and .93 respectively.

5.6.6 The Clinical Observations of Motor and Postural Skills (COMPS, Wilson et al., 1994) was used to identify subtle 'soft' neurological signs thought to be indicative of neurological immaturity. Each of the six items is scored from 0-12. Scores can then be converted to an age adjusted total weighted score. Scores of less than zero indicate difficulties with subtle motor and postural skills and above zero are classed as normal. In addition, these items have been associated with Sensory Integrative Dysfunction in the literature. Fairly sound reliability has been established. The reliability data is somewhat better than that reported for the Kineasthetic Sensitivity Test (KST) of Laszlo and Bairstow (1980b) used in the Hoare (1994) and Macnab et al. (2001) studies. For the purposes of this study the raw scores (0-12) were documented to identify ability in each of the six component items rather than

converted to a total weighted score. Age was controlled by including it as a covariate where appropriate in the analysis.

5.6.7 *The Matrix Analogies Test* (MAT, Naglieri, 1989) was administered to document non-verbal intellectual processing skills. This test consists of 4 subtests measuring different aspects of non-verbal processing – pattern completion, reasoning by analogy, serial reasoning and space visualisation. In view of its validity and reliability it is considered a suitable test of non-verbal intelligence for research purposes. MAT internal reliability is good across age groups. Correlations between the MAT and Wechsler Intelligence Scales for Children-Revised (WISC-R) reported in the manual were all significant: WISC-R Verbal scale, $r=.37$, $p<.001$; WISC-R performance, $r=.41$, $p<.001$; WISC-R Full Scale, $r=.52$, $p<.001$. The MAT was not incorporated into inclusion/exclusion criteria in view of the literature suggesting that children with DCD do not process visual spatial information well and would have found this test difficult (Wilson & McKenzie, 1998). This scale was chosen over the use of Raven's Matrices in view of its ease of administration and suitable cut-off points allowing for discontinuation of a test when a child was consistently failing responses and potentially aware of their frustration.

5.6.8 *The British Picture Vocabulary Scales* (BPVS, Dunn & Dunn, 1997) was used to provide an indication of verbal cognitive capability to identify children whose coordination difficulties may be related to more general learning difficulties. Although not a direct measure of verbal intelligence, BPVS standard scores are highly correlated with measures of verbal intelligence (WISC-III, Wechsler, 1992a; Dunn & Dunn, 1997). Although the process of measuring hearing vocabulary by picture selection (receptive language) is not functionally equivalent to intellectual tests such as the WISC which require the child to define words orally (expressive vocabulary), the vocabulary and similarities subtest scores have been shown to have the highest correlation with Full Scale IQ on the Wechsler Intelligence Scale for Children-III^{UK} (WISC-III^{UK}, Wechsler, 1992a, p.277) and general cognitive ability on the British Ability scales (Dunn & Dunn, 1997). Others have found that the Peabody Picture Vocabulary Test-

Revised (PPVT-R) from which the original BPVS was derived, was the best predictor of cognitive ability in young children (Dunn & Dunn, 1997). A standard score of <70 on the BPVS was considered to represent the possibility of a greater degree of learning difficulty (and more generalized developmental delay) which could account for any motor impairment and these children were not considered to have a diagnosis of DCD.

5.6.9 Self Esteem Checklist 'How I feel about myself' (Warr & Jackson, 1983)

was also given to the children over the age of seven years to complete. Research has indicated concern regarding the child with DCD's perception of their capabilities and the impact this has on perceptions of confidence and competence. This 8-item checklist has been used most recently in a prevalence study of mild mental retardation in the neighbouring borough of Croydon with good reliability (Simonoff et al., 2006).

5.6.10 Demographic Data

A number of socio-economic factors as well as pre-natal, infant and developmental medical and educational indicators have been identified as potential precursors to learning difficulties and movement problems in children (Nichols & Chen, 1981; Hadders-Algra & Lindhahl, 1999). As part of the clinical interview at the time of the initial assessment for the screening programme, the following data were collected:

- 5.6.10.1 Age, sex and preferred hand;
- 5.6.10.2 Source of Referral - Polatajko et al. (1995) studied the impact of referral bias influencing the profile (subtype) and extent of motor coordination difficulties in children referred to specialist services;
- 5.6.10.3 Waiting time – extent of time on waiting list for initial assessment which may impact on parents' recording of their child's difficulties as surveys may exaggerate a condition due to *over-endorsement bias* (Kroenke, 2001);
- 5.6.10.4 Other therapies received, currently or previously including alternative therapies such as craniosacral therapy;
- 5.6.10.5 Known and diagnosed co-morbidities, including learning difficulties;

- 5.6.10.6 Special Educational Needs level of support;
- 5.6.10.7 Other medical conditions, eg. asthma, congenital heart defects, epilepsy and those receiving pharmacological intervention such as Ritalin etc.;
- 5.6.10.8 Prematurity and/or adverse neonatal history;
- 5.6.10.9 Townsend scores of social deprivation were used to estimate socio-economic status in view of the potential impact of experience and opportunity on motor development and behaviour (Townsend, Phillimore & Beattie, 1988; Hadders-Algra & Lindhahl, 1999). Scores between -3 and +3 represent the middle rankings. Scores below -3 the least deprived and scores of 4 and above represent the most deprived. The Townsend scores are derived from postal codes associated with the most recent population census. In this instance, the 1991 census was used as the basis of the Townsend scores in the calculation.

In addition, The *Movement ABC Checklist (C-MABC)*, containing five parts, was completed for use in the screening study but, due to the poor return rate and incomplete forms, was not included in the current study (Green et al., 2005; Henderson & Sugden, 1992).

5.7. Assessment measures – Part II, Intervention Study – Pre, Post and Follow-up measures to evaluate treatment and maturation

In order to identify the natural maturational rate of this group of children, testing of motor skills was undertaken prior to the intervention period and at each cross-over point using categorical and dimensional measures of motor skill and behaviour with additional measures incorporated at the first and final testing point. (See Table 5.2). Regular monitoring of progress over the course of the project was felt important to identify whether any particular ‘subtype’ was more likely to mature spontaneously versus any subtype or factor which would contribute to more persistent difficulties. Various measures were included to consider not only the testing of motor skills in a clinical setting at discrete points in time, but the report of skills across contexts and

recent history. Along with the parental report of motor skills and socio-emotional development, at each point of testing assessment of the child's perception of their skills (participation and satisfaction/impression of change) in daily living tasks was also undertaken. At the end of the intervention trial, some additional measures were undertaken. These are outlined in section 5.8.

5.7.1 *Strengths and Difficulties Questionnaire (SDQ, Goodman, 1989)*

The *SDQ* (Goodman, 1997) was used to explore possible emotional and behavioural problems including poor social behaviour which would be contra-indicative of group participation and potential psychopathology which may have an impact on outcome. The *SDQ* incorporates questions covering 25 emotional and behavioural attributes of the child: 10 of which are considered to be strengths and 14 of which represent difficulties and one neutral item. Scores are generated using a 3-point Likert scale to indicate how far each attribute applies to the child. Summed scores can be obtained for total deviance, emotional symptoms, conduct problems, hyperactivity, peer problems and pro-social scales. Reliability and validity of the *SDQ* is satisfactory and this tool has been identified as a useful measure detecting emotional and behavioural problems of children and adolescents (Goodman, 2001; Mathai, et al., 2002). Cutoff scores for identifying risk of psychopathology have been obtained through studies of the mental health of populations of British children (Meltzer et al., 2000). Total scores of 13 or less are within the normal band, scores of 14 to 16 place children as borderline and scores 17 or above signifying abnormal scores representing the extreme 10% of the population and are associated with a substantial increase in psychiatric risk (Goodman, 2001). Cut-offs represent atypical scores for the emotion (≥ 5), conduct (≥ 4), activity (≥ 8) and peer relation (≥ 4) scales. The scores for the pro-social items are not incorporated (in the reverse direction) into the total difficulties score, as the absence of pro-social behaviours is considered to be conceptually different from the presence of psychological difficulties (Goodman, 1997).

Parents were asked to complete the SDQ prior to testing point one of the treatment study (as part of the initial information and consent package) to identify those students for whom group treatment would not be recommended. This test was re-administered at the end of the study to determine whether any of the characteristics may have changed. A score of 6 or over on the conduct subtest would indicate that the child had significant difficulties which may require individualised adult support and supervision to participate in activities and a group treatment programme may be contraindicated.

The following measures were used at each test point (points 1 to 5 in Table 5.1):

5.7.2 The MABC (Henderson & Sugden, 1992) was repeated to maintain consistency with the measure of motor performance used at the child's initial assessment in the screening programme (Part I). Children were matched with year age children in the 'Detective Club' to facilitate testing. Children undertake different tasks dependent on the age band and were tested on age appropriate tasks irrespective of previous test band. This test provided categorical data regarding the child's motor status.

5.7.3 The Bruininks Oseretsky Test of Motor Proficiency (BOTMP) – running speed, long jump and card sorting subtests (Bruininks, 1978) were undertaken to measure dimensional change in motor skill. These tests provide a linear scale of gross and fine motor proficiency. The BOTMP has been used as a standard to compare concurrent validity of more recent measures of motor capability (Bruininks, 1978; Croce et al., 2001). The three subtests were chosen from the short form of the BOTMP as they were distinct from tasks included in the MABC (e.g. a pegboard task is included in both the short form of the BOTMP and the MABC) and from clinical experience, were fun for the children to perform. Although there is a new edition, the 'BO2', recently published with updated reliability and validity (Bruininks, 2005), this was not available at the commencement of the project. All children undertake the same motor tasks irrespective of age.

5.7.4 Handwriting – The Evaluation Tool of Children’s Handwriting (ETCH, Amundson, 1995) scoring criteria was used to analyse changes in handwriting. A 20% change in performance level is accepted as indicative of change beyond that which would occur naturally (Amundson, 1995; Cheong, 2001). Children were asked to copy as much of a set text as possible in a one minute period. The paragraph was read out aloud prior to copying with each child having their own printed copy of the text. They were then told to ‘copy as much as they could but that they would be scored on how legible (neat and readable) it was’. Word and letter legibility were documented as the number of words/letters completed in the minute.

5.7.5 The Co-ordination Skills Questionnaire – CSQ was developed especially for this project to allow for completion within a group setting. Children were asked to complete a questionnaire requiring them to rank their skill level and satisfaction/improvement with performance in a number of skill areas associated with DCD and which reflected these children’s referrals to Occupational Therapy (see figure 2.1). This questionnaire was modelled on the *Canadian Occupational Performance Measure* (COPM, Law et al., 1994) which addresses the issue of skill acquisition, as perceived by the child, by asking the child to rank the importance of daily activities and then rate their skill ability and satisfaction with their performance in these items. In this adapted version, 9 items were selected according to the bias of the referral concerns outlined in figure 2.1. An additional item requesting the child to identify an activity they really wanted to be able to do and or do better was also included (see Appendix 6 for copy of CSQ). These individual choices were incorporated as activities during the treatment sessions (see section 5.9 for details of intervention). Children were required to rate their performance and satisfaction on each of the 10 items in the first instance.

The inclusion of a self-perception measure to evaluate outcome is based on the premise that children who feel better about their skills are more likely to participate in these activities and which may subsequently provide additional opportunities for practice and rehearsal impacting on skill development (Snyder, 2002). In accordance

with theories of motivation; success may provide the rewards which lead to intrinsic pleasure for competent performance and a desire to seek out those activities in which one is successful (White, 1959; Harter, 1983; Stellar & Stellar, 1985). Further support for the argument that perceptions of competence in motor skills are associated with motor capability, has been shown through studies indicating low levels of participation in physical activities amongst children reporting poor confidence and enjoyment in physical leisure activities (who were also found to have poor motor performance) in contrast to their peers reporting higher levels of enjoyment and participation (Hay & Missiuna, 1998). This is consistent with the cycle of 'activity deficit' put forward by Bouffard and colleagues in which 'demonstrated incompetence, lack of confidence, exclusion and withdrawal' from physical activities are evident in children with poor motor skills (Bouffard, et al, 1996, p61.). Segal et al (2002) indicate that children with DCD either tended to avoid or be excluded from motor activities that may expose poor performance and potential stigmatisation.

With the accumulation of evidence to suggest that low self-esteem is linked to children with both poor perceptions of their motor capability as well as poor skills, what is not known is how firmly established the 'activity deficit' cycle is amongst these children nor whether there are age variants occurring in either presentation or entrenchment. Causgrove Dunn and Watkinson (1994) found unusual responses to perceptions of competence related to poor motor skill in which the older child with poor skills was more likely to report better competence. In this interesting study, interviews of children suggested that the older child with motor difficulties was likely to use self-evaluation methods to formulate their responses such as degree of improvement and amount of effort expenditure eg. "I try hard" (Causgrove Dunn & Watkinson, 1994). Consistent with the current study's 'client-centred' approach to treatment, the measurement of self-perception of motor competence was felt to be an intrinsic aspect of change in the motor domain; although this was anticipated to take longer to change than actual skill as 'self-perception' is felt to derive from a reflection of personal competence or failure and therefore follow after skill development. The Harter's Self Perception Profile for Children (HSPPC, Harter, 1985) was not felt to be sensitive to

change over a short period (Peters & Wright, 1999). The HSPPC domain of athletic competence scoring system was felt to polarize 'traits' reflecting a child's natural and inherent capability in a task rather than rankings of skill ability which could reflect change (ie. The request for a child to stipulate whether they are more like a child who would prefer to play outdoors or indoors emphasizes a natural characteristic which may not change despite a change in ability to perform outdoor and more sporty type activities). In addition, in view of the requirements for expediency in testing administration, a shorter scale which captured the elements of performance rating and satisfaction with level of accomplishment was developed specifically for this study (see Appendix 6).

As the CSQ was developed along the format of the COPM, it incorporated tasks reflecting personal care, productivity/school work and leisure/social activities, adapted to allow for group administration (Law et al., 1994). To enable group administration of the questionnaire, 9 of the 10 tasks were pre-identified to reflect the majority of referral reasons and parental concerns. The domain of '*Importance*' was removed from the COPM to expedite administration. In addition, it was also felt that younger children may not be able to distinguish between the importance of performing compulsory daily living activities and undertaking leisure tasks. A 5-point response scale was used for ability rating which could be matched to semantic terms rather than the more ambiguous 10-point rating of the COPM. A 5-point response scale was used as a measure of satisfaction in performance for similar reasons and internal reliability tested (Cronbach, 1990). The inter-rater and test-test reliability for the COPM is established for adults and has been used for children with DCD (Law et al., 1994; Polatajko et al., 2001a). The first test point asked children to comment on Ability and Satisfaction and subsequent test points focussed on Ability and Improvement.

The *source of items* for the CSQ was generated from research findings and clinical experience. These were believed to represent putative traits as well as being easily identifiable by the children for self report. An ordinal scale was chosen as opposed to dichotomising responses into Yes or No (able or not able) in order to look at the

relationship between variables. Five scale points were felt to be better to avoid polarity of choices such as good:bad/better:worse to encourage children to contemplate how much they were like other children worse or much worse, the same or better or much better (Streiner & Norman, 2003). Utility, reliability and homogeneity of the items is reported in Section 6.5.10.

5.7.6 The DCDQ

Parents were asked to complete the DCDQ to rate their child's performance to ascertain whether parental perception of difficulties changed in conjunction with clinical assessment and/or over time. There have been no reported studies of the use of the DCDQ to monitor change and therefore the results from this study will provide details of reliability and stability over time of this instrument.

5.7.7 Profile of Neuropsychiatric Symptoms (PONS v.24.01.03, Santosh, 2003)

The PONS was used to register the parental perception of the degree of any difficulty their child may experience across a number of developmental – social, motor, learning, behavioural – domains. A 6 point response scale ranks opinions of parents as to the extent of a problem and the degree to which the problem interfered with the child or family's daily life across 30 behaviours totalling 60 questions. In the absence of normative data at this juncture, the total scores for the PONS were determined and contrasted with the other developmental and motor measures used in this study.

5.7.8 Medical, social and educational history form

An additional questionnaire was developed to allow parents to document any changes in the child's medical condition or family circumstances as well as sources of information, support or intervention that might have been sought during the period of the study. Parents were also asked to state whether they felt any support or intervention had been helpful (see Appendix 7).

5.8 Additional Assessment Measures at Final Testing

5.8.1 *Wechsler Objective Reading Dimensions (WORD, Wechsler, 1992b)*

The WORD was included as a widely used achievement test for school children and therefore considered to reflect academic attainments. Importantly also, in view of the number of children referred for concerns regarding handwriting problems, was the possible overlap of DCD with literacy problems. The WORD has well established psychometric reliability and validity (Wechsler, 1992b).

5.8.2 *Children's Hope Scale (Snyder et al., 1997; Snyder, 2002)*

This six-item self-report index was included to probe children's ability to initiate and sustain action toward a desired goal. The scale shows good construct, convergent, discriminant, and incremental validity and good reliability (Snyder, 2002).

5.8.3 *The Family Grid (Davis, 1999) and The Young Persons' Grid (Read & Davis, 1999)*

In view of the large numbers of parent and child reports used in this study to measure skill and progress, the '*Family Grid*' (Davis, 1999) and '*The Young Persons' Grid*' (Read & Davis, 1999) was incorporated at the final session to identify any conflicts parents may experience in defining their 'ideal' child versus their 'real' child. This checklist is based on Repertory Grid analysis following Personal Construct Theory (Kelly, 1991; Bannister & Fransella, 1986). This questionnaire may elicit any bias that parents or children may exert when negatively or positively reporting of their child's or own (respectively) performance/change in performance as well as inquire into the way in which parents and children maintain or alter their constructs regarding people and events. Unfortunately, these questionnaires use with children with DCD had not been considered prior to the study commencement and it had not been possible to incorporate it at the onset. It is not known how these individual constructs may be related to progress in motor or behavioural domains.

The children participated in four tests at each testing point: the MABC, the three BOTMP subtests, one-minute handwriting sample and the CSQ. Three additional tests were included at the final testing point: the WORD, Hope scale and Family Grid. Two hours were allocated for each group testing session although all but the final session were usually completed in 1 ½ hours. Parents completed 3 questionnaires at each testing point: the DCDQ, the PONS and the medical, social and educational history form. The SDQ was also included at the pre-intervention session as well as at the final session. Parents also completed the Family Grid at the final session. See Table 5.2 for testing protocol.

5.9 Intervention

5.9.1 *The CO-OP Approach*

A child-centred approach to intervention was adopted to consider the functional impact of DCD across environmental contexts (Coster, 1998). The intervention programme was based on the Cognitive Orientation to daily Occupational Performance approach (CO-OP, Polatajko et al., 2000; Polatajko et al., 2001b; Polatajko & Mandich, 2004). CO-OP is a cognitively based, child-centred intervention that enables children to achieve their functional goals. Based on theories of motor learning, it exploits the use of cognitive strategies to facilitate the learning of motor skills. Through this process the child gains knowledge of how, when and where to use specific strategies to support generalization and skill transfer (Missiuna et al., 2001; Bernie & Rodger, 2004). This approach was chosen with respect to the literature showing that children who are able to regulate their own learning, were then better able to approach tasks in a strategic manner, recruit effective problem solving procedures and reflect on their performance (Lamb et al., 1998). Scaffolding principles that are felt important to develop self-regulation of skills include: opportunities for children to rehearse/implement strategies specific to a task; explicit prompts and practice of the management and monitoring of these skills; and provision of feedback regarding how the information is used (Lamb et al 1998, p. 494-495).

These were adopted in an environment whereby the therapist acted as a mentor to guide the student through respective tasks.

Session structures were set prior to intervention and included the introduction of the global cognitive strategy, practice and implementation of domain specific strategies and consolidation (Polatajko, et al., 2001b). This process follows the Occupational Therapy frame of reference that — participation in meaningful activities is central to performance. Inherent within this is the concept that an individual's perception of ability contributes to satisfaction with performance and is deemed to be essential for long-term effectiveness (Law et al., 1994). Children were provided with the opportunity to participate in a variety of tasks aimed to help them achieve success and build confidence in their skills. Their own perception of their ability was monitored through the CSQ.

The main structure of the sessions focussed on an introduction to 'The Detective Club' and the global strategy (Goal, Plan, Do, Check) in the first and second sessions with a parent present. Domain specific strategies were then developed and practiced based on dynamical analysis of each child's performance in the tasks over the next 8 weeks. Domain specific strategies may include verbal guidance to support alterations to body position, attention to doing, task specification/modification, supplementing task knowledge, feeling of the movement, verbal motor mnemonics and/or verbal rote script (Mandich et al., 2001b). A review session of global and domain specific strategies was undertaken in week 11 with a parent present. The next six sessions were dedicated to each individual child's identified task (item 10 of the CSQ). Each of these weeks focused on only the one child's activity such that if the chosen task was bike riding, bicycles were brought in or donated so that every child had the opportunity to trial global and domain specific strategies for that task. The final three sessions were dedicated to a review of CO-OP principles, using a variety of tasks, with a parent present. In addition to parents attending the first two sessions, the 11th and final three sessions, they were asked to come for the final 10 minutes of each hour's

intervention in order to review the homework and domain specific strategies for the week. (See Appendix 8 for treatment activity schedules for the two age groups).

5.9.2 The Hawthorne effect

The ‘Hawthorne effect’ refers to an alteration or improvement in behaviour and/or productivity produced by the psychological effects of being singled out and made to feel important (Roethlisberger & Dickson, 1939). To control for the possibility of this being a factor in promoting change rather than any benefits specific to the intervention programme, parents were asked to undertake a 20 minute activity over a 20 week period with their child (eg. listening to a story), thus giving them ‘special attention’ that they would not otherwise have received (see figure 5.1 for schedule of ‘Special Times’ per group). Of note however, are recent criticisms of the conclusions made from the Western Electric’s Hawthorne studies from 1924 to 1932, which have focussed attention on a number of serious flaws and confounding variables, not least that of replacing two out of five subjects mid-experiment for being too slow (Rice, 2006)!

5.10 Analyses

5.10.1 Part I - Description of children and profile analysis

The demographic characteristics of the sample are discussed. The frequencies and distributions of children with and without movement difficulties and co-morbidities were contrasted to consider representation of the sample.

Factor analysis (FA) was used to explore the similarities and differences between multiple assessment variables to identify groups of associated (but not overly similar) variables, thus ascertaining which factors were similar enough and thus loaded together as possible ‘subtypes’ of coordination deficits. This is done much in the same way as determining correlations between pairs of variables but reduces the data set

from a large group of interrelated variables into smaller sets of uncorrelated factors. In factor analysis several variables may be examined simultaneously to see how much variance is shared and how much is 'unique' and then the variables that share the same variance are clustered together (Field, 2000b). This procedure is usually done to isolate different dimensions of a condition and has been used in previous studies to explore possible subtypes of DCD (Hoare, 1994; Macnab et al., 2001; Wright & Sugden, 1996). Although FA requires a larger sample, it was preferred to regression analysis as it was possible to explore the inter-relationship between variables rather than the relative ability of different variables to predict an overall motor ability. Principal component analysis was used to summarise most of the original information (variance) to a minimum number of factors that would account for the maximum portion of the overall variance (Hair et al., 1992). Providing sufficient factors (categories of associated variables) are evident, cluster analysis can then be used to explore the groupings of children with particular patterns of performance on the key variables. Cluster analysis is essentially the opposite of factor analysis. In this case, instead of forming groups of variables based on several children's test scores, the children are grouped together based on their responses across the variables. The groupings of children formed from different testing variables of alternative theoretical models could then be contrasted through the use of Discriminant Analysis.

Derivation of homogenous groups of children was undertaken using cluster analysis (Ward's method) to compare this data set with those of Hoare (1994) and Macnab et al.(2001). The various techniques of cluster analysis are distinguished primarily by different rules for the formation of groups, with the hierarchical agglomerative methods for clustering reportedly used the most frequently (Aldenderfer & Blashfield, 1984). Ward's method differs from other methods to link children in that there is no chain of similarity — rather the emphasis is placed on joining cases so that the variance within a cluster is minimised. Clusters are then merged to reduce the variability within a cluster (Field, 2000b). Mathematically, this means that the first case is considered as his/her own cluster. As each case is added, the average similarity of the cluster is measured. The difference between each case within a cluster and the

average similarity is calculated and squared, as per calculating standard deviations. Cases are then selected to enter a cluster if its inclusion (within the cluster) produces the least increase in error as measured by the sum of squared deviations (Field, 2000b). On repeat analyses when additional children are added to the equation, cluster numbering will vary depending on which child is taken as the first case and therefore the profiles were recoded for homologous analyses when children with additional comorbidities were entered into the analysis.

Euclidean distance was used to measure the distance between cases in relation to the index variable, in order to calculate the similarity of a subject to cluster group rather than analyse the shape or comparative distance of cases to cluster centroids (to avoid the use of the square root, the value of distance is often squared = "Squared Euclidean distance"). Skinner (reported in Aldenderfer & Blashfield, 1984), proposed a strategy to incorporate both correlation (association/shape) and distance ('Euclidean') in order to calculate the shape and size as well as dispersion of the clusters. This technique may have been preferential for this study however, as the Euclidean distance is one of the most popular statistical calculations and the published studies of DCD subtypes of Hoare (1994), Macnab et al (2001) and Wright and Sugden (1996) used Euclidean distances, this procedure was used to allow for more consistent comparison.

In contrast to Ward's method, iterative partitioning predominately works on the principle that the division of groups is maximised by each case's proximity to a cluster centroid, based on a predefined number of clusters. Thus the allocation of each case to a cluster is achieved by ensuring that an individual case is matched to the nearest centroid with a subsequent revaluation of the cluster centroid. This process is repeated until no data points change clusters. K-means passes (K-iterative) refer to the nearest 'reassignment pass' to reassign cases to the cluster with the nearest centroid, either inclusively or exclusively (Aldenderfer & Blashfield, 1984). Thus Ward's method minimises variance within the clusters and the K-means iterative procedure, maximises the proximity of each case to the centroid of a cluster.

Table 5.3 Table of investigations and main analyses

Investigation	Main Analyses
1. Sample characteristics which may influence analyses and study results.	Frequency and distribution analyses (Chi ² and Kolmogorov-Smirnov, ANOVA) of children with and without movement difficulties and co-morbidities.
2. Identification of different subtypes of co-ordination disorders amongst children referred to occupational therapy in the U.K. Comparison with previous sub-typing studies in Australia and Canada.	Factor and Cluster Analyses. Descriptive comparison of current subtypes to previous studies.
3. Ability of different theoretical models, used to explain co-ordination deficits and thus include alternative evaluation procedures, to predict similar group membership to that of the original modelling (categorisation) technique.	Multiple Discriminant Analysis
4. Influence of subtype of DCD, as identified in 2 or 3, on children's ability to benefit more from an intervention programme designed for children with DCD?	Wilcoxon test for intervention effects. Repeated measures ANOVA and Discriminant Analysis to explore influence of subtype on outcome.
5. Contribution of additional factors associated with motor development on motor skill and response to treatment response?	Logistic regression analysis and MANOVA: post hoc analysis including Bonferroni, Hochberg or Dunnett's T3 procedures, depending on equality of sample size, variance and linearity of progress.
6. Impact of emotional and behavioural characteristics of children on their acquisition of motor skills?	Correlation analyses, MANOVA, logistic regression and Discriminant Analysis

Ward's method (with the Euclidean distance measure) was used to determine the number and best fit of clusters within the sample and the internal validity of the clusters was validated by K-means iterative partitioning.

To look at the consistency of sub-groups of children, Discriminant Analysis was undertaken to compare the classification of children from these different theoretical models and relevant assessment variables to original cluster groups (Hair et al., 1992). Multivariate analysis of variance and logistic regression analysis was incorporated to explore the effects and/or interaction of other factors hypothesised to influence motor skill acquisition (see Table 5.3 for breakdown of main analyses).

5.10.2 *Part II – Treatment efficacy*

Qualitative descriptions of the extent to which each child's motor performance may have changed were explored. Wilcoxon Test was used to explore the effects of intervention with Chi² and Kolmogorov-Smirnov tests of children making progress with or without intervention. Repeated analysis of variance of movement skill change, contrasting clusters groups, was undertaken with post hoc analysis between 4 treatment phases. Post-hoc procedures included Bonferroni adjustment for multiple comparisons or Hochberg or Dunnett's T3 procedures depending on differences in sample size and variance. Effect size, where relevant, is reported as partial eta squared (η^2). Discriminant Analysis was used to identify the predictive value of any subtype to make progress with or without intervention.

Spearman rank correlations were performed to identify relationships between variables assessing motor skills, learning and academic ability. Logistic regression analysis (for the quantitative outcomes: BOTMP subtests, Movement ABC, VMI, BPVSS, ETCH and Self Perception Measures), was used to identify which of the factors identified in Part I of the study contribute to the treatment response.

Furthermore, in order to support the analysis of those factors which may contribute to treatment response, logistic regression was undertaken on the assessment data to

identify which procedures/information predicts the improvement in motor skills (see below). Any potentially confounding variables such as age, sex, or socioeconomic status, as well as resilience (Hope Scale) and expectations (Family Grid), were also considered as predictors in the regression equation.

The percentage of parents reporting emotional and behavioural difficulties in their children was calculated and compared to the SDQ UK normative data (Meltzer et al., 2000; Goodman, 2001; Green et al., 2006). MANOVA was undertaken to investigate the relationship of age and degree of motor impairment to SDQ scores for those responding positively or negatively to treatment. Correlation analyses, ANOVA and MANOVA comparison of parental responses on the DCDQ and the NeuroPsychiatric Symptoms Questionnaire over time were made. Chi-square test was used to contrast the effects of co-morbidity on outcome.

Analyses were carried out using the Statistical Package for Social Sciences (SPSS, Version 11, SPSS Inc., Chicago Illinois 1999).

CHAPTER 6 RESULTS

6.1 Part I – Sample Description

The following sections describe the subjects who participated in the first part of this project. As this is a convenience sample, emphasis is given to demographic characteristics and any known co-morbidity (that was not exclusory under the criteria set for the study) in order to extend the interpretation of the results to other populations of children with co-ordination impairments.

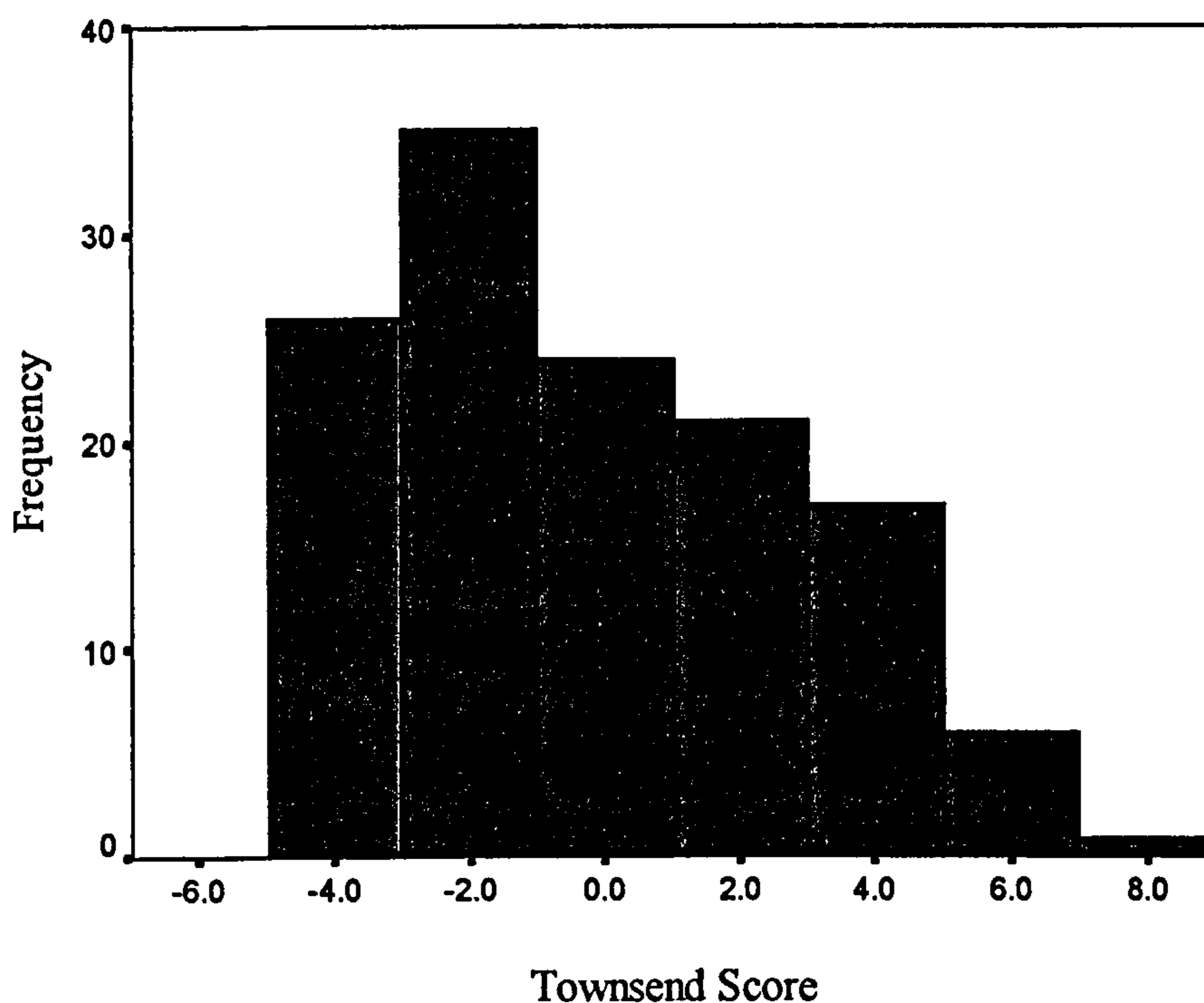
6.1.1 Sample characteristics by demographic data

Data were collected over a period of 2 ¼ years from 141 children who had been referred to a community based Occupational Therapy service due to concerns regarding motor coordination and whose parents had agreed to participate in a referral screening project (Green et al., 2005). The majority of these referrals came from medical practitioners (47%) with approximately one-third coming from teachers (28%). (See Table 2.1).

Amongst the total sample of children, there were 112 males and 29 females with 121 of these students right handed and the remaining 19, left handed. The children ranged in age from 5 years 2 months to 15 years 6 months with a mean of 8 years 7 months and standard deviation of 2 years (68% of children were between the ages of 7 and 11 years). The Townsend scores representing the socio-economic status of the families showed the majority of the students to come from middle-income/least deprived groups (74% or 96 of the 130 children for whom data were available). Figure 6.1 illustrates the fairly equal distribution of socio-economic status of the group in which -5 represents the 'most least deprived' and +9 represents the 'most deprived' families (Townsend, Phillimore & Beattie, 1988). Although there is a positive skew suggestive of more children in the least deprived group (z score of skew = 2.12), 74% of the children were from the middle ranking groups (-3 to +3). The range of rankings

from -5 to +7 allows for some preliminary exploration of the influence of socio-economic status on motor skills and motor development.

Figure 6.1 Distribution of socio-economic status of sample (Townsend et al., 1988)



There were a number of children who had an additional diagnosis either at the time of referral or obtained during the course of the study (n=60). The majority of these diagnoses represented developmental conditions such as Attention Deficit Hyperactivity Disorder (ADHD, n=12), Speech and Language Impairment (SLI, n=10) or Pervasive Developmental Delay including Autism (PDD, n=18). Thirteen children had a history of significant medical problems which may have influenced or be related to motor development including infant cardiac difficulties, infantile seizures or epilepsy, asthma, Horner's syndrome² or Pierre Robin's Syndrome³. Three children were significantly premature (< 32 weeks gestation), although only one of these children had been awarded a diagnosis of ADHD and was included under that group. Five children were considered to have moderate learning difficulties and attended special schools for children with moderate learning difficulties (MLD). However two

of these children obtained a British Picture Vocabulary Score (BPVS) standard score above 70. Investigation of the medical and educational history of these two children suggested they did not have MLD as defined by intellectual impairment but had been identified with significant problems with literacy and mathematics contributing to overall difficulties in learning and confidence (one of these two students did not demonstrate motor difficulties on assessment). Two children had Down Syndrome which was not listed on their referral form hence they were seen in the screening project but excluded from further analysis (See Tables 6.1 and 6.2).

Table 6.1 Subject Characteristics, Total Sample n=141

Gender	Male n= 112, Female n = 29
Age	<7 years n = 28, >11 years n = 17
Handedness	Right handed n = 121, Left handed n = 19
Estimated Verbal IQ	BPVS <70 n = 5, BPVS >130 n = 3
Townsend Scores	<-3 (least deprived) n = 26, >+3 (most deprived) n = 8
Special Educational Needs	SEN Action Plus n = 31, SEN statement n= 44

BPVS = British Picture Vocabulary Scale; SEN = Special Educational Needs

The extent of the motor difficulties of children identified with DCD or at risk of DCD is listed in Table 6.3. This table also shows the distribution of co-existing developmental or medical conditions in the different bands of motor impairment. Table 6.4 breaks down the group of children in the severe category to illustrate those children with more profound deficits achieving movement impairment scores well below the first percentile.

Table 6.2 Known Co-morbid conditions of children

Diagnostic group	Children with Co-morbidities		
	Total n=60 With and without motor difficulties	With motor difficulties n=38 MABC-TI \geq 10 & BPVS \geq 70	With motor difficulties n=34 included in initial cluster analysis
ADHD	12	5	5
PDD	18	11	9
MLD	3	0	0
Medical condition	13	11	11
Prematurity <32 wks	2 (+1)	2 (+1)	2 (+1)
SLI	10	9	7
Down Syndrome	2	n/a	n/a

MABC-TI= Movement Assessment Battery for Children Total Impairment Score, ADHD = Attention Deficit Hyperactivity Disorder, PDD = Pervasive Developmental Disorder, MLD = Moderate Learning Difficulty, SLI = Specific Language Impairment

The percentile ranking of the Movement Assessment Battery for Children (MABC) test was used to determine the extent of motor impairment for each child. In this study scores ranged from 10 to 34.5, with scores between 10 and 13.5 placing the child between the 6th and 15th percentile and therefore at risk of co-ordination difficulties. Scores on or below the 5th percentile (total impairment scores $>$ 13.5) represent definite motor problems. Total impairment scores of $>$ 17 place the child below the 2nd percentile (representing 2 or more standard deviations below the mean of a normative group), however the maximum possible is 40. Clinical experience suggests that the group of children obtaining total impairment scores \geq 30 (well below the 1st percentile) and also those with impairment scores between 20 and 30 represent the most profound difficulties. Whilst 32 children were felt to be in the borderline (more mild motor difficulties), 34 of the 43 children with severe motor difficulties were considered to have quite significant motor problems as indicated in Table 6.4. The highest score was achieved by a child in the 'other medical condition' category who had had significant cardiac surgery during his first year with additional reconstruction

of his trachea – since this period he has been healthy. The Kolmogorov-Smirnov test (K-S) of the distribution of all children with movement difficulties is significant [$Z(100) = .285, P < .001$], skewed towards a greater number of children having more severe movement problems.

Table 6.3 Extent of motor impairment in differing ‘diagnostic’ groups

Group n=100	Borderline 6-15%ile (%subgroup)	Definite 2-5 %ile (%subgroup)	Severe <2 %ile (%subgroup)
DCD ‘pure’ n=62	n= 25 (40%)	n= 12 (19%)	n= 25 (40%)
PDD n=11	n= 3 (27%)	n= 3 (27%)	n= 5 (45%)
ADHD n= 5	n= 2 (40%)	n= 3 (60%)	n= 0 (0%)
SLI n=9	n= 1 (11%)	n= 3 (33%)	n= 5 (56%)
Prematurity/medical n=13	n= 1 (7%)	n= 4 (31%)	n= 8 (62%)
Total n=100	n=32 (32%)	n=25 (25%)	n= 43 (43%)

Table 6.4 Subdivisions of children with severe motor impairment

Group n=43	ABC-TI scores ≥ 17.5 & <20	ABC-TI scores ≥20 & < 30	ABC-TI scores ≥30
DCD ‘pure’ n=25	5	17	3
PDD n=5	1	3	1
ADHD n= 0	0	0	0
SLI n=5	1	3	1
Prematurity/Other medical n=8	2	3	3
Total n=43	9	26	8

There were 62 children in the 'pure' DCD category of whom 25 (40%) were borderline, 12 (19%) definite and 25 (40%) were in the severe group. The K-S test of the distribution of the 'pure' DCD group was significant [$Z(62) = .269, P < .001$] with a degree of kurtosis with greatest numbers either being in the borderline or most severe category of movement difficulties. Of the three relatively 'pure' DCD children with very high total impairment scores, one child was on the at risk register for emotional abuse and it was questioned whether he also had ADHD but he did not meet full criteria for this diagnosis. The other two 'pure' DCD had significant literacy problems. There were 17 children with relatively 'pure' DCD in the remaining group of children with significant motor impairment (>20 and <30 total impairment scores).

Exploring these children's medical and developmental profiles in more detail, only two children were not on the Code of Practice for Special Educational Needs. These children had a mixed history including fostering (parent known to have a mental illness), history of asthma although no current or past steroidal treatment, questionable infantile seizures (investigations inconclusive), receipt of speech and language therapy for speech delay or stutter (this latter child was also bullied) or a tentative diagnosis of Deficits in Attention, Motor Control and Perception (DAMP) suggestive of a mixed profile of difficulties. There were no children attaining such high scores who could be considered to have had an uneventful developmental profile.

The children falling into the borderline group for motor impairments showed a similar spread of 'purity' versus co-morbidity, either current or historical. Only 6 of these 25 children were not reported to have had a potentially confounding developmental history and who were not on the Code of Practice for Special Educational Needs. Ten children had significant difficulties with literacy, 3 children had suffered from asthma when younger, four children had current or past speech and language difficulties (without being diagnosed as having an SLI), one had had meningitis and one had suffered several infantile seizures. A further child had undergone adverse family events.

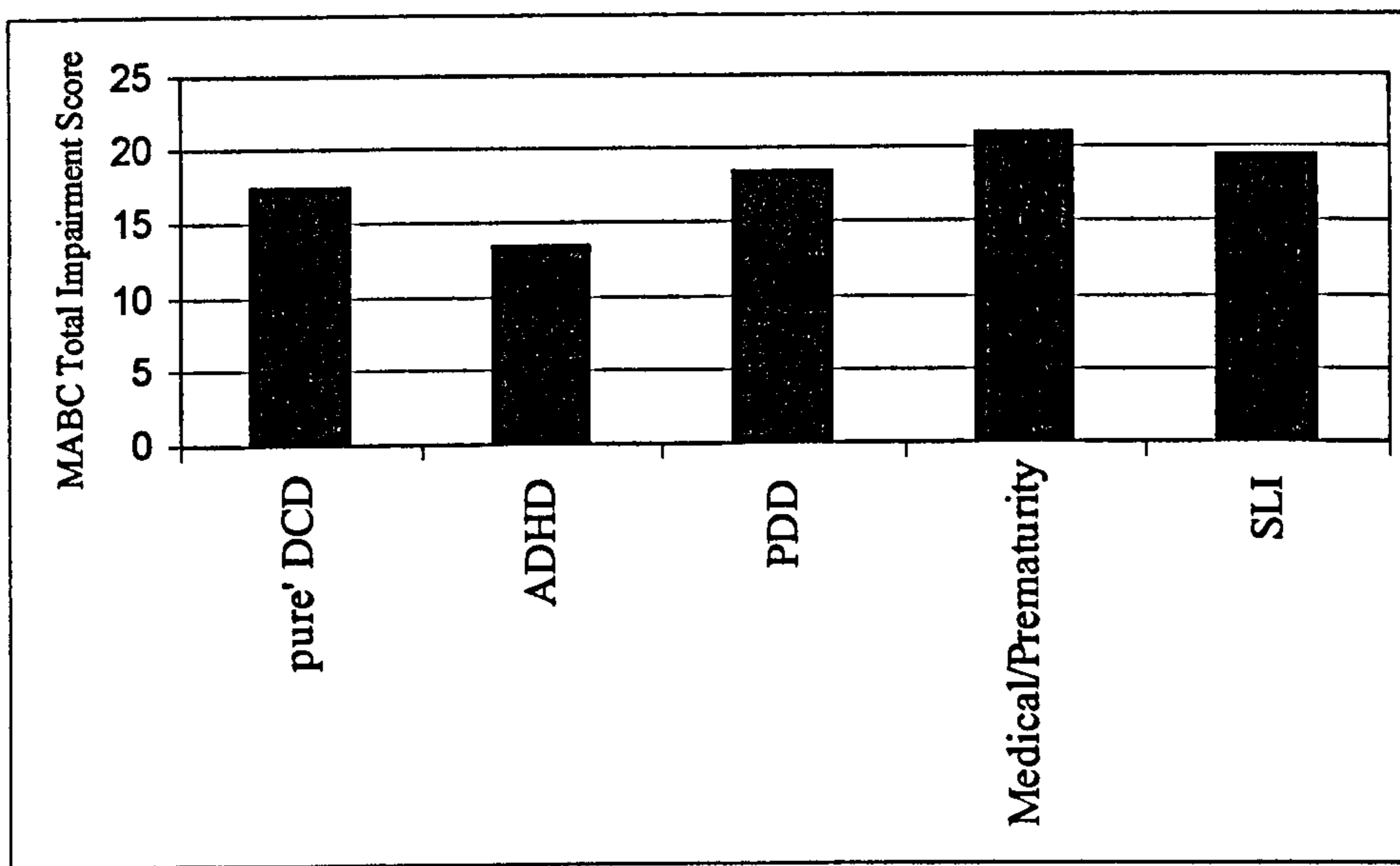
The Kolmogorov-Smirnov test contrasting the distribution of the extent of motor impairment of the 'pure' DCD group to that of children with known co-morbidities was not significant [$Z(100) = 1.01, P > .05$]. Chi² analysis of the 62 children with 'pure' DCD to the 38 children with known co-morbidity approached significance but was influenced by the skew of the co-morbid group which had more children in the severe category whilst the 'pure' DCD group had fewer children in the middle, definite group [$\chi^2(2) = 15.5, P = 0.6$]. However, ANOVA of the presence or not of a co-morbidity by extent of movement difficulty defined by the MABC TI score did not show any differences between the groups [$F(4,94) = 1.43, P = .23, \eta^2 = .057$]. There was also no difference in the distribution of the socio-economic status of children in the 'pure' DCD group compared to those with known co-morbidities [$Z(93) = .47, P > .05$] nor did the estimated cognitive abilities of the 'pure' and co-morbid groups differ [$F(1,98) = 1.3, P > .05$].

6.1.2 *Summary of sample characteristics*

In conclusion, this sample constituted a majority of boys (approximately 4:1 male:female ratio) and most of the students came from middle-income families. With respect to the known diagnostic characteristics of children and the extent of their motor difficulties — there did not appear to be any major differences across the range of motor difficulties (borderline through to the most severe) for those children with relatively 'pure' coordination difficulties as opposed to those who had an additional diagnosed condition. Those children with identified co-morbid conditions were not necessarily the most impaired in their movement skills. Figure 6.2 illustrates this comparison (degree of movement problems) across the diagnostic groups outlined in Tables 6.3 and 6.4. There were also no differences in SES or cognitive abilities of the 'pure' versus co-morbid DCD groups. Although 47% of the children with severe motor difficulties were known to have an over-lapping condition versus 18% of those classified as borderline, relatively few 'pure' DCD children could be said to have had an uneventful developmental (including learning and behavioural problems) or medical profile. The impact of known co-morbidity or reported social and emotional

difficulties on movement problems is explored further in sections 6.2.2, 6.5.6 and 6.5.7.

Figure 6.2 Extent of motor difficulty per diagnostic group



6.2 Part I – Subtypes of motor characteristics

This next section contrasts the generic profiles of perceptual and motor performance of children in the current study with those of previously published studies. Relative strengths and weaknesses on different perceptual and motor tests are explored for the ‘pure’ DCD group, the co-morbid DCD group and all the movement disordered children to determine the presence and stability of subtypes, in contrast to other published studies.

6.2.1 Part I – Subtypes of perceptual and motor performance

The profiles of perceptual-motor function were explored using Factor Analysis and Cluster Analysis in the children with co-ordination problems — both with and without other identified problems (see Table 6.2 above). Factor Analysis was undertaken to identify groups of related variables from the measures considered to be of importance with respect to the literature (both theoretical and experimental) and which

incorporated the same (or most similar variables) as those included in the study by Hoare (1994) and MacNab et al. (2001). Principal component analysis with varimax rotation summarised most of the original information (variance) to five factors accounting for 71% of the overall variance (Hair et al., 1992). The Kaiser Meyer Olkin statistic confirmed sufficient correlation amongst the variables to yield distinct and reliable factors (KMO= .726)

Table 6.5 Comparison of measures between studies

Variable	Hoare (1994)	MacNab et al.(2001)	Current
Same			
Visual Motor integration	VMI	VMI	VMI
Similar			
Non-motor visual perceptual	MFVPT	MFVPT	Visual subtest of VMI
Manual Dexterity	PURDUE	ULSD (BOTMP)	MD (MABC)
Static Balance	Static Balance (MAND)	Static Balance (TOMI)	Static Balance (MABC)
Different			
Kinesthetic Acuity	KST	KST	Finger to Nose (COMPS)
Dynamic Balance	50 yard dash	Running Speed (BOTMP)	Dynamic balance total score (MABC)

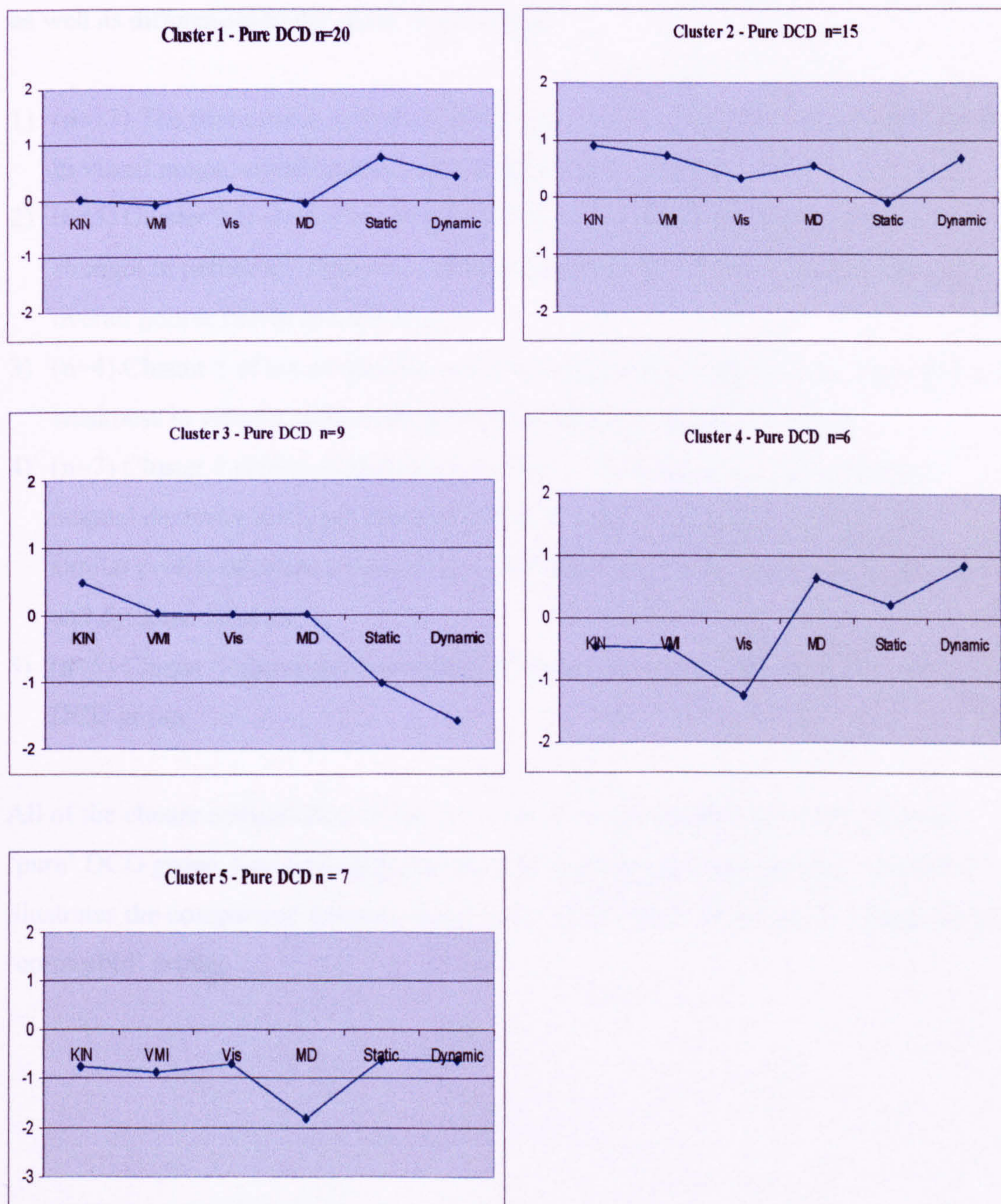
BOTMP = Bruininks-Oseretsky Test of Motor Proficiency; COMPS = Clinical Observations of Motor and Postural Skills; KST = Kinesthetic Sensitivity Test; MAND = McCarron Assessment of Neuromuscular Development; MFVPT = Motor-Free Visual Perceptual Test; VMI = Developmental Test of Visual Motor Integration; ULDS = Upper Limb Speed and Dexterity Subtest

In order to compare results with existing literature similar statistical procedures to that of Hoare (1994) and MacNab et al (2001) were used. As different methods of clustering produce different results and the variables entered into the analysis also influence results (MacNab et al., 2001) it was felt appropriate to replicate their approach as closely as possible. The variables entered into the equation constituted a 'best fit' based on the data collected. Table 6.5 sets out a comparison of the measures used in the studies of Hoare (1994), MacNab et al (2001) and the current study.

Preliminary hierarchical agglomeration cluster analysis was undertaken in order to identify the most appropriate numbers of clusters of children who grouped together on the variables used in the Factor Analysis (Aldenderfer & Bashfield, 1984). The point scores and standard scores of test results were standardised by transformation into *Z* scores so that 0 represented the mean on each variable for the group of children with total MABC impairment scores of ≥ 10 (e.g. children at risk or with definite to severe motor impairment). A five cluster solution was identified via Ward's method of centroid clustering (Ward's method joins cases within a group so that the variance is minimised). Validity of these clusters was confirmed by K-means iterative partitioning indicating a similar number of clusters (See section 6.2.2).

Data for cluster comparison were available on 91 children from the initial sample of 100 children identified with co-ordination difficulties. The DCD 'purest' group contained 57 children in which all known potential confounders of diagnosis or intellectual ability were ruled out. Figure 6.3 illustrates the five clusters making up groups of children which can be classified by profile of mean *Z* scores as:

- 1) (n=20) relative strength in static and dynamic balance items;
- 2) (n=15) relative strength in perceptual functions, manual dexterity and dynamic balance with a weakness in static balance;
- 3) (n=9) relative weakness in static and dynamic balance;
- 4) (n=6) relative weakness in perceptual functions with a strength in manual dexterity and dynamic balance;
- 5) (n=7) poor across all items with greater problems in manual dexterity.

Figure 6.3 Cluster profiles of the DCD 'pure' group (n=57)

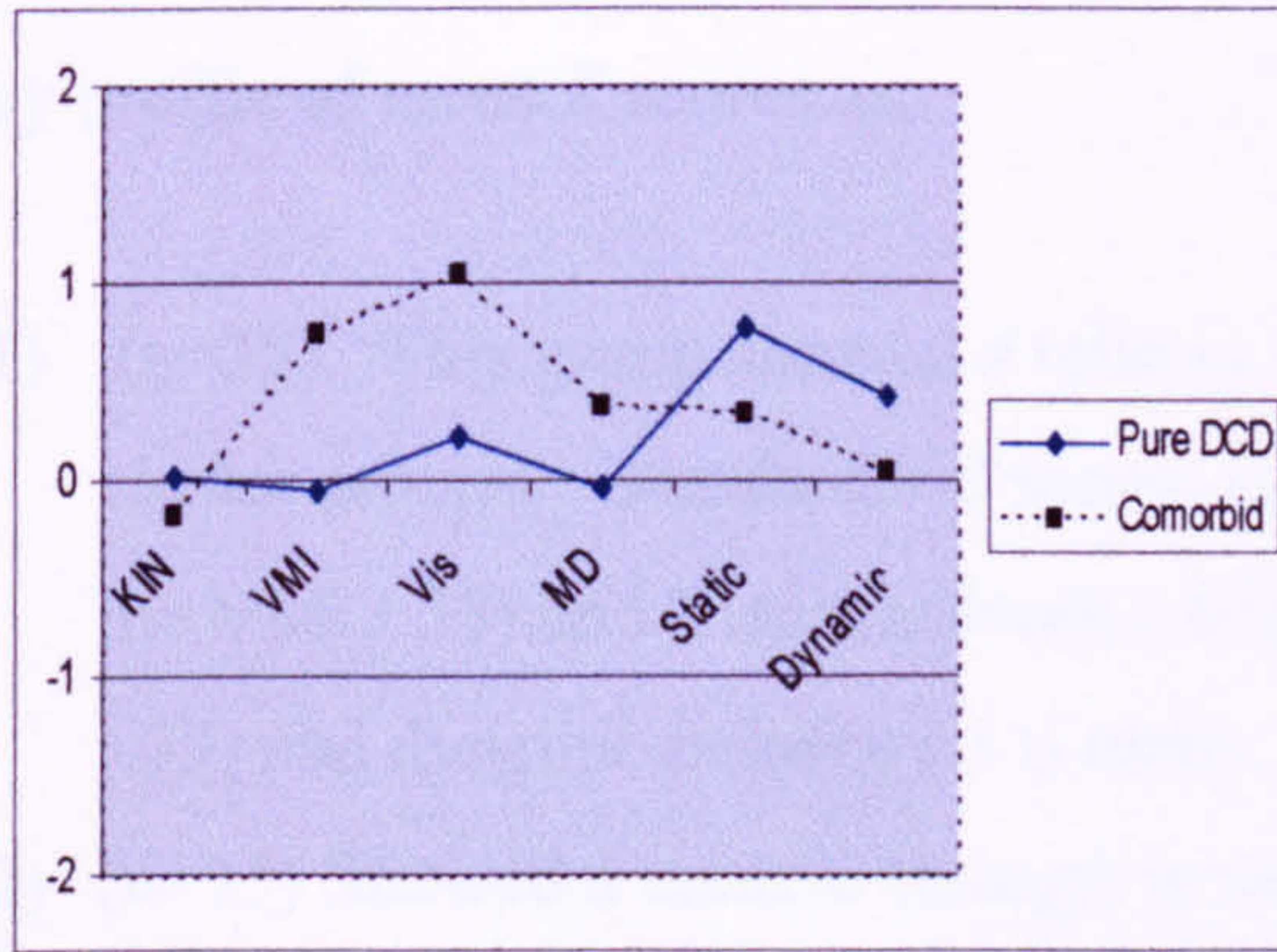
KIN = Kinesthesia; VMI = Visual-Motor Integration; VIS = Visual subtest of VMI; MD = manual dexterity of MABC; Static = Static Balance of MABC; Dynamic = Dynamic Balance subtests of MABC

The five clusters of children with additional diagnoses (n=34) show some similarities as well as differences to the 'pure' DCD group:

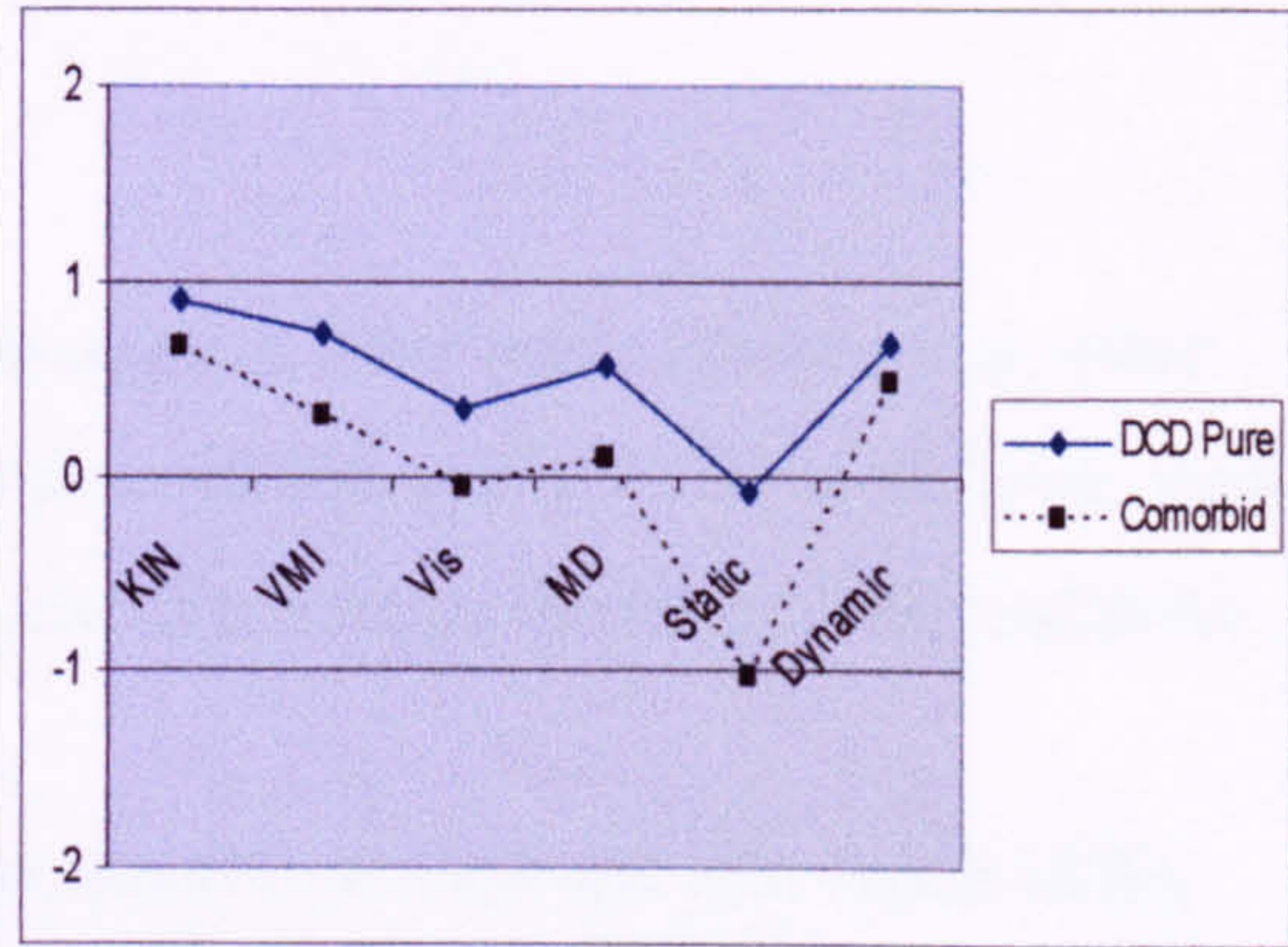
- 1) (n=13) The first cluster is similar to the 'pure' DCD group but with a better ability in visual motor, visual spatial and manual dexterity skills;
- 2) (n=5) Cluster 2 is similar to Cluster 2 of the 'pure' DCD group with a relative strength in perceptual functions, manual dexterity and dynamic balance although overall poorer scores in each domain;
- 3) (n=4) Cluster 3 of the co-morbid group is made up four children who showed a weakness in visual spatial skills as well as static and dynamic balance;
- 4) (n=7) Cluster 4 differs slightly from the 'pure' DCD group in having weaker manual dexterity skills yet marginally better visual spatial skills within their similar profile of relative weakness in perceptual functions and strengths in static and dynamic balance;
- 5) (n=5) Cluster 5 also makes up a group of generally low scores as do the 'pure' DCD group.

All of the cluster comparisons of the 'co-morbid' group match fairly well with the 'pure' DCD group, having a similar profile of strengths and weaknesses. Figure 6.4 illustrates the comparison between the profiles of the 'pure' DCD group set against the 'co-morbid' group.

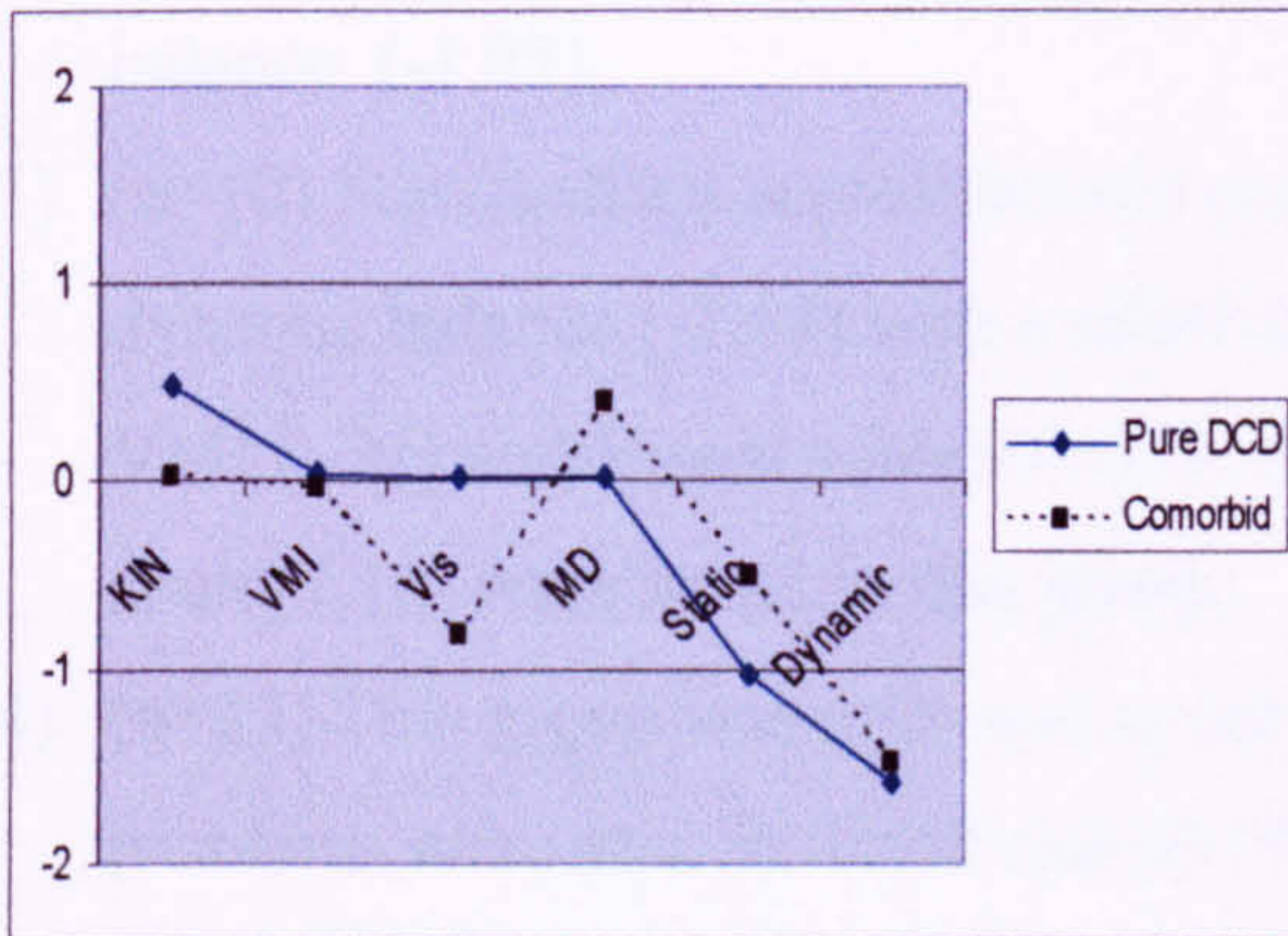
Figure 6.4 Cluster profiles of DCD 'pure' group and 'co-morbid' group



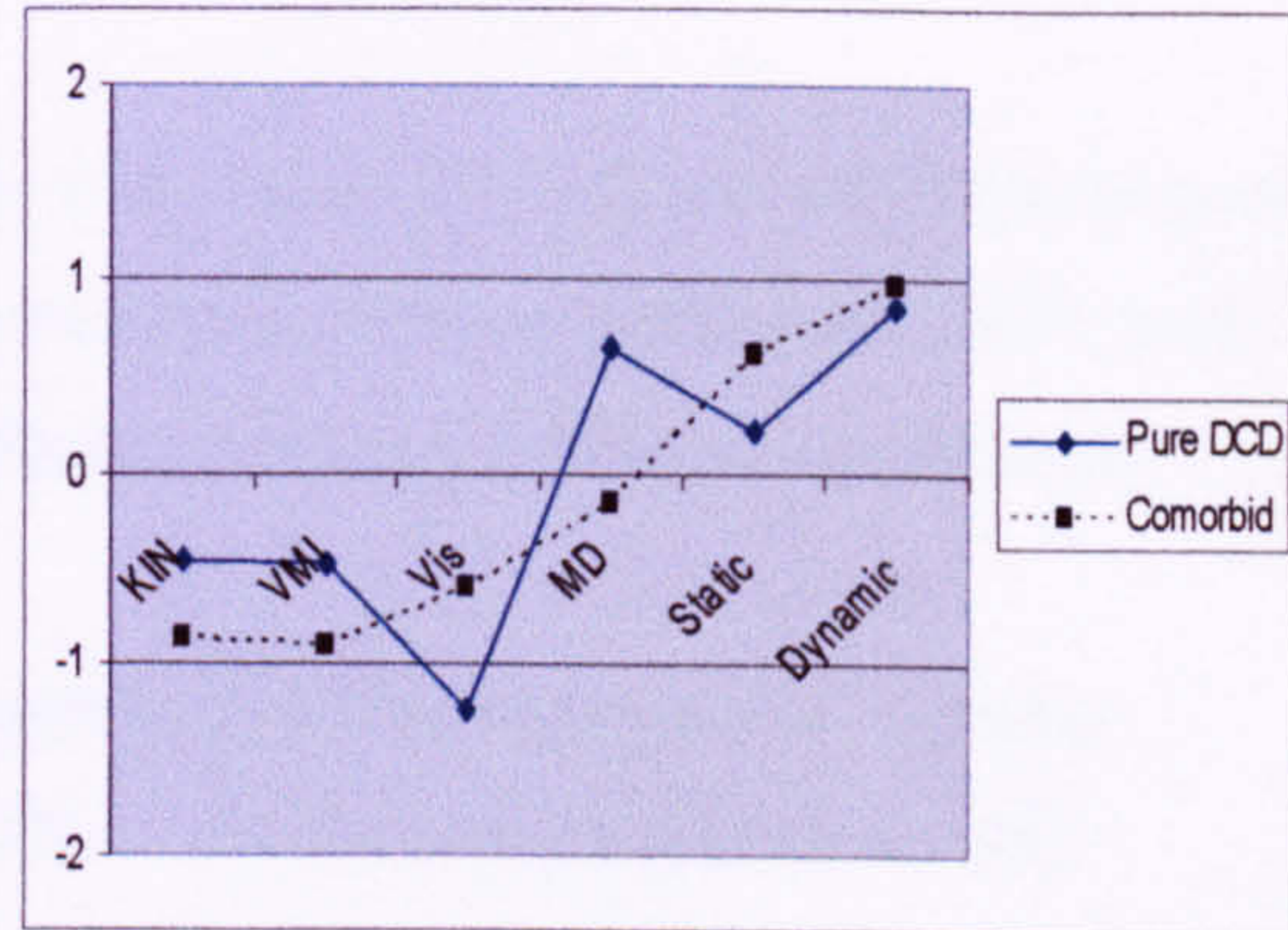
Cluster 1



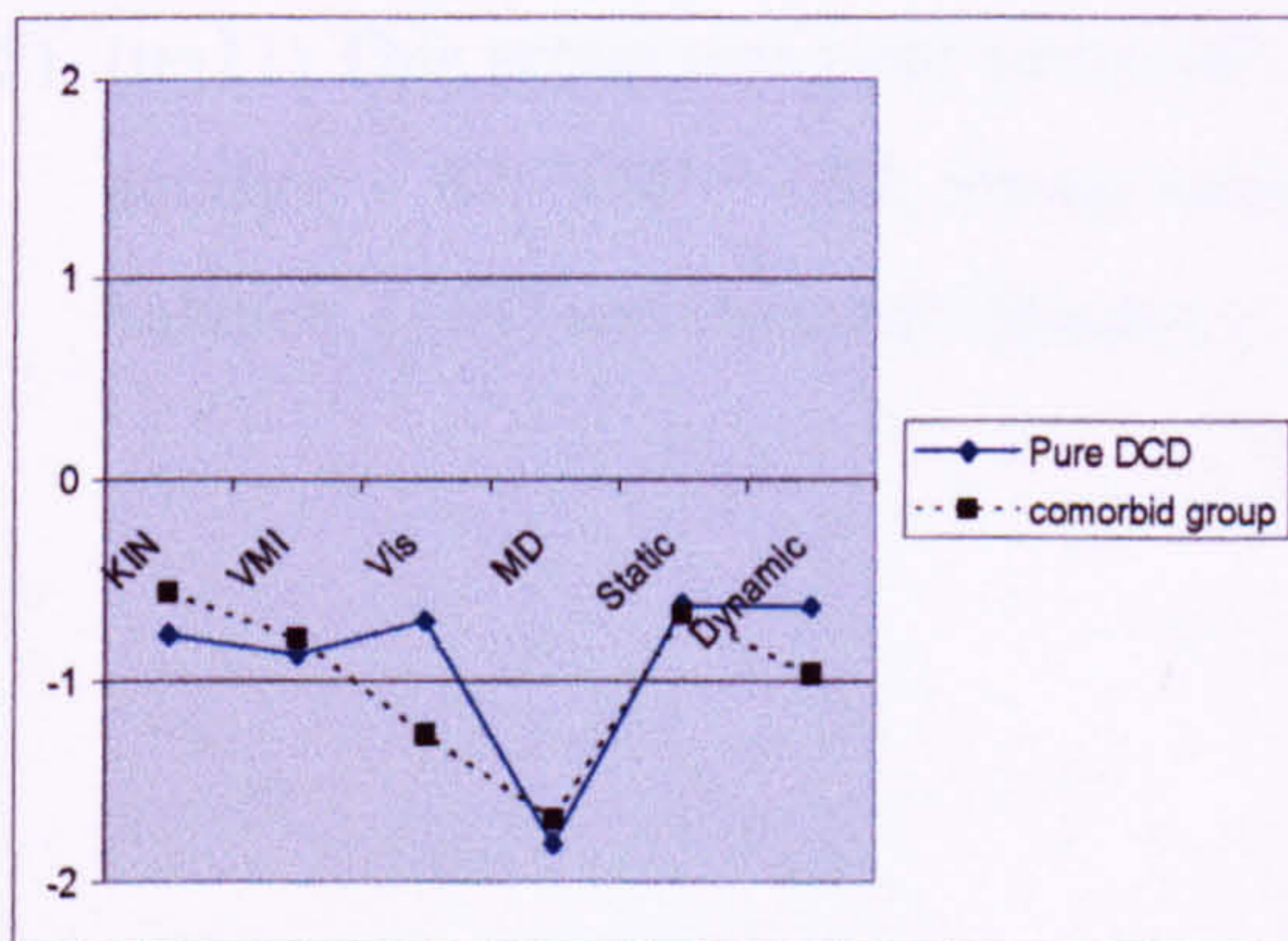
Cluster 2



Cluster 3



Cluster 4

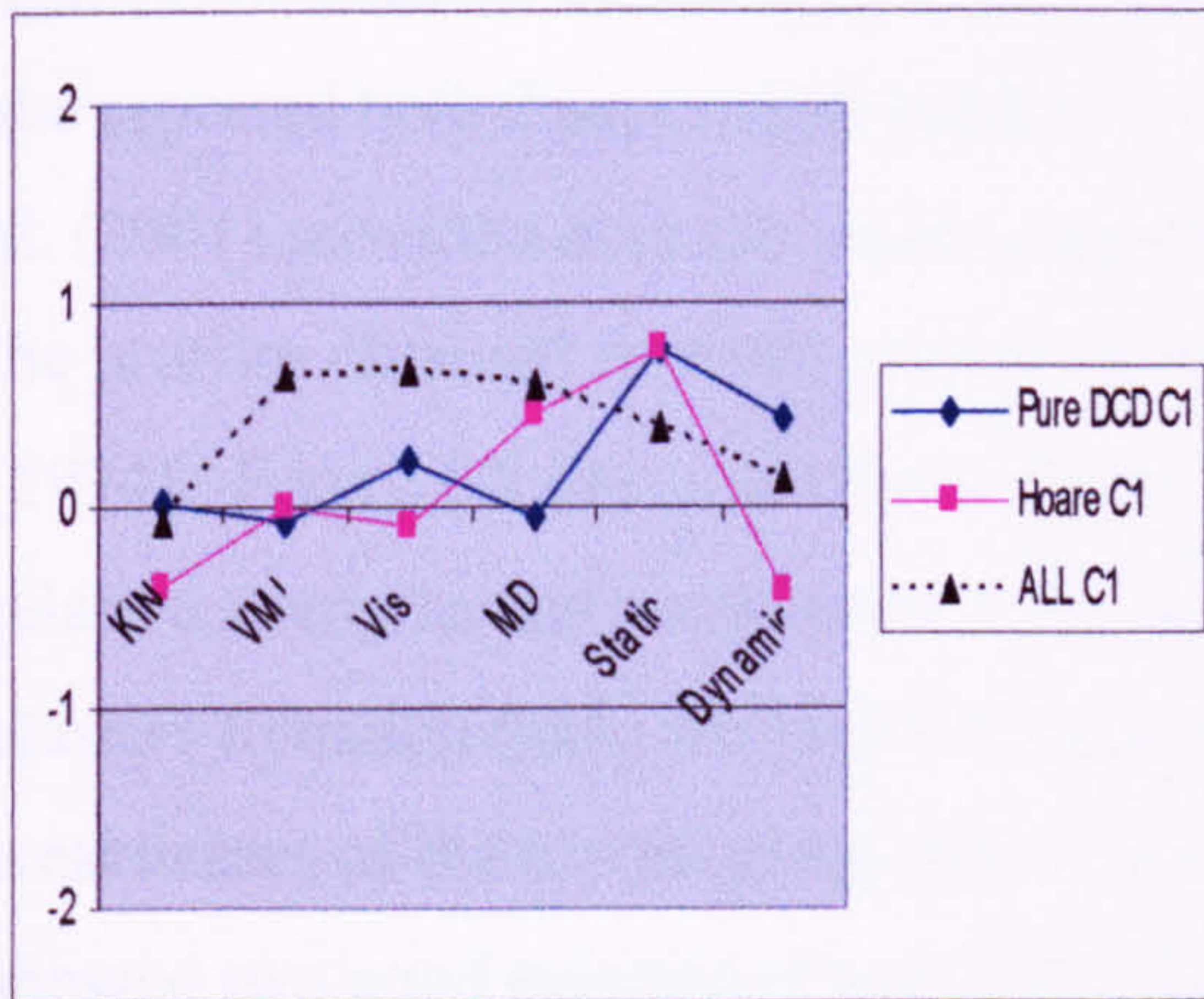


Cluster 5

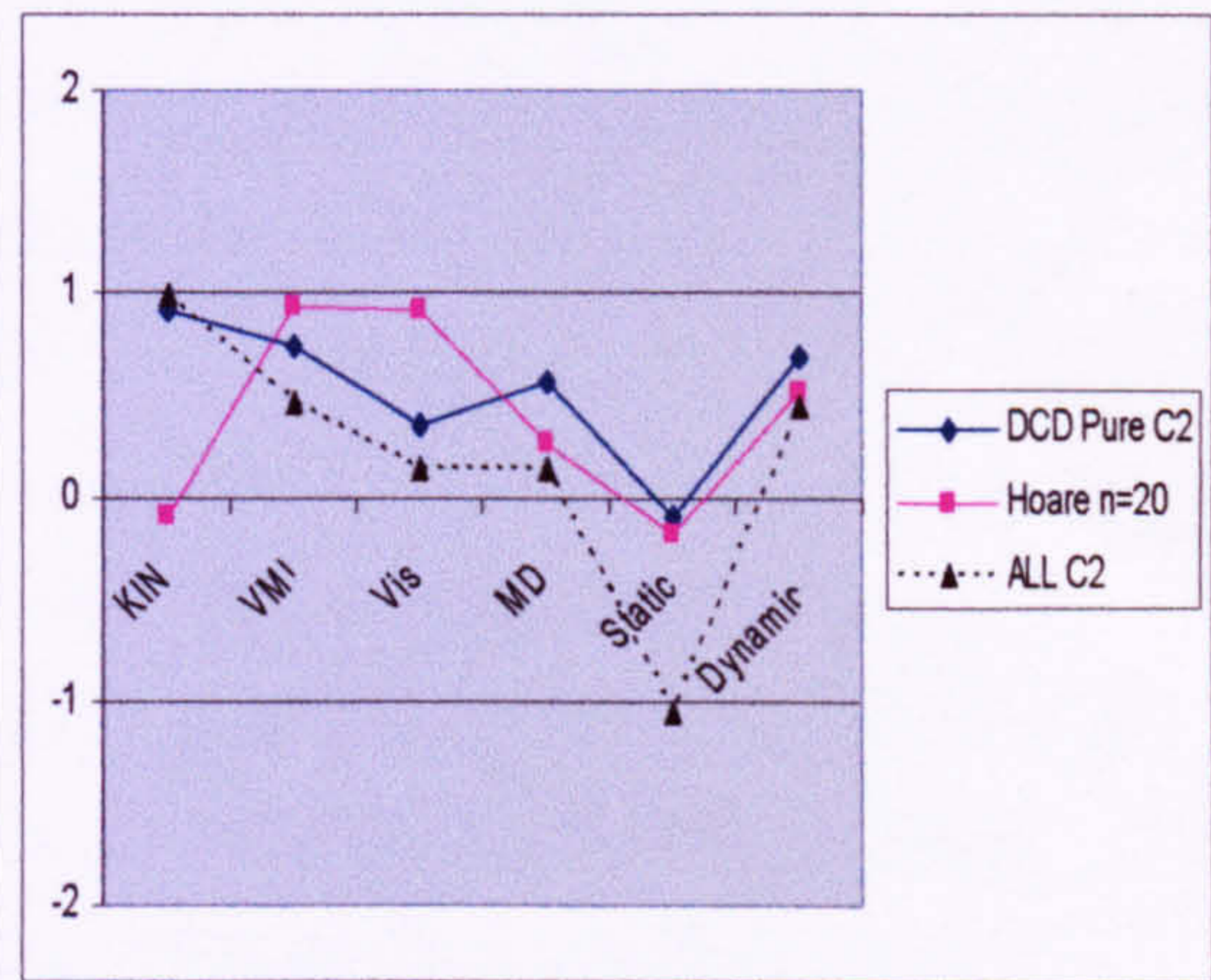
The final combined group contained 91 children made up of the 'pure' and 'co-morbid' groups. The five clusters identified children in groups which can be classified by profile of mean Z scores as:

- 1) (n=35). This group showed a relative strength in most items compared to other cluster groups. Standardised scores for kinaesthetic acuity (-.07) were lower than the VMI (.58) and Visual subtests (.64) and also manual dexterity (.50) and static (.39) and dynamic balance (.13) items;
- 2) (n=13) Showed a relative strength in perceptual functions and fine motor skills. Standardised scores for kinaesthetic acuity (.98), VMI (.45), VMI Visual subtest (.14), manual dexterity (.14) and dynamic balance (.43) were above those of static balance (-1.05);
- 3) (n=10) Standardised scores showed poor static balance (-.94) and particularly poor dynamic balance (-1.64) with a relative weakness in visual perceptual skills, both VMI (-.31) and Visual subtest (-.44). Manual dexterity (.11) and kinaesthetic acuity (.10) were better in this group;
- 4) (n=22) This group was poor across perceptual and fine motor tasks. Greater problems were seen in visual spatial (VMI = -.51 and visual subtest = -.48), kinesthesia (-.18) and manual dexterity items (-.24) with a relative strength in balance items (static balance = .81 and dynamic balance = .75);
- 5) (n=11) This group was poor across all items: perceptual functions (kinaesthetic acuity = -.67; VMI = -.83; Visual subtest = -.96), manual dexterity (-1.75) static balance (-.64) and dynamic balance (-.78).

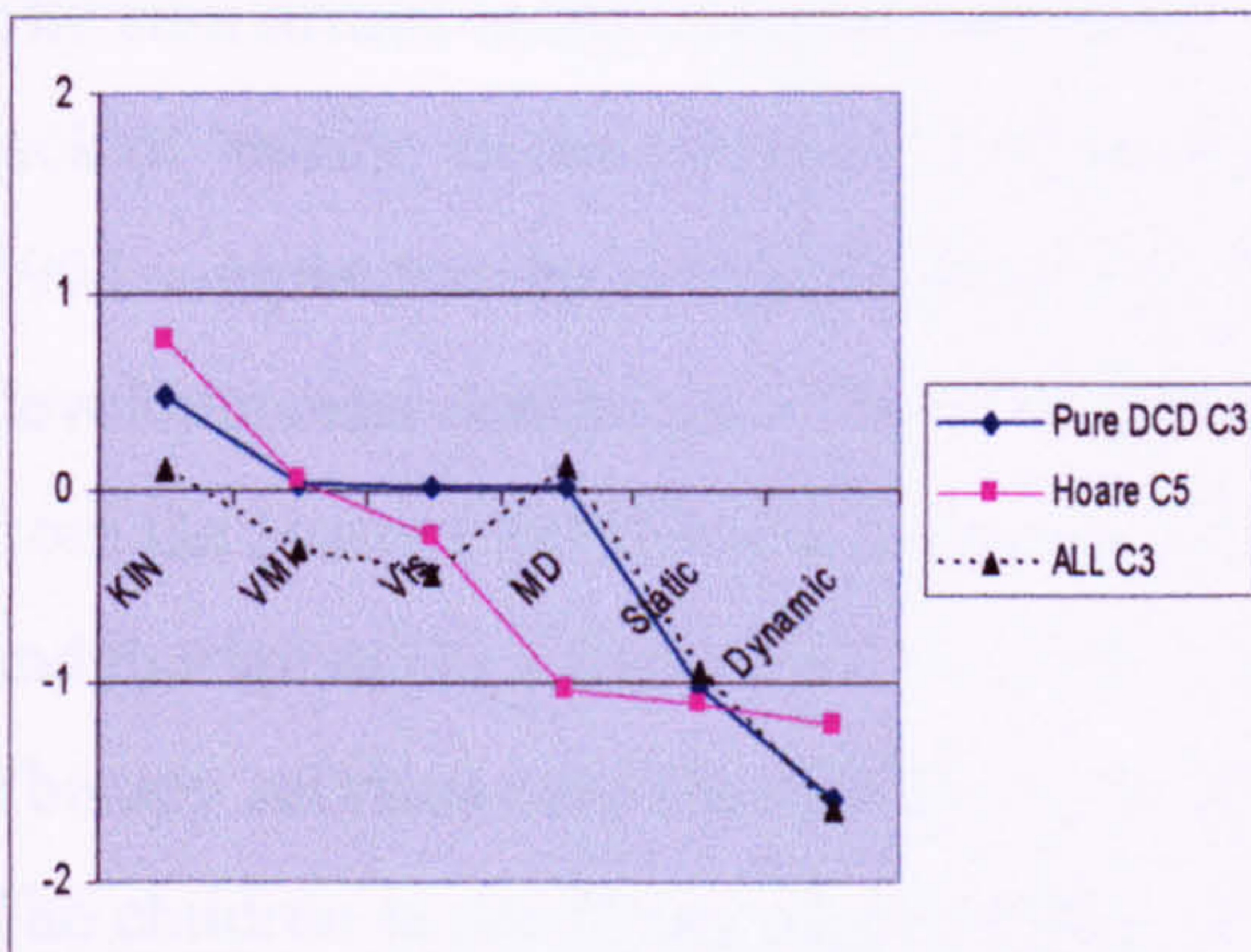
Figure 6.5 Comparison of clusters from the DCD 'pure group (n=57), final mixed group of children with motor difficulties (n=91) and Hoare's 1994 study (n=79)



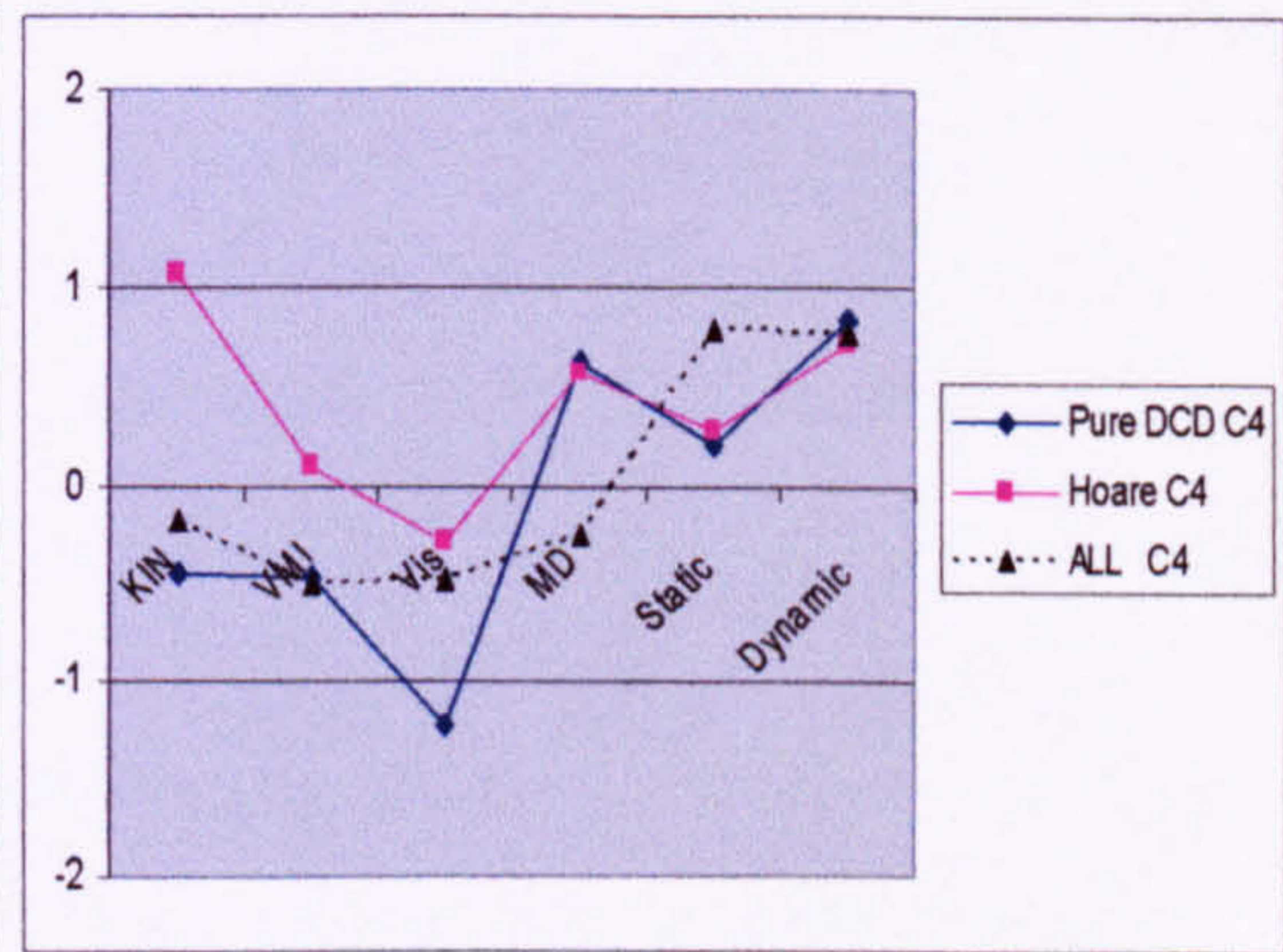
Cluster 1



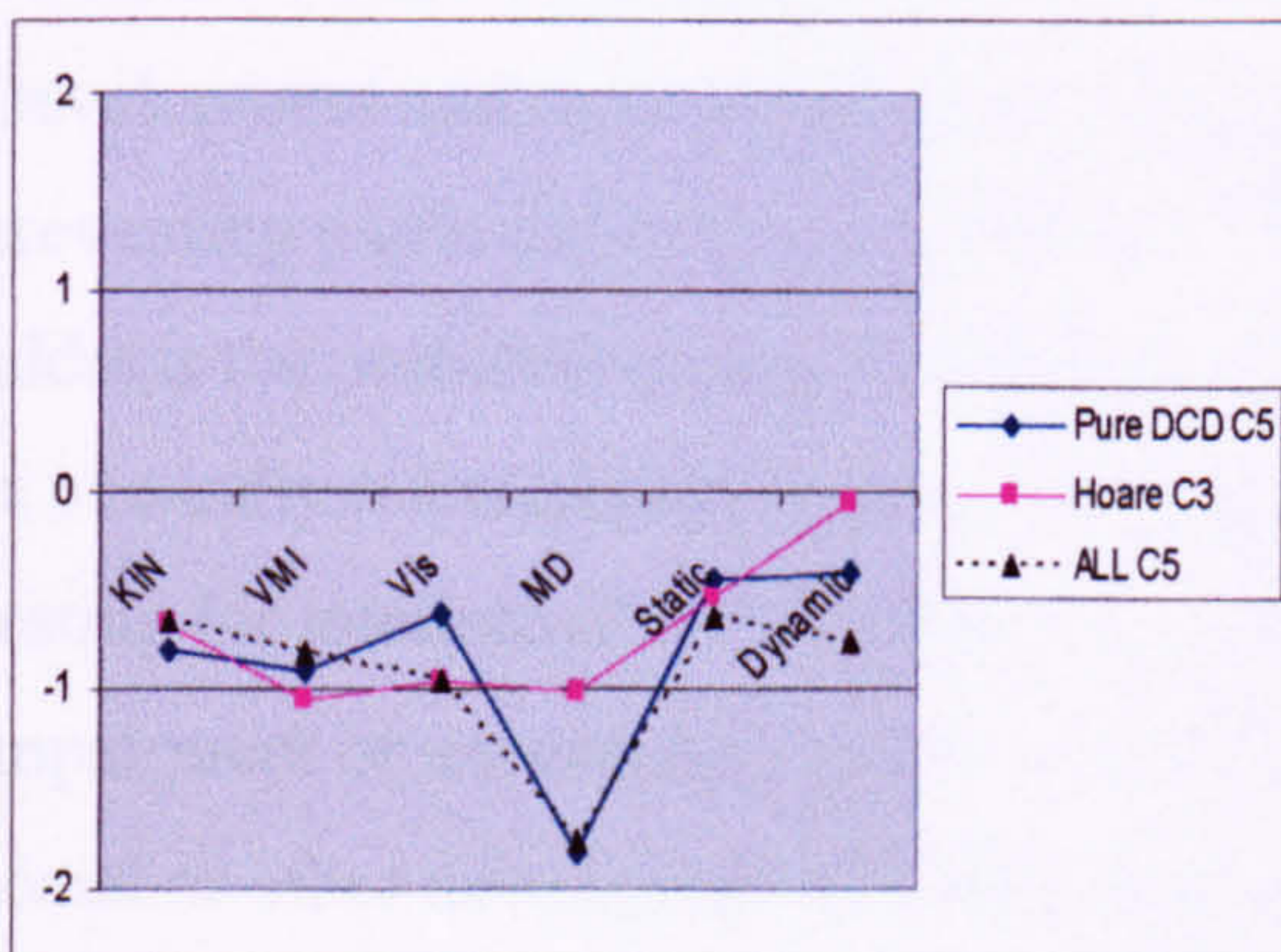
Cluster 2



Cluster 3



Cluster 4



Cluster 5

Visual contrasts were undertaken plotting both the 'pure' DCD clusters as well as the mixed groups containing all children with motor difficulties from the current study against the clusters obtained by Hoare (1994). This comparison was made possible as she reported both Z scores and standard deviations for each cluster whereas MacNab et al. (2001) provided only the means and standard deviations per group. The shapes of the profiles obtained from the current study were compared to those reported by Hoare (1994). Figure 6.5 illustrates these cluster comparisons. Visual analysis of the relative strengths and weaknesses from the 'pure' DCD group showed three of the five clusters to match fairly well with two approximations. The profiles of strengths and weaknesses of the mixed group (all children in current study) to Hoare's clusters showed two good matches (Cluster 1 and Cluster 5) and three approximations.

The similarities in the comparisons of the 'pure' and mixed DCD groups may reflect a lack of 'purity' in the current DCD group but more importantly, suggest that Hoare's 1994 sample may have contained an equally mixed group of children with a range of developmental conditions. This comparison is particularly noteworthy as the children from the Hoare (1994) study had been referred from similar sources (teachers, doctors and therapists) to a movement education programme (rather than an Occupational Therapy service) conducted at the local University (University of Western Australia). The children in the Hoare study (1994) *were assumed* to be free of additional and potentially co-morbid diagnoses; the confirmation of DCD made on the basis of a poor performance of >1 standard deviation on the McCarron Assessment of Neuromuscular Development and no reported physical impairments or intellectual disabilities preventing participation in mainstream schooling. MacNab et al. (2001) tried to address the probability of an increased risk of co-morbidity that is more often present in clinically referred populations (McConaughy & Achenbach, 1994). In addition to testing for intellectual impairment, they excluded children with known neurological impairment or uncorrected visual or auditory deficits, but did not address behavioural, social or other developmental factors that may have influenced motor performance.

6.2.1.1 Section summary

In summary, it would appear from descriptions of the sample and preliminary visual analysis of the subtypes that there were no substantive differences between either our 'pure' or combined groups of children with motor impairment and the samples of children included in either Hoare's (1994) or MacNab et al.'s (2001) studies. Based on this criteria, all of the children in the current study would have met the criteria set by Hoare (1994), if not more rigidly, in view of the fact that all children in the current study had estimated normal intellectual abilities on standardised testing using the BPVS and were free from physical impairment. The additional diagnostic categories reported in the current study emphasise the behavioural and social development of the children rather than any physical or intellectual disability. Of interest to the current hypothesis — with respect to the potential impact that the cluster type (motor profile) may have on outcome — the current sample had similar comparative results to Hoare's (1994) and Macnab et al.'s (2001) studies. Five clusters of children were identified with two clusters having a similar profile of strengths and weaknesses in perceptual and motor tasks to previous studies and three approximations.

6.2.2 *Stability of perceptual-motor subtypes with different 'co-morbid' associations*

To try and isolate the imponderable nature of the different profiles of children with motor problems who had additional identified diagnoses versus those without - the cluster analyses were rerun with each developmental condition entered in a step-wise fashion until all children with motor impairment were included. Table 6.6 shows the changes in numbers of children in each cluster as additional diagnostic groups were incorporated into the cluster analysis.

The children with Asperger Syndrome (AS) were added first (n=4) in view of the recognised prevalence of clumsiness in this condition (Green et al, 2002b; Rasmussen & Gillberg, 2000), followed by children with developmental conditions of ADHD and

SLI (n=12) in which a high incidence of motor impairment has also been documented (Gillberg, Gillberg & Groth, 1989; Hill, 2001). Children with other PDD including Autism were added next (n=4) in view of this diagnosis having been specifically ruled out under Criterion C and its assumption that PDD (including Autism) can explain the motor difficulties of these children. Finally all remaining children identified with asthma, infantile seizures, history of prematurity or cardiac problems, which may or may not be alluded to under 'medical' conditions of Criterion C, were added. The numbers of children changing cluster groupings at each stage of this procedure are illustrated in Table 6.6.

Table 6.6 Changes to cluster groups as additional diagnostic conditions were entered into the analysis

DCD original cluster	DCD Pure N=57	DCD + AS N=61		DCD, AS + Dev N=74		DCD, AS Dev & PDD n=78		All conditions N=91	
Cluster 1	20	23	-4 +6 +1 AS	17	-11+4 +1 Dev	26	-6 + 14 +1 PDD	35	-14+17 +5 GM
Cluster 2	15	13	-5 +2 +1AS	19	-2 + 5 +3 Dev	19	-5 +3 +2 PDD	13	-13 +6 +1 GM
Cluster 3	9	6	-3	12	-6 + 7 +5 Dev	12	-7 + 7 +1 PDD	10	-4 +2 GM
Cluster 4	6	12	-0 +4 1 AS	11	-4 + 1 +2 Dev	11	-6 + 6	22	-0 +10 + 1 GM
Cluster 5	7	8	-0 +1 AS	15	-0 + 6 +1 Dev	8	-7	11	-1 + 4 GM
DCD children who changed from original classification	0	11		17		16		24	
Children who changed from previous group		11		23		31		42	

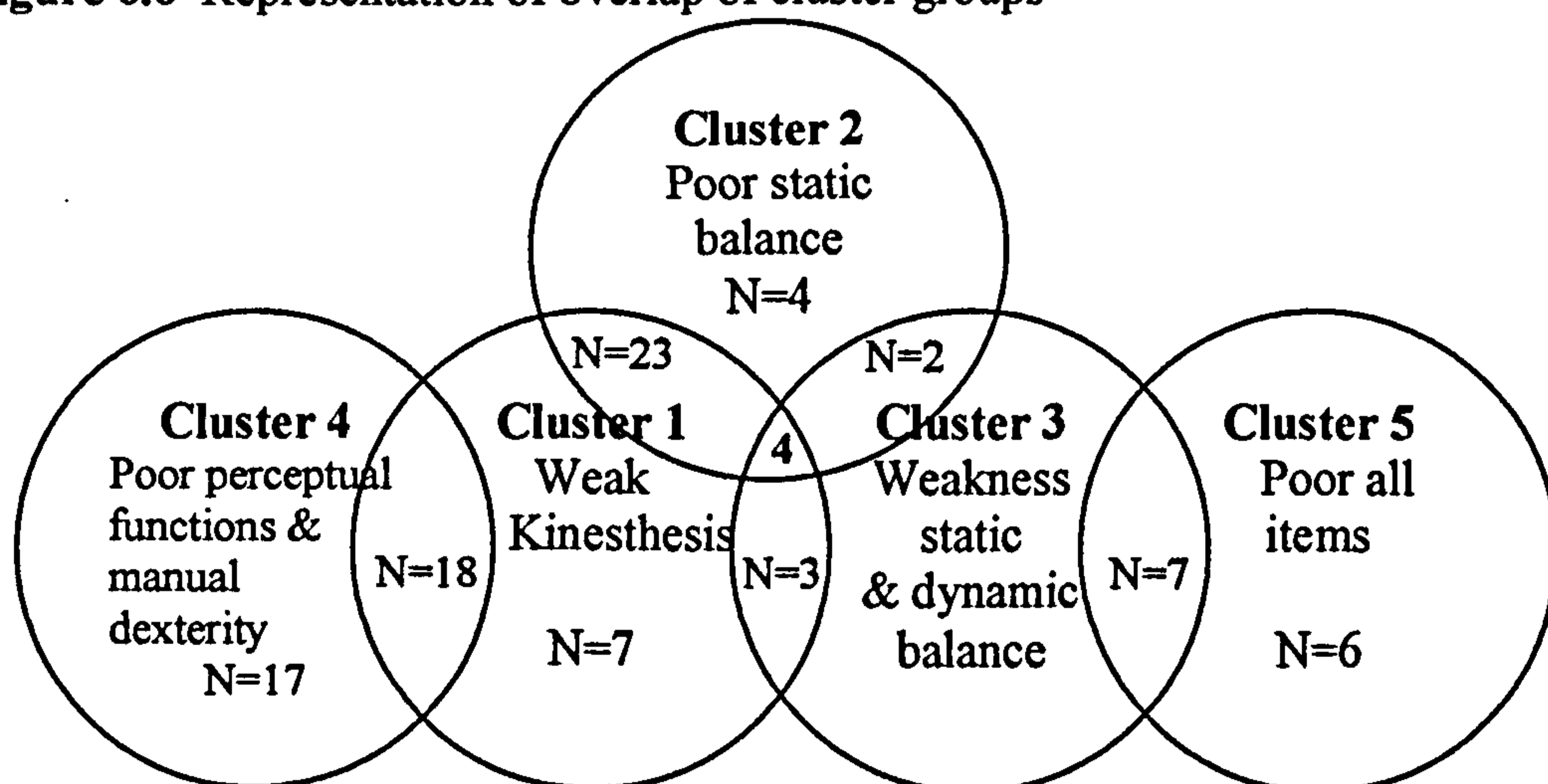
AS = Asperger Syndrome, Dev = Developmental conditions (ADHD or SLI)

PDD = Pervasive Developmental Disorder, GM = General medical condition (e.g. asthma)

On first analysis, the children moving between groups appeared to be the same children, potentially representing a small group of outliers. More detailed description of the children who changed groups however, showed that from the total of 78 children (this excludes the last group to be entered containing those children with general medical conditions), 53 children changed cluster groups at least once when children from additional diagnostic groups were included in the analysis (68%). In contrast only 22 of the 78 children did not change cluster grouping throughout the series of analyses (28%). Cluster 5 remained relatively stable (7 out of 13 children who entered this group at one time changed to another cluster group) in comparison to Cluster 3 where none of the children who entered this group remained throughout the analysis (21 children moved in and out of Cluster 3).

Although cluster centroids remained distinct, with the variables forming separate groups, the extent to which the clusters may overlap is illustrated in Figure 6.6. The overlap of the clusters was determined by the frequency in which children changed groups. For example, a number of children moved between Cluster 1, Cluster 2 and Cluster 3 however, no child from Cluster 4 moved to Cluster 2, Cluster 3 or Cluster 5. No child moved from Cluster 5 to Cluster 4, Cluster 2 or Cluster 1.

Figure 6.6 Representation of overlap of cluster groups



6.2.2.1 Section Summary

The central premise of the stability of the five clusters is called into question by the high numbers of children who changed cluster groups when additional children with additional diagnoses were added into the analysis. Table 6.6 and Figure 6.6 would suggest that the theoretical principle of five relatively distinct clusters is maintained through this process although individual children do not necessarily conform to this model.

6.2.3 *Part I – Stability of subtypes – cluster cohesion*

The results set out in section 6.2.2 would suggest that a five cluster solution inadequately distinguishes groups of children. Ward's method of cluster analysis had been used to identify the groups — this technique minimises the variance within the group but does not take into account the shape of the cluster or distance from the centroid.

The proximity of each child to a cluster centroid was tested through K-means iterative partitioning. Table 6.7 shows the mean Z scores for the index variables of the final clusters; contrasting Ward's method with the K-means iterative groups. This method identified three groups similar to Ward's method with one cluster having a more pronounced weakness in kinesthesia, a group with relative strengths in perceptual and motor tasks and another cluster being poor across the board.

Discriminant analysis was undertaken to identify which cluster from the K-means process best predicted cluster group membership from Ward's method. Table 6.8 shows the predicted membership by numbers and percentage of children matching groupings. From this analysis 63.7% of the original Ward cluster groupings were correctly classified (52 out of 91 children). Cluster 3 membership from Ward's method was not verified via K-means partitioning which possibly corresponds with the

lack of stability of this group (21 children moved in and out of this group when different diagnostic conditions were added to the cluster analysis).

Table 6.7 Comparison of Ward's and K-means iterative clusters, Z score means *

Cluster	1		2		3		4		5	
	Ward	K	Ward	K	Ward	K	Ward	K	Ward	K
KIN	-.07	-.46	.98	.22	.10	.04	-.18	.38	-.67	-.61
VMI	.58	.67	.45	1.21	-.31	-.34	-.51	.26	-.83	-1.15
VIS	.64	-.29	.14	1.39	-.44	-.14	-.48	.18	-.96	-1.10
MD	.50	.34	.14	.59	.11	.17	-.24	-.02	-1.75	-1.47
Static	.39	-.27	-1.05	.76	-.94	.73	.81	-.86	-.64	-.43
Dynamic	.13	-.50	.43	.06	-1.64	.77	.75	-.28	-.78	-.63

*Clusters reorganised for best fit changing 4 and 5

Table 6.8 Discriminant analysis of Ward's clusters to K-means groupings

Ward method	Predicted group membership				
	1	2	3	4	5
Cluster 1 n= 35	19	6	0	10	0
Cluster 2 n= 13	0	12	0	1	0
Cluster 3 n= 10	3	6	0	0	1
Cluster 4 n= 22	1	0	0	18	3
Cluster 5 n= 11	0	2	0	0	9
% 1	54.3	17.1	0	28.6	0
% 2	0	92.3	0	7.7	0
% 3	30.0	60.0	0	0	10.0
% 4	45.0	.0	0	81.8	13.6
% 5	0	18.2	0	0	81.8
63.7% of the originally grouped cases correctly classified					

These results suggest that clusters two, four and five of Ward's method are fairly distinct and potentially stable with Cluster 1 made up of more varied groups of children. Removing Cluster 3, which was not substantiated by the K-means process, with no child predicted to be in this group, improved classification to 71.6% (See Table 6.9).

Table 6.9 Discriminant analysis of Ward's to K-means groupings; Cluster 3 removed

Ward method	Predicted group membership			
	1	2	4	5
Cluster 1	19	6	10	0
Cluster 2	0	12	1	0
Cluster 4	1	0	18	3
Cluster 5	0	2	0	9
% 1	54.3	17.1	28.6	0
% 2	0	92.3	7.7	0
% 4	4.5	0	81.8	13.6
% 5	0	18.2	0	81.8
71.6% of originally grouped cases correctly classified				

The instability of cluster groups when entering children with different diagnostic conditions (most of which would not have excluded a child from a diagnosis of DCD) and the weak association between Ward's and K-means techniques, may in part be due to the philosophy of cluster analysis which is based on the use of interval data. Many of the measures used in this study contain ordinal data, transposed to interval data via sample dependent standardisation. Manipulating the scores in such a way would also have resulted in some loss of sensitivity of the scores in relation to test standardisation. The importance of this point in relation to the stability of the cluster groups will be debated further in Chapter 7.

6.2.4 Summary of subtype comparisons

This overall section has explored the notion of ‘homogeneous’ subtypes within a ‘heterogeneous’ group of children with DCD. Key findings are:

- The five subtypes obtained from the factor and cluster analyses of the children in the current study show some similarities to those obtained by Hoare (1994);
- The comparisons of the ‘pure’ and mixed DCD groups were not noticeably different to studies of Hoare (1994) and Macnab et al. (2001) suggesting that other researchers may also have had a ‘mixed’ group of children;
- Changes to the populations of children in each group were seen when additional children having known behavioural or social difficulties are included in the analyses with 68% of children changing cluster;
- Four of the five clusters based on the measures included in these preliminary analyses were confirmed through K-means iterative cluster analysis contrasting shape (distance from centroid) with overall variance of clusters and group prediction analysis;
- Cluster 3, a group with poor balance and relatively weak visual spatial and visual motor skills, was the most unstable with few children close to the cluster centroid and therefore was not confirmed through K-means iterative partitioning.

These results suggest that there may be some theoretical argument for subtypes of motor impairment but that individual children may not necessarily conform to the rules of classification. Further analysis of the hypothesis of subtype stability is explored in the next section.

6.3 Stability of subtypes from different theoretical perspectives

This section contrasts the subtypes obtained from different theoretical models for the basis of movement difficulties in children, with the original profiling undertaken in section 6.2. The main models to be explored are outlined in Chapter 3. A developmental model was explored in which skill acquisition is believed to occur on a linear and somewhat staged continuum, consistent with measurements of the extent of ability (disability) on different age-appropriately set tasks in comparison to a normative concepts/data. The process-oriented approach of Sensory Integration Theory is analysed in view of its impact on the therapy literature and clinical practice along with a neuropsychological model which places more emphasis on cognitive as well as perceptual skills thought to underpin and support motor action and movement organisation.

6.3.1 Developmental Model – Extent of motor impairment

Developmental models emphasise the importance of acquiring age appropriate competencies in skilled movement tasks (taking into consideration both speed and accuracy). Attainments with respect to the degree of overall motor ability were therefore plotted for each cluster group. Table 6.10 shows the representation of children in each cluster by the extent of their motor impairment as measured on the MABC total impairment score.

Cluster 1 had the majority of children with borderline motor difficulties (54%) with only 26% of children with the most profound problems (MABCTI \geq 20). Whereas, all of the children in Cluster 3 and Cluster 5 had severe difficulties, Cluster 5 was made up entirely of children with total impairment scores greater than 20.

Table 6.10 Comparison of extent of motor difficulty by cluster group

Cluster	Borderline MABCTI $\geq 10 \& \leq 13.5$	Definite MABCTI $14 \& \leq 17$	Severe MABCTI $> 17 \& < 20$	Profound MABCTI $\geq 20 \& < 30$	+Profound MABCTI ≥ 30
1 n = 35	19	7	5	4	0
2 n = 13	2	5	3	3	0
3 n = 10	0	0	1	7	2
4 n = 22	8	11	2	1	0
5 n = 11	0	0	0	6	5

This suggests that those children with poor static and dynamic balance, particularly those with weak visual perceptual functions (visual motor and visual spatial), are likely to have the most profound difficulties in a range of motor tasks to include ball skills. Discriminant analysis of whether severity of movement difficulty could predict cluster group correctly classified 45.1% of children. Chi² with Fisher Exact test (due to empty cells) was also significant reflecting the unequal distribution of movement severity between cluster groups [$\chi^2(16)=58.48; P < .001$]. The relationship of cluster type to severity of motor difficulty will be discussed further in relation to the outcome of those children participating in the treatment study (see section Part II – Outcomes).

6.3.2 Sensory Integration Theory

The main analysis up to this point has contrasted the clusters obtained from the current study to major published sub-typing studies particularly that of Hoare (1994). This has focussed on one model of motor impairment relating kinaesthetic, visual motor and visual spatial skills to manual and balance tasks. Of further consideration is whether children would be grouped similarly when different theoretical perspectives

— using different assessment procedures — are employed to identify movement difficulties. Despite a paucity of clinical evidence of treatment effectiveness, the theory of Sensory Integration (SI) has persisted over the past three decades as one of the most frequently used approaches for analysing and treating children with movement and learning problems (Mandich et al., 2001; B. Wilson et al., 1992; B. Wilson & Kaplan, 1994). Principal to this theory is the concept that the ‘integration’ of the senses, particularly tactile, proprioceptive and vestibular as well as visual and auditory, at a sub-cortical level is essential for skilled performance to emerge. Although the Sensory Integration and Praxis Tests (Ayres, 1989) were not used in the assessment of children in this study, comparable assessments were undertaken to include the six subtests of the Clinical Observations of Motor and Postural Skills (COMPS, B. Wilson et al., 1994) and representational (Rep) and non-representational (NonRep) gesture test (GT) as well as the Matrix Analogies Test (Naglieri, 1989) visual motor and visual spatial subtests of the Developmental Test of Visual Motor Integration (VMI, Beery, 1997) and balance items of the MABC. High et al. (2000) argued for the use of these or similar assessments to obtain information on sensory integrative dysfunction in children.

A preliminary factor analysis was undertaken on all the measures linked to SIT (computed from Z scores for the children with DCD $n=91$). The Kaiser-Meyer-Olkin (KMO) statistic was .713 and Bartlett’s Test of Sphericity was significant ($P<.001$) suggesting adequate sample size for these variables. Five factors emerged with an eigenvalue larger than one which explained 30.0%, 16.9%, 9.0%, 7.8% and 7.5% of the variance. Following orthogonal rotation (Varimax) it was clear that groups of variables were formed from: visual spatial and visuo-motor items: the COMPS proprioceptive and vestibular items; the gestural (praxis) items; COMPS Finger to nose, Asymmetric Tonic Neck Reflex (ATNR) and supine flexion items; and, the static and dynamic balance items (which formed a distinct group).

Ward’s Cluster analysis was used to identify groups of children forming clusters with the variables identified in the factor analysis. Data were available for 78 children. A

five cluster solution was used to correspond with the theoretical perspective (and factor analysis) of SI described in Chapter 3 and above.

Vestibular/proprioceptive deficits (n=16) = representational and non-representational gestures, prone extension, finger to nose, ATNR, supine flexion, static and dynamic balance were poor compared to visual spatial (MAT) and VMI tests.

Visual-praxis (n=14) = MAT, VMI, VMI Visual subtest (or MAT), VMI Motor Subtest.

Bilateral Integration and Sequencing (n= 27) = rapid forearm rotation, slow ramp movements and ATNR were weak in this group as were the visual spatial and visual motor tests of the VMI.

Somatodyspraxia (n=5) = relatively poor scores on representational and non-representational gestures, finger to nose or slow ramp movements, supine flexion, static and dynamic balance (no tactile tests were undertaken to verify this subtype).

Generalised SI dysfunction (n=16) = poor on all visual, sensori-motor and praxis items.

Discriminant analysis was run, contrasting these cluster groupings with those obtained via the original modelling technique, to ascertain whether the children remain grouped together despite a different theoretical approach to analysing their motor difficulties (see Table 6.11). The results of this discriminant analysis show only 44.9% of children to be correctly classified from the SI clusters to the original groupings.

Two SI clusters failed to predict the classification of any children into the original clusters. In view of the fact that individual detail is lost when test scores are aggregated, rather than contrast the defined clusters from the SI model to the original cluster groups, the individual tests from the model of SI were entered into a discriminant analysis and predicted better group membership (see Table 6.12).

Table 6.11 Discriminant analysis of SI groups to original clusters (n=78)

Original group	Predicted Group Membership from SIT cluster groups				
	1	2	3	4	5
Cluster 1 n= 29	20	0	3	0	6
Cluster 2 n = 12	6	0	3	0	3
Cluster 3 n = 9	0	0	4	0	5
Cluster 4 n = 21	3	0	7	0	11
Cluster 5 n = 7	1	0	4	0	2
% 1	69.0	0	10.3	0	20.7
% 2	50.0	0	25.0	0	25.0
% 3	0	0	44.4	0	55.6
% 4	14.3	0	33.3	0	52.4
% 5	14.3	0	57.1	0	28.6
44.9% of original grouped cases correctly classified					

Table 6.12 Discriminant analysis of SI variables to original clusters (n=88)

Original group	Predicted Group Membership from SIT variables				
	1	2	3	4	5
Cluster 1 n=33	22	5	1	4	1
Cluster 2 n = 12	0	10	0	1	1
Cluster 3 n = 10	0	0	7	0	3
Cluster 4 n = 22	0	1	0	20	1
Cluster 5 n = 11	1	0	1	0	9
% 1	66.7	15.2	3	12.1	3
% 2	0	83.3	0	8.3	8.3
% 3	0	0	70.0	0	30.0
% 4	0	4.5	0	90.9	4.5
% 5	9.1	0	9.1	0	81.8
77.3% of original grouped cases correctly classified					

Table 6.12 shows that the variables from an SI equivalent assessment are more efficient at predicting classification into original groups than the SI clustering model. See Appendix 9 for the standardised discriminant function coefficients (weights) and discriminant function loadings for these variables.

In order to contrast SI with a developmental model of skill attainment, the extent of children's motor impairment was plotted against their SI cluster group in Table 6.13.

Table 6.13 Comparison of extent of motor difficulty by SI cluster group

Cluster	Borderline MABCTI $\geq 10 \& \leq 13.5$	Definite MABCTI $14 \& \leq 17$	Severe MABCTI $> 17 \& < 20$	Profound MABCTI $\geq 20 \& < 30$	+Profound MABCTI ≥ 30
1 n = 16	8	4	2	2	0
2 n = 14	4	6	1	3	0
3 n = 27	7	8	3	6	3
4 n = 5	2	1	1	1	0
5 n = 16	3	3	3	4	3

These results are somewhat different to those of the original cluster analysis. The SI Cluster 2 identified children with visual spatial/visual motor problems as having relatively fewer problems across a range of manual dexterity, ball skills and balance items. The children with static and dynamic balance problems (SI cluster 5) without concomitant visual spatial and perceptual problems, were seen to have the greatest percentage of children with overall motor difficulties.

6.3.2.1 Section Summary

These results show that the variables from a Sensory Integrative theoretical perspective are stronger predictors of subtypes of motor performance than the clusters identified by the theoretical model of sensory integration. Performing the SI assessments would categorise the children differently from a theoretical basis than by their performance on individual tests.

6.3.3 *Cognitive (neuropsychological) models of motor impairment*

Over the past century psychologists and human movement scientists have investigated cognitive processes underpinning skilled motor performance (see Chapter 3). Central to current debates, is the discrepancy notion whereby specific developmental disorders of motor impairment are identified from a discrepancy between expected skills (based on overall intellectual quotient, IQ) and actual performance. In reality, researchers exclude children with intellectual quotients below 70 but do not address the discrepancy which may arise in children whose intellectual abilities are in the excellent to superior range but whose motor skills fall in the low average bands. As well as contrasting generalised intellectual ability to motor skill attainment, others have focussed attention on discrepancies between specific skills such as better language than visual processing ability (Rourke, 1989; Weintraub & Mesulam, 1983). In view of the relatively large sample size of the current study, data were analysed from a cognitive perspective. The variables measuring estimated verbal ability (BPVS scores), non-verbal reasoning (MAT: total standard score and subscales), visual motor and visual spatial ability (VMI and VMI visual subtests) and executive planning (representational and non-representational gesture) were included in a factor analysis, cluster analysis and discriminant analysis following the same procedures as for the SI data. Data were available for 85 children.

The Kaiser-Meyer-Olkin (KMO) statistic was .79 and Bartlett's Test of Sphericity was significant ($P < .001$) indicating an adequate sample size for these variables. Three

components were extracted with eigen values ≥ 1 . Following orthogonal rotation (Varimax) it was clear that three groups of variables were formed from:

- 1) the measures of estimated intellectual ability [verbal (BPVS) and non-verbal (MAT)] including three of the subscales of the MAT (reason by analogy, serial reasoning and spatial visualisation);
- 2) visual spatial, visuo-motor items, MAT pattern completion and verbal (BPVS) items; and,
- 3) executive planning tasks (gestural ability and pattern completion).

The first component (general intellectual functions) accounted for more than 40% of the variance. Although five clusters could be obtained via Ward's technique, the highest elevation (on the dendrogram) distinguished between only three groups of children. The discriminant function of the cognitive groups is poor, predicting membership of only two groups. Prediction was not improved by using the individual cognitive measures to predict membership to original cluster (see Tables 6.14 & 6.15).

Table 6.14 Discriminant analysis of 'Cognitive' groups to original clusters n=85

Original group	Predicted group membership from Cognitive cluster groups				
	1	2	3	4	5
Cluster 1 n= 32	25	0	0	0	7
Cluster 2 n = 12	8	0	0	0	4
Cluster 3 n = 9	2	0	0	0	7
Cluster 4 n = 21	8	0	0	0	13
Cluster 5 n = 11	0	0	0	0	11
% 1	78.1	0	0	0	21.9
% 2	66.7	0	0	0	33.3
% 3	22.2	0	0	0	77.8
% 4	38.1	0	0	0	61.9
% 5	0	0	0	0	100.0
42.4% of original grouped cases correctly classified					

Table 6.15 Discriminant analysis of 'Cognitive' variables to original clusters n=91

Original group	Predicted group membership from Cognitive cluster groups				
	1	2	3	4	5
Cluster 1 n = 35	18	11	4	2	0
Cluster 2 n = 13	5	3	4	0	1
Cluster 3 n = 10	1	3	2	2	2
Cluster 4 n = 22	5	3	3	2	9
Cluster 5 n = 11	0	2	2	0	7
% 1	51.4	31.4	11.4	5.7	0
% 2	38.5	23.1	30.8	0	7.7
% 3	10.0	30.0	20.0	20.0	20.0
% 4	22.7	13.6	13.6	9.1	40.9
% 5	0	18.2	18.2	0	63.6
35.2 % of original grouped cases correctly classified					

Correlation analyses of the MAT and BPVS standard scores were both *NEGATIVELY* associated with cluster groups (MAT $r = -.487, P = .001, n = 88$ and BPVS $r = -.374, P < .001$) suggesting children with better non-verbal and verbal skills are in Cluster 1 (the more mildly involved children). One-way ANOVA of MAT and BPVS standard scores showed a significant effect of cluster group [MAT: $F(4,83) 7.80, P < .001$; BPVS: $F(4,86) 4.89, P = .001$]. Using Hochberg post hoc procedure (due to unequal sample sizes but equal variance of scores between cluster groups) reinforced the view that children in Cluster 5 had the greater learning difficulties — including verbal, non-verbal and motor abilities (see Table 6.16). Cluster 5 differed significantly from Cluster 1 ($P < .001$), Cluster 2 ($P = .002$) and Cluster 4 ($P = .05$) on MAT standard scores (Cluster 4 also differed from Cluster 1, $P < .05$). Whereas on the BPVS, children in Cluster 1 had significantly better scores than children in Cluster 3 ($P = .05$) and Cluster 5 ($P < .01$).

Table 6.16 Means and standard deviations for MAT and BPVS standard scores for each cluster group

Cluster		1	2	3	4	5
MAT	Mean	101.19	98.31	92.2	91.81	79.73
	(<i>sd</i>)	(10.05)	(12.34)	(14.41)	(11.71)	(11.23)
BPVS	Mean	105.00	103.31	91.50	96.09	88.91
	(<i>sd</i>)	(13.14)	(14.32)	(8.28)	(12.50)	(16.10)

6.3.4 Summary of sub-typing analyses

Summarising these last sections suggests:

- There is only marginal stability of subtypes across the variables associated with different theoretical perspectives with even weaker association with clusters obtained from the different models;
- Discriminant function analysis of cluster groups, shows that children do not necessarily group together across different theoretical models;
- Children in the original Cluster 5 not only tended to be the most impaired in their motor skills, but they also had poorer visual perceptual skills which were associated with greater learning difficulties, both verbal and non-verbal, and were more likely to have a known co-morbidity.

6.4 Components of motor co-ordination – Relationship of perceptual, cognitive and motor planning/gesture abilities to motor performance

This section explores the relationship of the different testing variables to skilled motor performance. These variables were selected for testing in view of their historical association with theories of motor development as outlined in Chapter 3. Detailed analysis of the relationship of these variables was felt important in an attempt to understand the key components that may underpin competence in movement skills.

6.4.1 Cognitive abilities and visual perceptual functions

The relationship between cognitive abilities and visual perceptual functions and the impact these have on motor performance was explored through a Spearman rho correlation analysis [Non-parametric analyses were run to account for the lack of normality of the distributions of some of the data, especially the COMPS tests and NonRep GT subtest (due to two outliers)]. The matrix in Table 6.17 illustrates the relationship between cognitive functions, both verbal and non-verbal along with visual perceptual skills on children's ability to use tools and manipulate these dextrously. A high correlation is seen between non-verbal processing and visual spatial functions as would be predicted by the design of these tests (e.g. one of the MAT subtests specifically analyses the ability to process visual spatial relationships between objects). Both verbal and non-verbal abilities were linked to skilled manual dexterity as were visual motor and visual spatial skills but only the latter (visual spatial) was linked to the ability to throw and catch a ball. There were no other significant correlations between cognitive and perceptual functions and motor tests.

There were 37 completed self-esteem forms ('How I feel about myself', Warr & Jackson, 1983) from children with movement difficulties, only 12 of whom went on to participate in the intervention study. Therefore, detailed analysis of this measure was not undertaken as it was not possible to explore possible relationships between either subtype or outcome.

Table 6.17 Spearman Rho Correlation Matrix for Cognitive Variables, VMI, Visual and Motor Subtests and MABC total impairment, manual dexterity, ball skills and balance impairment scores

Standard scores	MAT	BPVS	VMI	Visual Subtest	Motor Subtest
BPVS	r= .499** p<.001 n= 88				
VMI	r= .495** p<.001 n= 88	r=.374** p<.001 n= 91			
Visual	r= .385** p<.001 n= 88	r=.346** p=.001 n= 91	r= .447** p<.001 n= 91		
Motor	r= .342** p<.001 n= 87	r= .301** p=.004 n= 90	r= .641** p<.001 n= 90	r=.379** p<.001 n= 90	
MABC TI	r= -.250* p= .019 n= 88	r=-.271** p=.009 n= 91	r=-.195 p=.065 n= 91	r= -.357** p=.001 n= 91	r=-.277** p=.008 n= 90
MABC Manual Dexterity	r= -.306** p= .004 n= 88	r=-.238* p=.023 n= 91	r=-.274** p=.009 n= 91	r= -.250* p=.017 n= 91	r=-.307** p=.003 n= 90
MABC Ball Skills	r= .005 p= .964 n= 88	r=-.149 p=.160 n= 91	r=-.013 p=.900 n= -1	r=-.248* p=.018 n= 91	r= -.036 p=.739 n= 90
MABC Balance	r= -.148 p= .170 n= 88	r= -.162 p= .124 n= 91	r= -.017 p=.873 n= 91	r=-.161 p=.128 n= 91	r= -.094 p=.376 n= 90

Bold text illustrates significant correlations: *=p<.05; **=p<.01

6.4.2 Cognitive abilities, kinesthesia, reflex integration and gesture

The Spearman Rho correlation analyses were expanded to include the perception of body movement, reflex integration and mime and imitation of body movement to motor skills.

The pattern of association seen in the correlation matrix of Table 6.18 shows the slow ramp movement and rapid forearm rotation tests of the COMPS to correlate with the visual subtest (SRM $r=.318, P=.002$; RFR $r=.285, P=.007$) and the RFR showed a weak association with the motor subtest ($r=.219, P<.05$) of the VMI. These two subtests require smooth sequencing of movements associated with cerebellar integrity as well as kinesthesia whereas the more predominate kinaesthetic test of finger to nose was only associated weakly with manual dexterity performance ($r=-.213, P<.05$). The COMPS subtests of Prone Extension, ATNR and Supine Flexion showed an association with the visual and motor subtests of the VMI but not with any motor performance item of the MABC. This is an interesting outcome in view of the hypothesised link with postural control (or strength) and reflex integration of these three subtests to motor performance.

Table 6.18 also illustrates a link between verbal reasoning and gesture production rather than the predicted link between gestural ability and internal modelling (visual spatial representation). The gesture test scores are predominately dependent on accuracy of spatial reproduction of movements towards the body or away from the body, some postures requiring a short repeated sequence (see Green et al., 2002b for details of scoring). Neither gesture subtest showed a correlation with motor performance. In view of the links between poor gesture ability and pervasive developmental disorder, removing these children from the analysis did not show any significant differences in means or standard deviations of representational or non-representational gesture test scores. Of note, are the lower mean scores on the gesture test of the current 'non-impaired' motor group (eg. children with MABCTI scores <10) and the 'control' group of non motor impaired children in Green (1997, see Table 6.19). Excluding the three children with PDD without motor impairment from the current group of children without movement difficulties did not change the means or standard deviations noticeably.

Table 6.18 Spearman Rho correlation matrix for all test variables

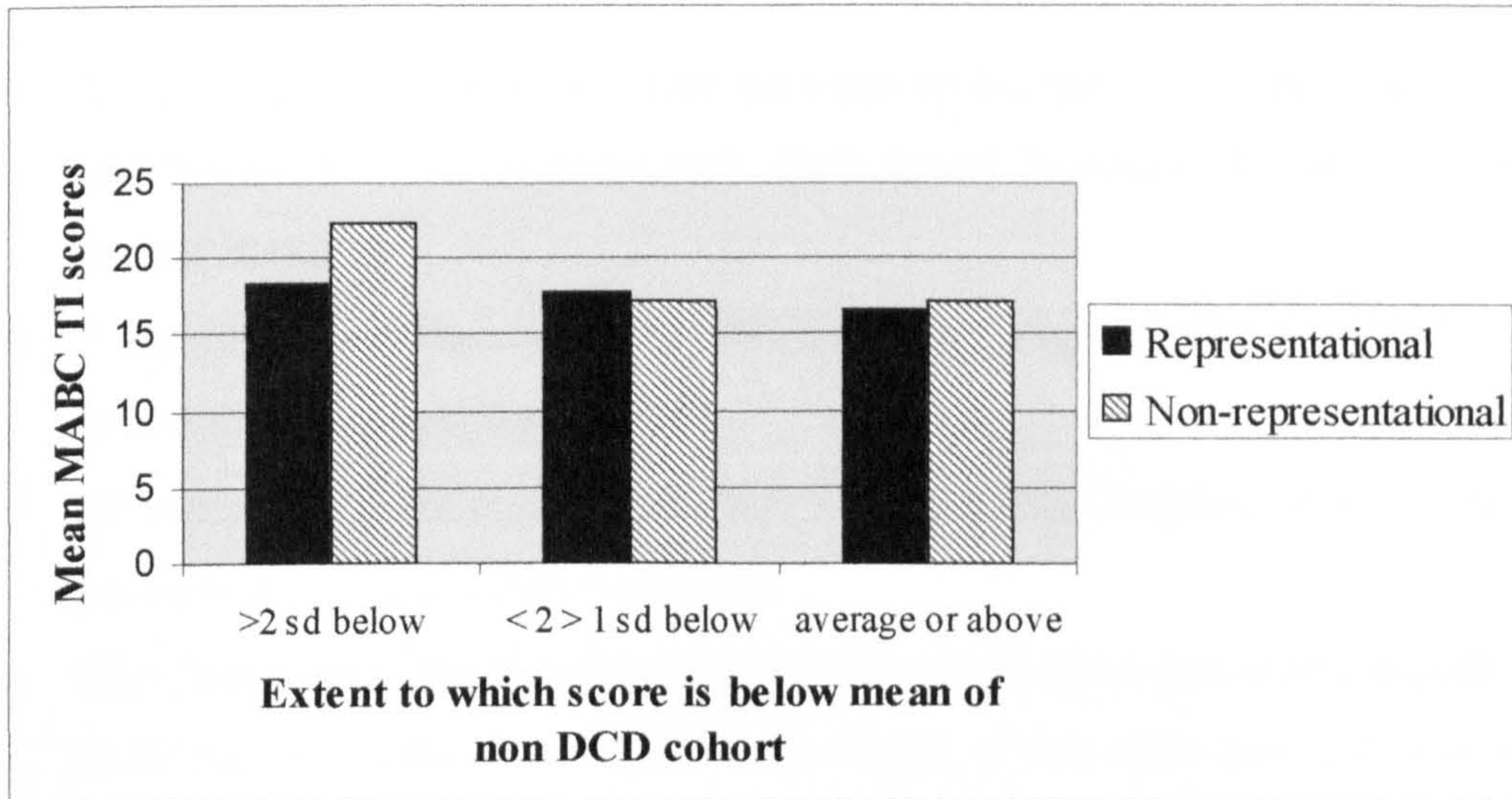
Standard scores	MAT	BPVS	VMI	Visual Subtest	Motor Subtest	Slow Ramp	RFR	Finger to Nose	Prone Ext	ATNR	Supine Flexion	Rep Gesture	NoRep Gesture
MAT						$r=-.133$ $p=.218$ $n=87$	$r=.048$ $p=.660$ $n=86$	$r=.031$ $p=.772$ $n=87$	$r=.186$ $p=.086$ $n=86$	$r=.070$ $p=.526$ $n=85$	$r=-.013$ $p=.906$ $n=84$	$r=-.047$ $p=.668$ $n=85$	$r=.229$ $p=.035$ $n=85$
BPVS	$r=.499$ $p<.001$ $n=88$					$r=-.036$ $p=.737$ $n=89$	$r=.062$ $p=.567$ $n=88$	$r=.111$ $p=.300$ $n=89$	$r=.148$ $p=.178$ $n=84$	$r=.018$ $p=.872$ $n=83$	$r=.011$ $p=.922$ $n=82$	$r=.218$ $p=.043$ $n=86$	$r=.244$ $p=.024$ $n=86$
VMI	$r=.495$ $p<.001$ $n=88$	$r=.374$ $p<.001$ $n=91$				$r=.123$ $p=.250$ $n=89$	$r=.175$ $p=.102$ $n=88$	$r=.159$ $p=.137$ $n=89$	$r=.062$ $p=.569$ $n=86$	$r=.271$ $p=.012$ $n=85$	$r=-.051$ $p=.646$ $n=84$	$r=.072$ $p=.528$ $n=86$	$r=.234$ $p=.030$ $n=86$
Visual	$r=.385$ $p<.001$ $n=88$	$r=.346$ $p=.001$ $n=91$	$r=.447$ $p<.001$ $n=91$			$r=.318$ $p=.002$ $n=89$	$r=.285$ $p=.007$ $n=88$	$r=.154$ $p=.151$ $n=89$	$r=.246$ $p=.023$ $n=86$	$r=.114$ $p=.299$ $n=85$	$r=.131$ $p=.234$ $n=84$	$r=.168$ $p=.121$ $n=86$	$r=.190$ $p=.080$ $n=86$
Motor	$r=.342$ $p<.001$ $n=87$	$r=.301$ $p=.004$ $n=90$	$r=.641$ $p<.001$ $n=90$	$r=.379$ $p<.001$ $n=90$		$r=.199$ $p=.062$ $n=88$	$r=.219$ $p=.041$ $n=87$	$r=.143$ $p=.184$ $n=88$	$r=.466$ $p<.001$ $n=86$	$r=.296$ $p=.006$ $n=85$	$r=.372$ $p<.001$ $n=84$	$r=.167$ $p=.124$ $n=86$	$r=.173$ $p=.112$ $n=86$
MABC TI	$r=-.250$ $p=.019$ $n=88$	$r=-.271$ $p=.009$ $n=91$	$r=-.195$ $p=.065$ $n=91$	$r=-.357$ $p=.001$ $n=91$	$r=-.277$ $p=.008$ $n=90$	$r=-.220$ $p=.038$ $n=89$	$r=-.212$ $p=.048$ $n=88$	$r=-.181$ $p=.090$ $n=89$	$r=-.270$ $p=.012$ $n=86$	$r=-.114$ $p=.301$ $n=85$	$r=-.142$ $p=.197$ $n=84$	$r=-.064$ $p=.558$ $n=86$	$r=-.184$ $p=.090$ $n=86$
MABC Manual Dexterity	$r=-.306$ $p=.004$ $n=88$	$r=-.238$ $p=.023$ $n=91$	$r=-.274$ $p=.009$ $n=91$	$r=-.250$ $p=.017$ $n=91$	$r=-.307$ $p=.003$ $n=90$	$r=-.175$ $p=.101$ $n=89$	$r=-.138$ $p=.200$ $n=88$	$r=-.213$ $p=.045$ $n=89$	$r=-.190$ $p=.079$ $n=86$	$r=-.185$ $p=.091$ $n=85$	$r=-.206$ $p=.060$ $n=84$	$r=-.054$ $p=.618$ $n=86$	$r=-.155$ $p=.154$ $n=86$
MABC Ball Skills	$r=.005$ $p=.964$ $n=88$	$r=-.149$ $p=.160$ $n=91$	$r=-.013$ $p=.900$ $n=-1$	$r=-.248$ $p=.018$ $n=91$	$r=-.036$ $p=.739$ $n=90$	$r=-.069$ $p=.518$ $n=89$	$r=-.172$ $p=.108$ $n=88$	$r=-.012$ $p=.911$ $n=89$	$r=-.107$ $p=.326$ $n=86$	$r=.041$ $p=.713$ $n=85$	$r=.104$ $p=.345$ $n=84$	$r=-.016$ $p=.883$ $n=86$	$r=-.087$ $p=.424$ $n=86$
MABC Balance	$r=-.148$ $p=.170$ $n=88$	$r=-.162$ $p=.124$ $n=91$	$r=-.017$ $p=.873$ $n=91$	$r=-.161$ $p=.128$ $n=91$	$r=-.094$ $p=.376$ $n=90$	$r=-.149$ $p=.163$ $n=89$	$r=-.143$ $p=.184$ $n=88$	$r=-.095$ $p=.375$ $n=89$	$r=-.152$ $p=.162$ $n=86$	$r=-.073$ $p=.509$ $n=85$	$r=-.144$ $p=.192$ $n=84$	$r=-.041$ $p=.707$ $n=86$	$r=-.112$ $p=.305$ $n=86$

Italic blue text = $P<.05$; Bold blue text = $P<.001$

Table 6.19 Means and Standard Deviations of the Gesture Test items for non-DCD children – past and current study

Means (<i>sd</i>)	Non-DCD (Green, 1997) N=20	Non DCD current N=30
Representational Gesture	35.56 (2.83)	31.05 (5.83)
Non Representational Gesture	33.30 (2.96)	32.88 (3.13)

The notion of whether a ‘dyspraxic’ subtype, (a group of children with particularly poor gestural ability) exists amongst children with DCD, was explored by investigating the extent to which representational or non-representational gesture problems contributed to poor motor performance. Using the means from the Non-DCD children aged 7-11 from Green’s earlier (1997) study on gesture, children were ranked as to whether they were more than 2 standard deviations below the mean, between 1 and 2 sd below or average/above average compared to the 1997 non-DCD cohort. A 2 (gesture type) by 3 (extent of gesture deficit) ANCOVA was performed with verbal and non-verbal processing ability entered as covariates (in view of their significant correlations with non-representational gestures, see Table 6.18) to determine effect of gesture problems on MABC total impairment scores. There was a main effect of non-representational gesture problems (>2 sd from Green’s 1997 mean) to motor impairment [$F(2,86) 3.61, P<.05, \eta^2 =.084$]; MAT standard scores contributed significant co-variance [$F(1,88) 5.29, P=.02, \eta^2 =.063$] and a significant corrected overall main effect [$F(9,79) 2.79, P<.01, \eta^2 =.242$]. These scores are illustrated in Figure 6.7. [Note: the presence of two outliers with low non-representational gesture test scores, which had skewed the distribution of raw scores, did not effect the results of this analysis which placed these two children in the group >2 sd below the 1997 mean].

Figure 6.7 Influence of Gesture on Motor Performance

Comparing the relationship of the testing variables of the motor impaired sample (DCD +/- co-morbidity) to the entire group containing those children without motor impairment did not show any startlingly different associations. Cognitive (verbal and non-verbal) items and VMI showed the strongest association with motor performance across all skills. The kinaesthetic and sequencing items of the COMPS showed an association with overall motor skill (MABCTI) and manual dexterity and the RFR was also linked to static balance but not dynamic balance. There were much stronger links of verbal reasoning (BPVS) to mime (representational gesture) and imitation (non-representational gesture).

6.4.3 *Section summary*

Analysis of the various components hypothesised to underpin skilled motor performance showed:

- A significant correlation was seen between verbal and non-verbal cognitive abilities and both visual motor and visual spatial functions with tasks involving manual dexterity;
- A significant correlation was identified between visual spatial functions and the ability to throw and catch a ball;
- No other significant correlations were found between cognitive and visual-perceptual abilities and motor skills;
- Significant associations were seen between visual and kinaesthetic sequencing skills that were related to overall motor ability with a slight association of the kinaesthetic test of Finger to Nose of the COMPS correlating with manual dexterity tasks;
- Gesture subtests correlated with cognitive measures, particularly, representational gesture to verbal ability and non-representational gesture to both verbal and non-verbal ability;
- Reflex integration as tested through the COMPS subtest of ATNR, did not correlate with tests of motor execution;
- A non-representational (dyspraxic) subtype showed more impaired motor skills.

6.5 Part II – Outcomes

6.5.1 Description of participants

The following section will describe the subjects who participated in the second part of this project — the intervention study.

In order to identify factors which might influence, not only response to treatment but also developmental outcome, all children under the age of 10 years 6 months who had been identified as being at risk or having a motor difficulty, irrespective of presence of known co-morbidity, were invited to participate in a two year intervention study (n=78). From this group, 47 families responded, 43 of these were able to commit to the project. There were no differences between the group of children whose families chose to participate in the two year treatment study and those who did not with respect to the extent of motor impairment on the MABC total impairment score, estimated verbal intelligence (BPVS standard score), identified co-morbidity, age or Townsend scores [$t(df\ 77) < 1.5, P > .05$ on these measures] (see Table 6.20). The length of time families had been on the initial occupational therapy waiting list emerged as a factor in families' willingness to participate in the treatment study [$t(df\ 77) = 3.82, P < .001$]. Participating families waited on average 9 months (sd= 5.76) as compared to an average waiting time of 14 months (sd = 6.57) for non-participating families. Of note however is the significant difference between groups on parents' report of the degree to which their child's motor difficulties may impact on skills at home and school (Developmental Coordination Disorder Questionnaire [DCDQ] total scores). Families opting in to the treatment project tended to rate their child's difficulties as slightly more severe [$t(73) -1.98, P = .052$]. No further details are available on the families who did not take up the option to participate in the treatment study although it may be surmised that a number of these families may have relocated during the preceding two years.

Table 6.20 Intervention Study, Sample Characteristics – Means (ranges)

	Age	BPVS	MABC-TI	DCDQ	SES (Townsend)
Participating DCD group n=43	97.7 (62-128)	99.42 (78-132)	18.7 (10-34)	39.3 (21-57)	-0.55 (-5 to 7)
Non- Participating DCD group n=35	97.0 (68-127)	98.86 (71-131)	16.46 (10-33.5)	43.9 (25-65)	-0.81 (-5 to 6)

Of the 43 families and children participating in the intervention project most were able to attend all 6-monthly review sessions, undertaken over a period of 2 years (an additional 3 months was required to collect outstanding data from the last test point). At the final testing point, 36 children were able to participate in the direct clinical assessment of their motor skills. This represents 84% of the original sample. This is fractionally less than the original estimate of attrition at 20%. The recommended sample size of 37 subjects was met for the first four review periods (minimum of 40 children attending for assessment) with 36 at the final session which is attributed to a number of different factors for the 7 children not completing the study.

Some children were unable to attend set follow-up appointments and, when possible to schedule, were seen individually either by the author (therefore not blind to treatment status) or another senior therapist (blinded to treatment status). Over the course of the study, 15 children were seen for an individual review with an average of 4 children at any one test point. Two further children had two individual assessments necessitated by moves out of area/family circumstances.

Furthermore, due to a number of different reasons there were occasions when incomplete data was collected for those children who attended for the 6 month clinical review. One child had refused to undertake any task involving a pencil until the very

last session. For some, family or other commitments resulted in them leaving the assessment session early. To accommodate those parents who had other obligations during the clinical review and were unable to stay at the clinic to complete the questionnaires during this period — stamped addressed envelopes were provided to encourage submission of these forms. There were a few occasions when these forms were not returned. Most of the children completed all tests during the clinical review. Although on some tests, particularly the self-esteem questionnaire, there were errors in completing the form which resulted in an inability to compute a total score. Despite these difficulties, at the final testing point 36 children were able to attend for clinical review and undertook most assessments with 35 parents completing questionnaires. Of these children, 36 also completed the handwriting test, 35 the self-esteem, personal construct and resilience questionnaires and 33 undertook a reading test. There were some assessment points when all three BO subtests were not undertaken for all children due to difficulties accessing sufficient running space. Data collection details are summarised in Table 6.21.

Attendance over the 20 week 'Detective Club' sessions varied although all managed more than 50% with the majority attending 16 out of 20. Two children, from different younger groups, appeared to find the group format difficult with evidence of anti-social behaviour (eg. oppositionality, kicking other children in the genitals, shouting/swearing). Following discussion with their parents, it was agreed to remove these two children from the group and set them a task to be undertaken as a 'Private Detective'. One of these children is suspected of having AS and the other has since been identified with a social impairment and emotional adjustment disorder. Both children continued to participate in the six monthly reviews. One of the older groups (Group D), showed evidence of difficult group dynamics, one boy in particular was consistently rude to the only girl in the group. As a result, the tasks chosen by the children in sessions 12-17 were undertaken individually with the final 2 sessions undertaken as a group.

Table 6.21 Details of numbers of children/families completing data over 2.3 years

Test point	MABC	DCDQ	BOTMP	HW	CSQ	PONS	SDQ	WORD
Winter 2003	42	38	37*	40	39	35	42	n/a
Summer 2003	41	39	40	40	38	38	n/a	n/a
Winter 2004	42	42	40*	41	41	38	n/a	n/a
Summer 2004	40	40	40	40	40	40	n/a	n/a
Winter 2005	36	35	36*	36	35	35	35	33

* not all the children undertook all three subtests of the BO at this test point (maximum missing number three children failing to complete one subtest at designated test point).

DCDQ = Developmental Coordination Disorder Questionnaire; BOTMO = Bruininks Oseretsky Test of Motor Proficiency Subtests; HW = Handwriting sample; CSQ = Coordination Skills Questionnaire; SDQ = Strengths and Difficulties Questionnaire.

6.5.2 *Influence of degree of motor difficulty on outcome*

The next section will report on overall outcome with respect to the extent of the motor difficulty as documented at the initial assessment. Children who made progress by maturation only will be contrasted with those who made progress only after intervention. The same classification of the extent of motor difficulties was used as outlined in Table 6.3 in which percentile rankings of the MABC total impairment score contributed to severity rating: Borderline scores represent the 6-15th percentile; Definite scores between the 2 and 5th percentile; and, Severe scores represent less than the 2nd percentile.

The initial screening project took 2 ¼ years and those children who had been seen for their initial assessment more than 6 months before commencement of the intervention study had repeat assessments undertaken (32 out of 43 children). Nine of the children having repeat assessments prior to the intervention study had worse skills on reassessment (one category worse). Seven children had made some progress in this period, however four of these seven children were observed to get worse prior to their intervention block, demonstrating a fluctuating rather than remitting natural course. The remaining 16 children showed no significant change in the period between their initial assessment and the pre-intervention study tests. Only 3 of the 32 children showed sustained maturational progress prior to their receiving intervention. Table 6.22 illustrates the outcome from initial assessment to final testing. [Borderline scores are categorised as band 1, definite as band 2 and severe as band 3].

At the beginning of the intervention study there were 11 children in the borderline group, 6 in the definite group and 25 in the severe group (see Table 6.22b). [*One child had made progress from his initial assessment the year before to show no impairment at the pre-intervention study phase. This child also had a diagnosis of ADHD and his assessment performance may have been dependent on whether it was a morning or afternoon session and dosage of Ritalin (his parents had continued concerns about the stability of his performance over time and requested he be included in the treatment study)]. At the end of the two years, 29 children had made progress over this period, 10/43 (23%) of whom improved without or prior to intervention being provided.

Improvements in the degree of motor deficit experienced by 19 of the 43 children in response to treatment were substantial with 11 of the children without measurable deficits in motor co-ordination following intervention. However, 4 children showed poorer motor skills at the end of this period (two of whom experienced adverse family events and one who appeared to have had a significant growth spurt) and 10 remained in the same category (six of these ten children had shown the most severe difficulties at the onset of the study and remained in that category). Tables 6.22 and 6.22b

illustrate the outcome of children from each of their initial and pre-treatment categories.

Table 6.22 Intervention Study – Change in extent of motor deficits from initial assessment to end of intervention project

Intervention Study n=43	No deficit (>15 th %ile)	Borderline (6-15 th %ile)	Definite (2-5 th %ile)	Severe (<2 nd %ile)
Initial category	0	11	12	20
Final category	15	8	12	8
Wilcoxon: negative ranks n=30, positive ranks n= 5, ties n = 8 Z = -4.34, P<.001				

Table 6.22b Intervention Study – Extent of motor deficits from pre-intervention assessment to end of intervention project

Intervention study n=42	No deficit (>15 th ile)	Borderline (6-15%ile)	Definite (2-5 %ile)	Severe (<2 %ile)
Initial category	1*	11	6	25
Final category	15	8	12	8
Wilcoxon: negative ranks n=29, positive ranks n= 4, ties n = 10 Z = -4.16, P<.001				

note: Wilcoxon analysis for initial MABC TI scores to final: Z = -3.53, P<.001

Wilcoxon analysis for pre-treatment MABC TI scores to final: Z = -3.62, P<.001

Table 6.23 illustrates the percentages of children making progress or getting worse dependent on initial severity of motor impairment. Please note that with the small numbers in some of the categories, one child showing a different response may shift the percentages from 9-25%.

Table 6.23 Numbers (*percentages*) of children changing category

Initial category	Worse	%	Same	%	Improved	%	Initial total
Borderline	3	27	2	18	6	55	11*
Definite	1	17	1	17	4	67	6
Severe	0	0	6	24	19	76	25
Final total	4	10	9	21	29	69	42

*excluding the child with ADHD whose medication may have influenced motor skills

Table 6.23 shows that 69% of children made measurable progress during the period of the intervention study. Table 6.24 and Figure 6.8 illustrate how many children made maturational change as opposed to responding to treatment. Table 6.24 illustrates the variable nature of progress with or without treatment. Although the motor difficulties of more children in the borderline group resolved by maturation alone, two of these 11 children got worse without intervention and one had poorer motor skills at the end of the study. The evidence from Tables 6.24 and 6.25 also suggests that children with the most severe motor difficulties are the most likely to require intervention. However, a more mild initial presentation does not necessarily mean that maturation will be sufficient to overcome the child's difficulties.

As attendance during the 20 week 'Detective Club' sessions had varied, overall progress (same/worse or improved) was contrasted with percentage of attendance with the 14 children who attended less than 75% of sessions compared with the 25 who attended 15 or more sessions ($\geq 75\%$). Chi² analysis was not significant ($\chi^2 = 0.56$, $P > .05$). It was not possible to identify which sessions may have been instrumental in assisting children to apply CO-OP strategies across tasks and potentially contributed to progress despite attendance at fewer sessions, although all children were recorded as having attended the first sessions in which the global strategies of the CO-OP were taught with their parents present.

Table 6.24 Numbers (percentages) of children changing category by the end point
Change pre (maturational progress) and post intervention

Category		Worse	%	Same	%	Improved	%
Borderline n=12	Pre	2	18	1	9	6	45
	Post	1	9	1	9	1 (+2)* ^W	18
Definite n=6	Pre	(1)* ^F	(17)	1	17	1	17
	Post	1	17	0	0	4	67
Severe n=25	Pre	n/a		(6)	(24)	4	16
	Post	n/a		(6)	(24)	15	60
Total n=43	Pre	2	7	2+(6)		10	23
	Post	2	5	1+(6)	21	19	44

*^W 2 children got worse prior to treatment and improved after

*^F 1 children got worse prior to treatment and fluctuated to show overall progress by the end

Table 6.25 illustrates the fluctuating development that a number of children had with or without treatment. In the severe group, six children made good progress prior to intervention, two of these families subsequently decided against participating in the 20 week treatment programme due to the time commitment to attend the intervention groups. One child maintained this progress following treatment. Three children in this category worsened after treatment although two improved six months post treatment and one showed a fluctuating course. Six of the children remained in the severe category, seemingly having the most intractable difficulties before and after treatment.

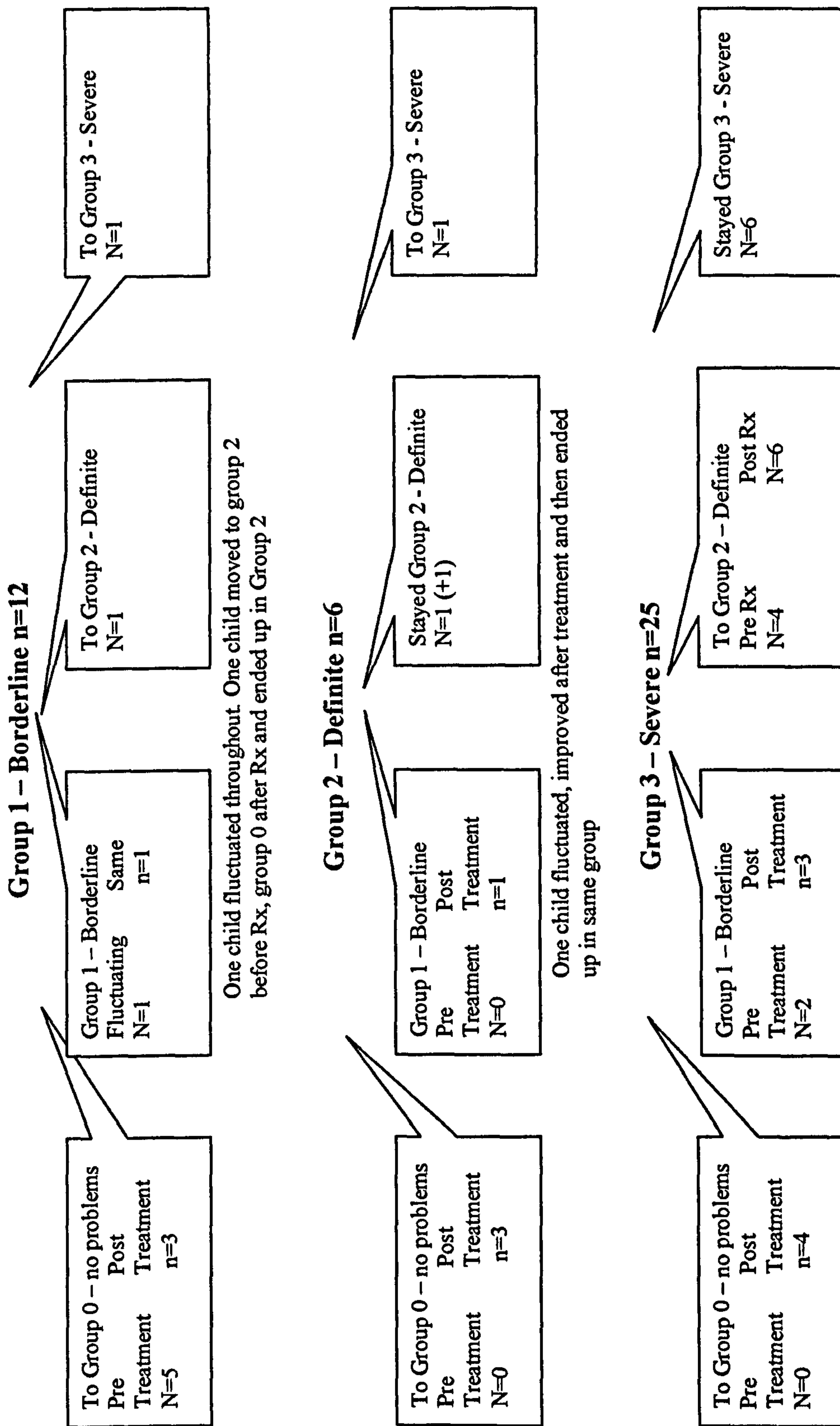
Table 6.25 Changes in motor status prior to treatment (maturation), response to treatment and progress following treatment

Initial	Maturation	Response to treatment	Sustained	Final Count
Borderline n=12*	4 improved 3 same 2 worse 2 fluctuated	3 improved 5 same 2 worse	8 same 1 worse 2 fluctuated	No problem n=8 Borderline n=2 Definite n=1 Severe n=1**
Definite n=6	1 improved 4 same 1 worse	4 improved 1 same 1 worse 1 no treatment	2 continued progress 0 same 1 worse 3 fluctuated	No problem n=3 Borderline n=1 Definite n=1 Severe n=1**
Severe n=25	6 improved 13 same 5 worse 1 fluctuated	13 improved 8 same 3 worse 3 no treatment	6 continued progress 9 same 1 worse 5 fluctuated 4 no follow-up	No problem n=4 Borderline n=5 Definite n=10 Severe n=6

*including child with ADHD whose medication may have influenced performance

** children suffered adverse family events during study

Figure 6.8 Category change of children during intervention study (based on pre-intervention study results)



The numbers of children making progress pre/post intervention in Figure 6.8 are slightly different from those in Table 6.24 due to some of these children continuing to make progress following treatment or who did not sustain maturational/intervention gains. In the borderline group, 3 out of 4 children sustained their initial maturational progress following treatment. 3 additional children showed a positive response to treatment, two of whom were able to maintain this. One of the children remaining in the borderline group at the end of the study, performed very well in the winter testing session (total impairment scores ranging from 5.5 to 13) with a much poorer performance documented consistently in summer holiday testing periods (total impairment scores ranging from 15 to 22). Three children had overall higher impairment scores by the end of the study although one of these children had made a good initial response to treatment (this child has since been diagnosed with AS). One of the children apparently worsening over time had suffered significant family disruption following parental divorce and two moves of home and school.

One of the six children with definite motor difficulties was seen to improve prior to treatment with three children benefiting from the intervention project. The one child remaining in this group showed a fluctuating course. He was extremely active although not diagnosed with ADHD. He showed a number of medical conditions most notable being food intolerance and a failure to thrive. His problems were reported to be seasonal with better performance in the summer. The child whose motor impairment scores worsened coincided with a move to secondary school and testing in Age Band 4. This child had been born prematurely with prolonged hospitalisation at birth. He had a diagnosis of ADHD and was well maintained on Ritalin. This child also had a brother with severe multi limb cerebral palsy and both parents were dyslexic.

Of the eight children who were in the severe motor impairment category at the end of the study, five had shown negligible progress throughout the study. Four of these children were known to have co-morbid conditions of ADHD, AS, Cardiac difficulties and Pierre Robin Syndrome³. One of the six, had resolving faecal incontinence and

had been progressing well throughout the study until the last session when moved up to age band 3 (MABC TI scores over time, 22.5; 18.5; 18.5; 15; 9; 30). The other child had moved out of area prior to his intervention block and was known to have been bullied at his new secondary school (follow-up data was obtained through the families continued participation in the monitoring programme). Of the two children who transferred into the severe group, one was known to have a very complex developmental history and the other child had had confounding social factors. There were two children who moved from the borderline group to the definite group by the end of the project. One child had initially made good progress to treatment but failed to sustain this (diagnosed with AS during the project). There are no known co-morbid, developmental or social factors which may have contributed to the other child's deterioration in performance. His worsening in performance corresponded with a change in age band from age band 3 to age band 4. There was a marked contrast in the static and dynamic balance subtest total from that of 1.5 on age band 3 to 12 on age band 4 (and 8 on six month follow-up). This child was also suspected of having had a significant growth spurt.

6.5.2.1 Summary of progress in relation to extent of initial motor impairment

In summary, 67% of children made progress over 2 ½ years; 21% of children remained in the same motor impairment category; and 10% of children were worse. A significant number of children benefited from participation in the study (Wilcoxon $Z = -4.16$, $P < .001$). Nearly twice as many children benefited from treatment than those who improved by natural maturation. Across all categories, 31% more children made progress following treatment (19 out of 29) as opposed to general maturation (10 out of 29). The greater number of children making progress following treatment was significantly more than those children who made no progress or progressed without treatment [$\chi^2(3) 10.67$, $P = .01$; K-S statistic $Z(43) 1.76$, $P < .01$]. The severity of motor deficit suggested a greater need for intervention as maturation alone was insufficient to overcome the extent of motor problems, however similar proportions of children from each category made

progress by maturation, response to treatment or had a fluctuating developmental course.

The next section will consider whether the profile of perceptual-motor difficulties is predictive of outcome.

6.5.3 *Influence of profile of perceptual motor skills (subtype) on outcome*

The major focus of this thesis was to explore the impact of qualitative aspects of movement on outcome as well as the degree of motor difficulty at initial clinical presentation. Part I of the project investigated qualitative distinctions of motor performance by identifying five relatively distinct clusters. This next section explores the impact of these subtypes/cluster groupings on outcome with and without treatment. The degree of change in motor ability that the children in each of the clusters made is set out in Tables 6.26 and 6.27 and Figure 6.8.

Table 6.26 Numbers of children improving (n=29), remaining the same (n=10) or getting worse(n=4)

Cluster	Worse	No Change	Improved 1 Severity level	Improved 2 Severity levels	Improved 3 Severity levels
1 n=14		3	8	2	1
2 n=9	2	1	3	2	1
3 n=5			4	1	
4 n=10	2	3	1	2	2
5 n=5		3	1	1	
Total n = 43	4	10	17	8	4

Table 6.27 Comparison of the extent of motor difficulty post-intervention by cluster group

Cluster	None MABCTI <10	Borderline MABCTI ≥ 10 & < 13.5	Definite MABCTI ≥ 13.5 & <17.5	Severe MABCTI ≥ 17.5 < 20	Profound MABCTI ≥ 20 & <30	+Profound MABCTI ≥ 30
1 n=14	8	3	2			1
2 n=9	2	3	3		1	
3 n=5		1	4			
4 n=10	4		3		3	
5 n=5		1	1		3	
Total n=43	14	8	13		7	1

Looking at the degree of deficit at the final testing point by cluster group, Clusters 4 and 5 continue to have the most children showing the higher degree of deficit. Table 6.28 shows each cluster group's maturation and response to treatment in more detail (change is recorded by ≥ 5 points on the MABC in a positive or negative direction if a category change has not occurred). Proportionally more children in Clusters 2, 4 and 5 made little or no progress without treatment with the majority of children in Cluster 2 getting worse prior to their intervention block. In contrast the children in Cluster group 2 responded well to treatment as did children in Clusters 1 and 4, although the children in Clusters 2 and 4 had greater difficulty sustaining their progress following treatment. Proportionally fewer children in Clusters 3 and 5 responded to treatment, with more children in Cluster 5 continuing to have difficulties at the end of the study. This may provide some evidence that visual perceptual problems may be associated with a poorer outcome, with or without treatment and/or associated with co-morbidity.

Table 6.28 Comparison of maturation and response to treatment by cluster
 Numbers of children getting better, worse or remaining the same

Cluster	Pre-treatment			Post-treatment			Sustained			Overall progress		
	+	-	=	+	-	=	+	-	=	+	-	=
1 n=14	4	4	6	7	1	5	3	1	7	9	0	5
2 n=9	1	7	1	5	3	1	2	2	3	5	1	3
3 n=5	2	0	3	1	3	0	2	1	1	4	0	1
4 n=10	2	4	4	5	1	3	4	2	2	5	2	3
5 n=5	0	2	3	1	1	2	1	0	2	2	1	2

+ = better, - = worse, = = same or fluctuating

Figure 6.9 Profile of change over time in mean MABC TI scores for each cluster group

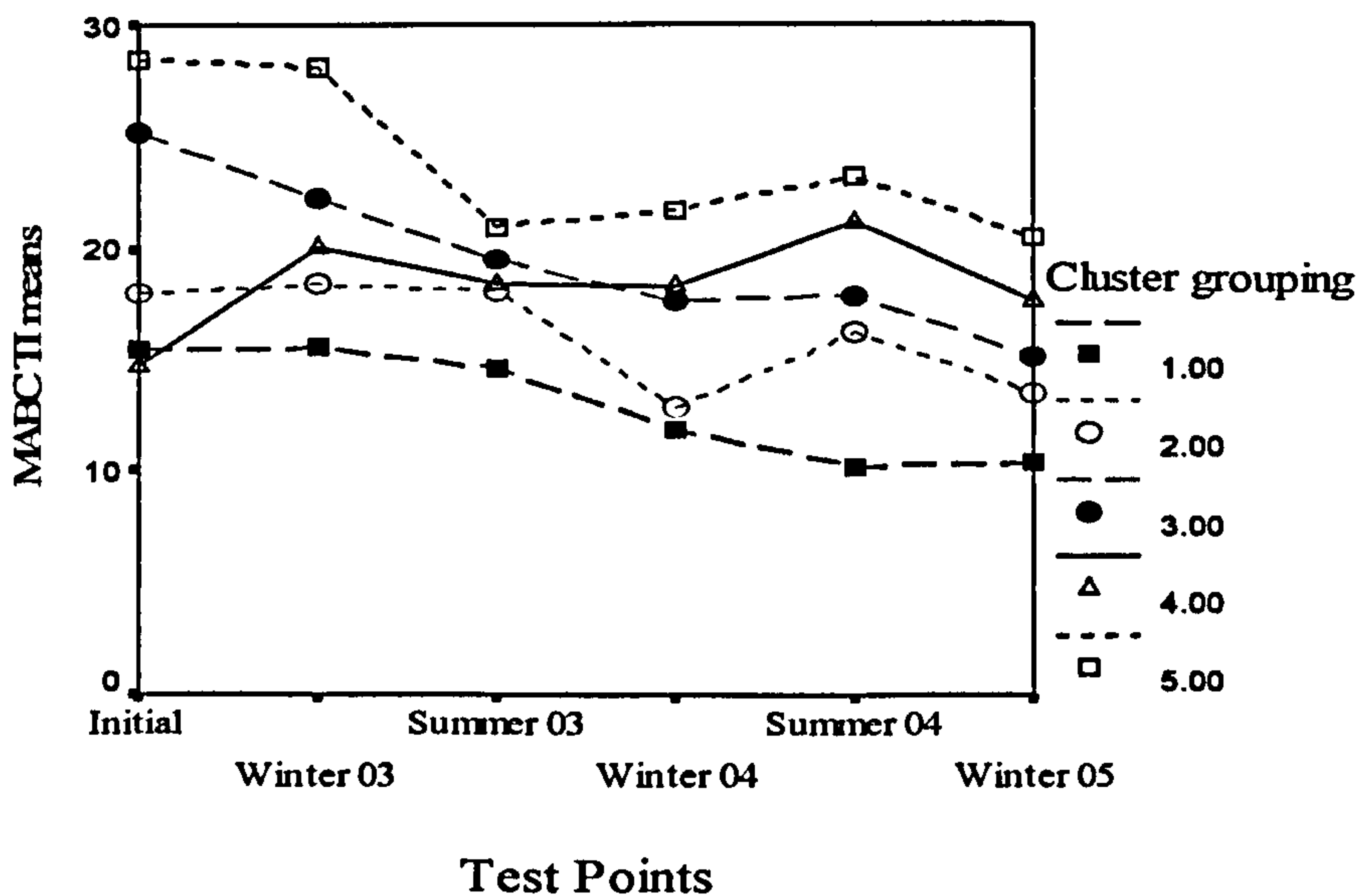


Figure 6.9 above shows the mean progress over time of the children in each cluster group as tested on the MABCTI. Repeated measures ANOVA showed a difference between cluster groups [$F(4,31) 4.04, P < .01, \eta^2 = .343$] with cluster 5 consistently having the greater degree of difficulty in comparison to cluster 1. Mauchly's test of sphericity was significant for MABCTI scores over time and therefore the Greenhouse-Geisser statistic was used which showed a main effect of progress over time [$F(13.34,103.4) 5.03, P < .01, \eta^2 = .14$]. There was no interaction between MABCTI score change and cluster group [$F(13.34, 103.4) 1.19, P > .05, \eta^2 = .133$].

Visual analysis of each subject's progress over time and their relative performance on different movement functions (manual dexterity, ball skills and balance tasks) shows a possible greater variability in Cluster 3 with and without treatment (see Appendix 10). All of the five children in Cluster 3 showed a changing pattern of strengths and weaknesses in motor tasks whereas 11/14 children in Cluster 1 and 5/5 children in Cluster 5 maintained a fairly similar profile with subtle changes following treatment. This would be consistent with the variability in the original cluster analyses – that is, there is a group of children (Cluster 3) whose performance and developmental trajectory is less predictable.

Comparing the clusters to outcome through discriminant analysis had limited predictive value of which children would make progress without treatment, with only 39.5% of children correctly classified. The results are virtually the same if the original testing variables, rather than cluster groups, were entered into the analysis.

6.5.3.1 Section Summary

Analysis of the qualitative differences between groups of children with DCD — comparisons of the cluster groups in relation to outcome — did not illuminate any factor which would predict which children would be most likely to mature without intervention nor those who might benefit more from treatment. Children in Clusters 4 and 5 continued to have the greater degree of motor deficit at the final

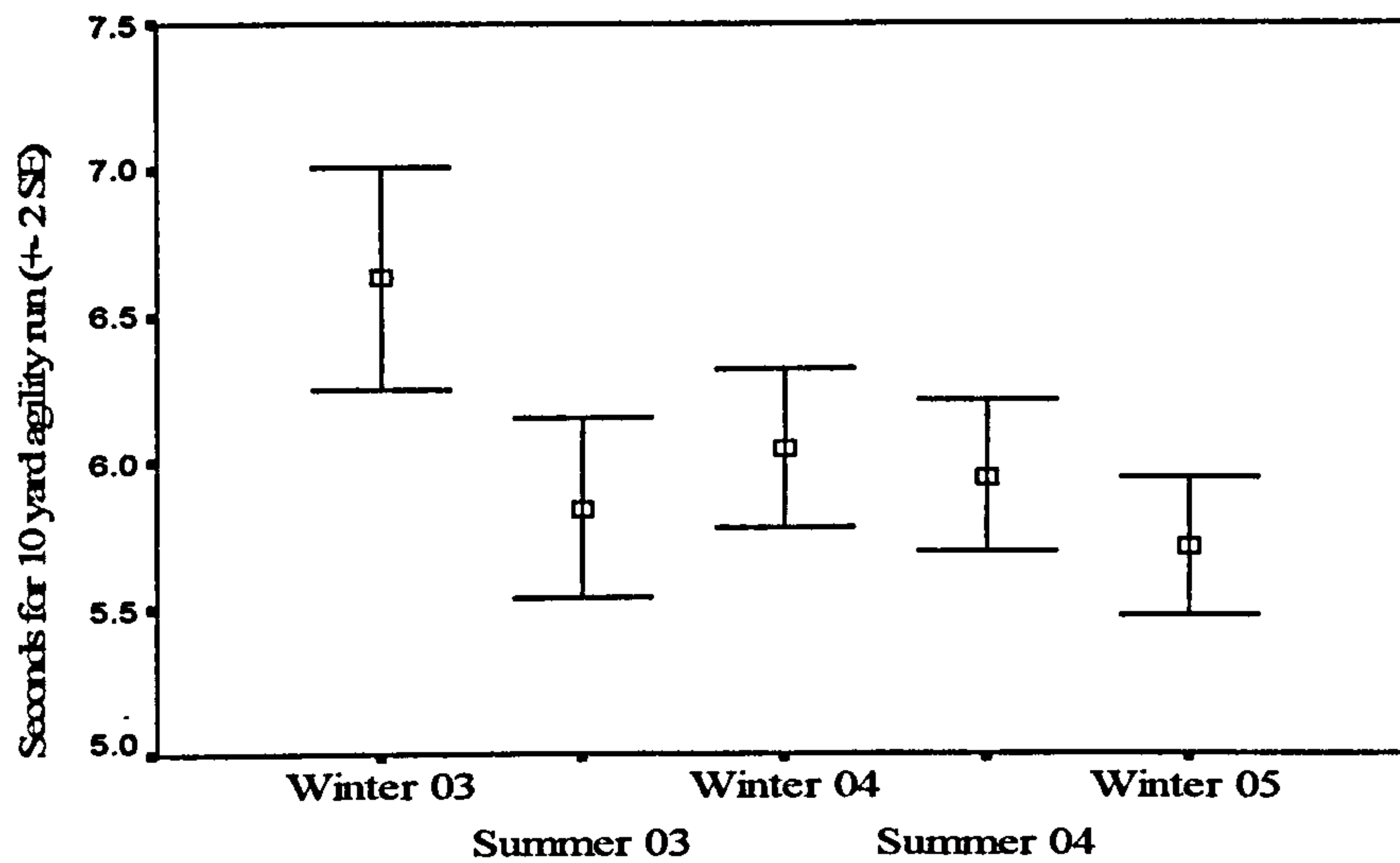
testing point. Children in Cluster 3 were seen to fluctuate the most in their profile of skills but made good progress overall. Statistical analysis of the mean MABC TI scores of each cluster group over consecutive testing points did not show a difference in the pattern of progress, with Cluster 5 tending to have the most difficulties.

6.5.4 Influence of profile of perceptual motor skills (subtype) on additional motor skill competencies

Subtests of the BOTMP were undertaken to measure dimensional change in specific motor skills. The three subtests chosen provide linear scales of gross and fine motor ability. The ability to run 10 yards and retrieve a block was timed in seconds with the shorter time representing the better score, the distance jumped from two feet landing on two feet was measured in inches and the ability to sort cards into blue or red piles was measured by counting the number of cards correctly sorted in 15 seconds. All children undertook the same motor tasks irrespective of age across all testing points.

Each of the BOTMP subsets was analysed using repeated measures ANOVA of the 5 testing sessions and contrasting the five cluster groups. For the running speed test there were 26 children who had data collected on all five testing points. The Levene test of homogeneity of variance, Box's test of equality of covariance and Mauchly's test of sphericity were not significant. Post hoc procedures were undertaken using Hochberg's procedure to account for the unequal sample sizes between cluster groups and Bonferroni adjustment for multiple comparisons. There was a main effect of running speed with all children having faster times at the end of the study [$F(4,21)$ 6.20, $P=.003$, $\eta^2=.579$]. There was no effect of cluster (eg. perceptual-motor profile) nor interaction between time (testing point) and cluster. Cluster 1 tended to be faster at each testing point. Figure 6.10 illustrates the test score means (± 2 standard errors) over each testing point.

Figure 6.10 Mean differences in B.O. running speed subtest scores



Using the same procedure to analyse jumping distance (using the Greenhouse-Geisser correction due to a violation of the specificity assumption) there was a main effect within the 25 subjects [$F(2.72, 54.39) 4.59, P=.008, \eta^2 = .186$] although the multivariate test result did not quite reach significance [$F(4,16) 2.835, P=.057, \eta^2=.400$]. Figure 6.11 below illustrates the general trend towards being able to jump further. Cluster 3 tended to be poorer on the standing long jump.

There was a main effect over time in the ability to sort cards (e.g. use both hands together in a cooperative manner) [$F(4,16)12.58, P<.001, \eta^2 =.770$] and again no effect of cluster or interaction between cluster group and time (Figure 6.12). The intercept for all three subtests was significant with Cluster group 5 generally having the worse scores at the beginning and end of the study and Cluster 1 showing the better performance throughout.

Figure 6.11 Mean differences in B.O. Jumping distance scores

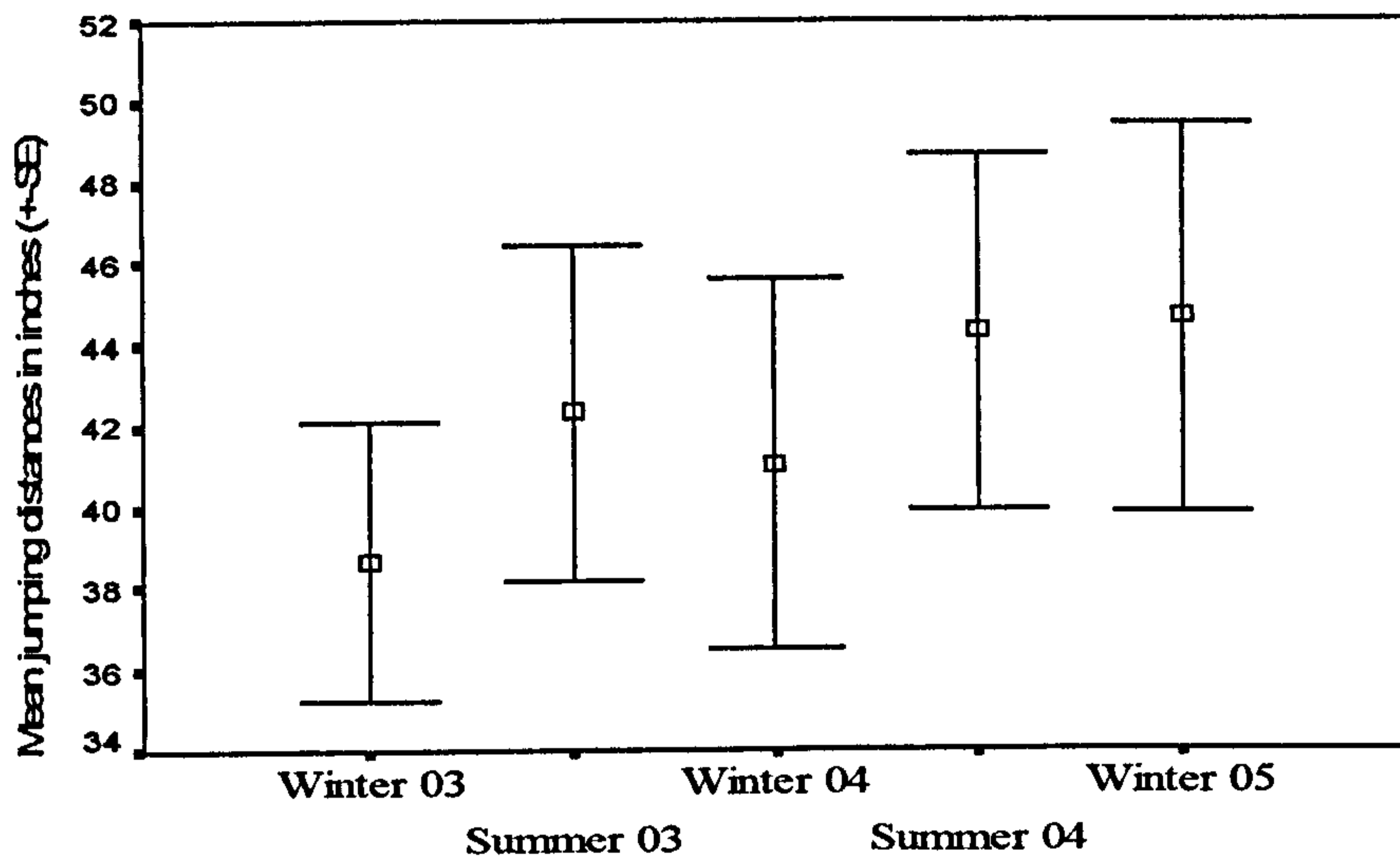
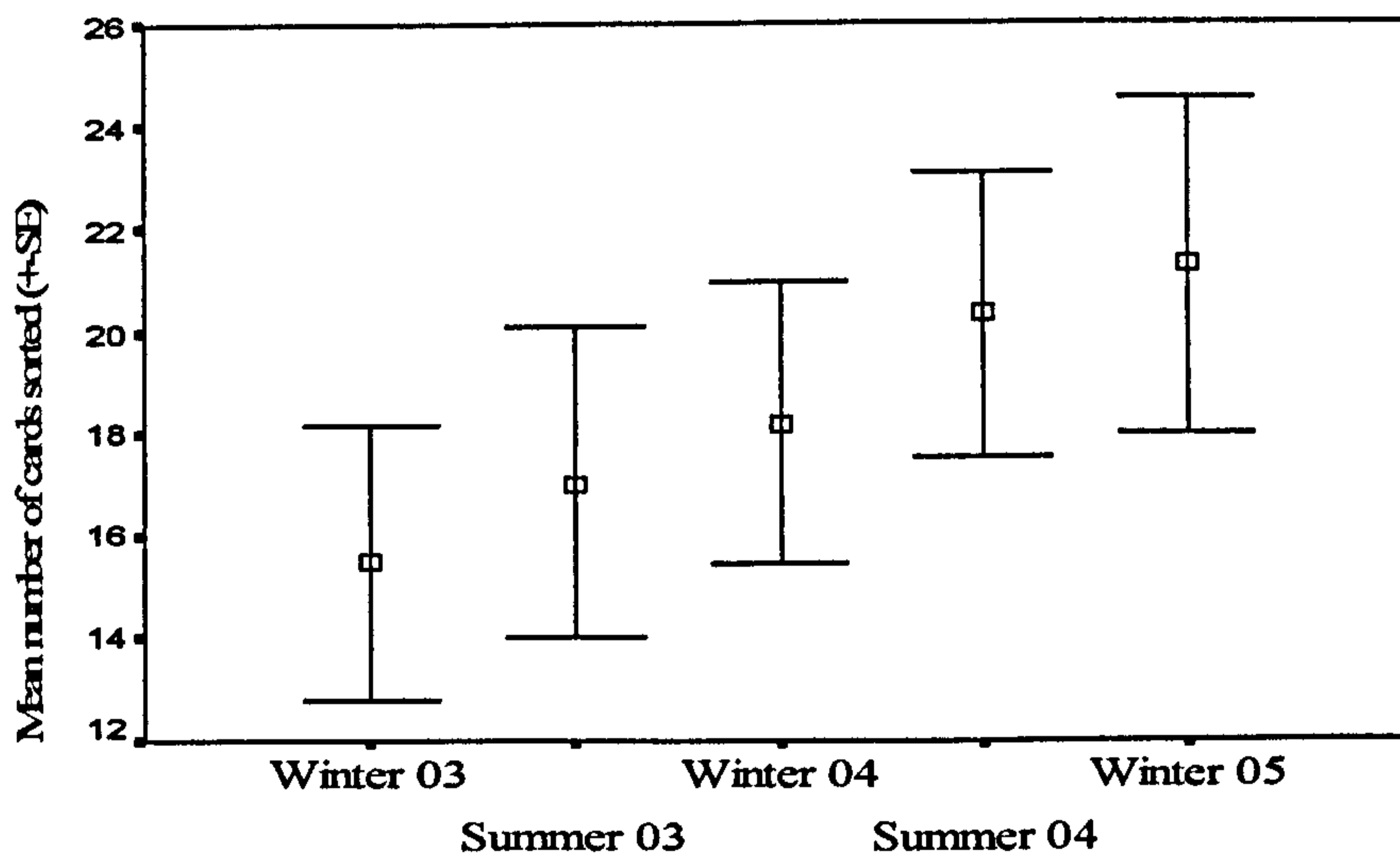


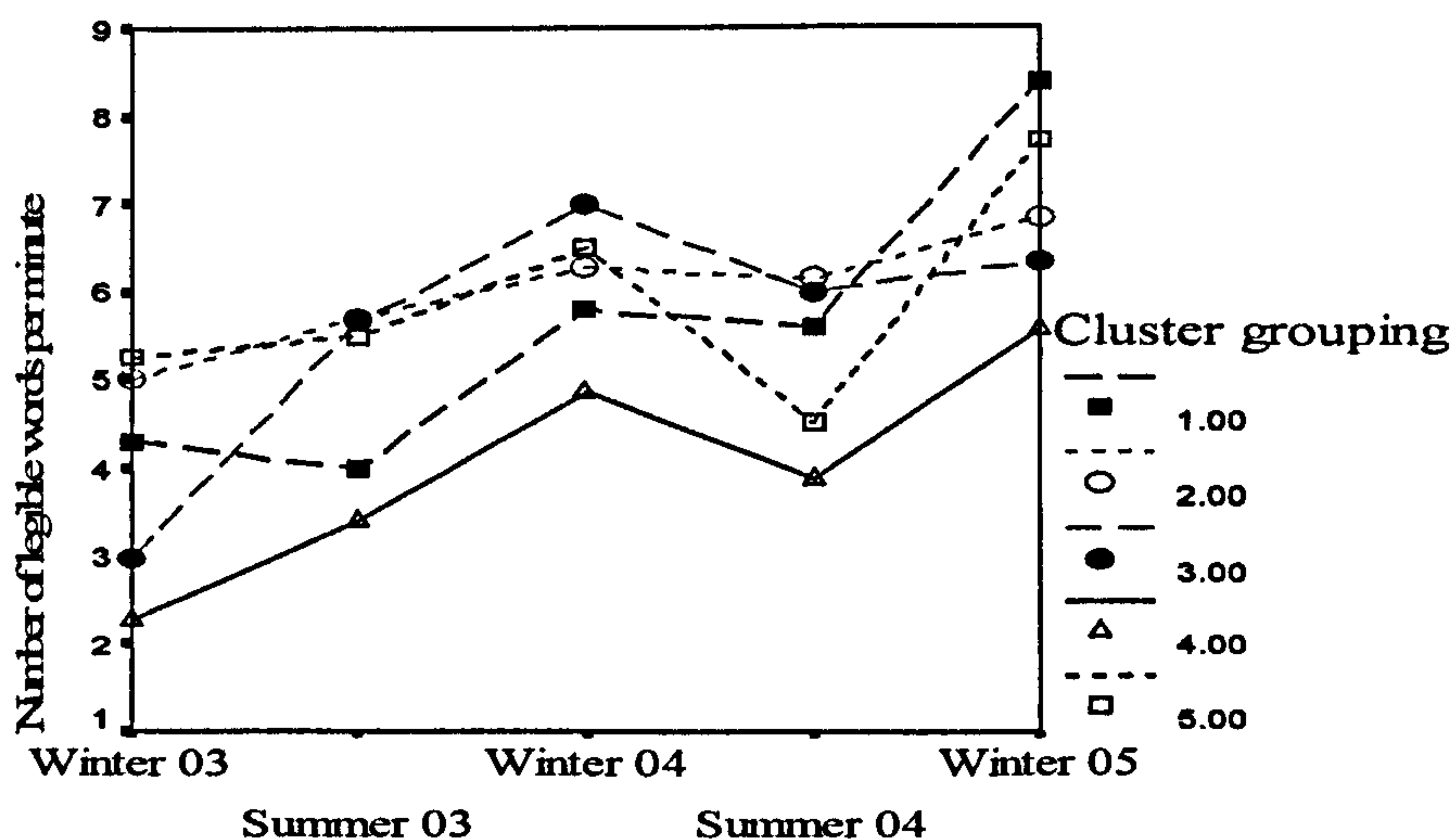
Figure 6.12 Mean differences in B.O. card sorting scores



A similar procedure was employed to explore the effect of movement impairment on handwriting progress. The Evaluation Tool of Children's Handwriting (ETCH) scoring criteria was used to determine the number of legible words and letters copied

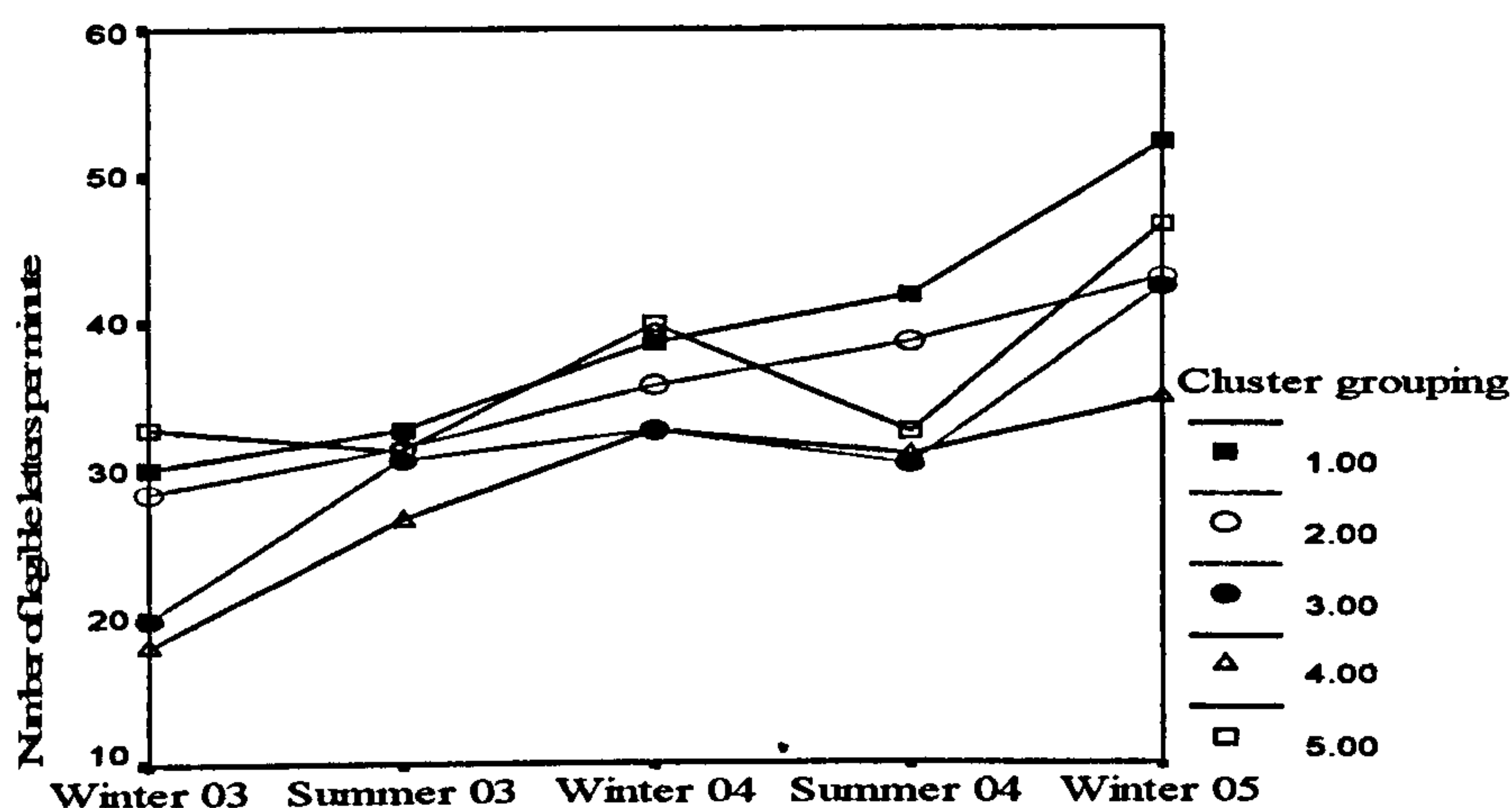
from a short passage of text. The same passage of text was used on each occasion. Repeated measures ANOVA of word legibility showed a significant effect of time [$F(4,23) 6.853, P=.001, \eta^2 =.544$]. There was no effect of perceptual motor profile (cluster group) nor interaction between cluster group and time. The greatest differences across all the children occurred between test point 1 (Winter 2003) and 3 (Winter 2004) and test point 1 (Winter 2003) and 5 (Winter 2005). Figure 6.13 below illustrates the improvement in handwriting. Interestingly with respect to word legibility, Cluster 5 children showed better word legibility than many of the other groups. Furthermore, there were no differences in MABC TI scores or manual dexterity (MD) subtest scores between children with poor handwriting and those with average or above skills, relative to this group of children with DCD [MABCTI: $F(5,34) 0.585, P>.05$; MD: $F(5,34) 0.533, P>.05$].

Figure 6.13 Cluster group mean changes in handwriting word legibility



Repeated measures ANOVA of letter legibility showed a significant effect of time with all groups improving [$F(4,23) 15.63, P<.001, \eta^2 =.731$]. There was no effect of cluster nor interaction effect between cluster and progress over time. The main differences for all the children occurred between Winter 2003 and Winter 2004, Summer 2004 and Winter 2005 with a slight dip in performance in the Summer of 2004.

Figure 6.14 Cluster group mean changes in handwriting letter legibility



6.5.4.1 Section Summary

In summary, with respect to the progress the children made in additional measures of functional motor performance (running speed and agility, jumping strength, card sorting and handwriting):

- improvements in performance were similar for all children, irrespective of cluster group.

6.5.5 Hawthorne Effect - 'Special Times'

Some of the improvements seen in the treatment groups may have been due to the provision of 'any' additional intervention particularly that provided by special attention or a change in routine, known as the Hawthorne effect (Miller, 1994). It is not possible to comment in depth on the possibility of the Hawthorne effect influencing intervention results as only 13 families recorded the special activity and special time engaged with their child. Countering this argument however, is that fact that 10 of these children made little progress, in fact 3 got worse, despite some of the families diligently recording their 'The Special Times' home intervention, suggestive of a more defined period of increased attention towards the child.

6.5.6 *Influence of other social or developmental factors on outcome*

The next section will discuss the influence of social factors or presence of other developmental disorders on outcome. Correlation analyses were run to ascertain the relationship of social, emotional and behavioural factors on outcome.

6.5.6.1 Socio-economic status

As mentioned in Section 6.5.1 there was no difference in Townsend scores of those children with DCD who participated in the treatment study and those who did not. There were no associations identified between Townsend scores and initial MABC TI scores, ($r=-.113$, $P>.05$), final MABC TI scores ($r=.146$, $p>.05$), nor degree of progress ($r=-.100$, $P>.05$). The Townsend scores were negatively correlated with prosocial behaviour on the initial but not final SDQ eg. reduced positive social behaviour scores were associated with higher degree of deprivation ($r=-.323$, $P=.039$).

6.5.6.2 Emotional and behavioural factors

The presence of emotional and behavioural difficulties was evaluated in the intervention group through analysis of the SDQ total and domain scores. There were 42 completed SDQ forms available at the beginning of the intervention study. Table 6.29 categorises the numbers and percentage of children reported to have social-emotional problems (reaching borderline/risk and cut-off scores on the SDQ) by extent of motor deficit at the beginning of the intervention study.

ANOVA showed no differences in the reporting of socio-emotional difficulties by extent of movement difficulty [$F(3,38) \leq .68$, $P>.05$ in all domains and total SDQ). Approximately 62% of children met cut-off scores for co-existing psychopathology and a further 14% were at risk. Only five children did not reach cut-off scores in at least one domain, three of whom had a borderline score in at least one or more

domain. These scores suggest that up to 88% of children in this study had significant deficits in at least one area of emotional development and behaviour.

Table 6.29 *Pre-treatment* – numbers of children reaching cut-off scores for emotional and behaviour difficulties on the SDQ (n=42)

SDQ MABC level	Total		Emotional		Conduct		Activity		Peer	
	Risk	Cut off	Risk	Cut off	Risk	Cut off	Risk	Cut off	Risk	Cut off
Borderline n=12	3	7	3	6	3	2	2	7	3	5
Definite n= 5	0	4	0	3	0	2	1	4	0	1
Severe n=25	3	15	2	16	3	7	1	18	2	11
Total n=42	6	26	5	25	6	11	4	29	5	17

Table 6.30 *Post-treatment* – numbers of children reaching cut-off scores for emotional and behaviour difficulties on the SDQ (n=35)

SDQ MABC level	Total		Emotional		Conduct		Activity		Peer	
	Risk	Cut off	Risk	Cut off	Risk	Cut off	Risk	Cut off	Risk	Cut off
No deficit n=11	3	5	2	5	2	0	2	6	0	4
Borderline n= 6	0	4	2	3	0	3	2	2	1	2
Definite n=11	2	7	0	7	1	3	1	9	0	7
Severe n= 7	1	4	0	5	1	1	1	3	2	4
Total n=35	6	20	4	20	4	7	6	20	3	17

Table 6.30 shows the repeated SDQ scores in relation to degree of motor difficulty at the end of the study. ANOVA showed no differences in the reporting of socio-emotional difficulties between these four levels of motor ability [$F(3,31) \leq 1.5$, $P > .05$ in all domains and total SDQ scores). At the end of the study 54% of

children met cut-off criteria with a further 13% at risk of psychopathology. Five of the children did not reach borderline or cut-off scores on at least one domain. Fifteen children changed category in relation to the degree of severity of their emotional or behavioural difficulties or changed at least 7 points. Seven children were reported to have less emotional and behavioural difficulties whilst eight had more problems. These scores are not significantly different from the initial SDQ scores, suggesting that up to 68%-84% of children may have deficits in at least one area of emotional development and behaviour, irrespective of progress in motor skills. Figures 6.15 and 6.16 illustrate the relationship between motor ability, age and SDQ scores at the beginning and end of the study.

Multivariate analysis of variance using a 3x3x6 factor model, did not show an overall main effect on the pre-treatment SDQ due to MABC level of ability and/or age banding. There was an interaction effect of age and motor ability and the reporting of conduct problems with 8 to 9 year old children reported to have greater problems than younger children. [$F(2,41) 4.05, P<.02$]. There was a trend towards children of 8-9 years of age to be reported as being more active and inattentive than younger children [$F(2,41) 2.75, P=.08$].

Figure 6.15 Pre-treatment SDQ scores by degree of motor deficit and age

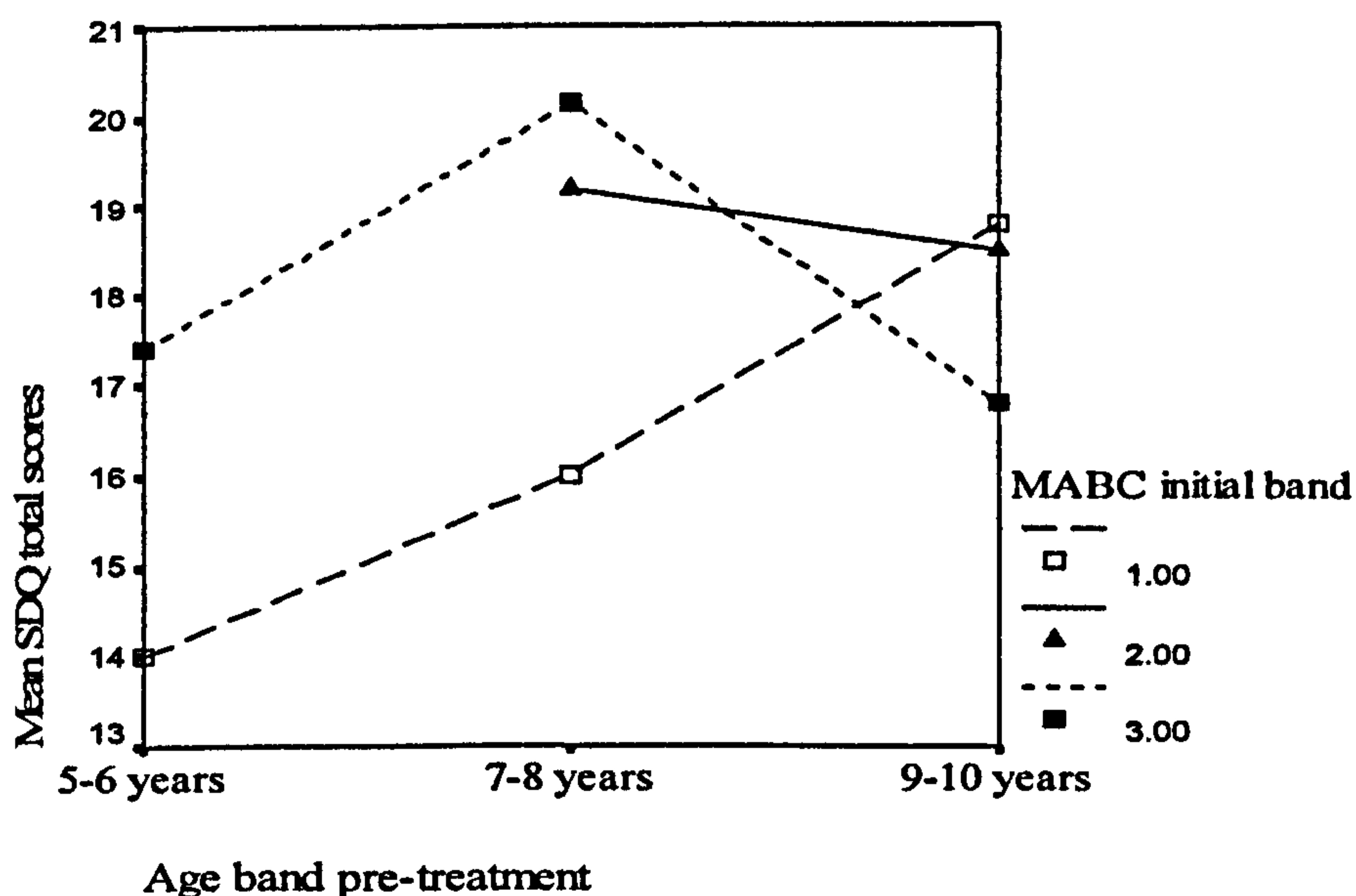
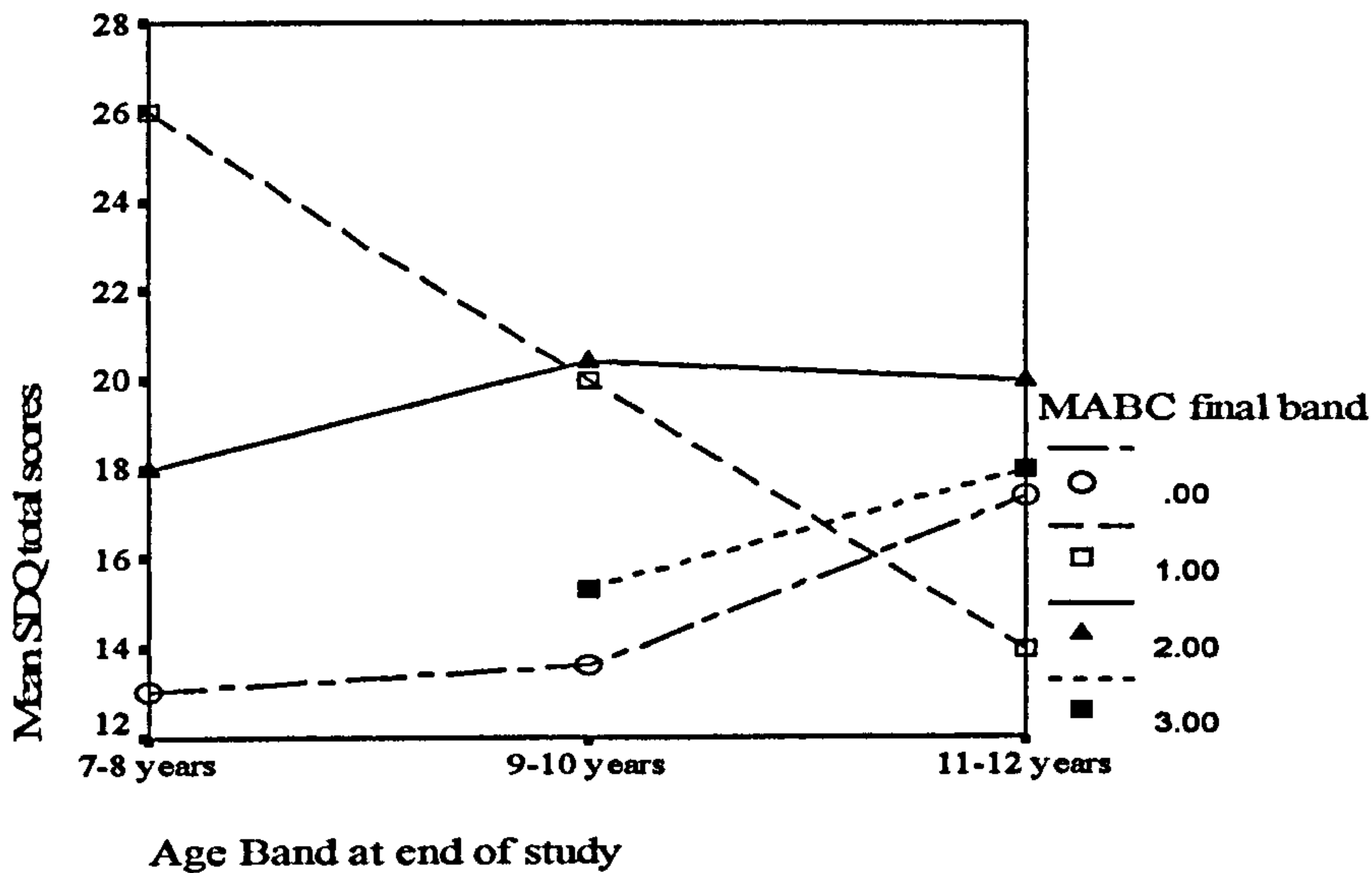
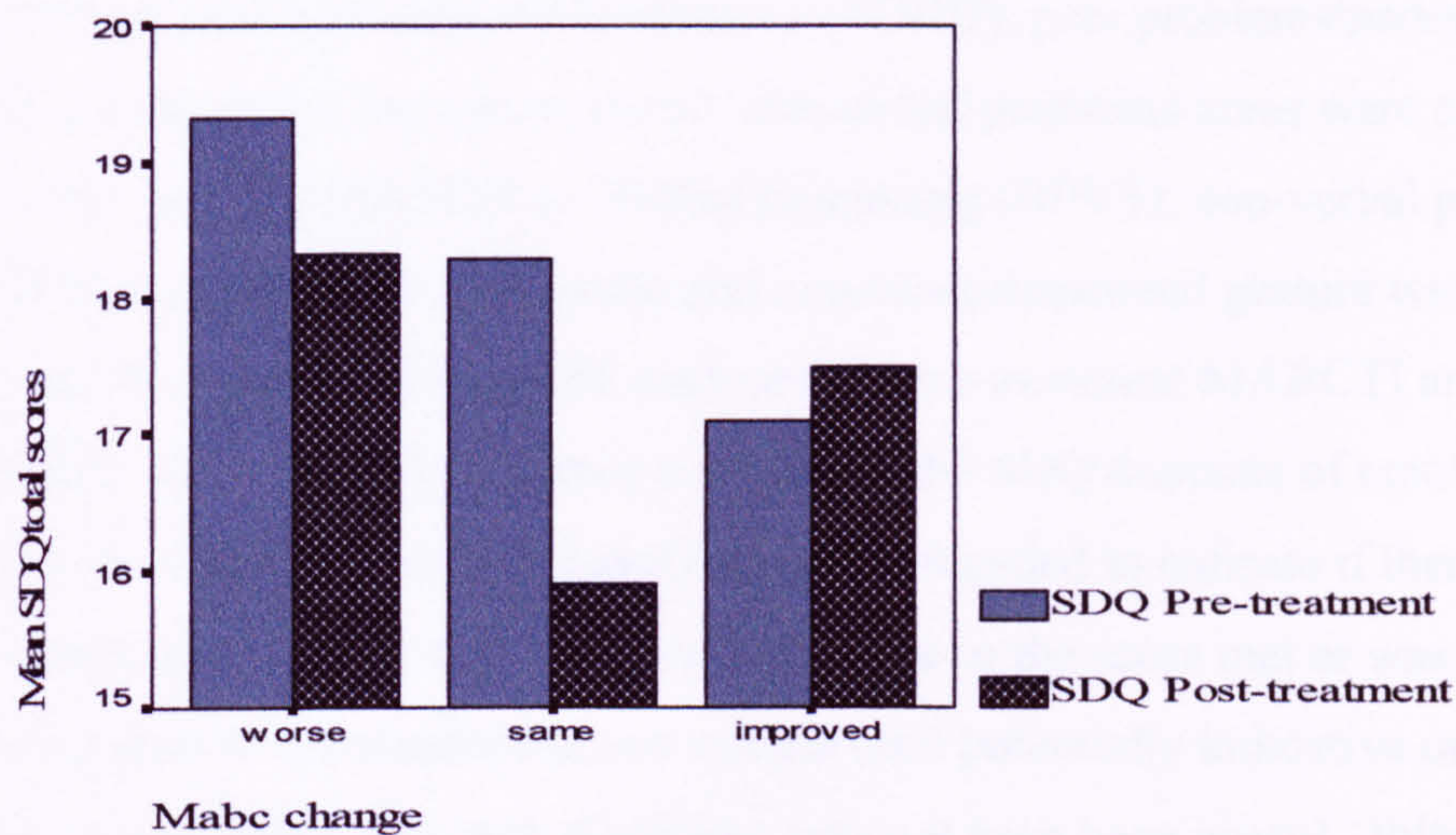


Figure 6.16 Post-treatment SDQ scores by degree of motor deficit and age



At the end of the study, there was no main effect of motor ability, age or interaction effect on reported social and emotional problems despite some children having moved into the no-impairment category and having sustained their improved motor ability for up to 1 ½ years. Neither conduct disorders nor hyperactivity/inattention were reported differentially between groups of children. Visual analysis of Figure 6.16 above, suggests that by the age of 11 years, many children who have a current or past history of motor difficulties are equally likely to present with emotional and behaviour problems. Figure 6.17 shows the lack of a clear relationship between progress in motor ability and expression of emotional and/or behaviour problems at the beginning or end of the study. Children who had made motor progress demonstrated more emotional and behaviour problems at the end of the study compared to those who stayed in the same category of motor impairment. Discriminant analysis shows that hyperactivity/inattention scores are most likely to predict a total SDQ score passing cut-off at the beginning of the study but that a child's reported conduct problems and inability to get on with their peers at the onset of the study are most likely to predict continuing social and emotional problems two years later.

Figure 6.17 SDQ total scores Pre & Post intervention categorised by motor progress



Repeated measures ANOVA of pre and post SDQ scores with respect to initial degree of movement impairment (borderline, definite, severe) showed a significant interaction between original severity rating and SDQ [$F(2,32) 4.88, P=.01, \eta^2 = 0.234$]. Children in the definite but not borderline group were reported to have fewer social and emotional problems at the end of the study although Discriminant Analysis did not necessarily predict that children in either the borderline or severe category would be at greater risk of persistent psychopathology.

Spearman correlation analyses compared the SDQ domain scores at the beginning and end of the intervention study with MABC total and subtest scores. At the beginning of the intervention study emotional problems on the initial SDQ were correlated negatively with balance difficulties ($r=-.378, P=.02$); peer problems correlated with poorer ball skills ($r=.353, P=.035$) and more positive pro-social behaviour was correlated negatively with manual dexterity ($r=-.377, P>.05$). This suggests that children with emotional difficulties had better balance, those showing peer problems were poorer at ball skills and the absence of pro-social behaviour was more likely to be linked to poor manual skills. Conduct problems were not associated with deficits in ball skills at the beginning or end of the study (Initial $r=-.047, P>.05$; Final $r=0.76, P>.05$).

The key variables thought to distinguish between neuropsychological profiles of children with hyperactivity/inattention (ADHD), peer problems/pervasive developmental delay and/or anxiety/emotional problems areas were explored further through MANOVA. Verbal processing (BPVS), non-verbal processing (MAT), representational gesture and non-representational gesture were entered as predictor variables along with each child's pre-treatment MABCTI and final MABCTI scores. The children's scores on the SDQ domains of emotion, conduct, activity/inattention and peer problems were recoded to indicate if there were no reports of problems, the score was borderline or the score met or was above cut-off in contrast to the standardisation sample (and potentially indicative of psychopathology although diagnoses may not have been given). Pillai's trace was insignificant, however there were significant effects between the three groups (no problem, borderline or risk) on parent ratings of peer problems and both representational and non-representational gesture [$F(2,6,40) 5.67, P=.041, \eta^2=.387$; $F(2,6,40) 4.81, P=.024, \eta^2=.391$ respectively]. The children considered to have borderline problems with their peers tended to have the highest gesture scores. Post Hoc procedures using Dunnett T3 due to unequal group sizes and unequal variance was significant between children without difficulties and borderline children ($P<.001$) and those with scores at or above cut-off ($P=.001$). The interaction between the risk of emotional and activity/inattention problems approached significance for representational gesture and was significant for non-representational gesture [$F(1,15) 3.41, P=.06, \eta^2=.313$; $F(1,15) 10.62, P<.001, \eta^2=.586$ respectively].

As children with PDD are known to have poorer abilities in gesture reproduction, the four children who had received a PDD diagnosis were removed from the analysis and the MANOVA rerun. This reduced the level of significance for the gesture items with respect to peer relations. Only the non-representational gesture subtest potentially approached significance [nonREPGT: $F(2,36) 3.13, P=.08, \eta^2=.343$] with the borderline group continuing to show the better gestural ability. The next four figures illustrate these results. Figures 6.18 and 6.19 show that children

whose parents rated their child's difficulties with peer relations beyond the cut-off for problems on the SDQ, did not necessarily have the greatest difficulties with gesture production that might reflect a dyspraxic subtype more linked to social impairments, at the onset of the study. In fact, the opposite could be said to be true in which children with poorer gesture production were less at risk of social deficits.

Figure 6.18 Representational Gesture and risk of peer problems on SDQ
N=37 (subjects with PDD removed)

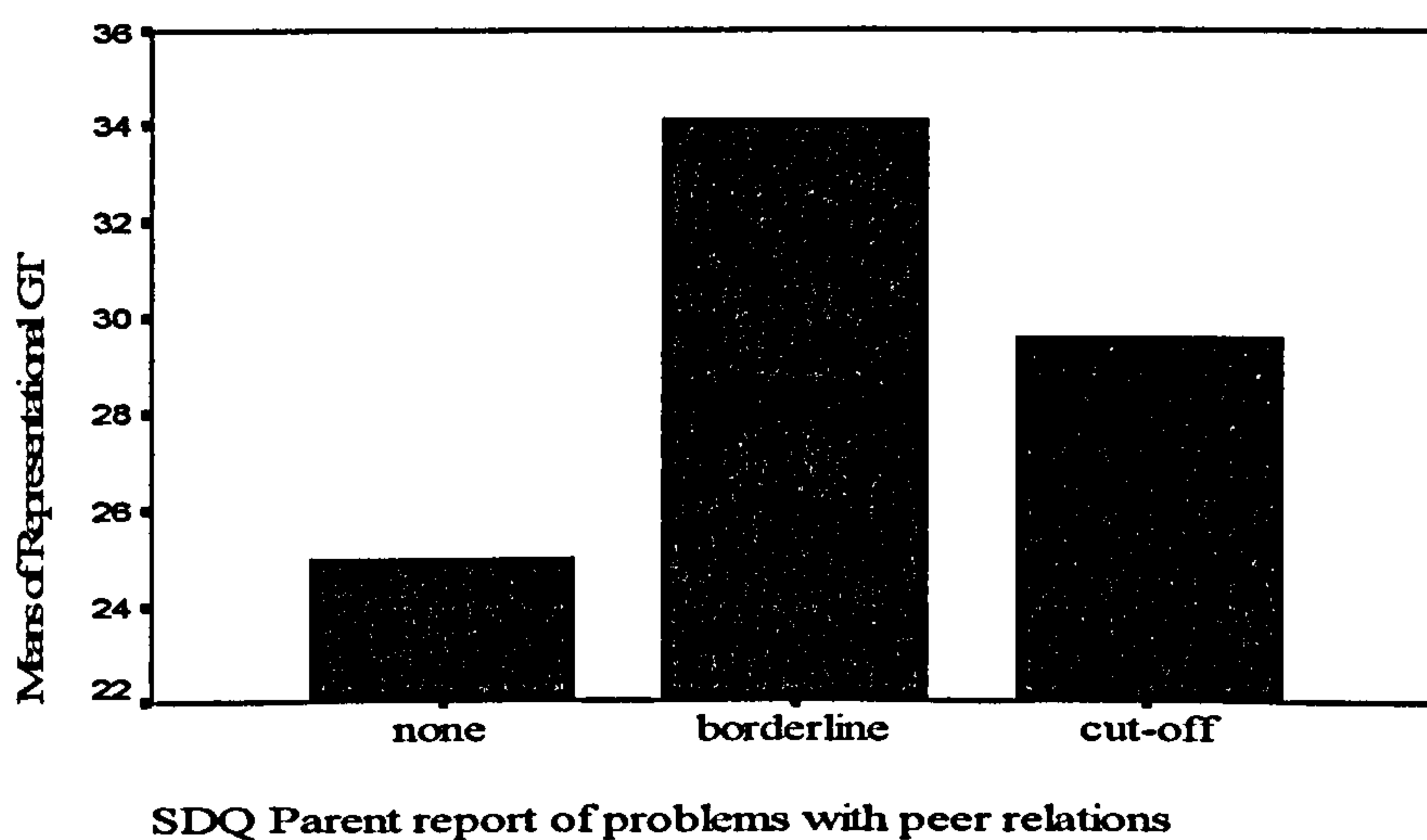


Figure 6.19 Non-representational Gesture and risk of peer problems on SDQ
N=37 (subjects with PDD removed)

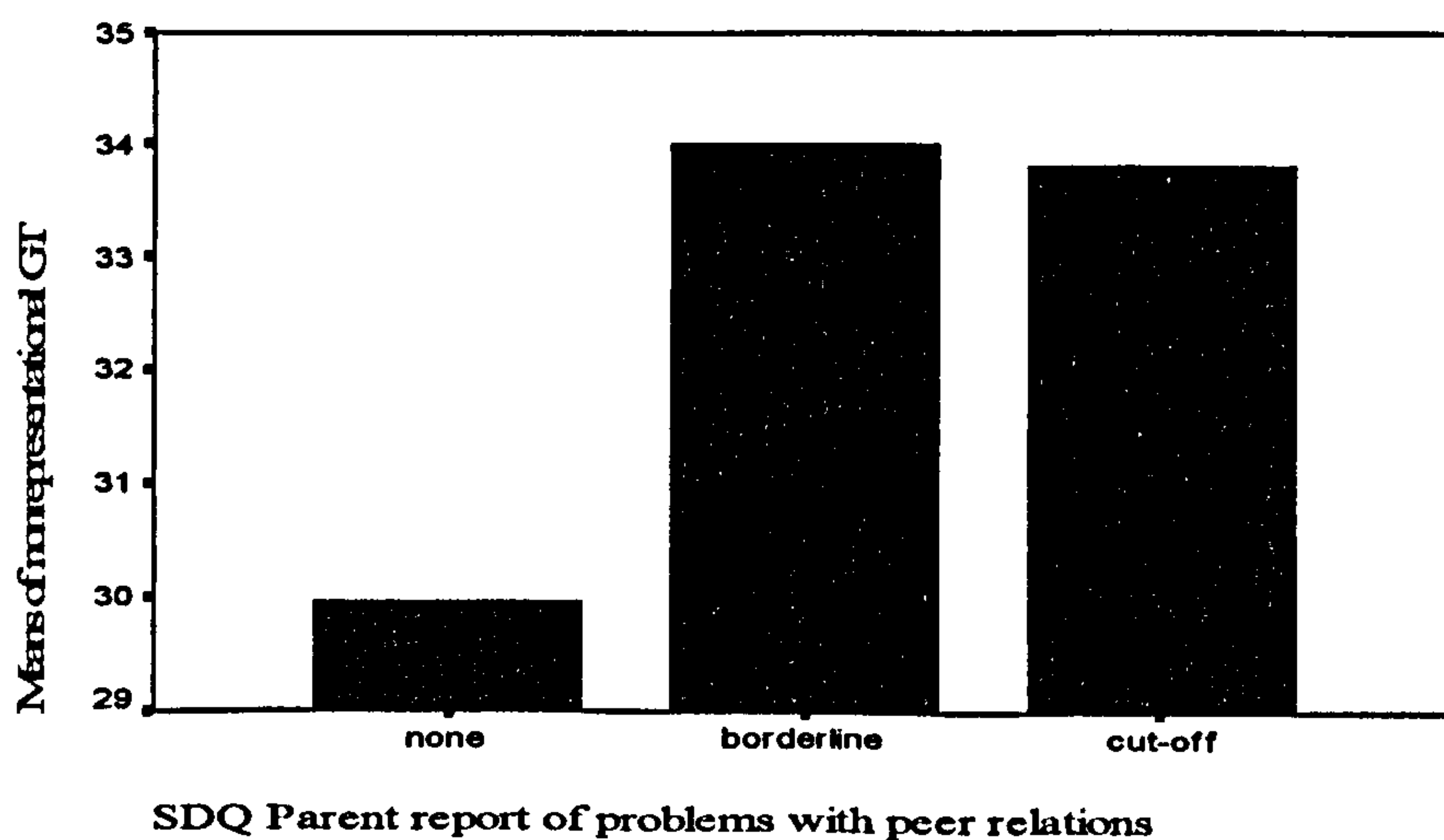


Figure 6.20 MABC Total impairment scores pre-intervention and risk of peer problems on SDQ

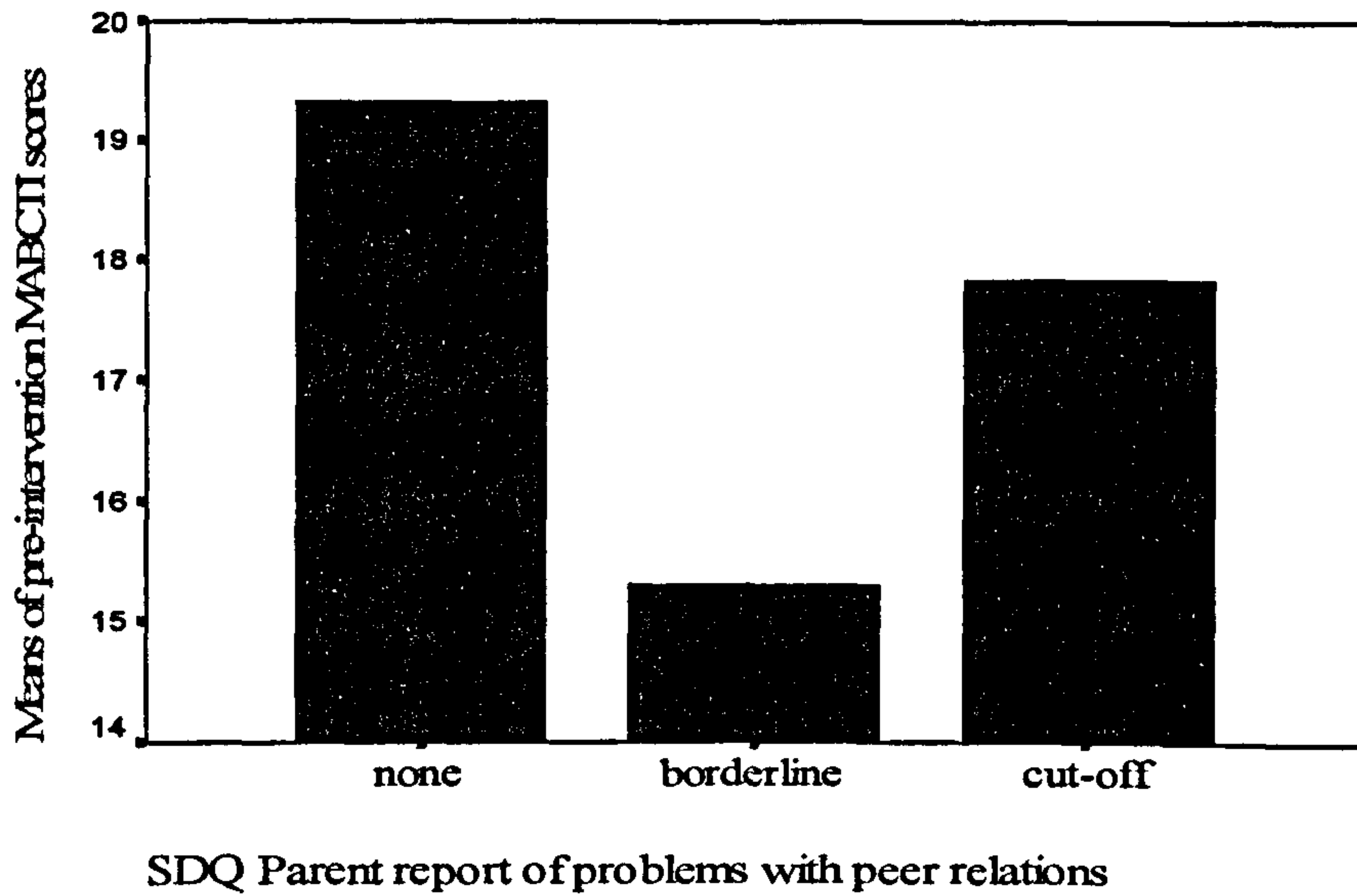
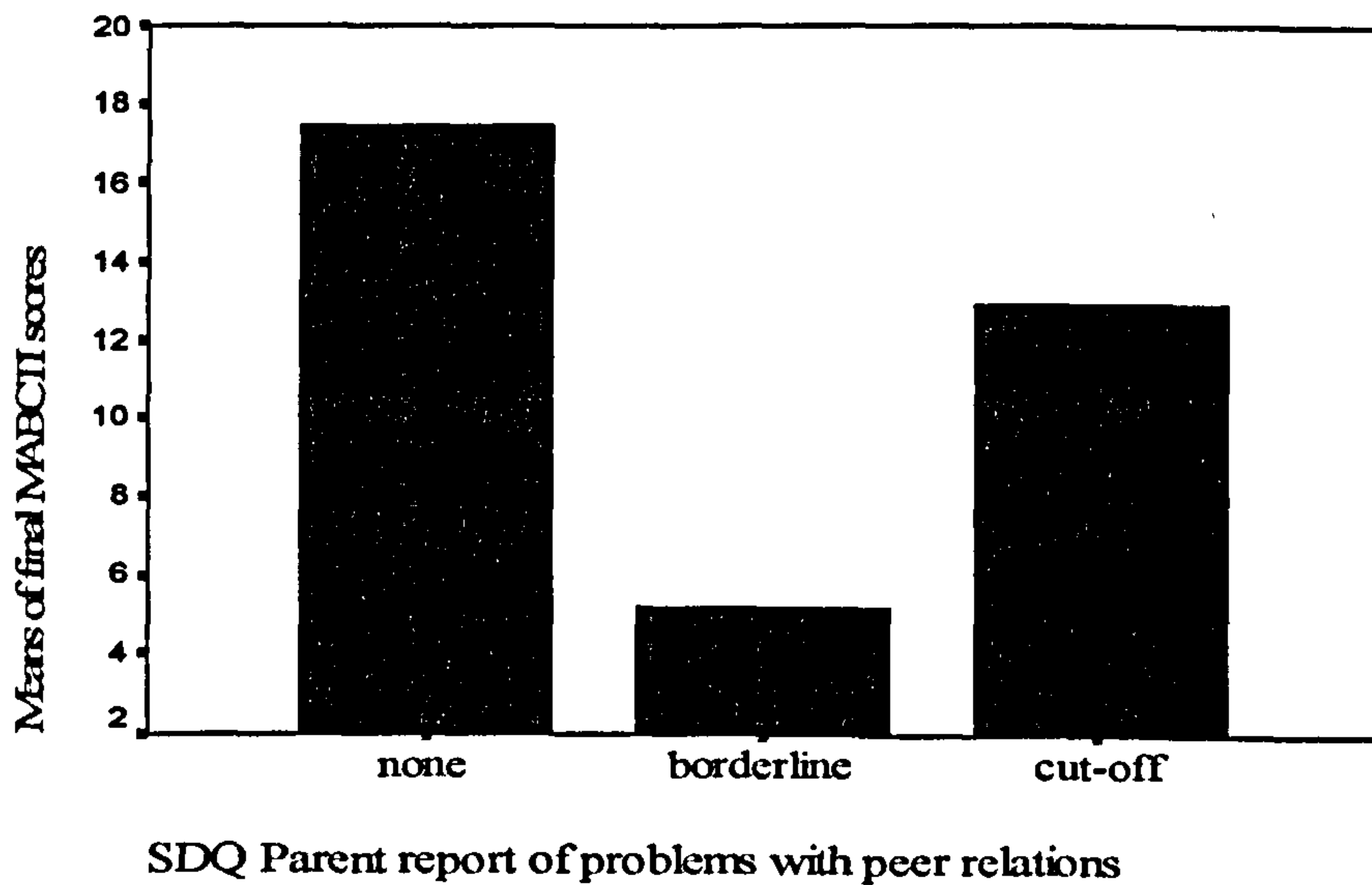


Figure 6.21 MABC Total impairment scores on final testing and risk of peer problems on SDQ



In contrast, those children with definite to severe movement difficulties at the beginning or end of the study as measured by their performance on the MABC, were as likely to have peer problems as not. Whereas, children rated by their parents as being at risk of peer relations difficulties had the better motor skills, both at the beginning as well as at the end of the study (see Figures 6.20 and 6.21).

The absence of any significant effect of the expression of emotional and behaviour problems (either at the beginning or the end of the study) on motor progress, along with the relatively few significant correlations, at fairly low levels of significance, do not allude to a relationship between psychopathology and motor performance which can be explained by the degree of motor impairment or age (Green, Baird & Sugden, 2006). However, there may be some link between gesture ability — particularly representational gesture indicative of the ability to impart meaning with movements — and a PDD diagnosis. Removing these children from the SDQ analyses suggests that gestural ability may have a differential impact on children with coordination impairment with, versus without, a formally recognised social impairment.

6.5.6.3 Section summary

Hyperactivity/inattention scores on the SDQ were seen to predict a total SDQ score passing cut-off at the beginning of the study but was not predictive of continuing problems. A child's reported conduct problems and inability to get on with their peers at the onset of the study were most likely to predict continuing emotional and behavioural problems two years later. Better gestural ability, both representational and non-representational, appeared to be linked to problems with peer relations although removing the children with a diagnosis of a social impairment from the analysis reduced the significance of this association. There was however, no clear relationship between emotional and behavioural problems and degree of motor difficulty or outcome.

6.5.7 Influence of known co-morbidity

Reiterating comments at the beginning of this chapter, the importance of sample selection and description cannot be over-estimated. In view of the inclusion in both parts of this study of some children who may have been excluded under Criterion C of DSM – IV criteria for DCD, the impact of having a known co-morbidity on both motor presentation and outcome will be discussed in more detail in this section.

Table 6.31 Part I - Children with DCD, known co-morbidity per cluster group

Cluster	PDD	ADHD	Medical	SLI	Co-morbidity %
1 n=33	3	2	5	3	39
2 n=13	1	1	1	2	38
3 n=10	0	1	2	1	40
4 n=22	2	2	1	1	27
5 n=11	1	0	4	0	45
Total n=89	7	6	13	4	34

Table 6.32 Intervention project - Children with known co-morbidity per cluster group

Cluster	PDD	ADHD	Medical	SLI	Co-morbidity %
1 n=14		3	2	1	43
2 n=9	2	1	2	1	67
3 n=5			1		20
4 n=10	2	3	2	2	90
5 n=5		3	1		80
Total n=43	4	10	8	4	60

Comparison of the above two tables shows the intervention group to have a much higher level of co-morbidity in each cluster than the total sample. This may be relevant when considering that the children with the most resilient and severe problems, with total impairment scores at the end of the project, well below the first percentile on the MABC, were all in clusters 4 and 5 (visual-motor and visual spatial difficulties) or known to have a co-morbidity. Chi² analysis of children with and without a diagnosis of a known co-morbidity and progress shows significantly more children with co-morbidity to remain the same or get worse during the study [$\chi^2(2) = 9.70, P < .01$]. Just over a third of children with an additional diagnosis however, did make good progress (see Table 6.33).

Table 6.33 Extent of children's progress related to co-morbidity status

Progress	No co-morbidity	Yes Co-morbidity	Total
Worse	2	2	4
Same	3	7	10
Improved	24	5	29
Total	29	14	43

6.5.8 Influence of known adverse events

During the course of the intervention project, two children were identified with a PDD through non tertiary investigation (subsequently labelled as such in all analyses), two children suffered adverse family circumstances (divorce with move of family home and school) and one child experienced significant mental health stress as a consequence of family disturbance. One child may have suffered a major epileptic seizure (not confirmed with EEG) with resolving hemiplegia and his parents withdrew him from the project. These children are discussed in the analyses in which their performance shows them to be relative outliers.

6.5.9 Parent perception of their child's progress

6.5.9.1 Parental perception of their child's motor skill progress

Spearman rho correlations were run contrasting parent reporting of movement skills using the Developmental Coordination Disorder Questionnaire (DCDQ) with clinical assessment of motor ability on the MABC at each of the 5 testing points for the intervention group. By design all DCDQ scores at initial assessment were below 58, indicating a degree of parental concern over their child's motor ability in daily tasks at home and school.

In Table 6.34 the correlations are specifically stated where they are significant for DCDQ total scores in relation to MABC total impairment scores. [The correlations of the DCDQ and MABCTI for the entire sample were significant at initial testing as well as the subset of 100 children reported by Green et al., 2005]. The correlations of each DCDQ domain to other DCDQ total scores throughout each test point are all significant ($r > .721$, $P < .001$ for all testing sessions). Similarly each MABCTI correlated significantly with other MABCTIs at each test point ($r > .464$, $P < .003$ for all testing sessions).

The correlations between the DCDQ total and subtest scores increase after the first year. From February 2004, the significant associations between parent report and clinical testing are seen between tests undertaken at the same time. Parents' reporting of their child's motor ability on the DCDQ showed a moderate correlation with their child's clinical assessment of motor skill – albeit with a slight time lapse between progress measured clinically and observations of improved motor skill at home and school. Although children receiving their intervention in year two were seen to have marginally more movement difficulties at the start of the study, they showed no differences in their response to treatment [$\chi^2(2) = 2.97$, $P > 0.05$].

Table 6.34 Significant Correlations between DCDQ and MABC TI scores

DCDQ Date Mean (SD)	MABC Winter 03	MABC Summer 03	MABC Winter 04	MABC Summer 04	MABC Winter 05
DCDQ Winter 03 38.3 (10.15)			$r=-.369^*$ $p=.025$ $n=38$	$r=-.352^*$ $p=.038$ $n=38$	
DCDQ Summer 03 41.4 (10.77)			$r=-.495^{**}$ $p=.002$ $n=39$	$r=-.545^{**}$ $p=.001$ $n=39$	$r=-.428^*$ $p=.015$ $n=39$
DCDQ Winter 04 43.0 (11.45)			$r=-.498^{**}$ $p=.001$ $n=42$	$r=-.482^{**}$ $p=.002$ $n=42$	$r=-.439^{**}$ $p=.008$ $n=42$
DCDQ Summer 04 44.6 (12.04)		$r=-.363^*$ $p=.025$ $n=40$	$r=-.493^{**}$ $p=.001$ $n=40$	$r=-.621^{**}$ $p<.001$ $n=40$	$r=-.587^{**}$ $p<.001$ $n=40$
DCDQ Winter 05 43.8 (12.40)				$r=-.374^*$ $p=.029$ $n=35$	$r=-.337$ $p=.048^*$ $n=35$

Table 6.35 Numbers of parents reporting movement difficulties on the DCDQ

Extent of motor problem	Feb 2003 n=38		Aug 2003 n=39		Feb 2004 n=42		Aug 2004 n=40		Feb 2005 n=35	
	No.s	%	No.s	%	No.s	%	No.s	%	No.s	%
Definite	32	84	28	72	30	71	26	65	24	69
Borderline	5	13	7	18	7	17	8	20	4	11
No deficit	1*	3	4	10	5	12	6	15	7	20

* This child had originally scored in the borderline area and DCDQ score at pre-treatment was 59 – one point over cut-off

Table 6.35 above, shows the gradual increase in percentage of parents who reported improvements in movement skill in daily tasks with 20% of parents ratings placing their child in the normative range by the end of the study (DCDQ norms currently based on a Canadian population). Analysis of variance was run using a repeated measures model to identify whether changes in reporting of motor skills by parents corresponded to their child's outcome (worse, same or improved motor skills on MABC total impairment scores). There were 27 children with correctly completed DCDQs for all test points. Age was hypothesised to impact on parent reporting and placed as a covariate. Bonferroni adjustment was used to accommodate for multiple comparisons. Reporting Pillai's trace due to uneven sample sizes in each group, a main effect of the DCDQ was obtained [$F(4,20)$ 4.02, $P=.015$, $\eta^2 =.445$] and age was a significant covariate interacting with the parents report of movement difficulties [$F(4,20)$ 4.12, $P=.013$, $\eta^2 =.452$]. Levene's test was not significant however the within group factor of DCDQ scores over time violated sphericity and the Greenhouse-Geisser statistic is reported to correct for this. There were no main effects nor interactions for the within subject contrasts [DCDQ: $F(2.56,58.81)$ 2.69, $P=.063$]. There was a significant difference in the intercept with parents tending to rate children who got worse overall as poorer than children who got better although with the Bonferroni adjustment to account for repeated testing, this did not reach significance ($P>.05$). The mean of the total DCDQ scores for the children who got worse over time tended to be some 10 points below that of the other two groups, although due to the small numbers of the 'worse' group ($n=3$) and variance of the group, no statistical difference was detected. Figure 6.22 illustrates the differences in parental reporting in contrast to clinical outcome of motor skills.

Contrasting the perceptual-motor profile of children with parent reporting of their motor difficulties had similar results with parents rating children in Cluster 1 as less severe. Similarly, Cluster 5 represented children showing the least change over time, consistent with parental report (see Figure 6.23).

Figure 6.22 DCDQ compared to motor progress (MABCTI overall change)

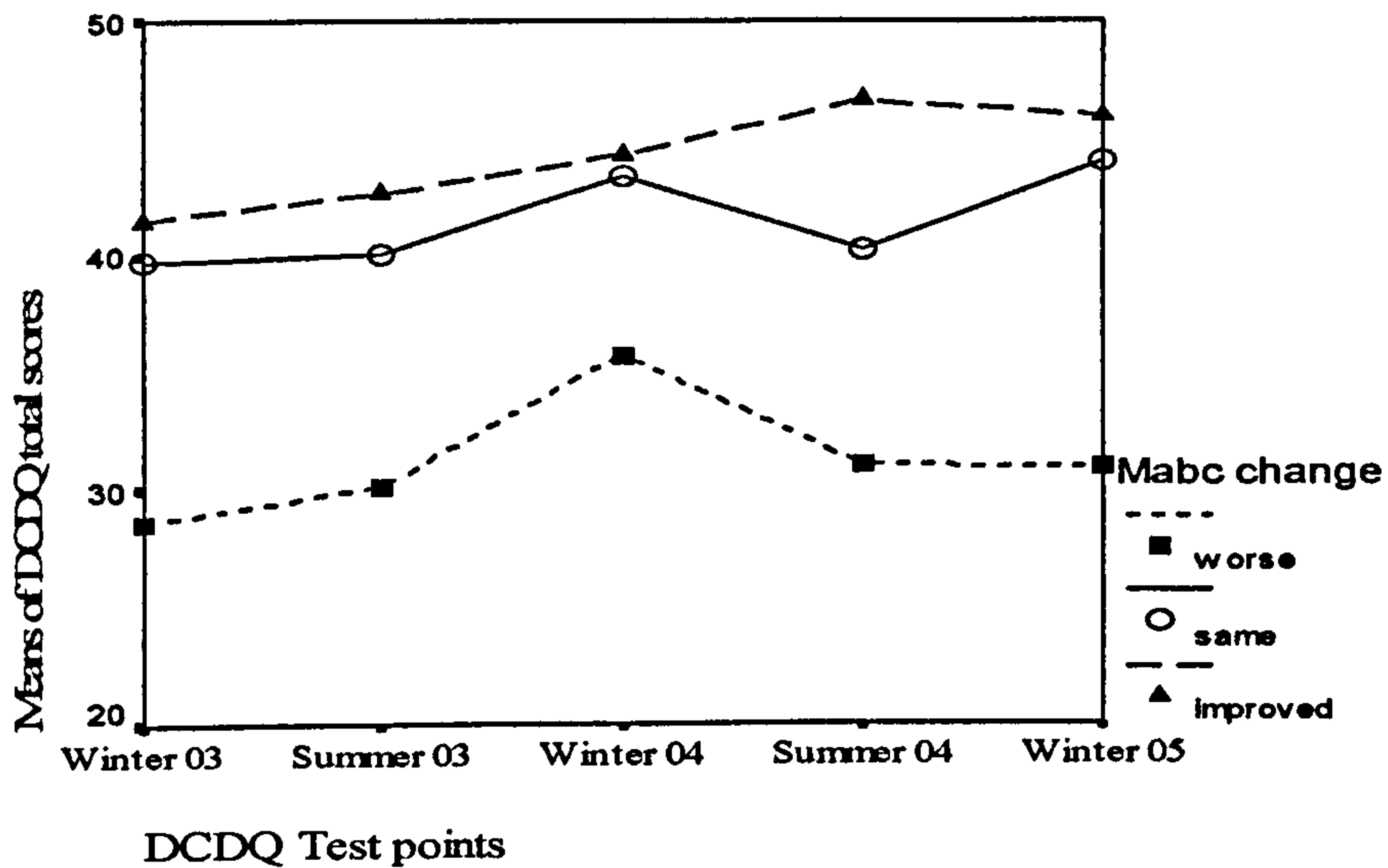
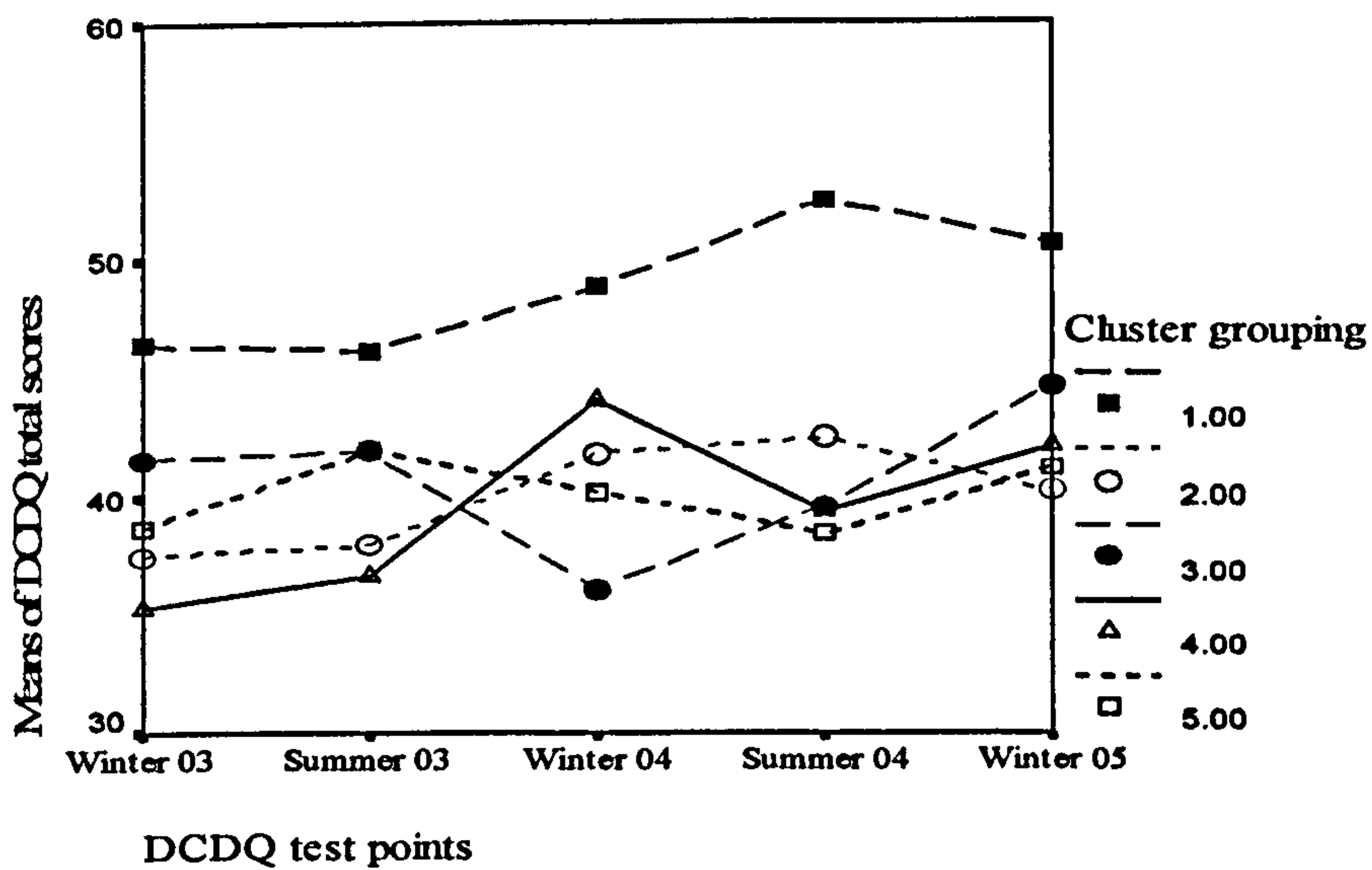


Figure 6.23 DCDQ scores over time contrasted to cluster group



It appears that the DCDQ does have some sensitivity to measure differences in the extent of movement difficulties. The DCDQ's sensitivity to detect change over time within this relatively small DCD population was somewhat delayed and potentially influenced by other variables.

6.5.9.2 Parental perception of their child's overall developmental progress

As a large proportion of the analyses were based on parental report of the progress of their child's motor skills and also general developmental and behavioural attainments, the association between these variables is analysed in the next section. Table 6.36 shows the means and SDs over time of the DCDQ (score range 17-85) and Profile of neuropsychiatric symptoms (PONS, score range 60-360).

Table 6.36 Parent report of their child's motor skills and neuropsychiatric symptoms over time

		Initial n=42	Feb 03 n=35	Aug 03 n=38	Feb 04 n=38	Aug 04 n=40	Feb 05 n=35
DCDQ	Mean	39.38	38.30	41.36	43.00	44.60	43.80
	SD	9.71	10.15	10.77	11.45	12.04	12.40
PONS	Mean	n/a	286.74	288.53	298.70	299.16	298.51
	SD	n/a	39.01	44.38	34.84	34.39	44.92

In view of the differences in these scales, scores were transformed into Z scores and a Pearson correlation analysis was run. This shows significant correlations at each testing point between parents who reported negatively about their child's motor skills also reporting negatively on other aspects of their behaviour and development and vice versa.

Table 6.37 Correlations of DCDQ and PONS at each test point*

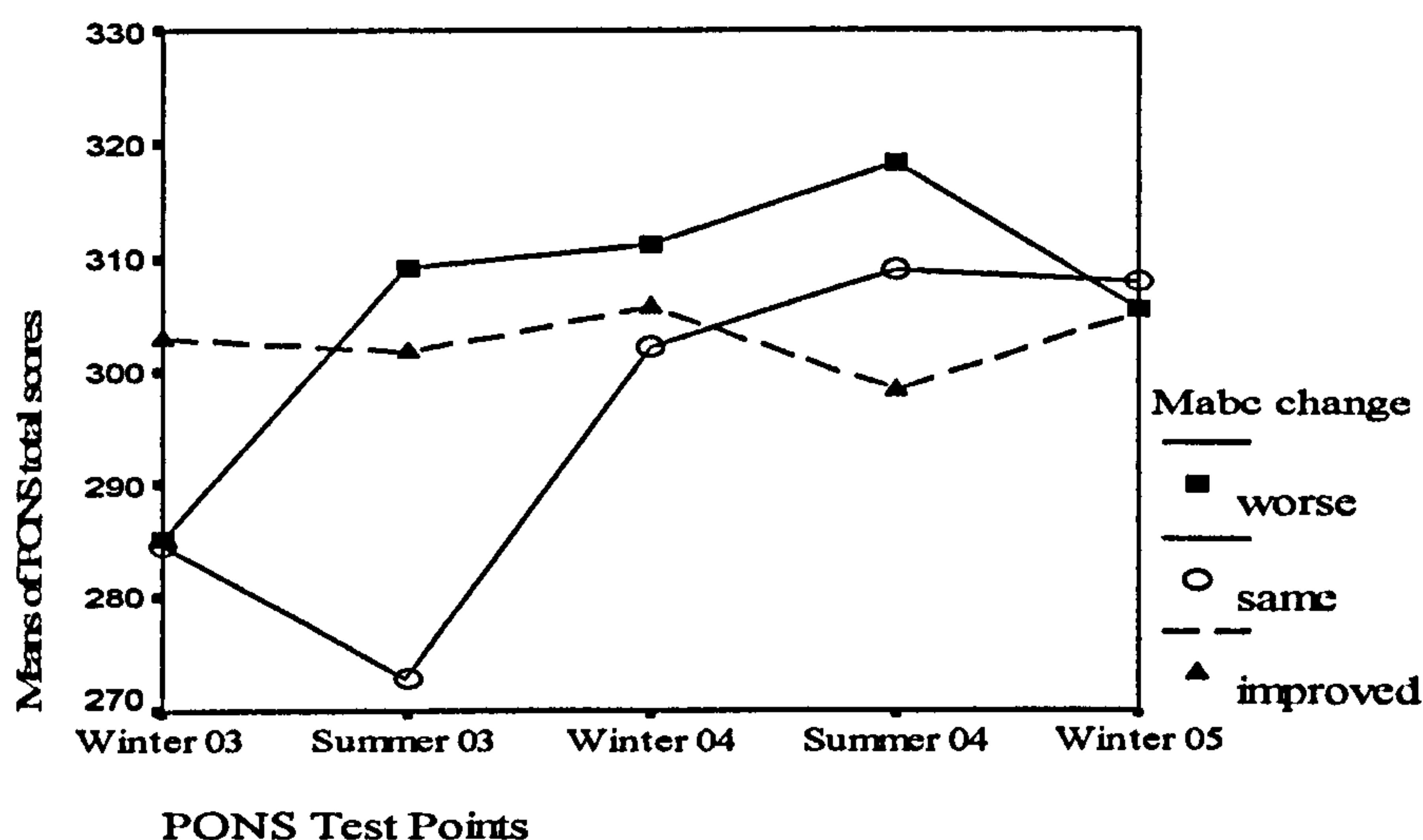
	Feb 03	Aug 03	Feb 04	Aug 04	Feb 05
r	.411	.439	.408	.396	.375
number	35	38	38	40	35
significance	.014	.006	.011	.011	.026

*Similar levels of significance were found for Spearman's rho of raw scores.

Repeated measures analysis of parent report on the PONS was contrasted with the groupings of children who got worse or better. There was no main effect over time

of the PONS ($F(4,15) 1.97, P > .05, \eta^2 = .345$) [Mauchly's Test of Sphericity non-significant]. Multivariate analysis including age as a covariate and contrasting children who got worse, stayed the same or improved over the two year period approached significance [$F(4,15) 2.92, P = .057, \eta^2 = .438$]. See Figure 6.24 below. This profile is somewhat different from that of the DCDQ. It appears that after the initial reporting of behaviour, the children who got worse were rated higher (therefore fewer neuropsychiatric symptoms) than the other children. These results should be interpreted with caution as there were only 3 children in the 'worse' category with complete data sets.

Figure 6.24 PONS scores contrasted to overall outcome on MABC



6.5.9.3 Section Summary

Parent report of their child's motor difficulties showed a high correlation after the first year with clinical testing of motor skills — when children's motor skills showed a greater range of ability. Of note, was the more consistent reporting of neuropsychiatric problems (other than Summer 03 when children who had not improved ^{were} rated by their parents as having more problems) with overall psychosocial and developmental adjustment showing relatively little change over time.

6.5.10 Child's Perspective / Child's Perception of Progress

Although much has been made of the child's performance and progress based on standardised clinical assessment and parent report of progress in motor skills, this next section will consider the child's perspective of their ability to perform functional motor tasks such as tying shoelaces.

The Co-ordination Skills Questionnaire (CSQ) was administered to children in the intervention study at each testing point. This is a 10 item questionnaire developed for children to report on their perceived ability and satisfaction (sense of improvement) in motor tasks (see Appendix 6). The tasks were selected from the eight most frequently cited referral reasons for the larger group of children participating in this study. In order to condense the areas of concern expressed by referrers some of the reasons were collated under one heading eg. catching, throwing and using a racquet. The personal hygiene question regarding use of toilet paper was included as clinical experience shows it to be frequently mentioned as an area of difficulty during the assessment or intervention process. The 10th question is an activity children chose themselves as one they wished to work on during the Detective Club sessions. One of the most popular activities chosen by children (outside of football skills for many of the boys) was cycling followed by roller-skating. These questions are theoretically consistent with the Canadian Model (Measure) of Occupational Performance (COPM) representing a number of questions concerning personal care, productivity (school work) and leisure time and considered to have good face validity.

The questionnaire was administered every 6 months with approximately 4-6 children in each group with two supervising staff. Notes taken during these sessions show persuasive power/peer pressure to be more evident in the first session but less so later on as children seemed happier to acknowledge they were not good at something in front of their peers.

To determine the suitability of these questions, internal reliability was calculated in the first instance. Cronbach's alpha was run on the 10 questions, running the perception of ability separately from the responses for satisfaction and progress. Internal reliability analysis for the ability scale was moderate: First session total Alpha = .686 (five items with less than .4 squared multiple correlations); The final session total Alpha = .789,

The questions of use of toilet paper and fine motor skills (puzzles/lego) had the lowest item correlations for our small group made up of 37 boys and 6 girls. However, these two items were the most likely to correlate negatively with MABC tasks (e.g. the worse they thought they were on this question the more likely they were to have problems in manual dexterity and balance) with the implication that these two items may be important with respect to sensitivity to motor difficulties but least likely to distinguish between children who have already been identified with movement problems (see Table 6.38 below for correlations of CSQ with MABCTI). Children appeared to be relatively consistent in their ratings of their skills over time.

Correlations of the CSQ between each test point are all high except that of the Summer 2003 with the first questionnaire in the Winter of 2003 ($r=.457, P=.01$ between Summer 2003 and Winter 2005; all other contrasts $r\geq.524, P\leq.001$).

Although a number of the individual items correlated with MABC TI and subtest scores, the CSQ total score did not correlate significantly at any point with MABC (see Table 6.38).

The use of toilet paper and fine motor questions, as well as the question regarding the child's own choice activity, were significantly correlated with the MABC. The ball skills questions were also significantly correlated with parent report but positively so with Manual Dexterity subtest of the MABC (clinical impression is that this may be a correct association as a number of the boys were very good at ball skills — potentially motivated in this area — but were seen to have very specific fine motor movement difficulties).

Table 6.38 Significant correlations between DCDQ or CSQ and MABC TI Scores

	Winter 03		Summer 03		Winter 04		Summer 04		Winter 05	
	DCDQ	CSQ	DCDQ	CSQ	DCDQ	CSQ	DCDQ	CSQ	DCDQ	CSQ
MABC Winter 03					$r=.37$ $p=.02$		$r=-.35$ $p=.04$			
MABC Summer 03					$r=.50$ $p<.01$		$r=-.55$ $p<.01$		$r=-.43$ $p=.01$	
MABC Winter 04					$r=.50$ $p<.01$		$r=-.48$ $p<.01$		$r=-.44$ $p<.01$	
MABC Summer 04			$r=-.36$ $p=.02$		$r=-.49$ $p=.01$		$r=-.62$ $p<.01$		$r=-.59$ $p<.01$	
MABC Winter 05							$r=-.37$ $p=.03$		$r=-.34$ $p=.05$	

All of the self ratings of ability correlated positively and significantly with ratings of satisfaction with skill. A number of the ratings of ability and satisfaction correlated with other ratings such as group games with ball skills (in this instance the examples given in the CSQ were ball games rather than board games so this correlation shows some face validity). Interestingly, neat and legible writing was correlated with the ball skills, tying shoelaces and organisation of materials questions (See Table 6.39).

Table 6.39 Significant correlations between items of the CSQ

	Ball Skills	Writing	Group Games	Own Choice
Ball skills		$r=.383^*$	$r=.443^{**}$	
Tying shoelaces	$r=.410^{**}$	$r=.400^{**}$		$.484^{**}$
Organisation		$r=.427^{**}$		
Group Games	$r=.443^{**}$			
Gross motor				$.338^*$

* = $P<.05$; ** = $P<.01$

6.5.11 Contrast of parent to their child's opinions of their motor abilities

Correlation analyses were undertaken comparing the parents' opinions of their children's motor skills via report on the DCDQ with the children's own perception of their abilities on the CSQ. There were only two significant correlations, neither of which corresponded to the same test point (see Table 6.40).

Table 6.40 Significant correlations between parent and child perception of motor skills

	Winter 03 DCDQ	Summer 03 DCDQ	Winter 04 DCDQ	Summer 04 DCDQ	Winter 05 DCDQ
CSQ Winter 03					
CSQ Summer 03			$r=.326$ $p=.049$		
CSQ Winter 04					$r=.442$ $p=.010$
CSQ Summer 04					
CSQ Winter 05					

From the more significant associations seen previously with the DCDQ and MABCTI (Table 6.38), it would seem that parents were more 'in tune' with the child's abilities, or at least the DCDQ is more closely aligned to the MABC than the CSQ which explores perceptions of competence across a range of daily living tasks.

Although there were no significant correlations for the CSQ total scores and the MABCTI at any testing point, significant correlations were noted for the child's Hope scores taken at the final testing point and all but the first self perception (CSQ) total score (see Table 6.41 below). The final testing session showed a particularly strong relationship between positive thinking and a sense of competence performing motor tasks.

Table 6.41 Comparison of child's Hope Scores with child's perception of motor ability (CSQ)

	CSQ Total Test point 1	CSQ Total Test point 2	CSQ Total Test point 3	CSQ Total Test point 4	CSQ Total Test point 5
HOPE total	$r=.201$	$r=.405^*$	$r=.363^*$	$r=.370^*$	$r=.638^{**}$
Test point 5	n=33	n=31	n=34	n=35	n=35

* = $P < .05$; ** = $P < .01$

Visual analysis of the plots of the CSQ over the 5 test points shows a similar distinction to that of their parents between the children who got worse versus those who stayed the same or improved (see Figure 6.25). Repeated measures analysis ($n=28$ with complete data), did not show any main effect of time, age, level of progress or ratings of the child's initial degree of motor deficit. With only 3 children in the 'worse' category, these results should be viewed with caution.

Figure 6.25 Child's perception of skills (CSQ) scores contrasted to overall outcome on MABC

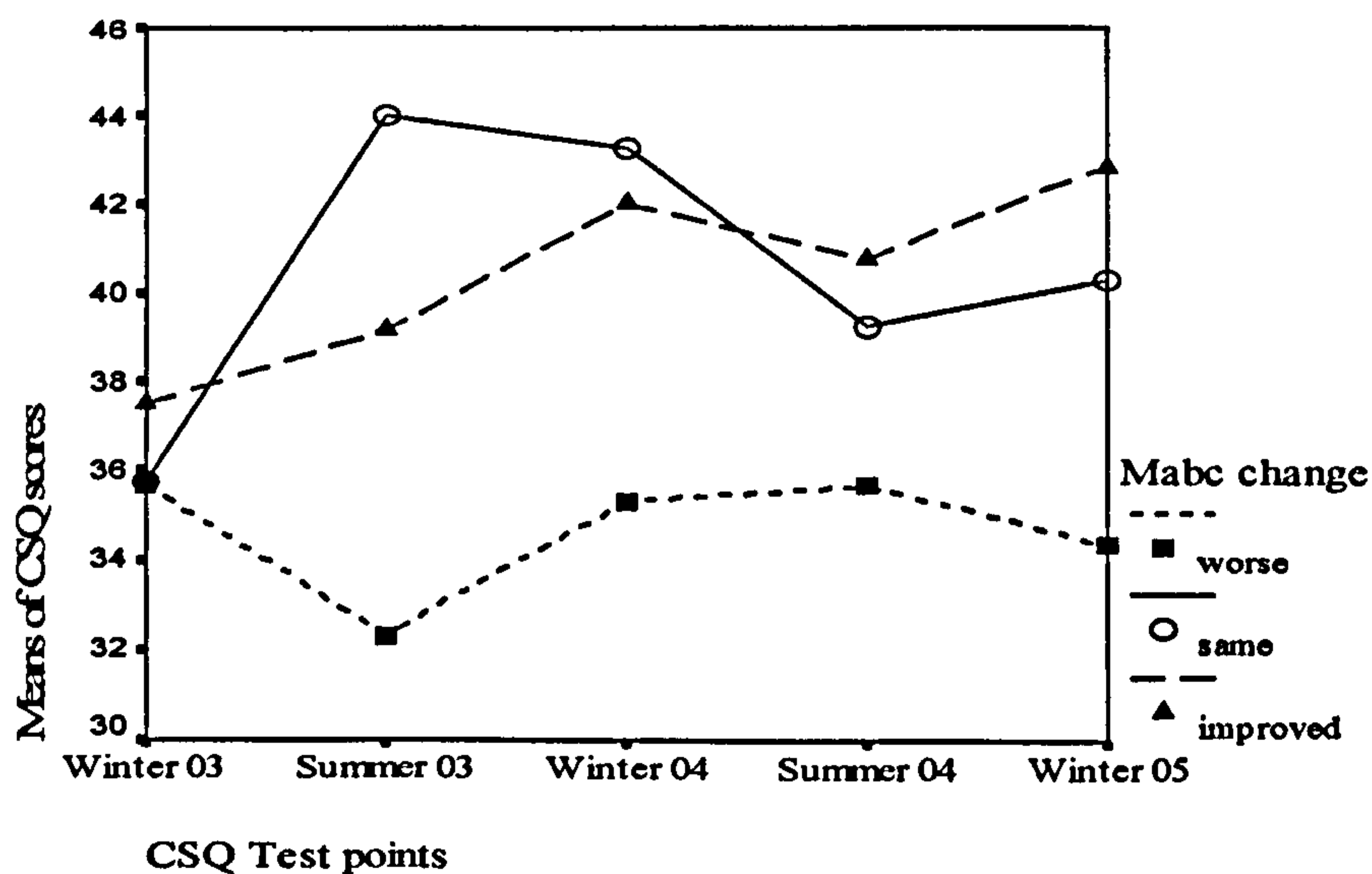
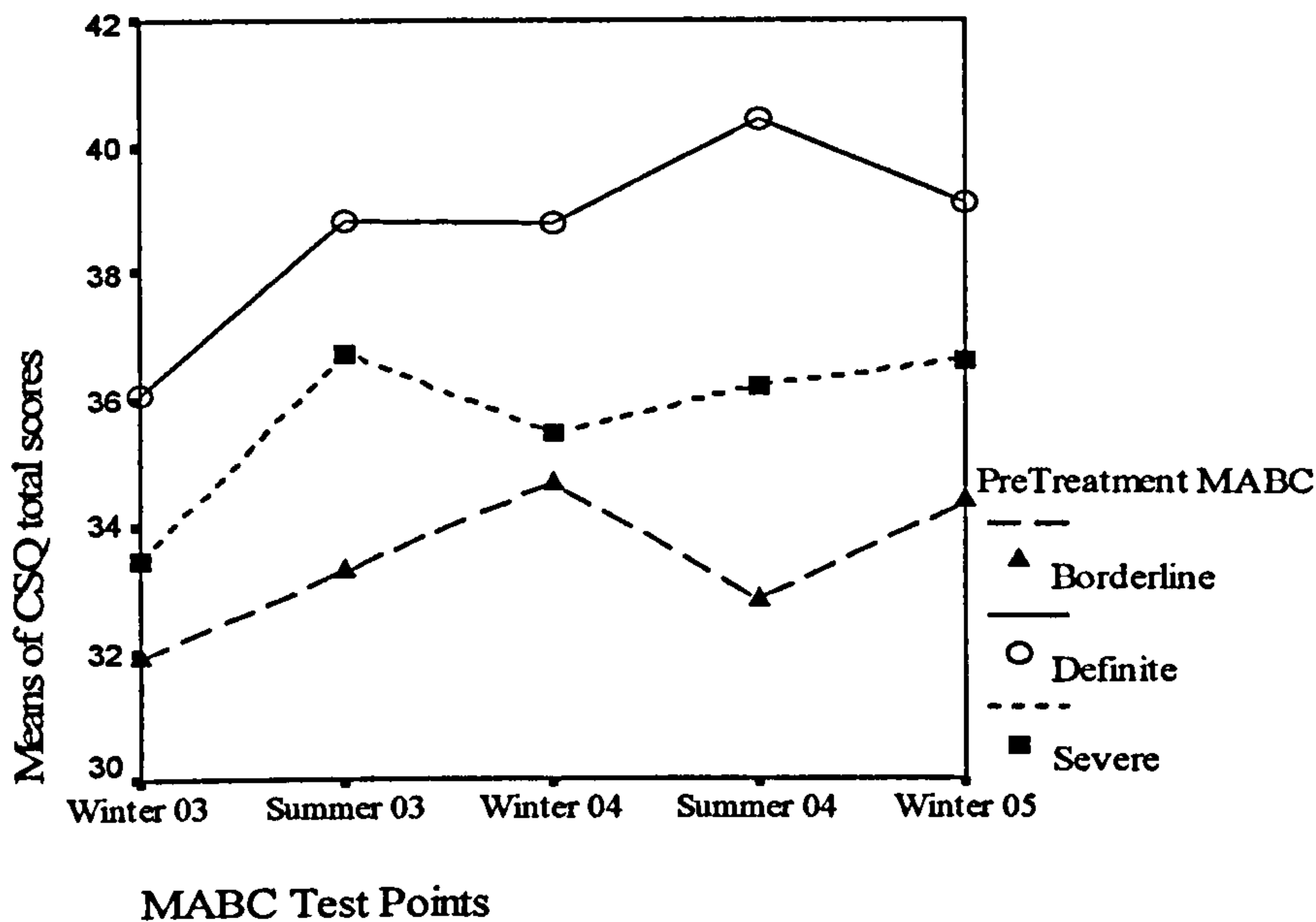


Figure 6.26 Child's perception of skills (CSQ) scores contrasted by degree of initial motor deficit



Visual analysis of the above figure (Figure 6.26) shows children who were the least impaired at the onset of the study (the borderline group), perceived themselves as having the greater difficulty in daily living tasks as shown by lower CSQ scores.

6.5.12 Influence of parental expectation & internal resilience of children on outcome

This next section will explore whether discrepancies in expectation may influence coping strategies and outcome. The Family Grid was undertaken to explore the attitudes that parents and children have to each other. Discrepancy scores for the Family grid questionnaire were calculated for each parent self opinion, each child's self opinion and the parent towards their child and child towards their parent.

[Additionally, the tendency of a parent to view both themselves and their child in the same positive or negative light was calculated by subtracting their scores for their child from their own discrepancy ratings]. Values less than zero reflect more similar attitudes of their own and parents' abilities and characteristics. Positive values show them to have a more positive opinion of themselves than their child or parent and vice

versa. Z scores were computed to identify which parents were more likely to have discrepant views of their ideal child versus their real one and the impact that this might have on outcome. Z scores were also computed for a child's discrepancy between their real and ideal self. These scores were ranked so that scores greater than 1 SD above the group mean [higher discrepancies in attitudes towards their real (versus ideal) child or self], were ranked lower than those Z scores plus or minus 1. Z scores representing more than 1 sd below the group mean (eg. less discrepant views) were ranked higher. ANOVAs of these Family Grid rankings were then undertaken. There was no effect of discrepant parental attitudes towards their children and outcome [$F(2,33) 0.52, P > .05$]. Similarly, there was no effect of a child's reduced attitude of self compared to an ideal self and their motor outcome [$F(2,32) 2.33, P > .05$].

Children's overall impression of their ability to problem solve and learn from mistakes, to get things done and do things well was measured via Snyder's Hope Scale. This questionnaire was designed to determine a child's resilience to their difficulties, perhaps giving an indication of their ability to persist with difficult tasks. ANOVA of the total Hope score (range 6 to 36) was compared to children's outcome on the MABC (eg. worse, same or improved). No differences were found between outcome groups and total Hope scores [$F(2,32) 0.37, P > .05$]. Furthermore, there were no significant correlations (of the Z scores) and/or discrepancy scores and overall outcome so no further analysis was undertaken.

The children's self perception of their skills as measured by the CSQ was contrasted with outcome. The means of children who got worse, stayed the same or improved showed an emergent difference at test point 2 with a significant difference emerging at test point 3 with children who ended up worse overall rating themselves as worse across most items but by the end of the study, there were no differences in the group means (see Table 6.42). These results may in part be due to the small numbers of children whose motor skills deteriorated.

Table 6.42 ANOVA results of CSQ by MABC outcome (better, same, worse)

	<i>F</i>	(df)	significance
CSQ Winter 03	0.15	(2,28)	>.05
CSQ Summer 03	2.97	(2,35)	=.06
CSQ Winter 04	4.77	(2,35)	=.015
CSQ Summer 04	1.11	(2,33)	>.05
CSQ Winter 05	1.50	(2,32)	>.05

Parental attitudes towards their child would not seem to be a factor influencing their child's outcome on motor testing. It had been hypothesised that parents with less positive attitudes towards their children may, possibly unwittingly, undermine their child's confidence especially with the degree of encouragement they provide when their child is attempting new motor tasks. A similar reasoning provided the basis for contrasting a child's perception of their abilities and characteristics, comparing their real self to an ideal and resilience to problems they may encounter. The implication being that lower self esteem (high discrepancy) and poor resilience (low Hope scores) may have some bearing on their willingness to participate and persevere in tasks they find difficult. This was not born out in the initial analysis of Family Grid results nor on the Hope scale.

6.5.13 Influence of learning and academic factors on outcome

In view of the proposed link between intellectual development and motor learning, the relationship between the cognitive variables of the MAT and BPVS and the motor skills of children was explored using Spearman correlation analyses. Standard scores of the MAT and BPVS were negatively associated with cluster groups of the children in the treatment group ($r=-.477, P=.001, n=43$ and $r=-.343, P=.024, n=43$ respectively) again suggesting that children with better non-verbal and verbal skills are in Cluster 1 (the more mildly involved children). As with the original (total) DCD sample, the clusters of the smaller group of children participating in the treatment study were

contrasted using one-way ANOVA of MAT and BPVS standard scores. This showed a significant effect of cluster group for non-verbal tests but not verbal reasoning [MAT: $F(4,38)$ 4.28, $P=.006$; BPVS: $F(4,38)$ 1.85, $P>.05$]. Using the Hochberg post hoc procedure due to unequal sample sizes but equal variance of scores between cluster groups showed Cluster 5 to have poorer non-verbal skills than Cluster 1 ($P=.01$) and Cluster 2 ($P=.01$) (See Table 6.43 for means and standard deviations for each cluster group in the intervention study).

Table 6.43 Means (standard deviations) of BPVS and MAT scores for cluster groups

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
BPVS	103.8 (10.4)	102.2 (15.2)	91.8 (7.3)	98.7 (8.2)	91.2 (15.1)
MAT	99.6 (7.3)	100.4 (13.1)	89.4 (13.0)	94.7 (7.0)	82.4 (6.2)

As expected the BPVS correlated highly with WORD measures of Basic Reading ($r=.506$, $P<.005$, $n=33$); Spelling ($r=.479$, $P=.005$, $n=33$); and, Comprehension ($r=.607$, $P<.001$, $n=33$). MAT standard scores also correlated with WORD comprehension ($r=.428$, $P=.013$, $n=33$) but none of the other WORD scales. Binary logistic regression of these (variables related to academic ability) to predict outcome (improved or did not) showed only the BPVS standard scores (SS) to place children at some advantage [BPVS SS $\exp\beta= 1.13$, $P=.02$].

The influence of cognitive factors, particularly verbal ability, on outcome may also have been a factor in outcome as the CO-OP approach used in treatment was developed from a cognitive model of motor learning with key components of this therapeutic intervention including verbal rehearsal, use of mnemonics and verbal (self) guidance. As such, it was hypothesised that children with better verbal and cognitive ability may benefit more from participation in the study. Similarly, modelling and imitation are also key instructional techniques and therefore visual spatial skills and gesture ability may also have contributed to children's progress. Binary logistic regression was employed to determine which of these variables, if any, predicted

whether children did or did not improve in their motor performance by the end of the study. The BPVS standard score (SS), MAT SS, GT Representational and GT Non-Representational Z-score differences from 1997 mean and the VMI visual subtest SS were entered simultaneously. Again, only the BPVS SS showed some ability to predict outcome with better verbal ability corresponding to an increased likelihood of making progress [BPVS SS $\exp\beta = 1.15$, $P = .04$].

As it was seen previously (Section 6.4.2) that poor non-representational gesture ability was significantly associated with poor movement skills at the onset of the study, cross tabulation of gesture ability to outcome was undertaken. Figures 6.27 and 6.28 illustrate that, although there was a significant difference between groups with poor gesture ability, problems representing the actions of objects did not necessarily contribute to ability to make progress [Representational $\chi^2(2) 5.15$, $P = .049$; Non-representational $\chi^2(2) 2.82$, $P > .05$].

Figure 6.27 Contribution of Representational Gesture to outcome

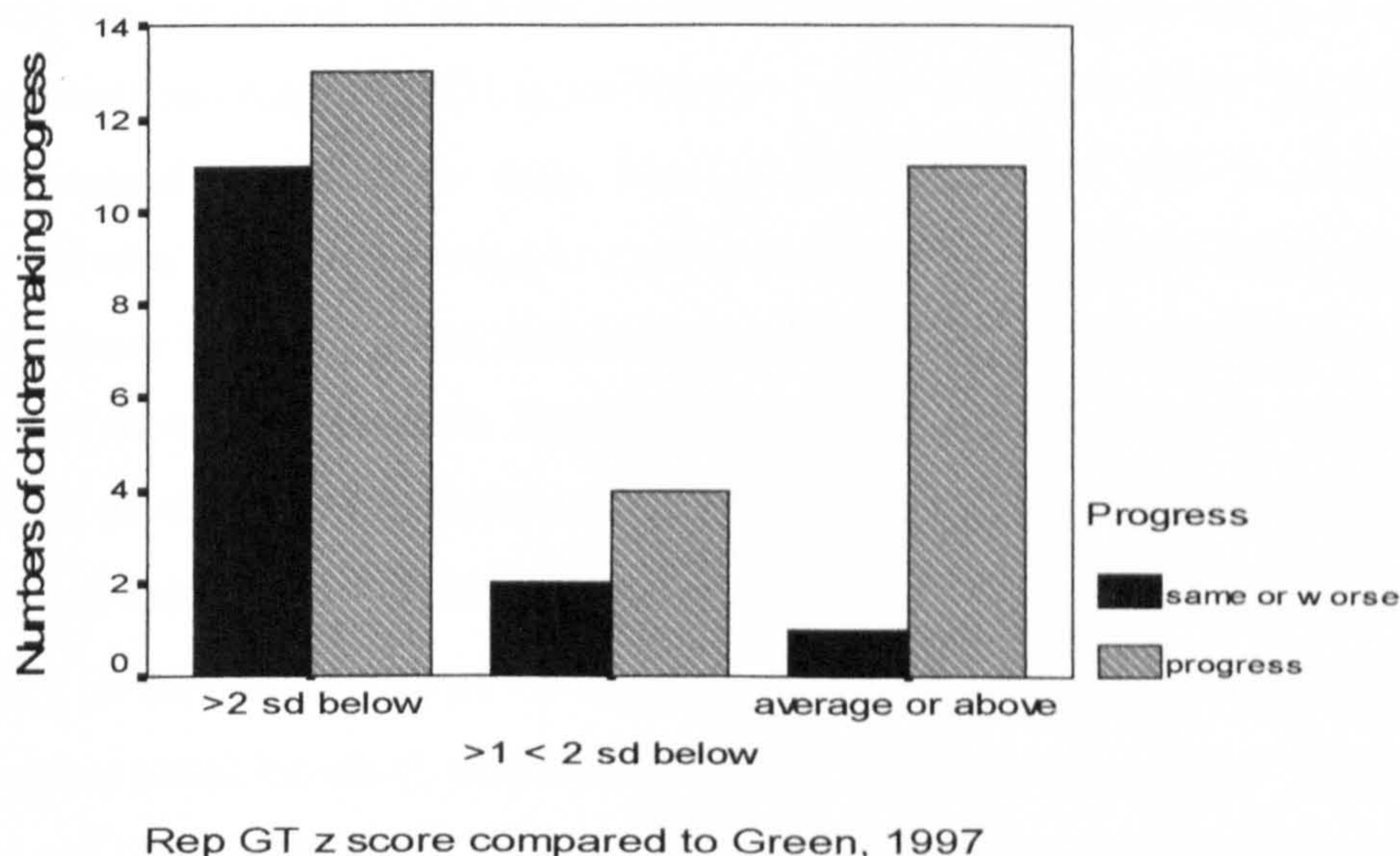
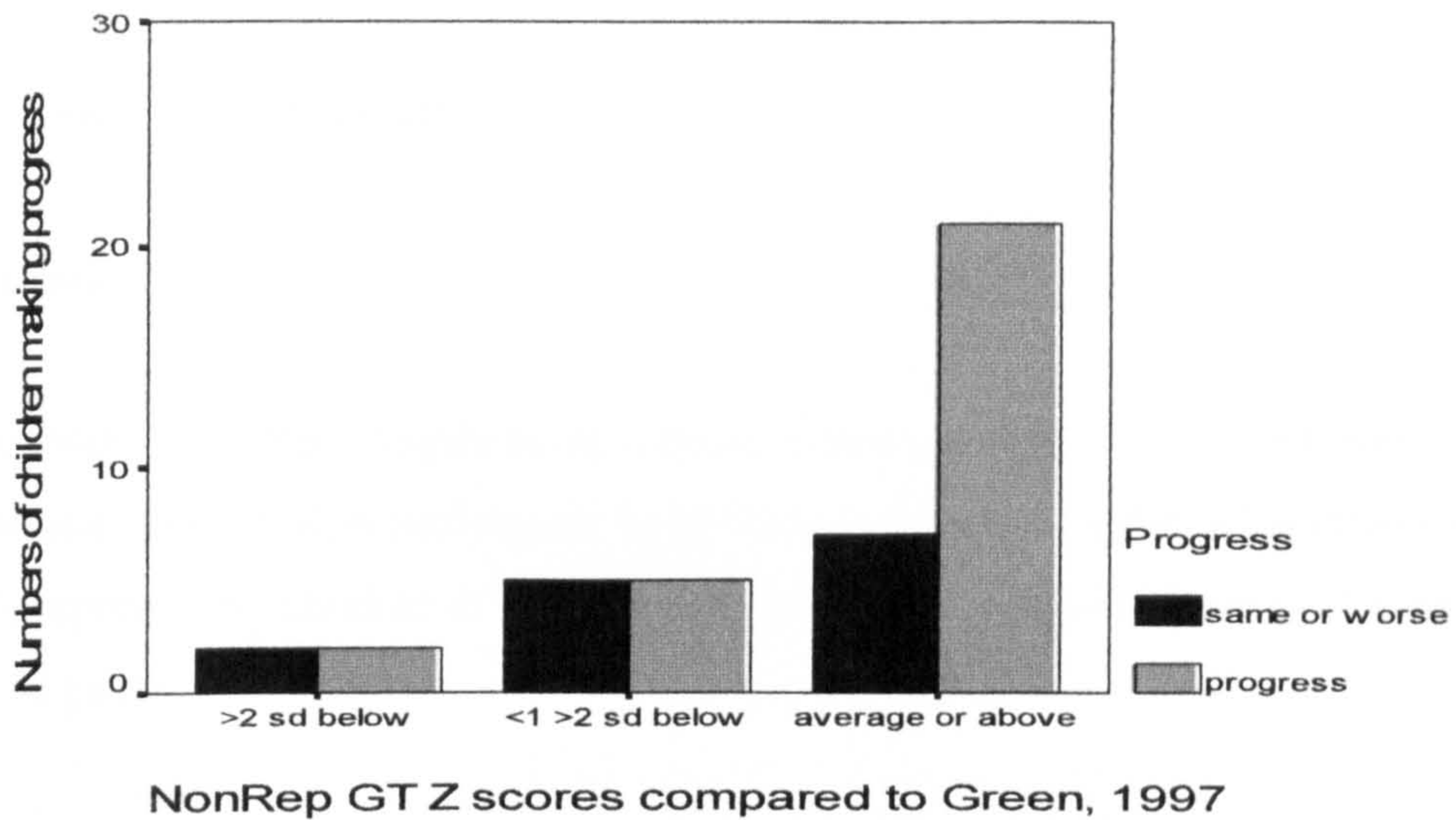


Figure 6.28 Contribution of Non-representational Gesture to outcome

6.5.14 Influence of multiple factors on outcome

In order to identify whether any of these factors, analysed separately, might predict outcome when considered together, the assessment variables of motor and estimated cognitive ability (extent of impairment MABCTI, VMI, BPVS and MAT standard scores) were analysed. In view of the small numbers of children who got worse ($n=4$) this group was combined with those who continued to have the same degree of motor impairment at the end of the study. Binary logistic regression was run, classifying children who made improvement or not as the dependent variable, exploring in the first instance key assessment variables hypothesised to predict outcome: original extent of movement difficulty (MABCTI), nonverbal ability (MAT), verbal ability (BPVS), possible socio-emotional difficulties (SDQ total scores) and presence of known co-morbidity. Of these, only the BPVS score was significant ($\exp\beta=1.49$, $P=.02$). A further binary logistic regression was run, entering the BPVS scores along with other variables which may have predicted response to treatment: SES, Hope scale and literacy (WORD). None of these other variables contributed to an ability to predict outcome.

6.6 Summary of Results

The sample

The cohort of children, despite being a convenience sample from one particular community in the UK, would appear to be fairly typical of samples of children with DCD, representing children of middle ranking socio-economic status with 1:4 ratio of boys to girls.

Although there were some children with known additional diagnoses within this cohort, there do not appear to be any major differences in the extent of motor difficulties for those children with relatively 'pure' versus 'co-morbid' DCD. Relatively few 'pure' DCD children could be said to have had an uneventful developmental, learning or medical history and profile.

Subtypes

Five clusters of children describing qualitative differences in perceptual and motor profile were identified. Two clusters were seen to have a similar pattern of skills to those described by Hoare (1994) and Macnab et al. (2001) with the remaining three clusters being a very close approximation.

The clusters remained fairly distinct in qualitative type when entering children with different diagnostic conditions. However, the presupposition of five distinct cluster types is refuted by the numbers of children who changed cluster groups when children of different diagnostic categories were included in the analysis (eg. when the four children with AS were included, 11 children with 'pure' DCD changed group).

Cluster 5 contained children who were poorer across all perceptual and motor tasks and Cluster 3 was the least stable, representing a group of children with poor balance and relative weak visual motor and visual spatial skills.

Subtype Stability from different theoretical perspectives

The clusters obtained from different theoretical perspectives — notably SI and neuropsychological frames of reference — did not predict group membership consistent with original cluster modelling technique. The assessment variables associated with SI were stronger predictors of subtypes of motor performance than the clusters identified by this theoretical model. Only 42.4% of original grouped cases from the neuropsychological frame of reference were correctly classified. Children in the original Cluster 5 were seen to be the most impaired across cognitive, perceptual and motor tasks and contained the higher percentage of children with known co-morbidity.

Components underpinning skilled motor performance

Significant correlations were obtained between verbal and non-verbal cognitive abilities and also visual motor, visual spatial and kinaesthetic functions with manual dexterity tasks but not with other movement skills except for visual spatial skills which were seen to be associated with ball skills.

Gesture tests, traditionally associated with motor planning (praxis) correlated with cognitive but not motor ability.

A group of children who had particular difficulty on non-representational gesture were seen to have significantly poorer motor skills.

Neurological maturation, partly observed through reflex integration (ATNR), was not associated with tests of motor execution.

Outcome related to degree of initial motor impairment

A significant number of children benefited from participation in the study and progress was seen to be unrelated to degree of initial motor impairment. Significantly more children made progress following participation in the group treatment programme than by maturation alone. The severity of motor problems at the onset of the study suggested a greater need for intervention as any maturational progress was insufficient to overcome the extent of motor impairment.

Outcome related to profile of perceptual-motor difficulties (cluster type)

Although children in Clusters 4 and 5, the most impaired at the onset of the study, continued to have the greater proportion of children with severe motor problems at the end, a child's original cluster grouping did not predict outcome, either maturational or in response to treatment.

Children in Cluster 3 were seen to fluctuate the most in their profile of skills but made good progress overall. Patterns of progress, as documented by mean MABC TI scores of each cluster group over consecutive testing points, were similar across groups.

Outcomes and progress on additional measures of functional motor performance

Improvements in performance were similar for all children, irrespective of cluster group

Influence of other developmental or social factors on outcome

A child's reported conduct problems and inability to get on with their peers at the onset of the study were most likely to predict continuing emotional and behavioural

problems two years later however, there was no relationship between emotional and behavioural problems and degree of motor difficulty or outcome.

After the first year, parent report of their child's motor difficulties was associated with clinical testing of motor skills. Their reports of their child's risk of neuropsychiatric problems showed little change over time. Adverse family events were noted and may have had a negative impact on at least two children's progress.

Children's ratings of their ability correlated positively and significantly with ratings of satisfaction with skill yet were not associated with clinical testing of ability on the MABC. A number of the individual items of the CSQ correlated with MABC TI and subtest scores. Children's positive sense of their ability to solve problems and achieve their goals, as measured by the Hope Scale, was significantly correlated with their sense of competence performing movement skills.

Visual analysis of the results shows children who were the least impaired at the onset of the study to perceive themselves as having the greater difficulty in daily living tasks.

Neither parental attitudes towards their child, nor the child's of themselves or their parents, would seem to be a factor influencing a child's outcome on motor testing. Lowered self esteem (high discrepancy on the Family Grid) and poor resilience (low Hope scores) were not seen to interact with other developmental factors to influence outcome.

Cognitive measures and academic skills of reading were not correlated with motor outcome (worse, same or improved).

Overall Summary

Five subtypes of DCD were identified in a large group of children which were not found to influence progress with or without intervention for a smaller subset of these children. Clusters obtained from different theoretical perspectives did not predict similar group membership. Some of the children with perceptual problems (kinaesthetic and visual) as well as the more severe motor problems at the onset of the study continued to have greater difficulties at the end. The children with more persistent and severe perceptual-motor difficulties may be at greater risk for co-morbidity.

CHAPTER 7 SUMMARY, DISCUSSION AND CONCLUSIONS

7.1 Study aims

This study endeavoured to validate whether subtypes of DCD are clinically meaningful and thus relate to differences in outcome. Using a mixed qualitative and quantitative experimental design, a number of questions were addressed regarding the nature of DCD:

- i) Are there distinguishable subtypes of perceptual and motor performance in a group of children with Developmental Coordination Disorder in the UK and, if so, how do these compare with published studies from Australia and Canada?
- ii) How well do different theoretical models, used to identify subtypes, predict original group membership?
- iii) How do these subtypes influence outcome, with and without treatment?
- iv) What impact do additional factors associated with motor development have on movement skill and treatment response?
- v) How do emotional and behavioural characteristics of children influence the acquisition of motor skills?

The first part of this study investigated the presence of distinct profiles of motor behaviour in a controlled clinical environment. The second study tracked the maturation over time, with and without intervention, of a smaller subset of these children identified with movement problems. This information is used to contrast the differing theoretical perspectives to understanding DCD.

7.2 Summary of study findings

A large convenience cohort of children with movement difficulties, identified from referrals to a district Occupational Therapy service, was found to be equivalent, in size and type, to samples of children used in previously published sub-typing studies

(Hoare, 1994; Macnab et al., 2001). Factor and cluster analysis identified five fairly distinct subtypes differentiating children on their perceptual and motor performance. Two of these clusters showed a very similar pattern of skills to those identified by Hoare (1994) and Macnab et al. (2001), with the remaining three showing a close approximation. Although the group with movement difficulties contained a number of children known to have additional co-morbidities (n=48), comparative analysis of their movement profiles did not illuminate major differences in performance to those with a relatively 'pure' DCD (n=62). Of interest, however — despite the relative stability of the five profiles of perceptual and motor skills — were the numbers of individuals whose cluster allocation changed when the sample was manipulated to include or exclude those with differing additional diagnoses. Discriminant function analysis of cluster groups, obtained from the testing variables associated with different theoretical perspectives, did not predict similar group membership to the original categorisation. Within the group of children with DCD (pure and mixed), very few significant correlations were identified between hypothesised underlying components and motor output.

In the second part of this project — the intervention study — a significant number of children benefited from participation in group intervention programme using the Cognitive Orientation to Occupational Performance (CO-OP) approach. Progress was unrelated to the degree of initial motor impairment or pattern (subtype) of perceptual motor skills although those with the most severe movement difficulties in combination with perceptual problems (relative to this group) were most likely to show persistent movement difficulties at the end of the study. Two of the four individuals whose motor skills appeared to deteriorate were known to have had adverse family events during the period of the study. Better verbal ability on the BPVS at the onset of the study was the only variable marginally predictive of progress. Children with a known co-morbidity were less likely to make progress in their movement skills over the course of the intervention study although no other specific developmental or social factor was found to relate to progress in performing motor skills. The implications of these findings are discussed in the following sections.

7.3 Subtypes in DCD

7.3.1 Are there distinct subtypes of co-ordination disorder?

The principle enquiry of this study considered whether homogeneous subtypes exist in what historically has been described as a heterogeneous group of children with a broad range of motor and behaviour profiles, with the clinical relevance of such subtypes being of paramount importance. The development of motor coordination is a complex function that is poorly understood, so the likelihood of identifying clear and distinct profiles of performance in a group of children with DCD was highly improbable, especially contrasting these across theoretical perspectives when considering the discrepant views of motor development and motor impairment. However, the high numbers of children presenting to clinical services with a primary problem performing movement tasks and the documented higher risk of a negative outcome in adolescence and young adulthood associated with poor motor skills in childhood, suggests that a detailed exploration into what factors (from the different theories) may contribute to a more positive (or negative) developmental trajectory, may nevertheless be worthwhile (COT & NAPOT, 2003; Hellgren et al., 1993; Rasmussen & Gillberg, 2000; Sigurdsson, vanOs & Fombonne, 2002).

Having ascertained that the cohort was comparable to other studies of children with DCD — albeit using a broader definition of Criterion C as recommended by the Leeds Consensus Statement (LSC, 2006) — five subtypes were identified through factor and cluster analysis of the same and similar variables used in previous sub-typing studies. Consistent with the previous studies of Hoare (1994), Macnab et al. (2001) and Miyahara (1994) and that of Jongmans (1994), a group were seen to perform relatively well on a measure of static balance (Cluster 1, with Cluster 4 also performing well on dynamic balance). Similar to these other studies, another group were found to be poor across all perceptual and motor measures (Cluster 5). A further group, Cluster 3, was found to be similar to one of Hoare's (1994) subtypes in which perceptual ability was relatively competent compared to motor performance skills with Cluster 4 presenting

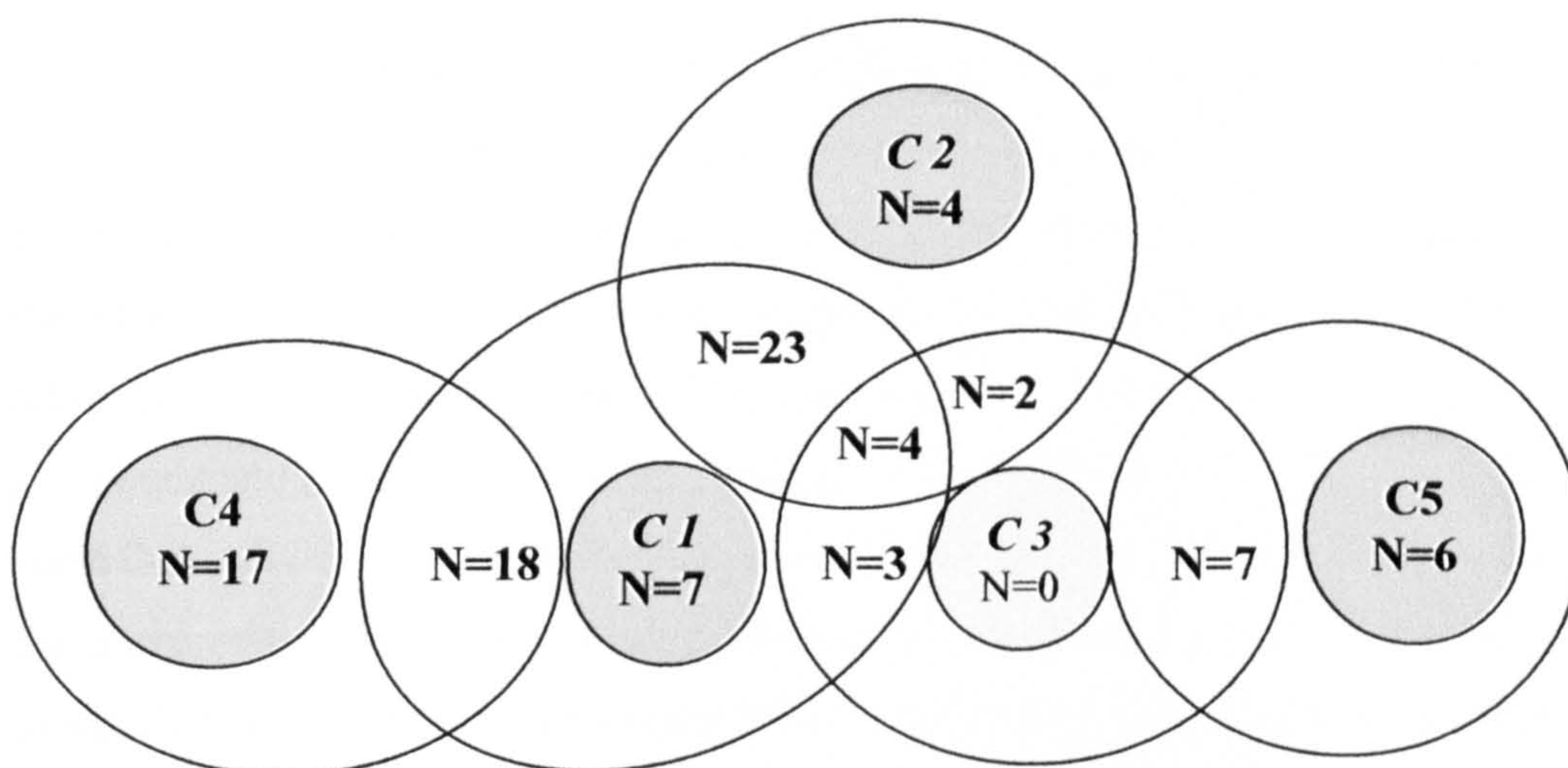
with an opposing profile of poor perceptual ability in contrast to relatively good motor performance (note that Hoare's comparative cluster to this group showed competence in kinaesthetic but not visual perceptual functions). Cluster 2 was comparable to that of Hoare's (1994) with a particularly pronounced difficulty in static balance, although this cluster showed relative competence in kinaesthesia in contrast to that of Hoare's group. It might be tempting therefore to conclude that as many as five distinct subtypes exist in DCD to include children with:

1. Better balance skills compared to overall motor difficulties
2. Particularly poor static balance skills
3. Poor perceptual ability to better motor performance
4. Better perceptual ability to poor motor performance
5. Poor at all perceptual and motor tasks

If excluding the perceptual profiles, these groups would be analogous to the motor profiles identified by Piek, Baynam and Barrett (2006): relatively poor fine motor skills, gross motor skills or complex motor skills.

However, the changes that occurred in group membership when the children with known co-morbidity were added consecutively to the 'pure' DCD groups, illustrate weaknesses in cluster structure. Rather than those from each co-morbid group being added to existing clusters, on each occasion between 18% and 46% of children, previously allocated a cluster group, changed relative profiles. Cluster 3 was particularly vulnerable to changes in group membership. Figure 6.6 may have been better represented by illustrating a more significant overlap of Cluster 3 to those of 1, 2 and 5 to show the spread of scores with the majority of individuals placed outside of the centre (grey) area representing the group means (See revision below in Figure 7.1). Thus, the central premise of the relative uniqueness of the five clusters is called into question by what would appear to be a large number on the outskirts of the clusters; over 68% of children changed cluster group at least once during these analyses.

Figure 7.1 Revised Representation of overlap of cluster groups from Figure 6.6



Despite the overlaps in group profiles, it would appear that the centres of each cluster remained distinct (identifying it as a homogenous group), evidenced by the higher than expected likelihood of the match in the discriminant analysis between the groupings from Ward's (variance) and K-Iterative partitioning (distance from centroid). With five cluster groups, an expected match would be 20% and the discriminant analysis predicted 63.7% and 71.6% correct classifications, with five and four cluster groups respectively.

The high number of children who were re-categorised when those with different diagnoses were entered into the analysis, may in part have been due to the technique of cluster analysis. The mathematical procedures within cluster analysis are based on the assumption of the use of interval data. Most of the measures in this study involved ordinal data which were then transposed to interval data, via sample dependent standardisation. Thus, varying the individuals in the sample would change the standardised score for each child, a function which is particularly dependent on the extent of any outliers. For most cluster groups, a lower or higher score of one child, on one or more tests, would have changed the group make-up by 10%.

A further point to make, concerns the use of quantitative data to describe discrete groups. Errors of classification are inherent within this procedure as quantitative test criteria can not capture all categorical types due to the intrinsically fuzzy margins at the edges of continuous distributions. Although the theoretical principle of five relatively distinct clusters (achieved through analysis of the results on typical perceptual and motor assessments), is partly supported by these findings, it would seem that individual children do not necessarily conform to this model, thus rendering the interpretation of an individual profile as relatively meaningless. To test the extent to which these results may have been influenced by the model of movement deficit employed, the original cluster groups were compared to three differing theoretical models of motor impairment.

7.3.2 Are these subtypes stable across theoretical perspectives?

Three perspectives of children's perceptual-motor development were contrasted with the original sub-typing analysis; a developmental model (extent of motor impairment), Sensory Integration theory (SI) and a general cognitive/information processing model.

Exploring the extent of movement difficulty related to cluster group in the first instance, suggested that Cluster 5, containing children with problems across all perceptual and motor tests, was most likely to have the more severe movement problems and Cluster 1, those showing relative competence across these measures, had the highest percentage of children with borderline movement problems; a not unexpected result considering the description of these groups. However, children from Cluster 3 (which overlapped with Cluster 5) had 2 individuals with very profound movement problems (≥ 30 MABCTI scores) and all groups had representation in the next category of severity (≥ 20 & < 30 MABC TI scores). A particular type of perceptual motor deficit would not, therefore, provide any protection against severity of problem. This would be somewhat counter to the arguments initially posed by Gesell (1928; 1945) and McGraw (1945) and more recently by Jeannerod (1997), who describe increasing perceptual motor capability with

maturation of appropriate pathways in the brain and corresponding improvements in coordinated systems for performing complex movements. It should be mentioned however that much of Jeannerod (1997) and Goodale et al.'s (1996) descriptions of neurological processes underpinning perceptual-motor performance come from animal models or studies of adults who have lost capability through insult or disease. The studies of children employed by Touwen (1979), Hadders-Algra, Brogen & Forssberg (1998) and Bottos et al. (1989) also suggest a stronger link between neural maturation and motor development. However, the results set out in Table 6.18, exploring the associations between neuro-motor control and motor performance, illuminated very few significant correlations. The COMPS subtests of Slow Ramp Movement and Rapid Forearm Rotation, both reflecting cerebellar integrity, had relatively low Spearman rho correlations ($r=-.220$ and $r=-.212$ respectively) with MABC TI scores and only the Finger to Nose item was associated with manual dexterity ($r=-.213$). Surprising also, was the lack of association between tests reflecting postural control (Prone Extension and Supine Flexion) and neural maturation (ATNR) which were not associated with MABC items but rather showed significant correlations with the motor subtest of the VMI. It is difficult to interpret these rather anomalous results from a 'maturation' theory of the development of motor skills. Dynamical systems theory provides a more apposite rationale for these variations in development and the associations between components of movement and motor performance. From this perspective, strengths in perception-action coupling are considered to be more directly linked to "the specific task at hand and the individual's expertise in that task" (Thelen & Smith, 1994, p 37). Thelan and Smith (1994) provide a number of elegant studies to show the independence of neurological/anatomical maturation from skill accomplishment when either the task or infant's experience is manipulated.

As classical interpretations of developmental maturation models were not robustly supported by the results, so neither the clusters obtained from an SI nor cognitive perspective provided good prediction of original group membership. Although, results on the assessment variables (rather than theoretically defined clusters) gave better predictions of the original cluster modelling technique, it would seem that the clusters

formed from the model of SI and the original model of perceptual-motor performance are not sufficiently robust to match children with a particular set of problems to those observed from another perspective. The a priori decisions as to which variables represent these theories and should be grouped together (also supported by Factor Analysis), provide hypothetical associations that are not upheld by the cluster and discriminant analyses. Of particular note are the results set out in Table 6.11 which shows two of the five SI cluster groups to have no representation. In contrast Table 6.12 shows quite significant predictions for the five cluster groups obtained from the SI individual test scores (66.7%, 83.3%, 70%, 90.9%, 81.8% for each cluster).

The better predictive ability of the SI variables over the cognitive measures provides some evidence that these assessments, representing SI, offer an explanation for movement, as well as mild (specific) learning, problems. However, SI as a theoretical construct linking particular assessments, provides a weaker paradigm for explaining movement problems. The cognitive measures may have been less predictive of perceptual-motor cluster in this instance in view of the sample being skewed with all children, by design, having a movement disorder. A more credible argument in defense of the cognitive discrepancy theory could be posed by contrasting the entire group (N=139) in the study via the same procedures so as to include children without movement problems as well as those with a greater degree of intellectual impairment (but not including the two individuals with Down Syndrome).

The association of cognitive functions involving visual processing with motor performance was explored along the lines of Rourke (1989) and Weintraub and Mesulam (1983), who describe a more direct association between visual spatial problems and movement difficulties as Non-verbal or Right Hemispheric learning difficulties respectively. Consistent with their hypotheses, the correlations between the non-verbal and visual spatial skills (MAT, VMI Visual Subtest and VMI motor subtest) to motor performance, were all highly significant, especially to manual dexterity (see Table 6.18). These results are also compatible with Wilson and

McKenzie's (1998) conclusion that visual perceptual deficits were the most likely problem amongst children with DCD.

The relationship of visual spatial mapping to movement representation (mime) and imitation was explored in more depth by ranking children's performance on the gesture subtests according to the extent to which they differed from a non-DCD group identified by Green (1997). The possibility of a 'dyspraxic' subtype within the group, representing those with greater difficulties with the body schema and visual imagery of movement, was given credence by the significantly poorer motor skills associated with children whose imitation ability was more than two standard deviations below the means obtained for the non-DCD group of Green (1997). How the current 'dyspraxic' subtype compares to that proposed by Gernsbacher and Goldsmith (2000) in children with Autistic Spectrum Disorders (ASD) is hard to determine, however Green et al. (2002b) concluded that differences between DCD and Asperger Syndrome (AS) in performing gestures, are more a matter of degree than quality (referring in this instance to the relative strength of representational to non-representational gesture production). Of interest though, when looking at the results of Chaminade, Meltzoff and Decety (2005) — who found an association of poor imitation skills and poor representation of body schema or visuo-spatial description of one's own body, linked to left or right parietal dysfunction respectively — is the consideration of a further subdivision of imitation deficit amongst children with DCD. Are there some children with DCD who are more closely associated with those with ASD who have problems across all aspects of imitation (object action representation and movement imitation) versus some whose problems are limited to poor body schema and imitation of body movements? Notwithstanding these results (imitation problems linked to greater movement deficits), the longer term monitoring of those in the intervention study did not suggest that this original 'dyspraxic' deficit played a significant role in outcome. In this respect it would be interesting to repeat the studies of Livesey (2002), Lust et al. (2006) and Wilson and colleagues with larger samples in order to subdivide children with DCD to those with and without visual spatial and/or gesture problems (Maruff et al., 1999; Wilson et al., 1997; 2004; J. Williams, et al., 2006).

7.3.3 *Summary*

The initial analysis of subtypes showed some stable patterns of perceptual-motor performance yet individual children did not conform to these models. The comparative validity of these subtypes when contrasting the initial groups with different theoretical constructs was also found to be quite weak. An assumption of some degree of coherence of these motor profiles is further challenged by the potential impact of co-morbidity on perceptual, cognitive and motor capabilities. Perhaps, rather than conceptualise sub-types by perceptual-motor profile, a more appropriate direction would be to consider the nature of a sub-type by association with behaviour or other developmental (eg. learning) problems. This issue is explored further in section 7.4.4 when considering the influence that co-morbidity may have had on the presentation and outcome of children with DCD.

Overall, these results suggest that the various assessments reflecting the different theories may perhaps be testing similar features, but the theoretical models to describe the strengths and weaknesses on these tests are less robust. Cicchetti (1994) recommended that diagnostic instruments need to be systematically linked to a comprehensive clinical theory to be useful. The assessments used in this study were compilations of clinical tools compiled to represent the various arguments for/against problems underpinning motor performance rather than specifically designed to test out theoretical perspectives. As such, it is not surprising therefore that the groups of children obtained from the different cluster analyses were not diagnostically more precise.

It is plausible to consider that part of this loss of predictive power when using the theoretical cluster groupings rather than individual test scores in the discriminant analysis, is due to the loss of sensitivity when aggregating scores and forcing dimensional ability (continuous data) into categorical groups. However, very few correlations were identified between (hypothesised) underlying components — scores from test items rather than cluster profiles — and motor output within the group of

children with DCD (both pure and mixed). This rather equivocal relationship between theories and motor performance, attests as much to the complexity of motor development as to the failure of any one model's ability to explain individual variance. There is a need for a more robust theory of motor impairment – and then perhaps it would be a good predictor of children with particular types of problems from another perspective. But, what would a theory of motor impairment include and how precisely can it be defined? Perhaps the conclusions of Seminar 1 of the Leeds group best articulate the need to collate and draw from the literature of child development to include motor, behaviour *and* learning, when describing features of DCD (LSC, 2006).

7.4 Outcome

7.4.1 What is the influence of the extent of motor impairment on outcome?

Nearly two thirds of the children with DCD benefited from participation in the study, with significantly more students making progress following treatment rather than from maturation alone. A similar proportion of children from each category of motor impairment (borderline, define or severe) made progress either by maturation or response to treatment or showed a fluctuating profile, although maturation alone was insufficient for some of the children in the most severe category of motor impairment to overcome all of their movement problems during the period of the study. These results somewhat challenge those of Cantell, Smyth and Ahonen (2003) who suggested that there were two distinct pathways for DCD – one of persistence and the other of resolution. However, their conclusions were based on the persistence or resolution of movement difficulties at a later age, between the ages of 15 and 17 years, from amongst children who had been identified with movement difficulties between the ages of 5-11 years. Pubertal and post-pubertal stability of movement profile is not an area that has undergone much research. Visser, Geuze and Kalverboer (1998) found that growth spurts (rapid change in height) negatively influenced motor performance in a population of adolescents but that children with DCD were not affected to the same extent. During this period of development, Visser et al. (1998)

found that a majority of children with DCD caught up with their peers. Luning et al. (1992) also found beneficial effects of puberty in reducing the impact of minor neurological dysfunction (MND). Their results are similar in essence, to the study of Cantell et al. (2003) suggestive of a two-track process and also to those of Hadders-Algra and colleagues who describe two distinct forms of MND — simple and complex — with the latter more likely to contribute to persistent problems in movement, learning and behaviour (Hadders-Algra et al. 2002; Soorani-Luning et al., 1994). Cantell et al. (2003) and Henderson and Hall (1982) also considered the question of whether the complexity of movement and behaviour problems might indicate whether a child is more likely to have persistent difficulties. However, due to the use of tests with possible ceiling effects, neither the study presented by Cantell et al. (2003) nor that of Visser et al. (1998) were able to identify the criticality of specific perceptual-motor profiles in predicting which children would fall into the persistent or resolving groups.

Some studies of motor disorders such as cerebral palsy (CP) suggest that it is the severity rather than type of impairment (eg. hemiplegia versus diplegia) that predicts participation and success in daily activities (Schenker, Coster & Parush, 2005). In the current study, there was no clear-cut evidence to suggest that children with DCD with more severe movement difficulties — less than the fifth or first percentile — would not make progress; rather, the extent of their motor difficulties at onset may mean that progress was insufficient for some of them, to move them into the non-impaired group. Without revisiting this group at age 15 years, it is not possible to conjecture how these results compare to those of Visser et al. (1998) or Cantell et al. (2003).

Sugden and Chambers (2005) report on the outcomes of 31 children between the ages of 7 to 9 years, 23 of whom were in the bottom 5th percentile at initial assessment. Maturation change at 8 weeks showed four individuals to have greater movement difficulties and one child improving from the bottom 5th percentile. After a mix of either parent or teacher led intervention, three of the 31 children made little or no

improvement, the remainder showing some progress. Consecutive testing periods without intervention reflected a variety of profiles with some maintaining the progress they had made but a number of children gradually reverting to baseline scores. These authors argue that there are a group of children who make good and sustained progress with intervention, a group who need additional practice to maintain the gains made in treatment programmes and a smaller group who may require more specialist intervention (Sugden & Chambers, 2005). It would be interesting to follow the children from the current study and those of Sugden and Chambers (2005) to post-pubertal age to ascertain whether three pathways are evident for children *who have received treatment for DCD*: resolution, interim resolution/variability in maintenance of skills and persistence.

7.4.2 *What is the influence of intervention on outcome?*

The ability to learn new strategies for motor performance that can generalise to other motor tasks was rather surprising considering the relatively prompt effects of some of these results; that is, a significant number of children made good progress on tests of motor execution *immediately following* their involvement in an intervention programme that did not focus on practice of specific gross or fine motor skills (See Table 6.25). The CO-OP approach, developed from that described by Henderson and Sugden (1992) and based on Fitts and Posner's (1967) model of motor learning, describes three stages occurring between that of a novice and skilled performer: cognitive, associative and automatic (Polatajko & Mandich, 2004). The emphasis of self-reflection on the specific strategies employed to accomplish tasks, that had been identified as important to parents and children in the CO-OP approach, may also allow for motivational incentives that inadvertently reinforce strategy use across tasks that were not practiced over the intervention period. Fortunately for the children, but unfortunate for understanding more specific aspects of intervention that may contribute to progress, only four (out of 43) individuals showed poorer motor skills (MABCTI) at the end of the study, two of whom had undergone significant adverse family events during this period. Furthermore, another of these children was

suspected of having had a significant growth spurt during the final year of the study which may have influenced his test results, particularly static and dynamic balance and also strength and timing required for the standing jump. As biomechanical factors of height and weight were not measured this can only remain conjecture. As a consequence, it is very difficult to attribute blame to any particular subgroup or variable that might be a marker for children who will have persistent and possible worsening of movement problems. To try and elicit some information from these results, those who got worse were combined with those who remained the same at the end of the study to form a group — children who did not improve — that could be contrasted with those who benefited with and without intervention. Although, the severity of motor deficit suggested a greater need for intervention, as maturation alone was insufficient in some cases to overcome the extent of motor problems, those from the borderline and definite, as well as the severe, motor impairment groups were also seen to make progress by maturation, respond to treatment or show a fluctuating course. Thus, initial classification of extent of movement problems would appear to be no guarantee of a resolving or persisting deficit.

Concurrent and persistent problems in social and emotional adaptation have been reported in previous studies, with the association strongest amongst those children whose motor decrement did not resolve (Geuze & Borger, 1993; Gillberg & Gillberg, 1989; Gillberg, Gillberg & Groth, 1989; Hadders-Algra et al., 1988; Hadders-Algra et al., 2002; Losse et al., 1991; Soorani-Luning et al., 1994). A number of studies have shown that children with coordination disorders are at risk of low self-esteem which may be associated with social (exclusion) and emotional difficulties (Cantell, Smyth & Ahonen, 1994; Green et al., 2006; Segal et al., 2002; Skinner & Piek, 2001; Watkinson et al., 2001). The effect of having poor motor skills has been associated with reduced physical activity, with generalised self-efficacy accounting for 28% of the predilection of children's participation (Cairney et al., 2005). Contrasting this however, is the work of Rose, Larkin and Berger (1998) which suggests that movement competence and motivational orientation towards sports are not necessarily linked.

To explore the possibility of an association between social and behaviour problems to progress, or lack of it, in motor skills; social and emotional development was measured via the SDQ (beginning and end) and the PONS (throughout) over the course of the intervention project. More closely aligned with the results of Schoemaker and Kalverboer (1994), significant socio-emotional difficulties did not distinguish between children with borderline or severe movement problems, at either the beginning or the end of the project. Although children of 8-9 years of age were reported to have been more inattentive and overactive at the beginning of the study, this distinction was not evident by the end. Furthermore, no linear relationship was seen between progress in motor ability and expression of emotional and/or behaviour problems and surprisingly, more children who had made motor progress were reported by their parents to have social or emotional problems at the end of the study than they had had at the beginning. The small numbers not improving in their motor skills (n=14), irrespective of the severity of their initial movement problems, precludes further discussion on why these results are seemingly quite different from other studies. It would certainly be quite premature to consider that the causal direction of the social and emotional problems of children with DCD comes from their poor motor skills and reduced participation in sports and games. Rather, the social and emotional problems may arise from a different, but commonly associated, underlying deficit(s) (Shoemaker & Kalverboer, 1994).

7.4.3 What is the influence of subtype on outcome?

The answer to this question is rather straightforward, at least superficially so, as no particular subtype of perceptual-motor difficulty was predictive of outcome. These results suggest that: detailed analyses of children with movement difficulties are rather perfunctory; and, further, contribute to a disassembly of the notion of a typology of co-ordination in which those who have fine motor difficulties with visual spatial problems may somehow be different from those who have problems with static and dynamic balance but show no proportional disadvantage on perceptual tests. This is

evidenced through the lack of advantage conferred on outcome — either maturational or following intervention — of any particular profile of movement difficulty.

Visser et al. (1998) as well as Cantell et al. (2003) showed a similar lack of association between ‘type’ of movement difficulty and outcome, although Cantell et al. intimate that children with more problems in dynamic balance were greater in the persistent DCD group. These researchers attribute some of their results to differing degrees of participation in physical exercise/sports, with those from the intermediate/borderline group more likely to be involved in sports, as originally suggested by Cantell et al. (1994). The influence of dynamic balance/gross motor difficulties in persistent movement problems would also be consistent with the findings of Piek et al. (2006) reflecting the greater impact of these problems in boys. This would suggest that Cluster 3 children, with greater problems in dynamic (as well as static) balance, would be linked to those who made no progress, which was not the case. Although, the various snap-shots of changes in motor skill show that Cluster 3, was not only the most unstable group with children on the boundaries rather than closer to the centroid, but that these individuals were the most variable in their pattern of progress over time (see Appendix 10).

The lack of any clear relationship between subtype and degree of motor impairment is also in contrast to studies of children with motor disorders. From studies of six children with cerebral palsy, Woollacott et al. (2005) suggested that the short term responses to training in reactive balance control resulted in a number of improvements in directional response to postural displacement (centre of pressure), speed and amplitude of muscle activity as well as the emergence of a distal-proximal muscle sequence, reflected changes in neural factors that were dependent on both *severity* and *type* of motor involvement of the child. Children with spastic hemiplegia were able to sustain the advantages of forward sway one month after postural training but those with spastic diplegia reverted to baseline levels. The interaction of the severity and type of co-ordination difficulty, as well as some of the numerous possible variables contributing to outcome, will be debated in the next sections.

7.4.4 Singular or Specific – Can subtypes be associated with other developmental conditions?

Recent papers have highlighted the increased incidence of co-morbidity in other developmental conditions with DCD (and vice versa, a high incidence of movement difficulties in children diagnosed with a variety of developmental disorders). It had been anticipated that children with a particular diagnosis such as AS or Attention Deficit Hyperactivity Disorder (ADHD) would have had more similar motor profiles representing, in these examples, perhaps representational (including visual spatial) or attention problems respectively. Thus children with AS may have been expected to fall into cluster 4 or 5 which contained children with poorer visual spatial skills and relatively better ability in basic motor functions such as static and dynamic balance (see Green et al., 2002b for a fuller description of the motor difficulties in AS). In fact, the four individuals with AS were best compared to each of the clusters (except Cluster 3) suggesting a very mixed profile of perceptual and motor skills within this specific developmental condition. The results of Nichols and Chen's (1981) study, reiterate the complex interaction of multiple factors (pre-natal, peri-natal and post natal) and influence on developmental outcome.

The same variability is seen when analysing the perceptual and motor profile of children with ADHD. The five individuals with ADHD were spread between clusters 1, 3 and 4 but not 2 and 5. As mentioned in Chapter 4, Pitcher, Piek and Hay (2003) approached this problem differently by contrasting the profile of behaviour problems and motor impairment in subtypes of children with ADHD: predominate inattentive type (ADHD-PI), hyperactive/impulsive (ADHD-HI) and combined (ADHD-C) subtypes. Of note when contrasting their results with the current study, was the significantly lower verbal IQ amongst any ADHD subtype when accompanied with DCD. Furthermore, those from the predominately inattentive subtype were more likely to be most affected by poor motor performance. Despite a main effect of group for manual dexterity and ball skills on the M-ABC subtests with the ADHD-PI and ADHD-C differing from the comparison group, the only items showing a difference

between ADHD groups were those of ball skills in which the ADHD-HI performed better than the ADHD-PI. More interesting however is the comparison of the profile of skills between ADHD subtypes. There was a linear trend with the ADHD-HI having the least difficulty across all tasks and the ADHD-PI having the worst, suggesting a distinction of subtype by level of severity of motor impairment (when movement problems are present) rather than qualitatively distinct movement difficulties. This distinction between co-morbid groups by level of severity is not held up in the current study in which no significant differences were found in the extent of motor impairment between the different co-morbidities and children with 'pure' DCD. However, significantly more children with a co-morbid condition made little or no progress suggesting a possible interaction between co-morbidity and severity or type which requires further exploration with a larger sample.

The recommendation of Pitcher, Piek and Hay (2003), that motor skills disorders be considered a differential diagnosis under ADHD rather than a consequence of inattention or distractibility, is supported by Schoemaker et al. (2005). These researchers found that children with ADHD were likely to have impaired graphic ability (related to slower, inaccurate strokes with increased pen force) when compared with a comparison group without ADHD (Schoemaker et al., 2005). The results of Hood et al. (2005) in an investigation of the response to methylphenidate on cognitive attention, showed improvements in the ADHD group, although they did not make an attempt to qualify the results by ADHD subtype. The proposed mechanism of methylphenidate medication increases availability of dopamine to enable children with ADHD to keep a higher degree of control over their attention. A further study by Schoemaker and colleagues found beneficial effects of methylphenidate on manual dexterity tasks, providing evidence for increased attentional demands of fine manipulative skills, but that changes to handwriting quality were inconclusive with 4 of the 11 children with ADHD+DCD remaining the same and one whose performance deteriorated (Flapper, Houwen & Schoemaker, 2006). Further research should combine these studies and explore differential responses to methylphenidate for children with DCD and ADHD+DCD to investigate whether improvements in

sustained attention contribute to immediate changes in motor performance or changes in acquired skills as a consequence of greater persistence for practicing difficult tasks. If immediate improvements in performance are noted across a range of motor skills, the motor difficulties would more likely be a consequence of inattention and thus an additional layer of functional impairment rather than a more distinct subtype.

Although theoretical arguments have been advanced connecting ADHD and DCD, as yet, the mechanisms underpinning attention deficits and inadequate response inhibition linking these problems to motor performance remain unclear (Livesey, et al. 2006; Sergeant, Piek & Oosterlaan, 2006). The effects of inattention on fine motor ability require further investigation before one can go as far as stating that ADHD with DCD forms a more distinct subgroup of ADHD. There is a similar lack of evidence to support the differentiation of subtypes of DCD by association with other developmental disorders such as AS/ASD or Speech and Language Impairment (SLI).

Gender differences

The majority of females in this study were in Cluster 1 (n=9 out of 19), although the proportional distribution of females across all clusters is similar to that of males. Nolan, Grigorenko and Thorstensson (2005) found significant differences in postural control between 9 and 10 year olds, with boys showing much greater postural sway than girls with both eyes open and eyes closed. In their study there were no differences between gender at ages 10-16 years with eyes open, although boys tended to show more postural sway with eyes closed. It is not known how differences in postural control manifest between the males and females with DCD, but these authors recommended that the measurement of balance should be investigated separately between gender. This may well have had implications for the current results in which 3 of the 6 girls in the intervention study were seen to have little to no motor problems as measured by the MABC at the end of the study. The MABC does not differentiate between males and females and subsequently, the motor difficulties of the girls may have been underestimated and the consequent impact on self perception missed.

Learning

It is worth discussing the extent to which more specific difficulties with learning may be associated with DCD and be considered a potential conjoined subtype. Wilson, Maruff and Lum (2003) examined the motor learning ability of ten children with DCD matched to controls. Although their study was very small with a large variability of movement skills (N=10 with MABC TI scores between 11 and 22) in the DCD group, and no indication of intellectual level was provided, their findings suggest that procedural learning (the process of acquiring motor routines or sequences in an incidental manner) for simple sequential movements appears to be intact in DCD. This would be consistent with the results from the COOP groups, where children were seen to make progress in fundamental motor skills despite lack of repetition and practice.

What was not explored in the current study was the potential interaction effect between cognitive ability and subtype (due to insufficient numbers of children across the higher and lower IQ ranges). For example, do children with DCD with VIQ greater than 120 differ from those with more average verbal ability or do children with DCD with a significant verbal to performance IQ discrepancy differ from those without? Of note from the intervention study however was the lack of any association between academic attainments such as spelling and reading (WORD scores) and outcome, suggesting that this particular aspect of learning was unrelated to the ability to make progress in motor skills.

7.4.5 What additional factors combine to influence outcome?

A number of additional factors that have been identified as influencing development were explored, including: socio-economic status of the family; emotional and behaviour problems of the children; and, self and parent perception of ability. The final review of the intervention project also investigated resilience (hope) and any

discrepancy between expectation and reality of achievements. None of these variables was seen to contribute directly to outcome. These results are consistent with those of Lackaye et al. (2006) of students with specific learning difficulties, in which they concluded; past, present and future worries of children may confound interpretation.

As with studies of ADHD, the quality of relationships within the family and at school can be considered as maintaining or protective factors (Taylor et al., 2004). Two of the children with worse MABC TI scores at the end of the study were known to have undergone significant adverse family events. Unfortunately, the Family Grid and Hope Scales were not undertaken at the beginning of the study and it is therefore difficult to make a supposition as to whether discrepancy in expectation — either parental or child — is offset by any internal resilience. Böhm et al., (2002) identified paternal education as the single most important predictor of IQ, in children at 5 ½ years who had been born prematurely or at term. It is unclear what the exact relationship of SES, as designated by the Townsend Score, is to educational level although there is a presumption that parents who have received a higher level of education are more likely to be in employment, with a higher standard of living associated with higher levels of education, reflected in the quality of housing. SES was not associated with the extent of motor problems nor did binary logistic regression analysis indicate that SES played a factor in predicting which children would respond to treatment. These results would be consistent with those of Schneider and Scher (2000) who found working class/unemployed parents more likely to engage in activities with their children than middle class families, who employed others to play/tutor their children, despite what they expressly stated on questionnaires regarding their attitudes towards their child's learning and responsibilities for teaching. Consequently, it is very difficult to prise out any impact or interaction of parental attitude and SES on outcome from the results of a study not expressly designed to investigate these factors.

It was certainly conceivable that parental perspectives of their child's skills may have resulted in differing degrees to which they reinforced strategies at home or supported

their child in overcoming their problems. If considering parental views as a more valuable representation of outcome, only 7 out of 35 parents rated their child's motor performance as typical at the end of the study despite 15 children with motor skills in the normal range. The results show more significant correlations between MABC (clinical testing of ability) and DCDQ scores at the end of the first year of the intervention study. This result may in part be due to the larger spread (range) of MABC TI and DCDQ total scores as children began to sustain improvements. More children had total impairment scores below 10 by this time and DCDQ scores greater than 58 in the second year of the study. Tracking the mean scores of the DCDQ however, suggests that there may be a slight rebound effect for the final DCDQ as parents may have been worrying about the end of the study and subsequently reported more harshly on their child's skills. Any continuing concerns they may have had for their child's overall development may have impacted on their ratings of their child's motor skills.

An alternative perspective of 'Whose outcome is valid?' is considered via the children's ratings of their ability. Although reliability and validity of the CSQ remain untested, the children's rankings of their ability correlated positively with their satisfaction in performing motor tasks, with some of the individual items correlating with MABC TI and subtest scores. Furthermore, their sense of positive capability in solving problems and achieving their goals (measured by the Hope Scale) was significantly related to their self perception of competence in motor tasks. Despite the 'resilience' of many of the children, this factor on its own or in combination with other variables did not predict who would make progress.

It had been surmised earlier that a dyspraxic subtype may form a more distinct group of children who show a different response to treatment and/or outcome. Although poorer ability on non-representational gesture (imitation skills) was associated with poorer motor execution, this factor did not contribute to the ability to make progress with or without intervention. Rather, the only variable likely to predict outcome — although not particularly strong — was the BPVS standard score (verbal ability).

7.4.6 Summary

Despite evidence to suggest the presence of homogenous subtypes within DCD, the groupings of children from differing theoretical perspectives did not hold up to cross-examination. Neither perceptual-motor subtype nor potentially distinctive association of DCD with other developmental disorders was associated with outcome. As a consequence, the implications of specific profiles of perceptual motor performance remain rather nebulous. The complexity of child development, however, becomes ever more apparent.

The CO-OP approach used in this study was, however, found to be beneficial for a significant number of children with all types of motor profiles and or adjunctive disorders/difficulties. The group format was also found to be an efficient intervention that compares favourably to the individual programmes reported in the literature. In line with the results of Sugden and Chambers (2005), there would appear to be three rather than two pathways for children with DCD at a younger age: resolution, transient resolution/fluctuating course and persistence.

7.5 Discussion of study variables

There are a number of variables, outside of the ones specifically studied, that may have influenced the results. Some of these are answerable whereas others could have been moderated under different circumstances. These are discussed in the following section.

7.5.1 Design

The design of this project was limited in part by its opportunistic nature to explore data collected during the clinical assessment of children who had participated in a screening project in the same borough of SE England. However, the sample compared favourably to other studies of children with DCD. The type of data collected at initial

assessment, although broad in nature, was restricted to those assessments available (or easily obtainable) which represented the main theories of DCD, rather than selected purposefully for the project. Also, the original screening project was designed to meet government waiting list initiatives and therefore had a bias towards clinical feasibility with the choice of selected assessments. This factor, as well as the limited resources available, contributed to the decision to undertake a group treatment programme and assess children in small groups. On the other hand, the group assessment and intervention model, helped ensure that groups underwent a similar protocol.

Lack of substantial funding for the intervention project prohibited the incorporation of a tightly controlled randomised trial. Although all attempts were made to ensure lack of bias amongst the testers, there were some occasions when the researcher reviewed individual children however this proportion was less than 10% at any one testing point.

7.5.2 Sample/participants

As the cohort of children was limited to one specific district in the UK who had all been referred to a clinical service, there was an increased risk of additional deficits and potential co-morbidity in the group (McConaughy & Achenbach, 1994). A comparative sample of children randomly selected from non-clinical or educational services and/or a different district in which alternative referral criteria were in place, would support the generalisation of these findings to a wider population of children with DCD. The few numbers of each type of co-morbidity in the intervention study limited the analyses of the influence of specific co-morbidities on movement performance over time.

The attrition rate during the 2 year intervention project was slightly less than estimated with 84% able to attend the final testing session. There were a number of cases of missing data at each test point. This would appear to be the unavoidable consequence of a protracted study involving human subjects. Missing data were no more than one

or two questionnaires per child except in one instance in which one child refused to undertake any written sample until the last testing session. Data were not pro-rated to estimate missing scores as clinical experience — and these results — attest to the variability of performance.

The self-selected nature of the children participating in the intervention study may have resulted in decisions by parents of children with more severe or complex motor and/or developmental problems to encourage their children to attend. The length of time families had been on the initial occupational therapy waiting list emerged as a factor in their willingness to participate in the treatment study. At a superficial level, the only differences between participating and non-participating children were marginal and related to the level of parental concern (lower DCDQ scores); however, a higher percentage of children with co-morbidities participated in the intervention project than in the initial sample. Without SDQ scores on the non-participating children it is not possible to estimate whether concomitant difficulties with behaviour and emotional adjustment may have been greater in the ‘treatment’ group. As children with known co-morbidities were seen to improve less than children without, it is unfortunate that the smaller numbers of these children in the intervention study prohibited analysis of a potential interaction between the co-morbid diagnosis and cluster type (perceptual motor profile). Irrespective of the presence of a known co-morbidity, concerns remain that this lack of impartiality in subject selection — both in the total and intervention cohorts — may have resulted in the sample containing more severely involved cases, particularly in the treatment groups. This limits comparison with other longitudinal studies involving populations of children (Cantell, Smyth & Ahonen, 2003).

7.5.3 Procedures

Timing

Early intervention is more typically discussed with reference to infants — that is early in life — however it may equally be applied to ‘early in the expression of the

condition' (Blauw-Hospers & Hadders-Algra, 2005). It had not been possible to control for the timing of intervention and there were significant differences in the length of time children waited between confirmation of a diagnosis of DCD and the opportunity to participate in the intervention project. The contrast between the children waiting more than 6 months and those who had received a more recent diagnosis before participation in the intervention study, showed those more recently diagnosed to have marginally more movement difficulties at the start of the study although there were no differences in their response to treatment.

Intensity of intervention

The duration of the intervention project and the intensity of treatment may have impacted positively or negatively on results. Contrasting different degrees of treatment intensity when providing physiotherapy for 56 children with cerebral palsy, Bower, et al. (2001) found that the initial advantage of intensive therapy was not sustained 6 months afterwards (median physiotherapy time was 44 hours over three months, 3.67 hours per week, in the intensive group contrasted with 6 hours over three months of a typical physiotherapy regime). Additionally, in their study, intensive therapy was considered tiring and stressful by many of the participants who were glad when the intensive therapy ended. It is unlikely that the intensity of the CO-OP intervention programme (one hour weekly over 20 weeks) would have contributed to a sense of 'therapy burn-out' in these families. It is however more plausible that the overall duration of the project contributed to some waning of interest and support from families, with a consequence that children participating CO-OP groups in year two of the project may not have benefited from intervention to the same extent. However, this was not seen to be the case with both year groups having similar outcomes. Any disadvantage of waiting for treatment may have been offset by the increased experience of the therapist leading the groups.

Type of intervention

It had not been the purpose of this study to investigate the effectiveness of the CO-OP approach per se. Of interest, rather, were the potential differential effects of treatment as a consequence of sub-type classification. The CO-OP approach was followed, not only due to recent studies of its efficacy, but also owing to its defined protocol enabling replication and parent involvement. Reviews of the benefits of early intervention, with infants born preterm or diagnosed with cerebral palsy or Down Syndrome, have concluded that those programmes that incorporated enhanced parent-infant interactions showed a greater beneficial response (Blauw-Hospers & Hadders-Algra, 2005; Mahoney, Robins & Perales, 2004). In the current study, the extent to which parents reinforced strategy use at home may have played a factor in the variable responses to treatment of some of the children, although this was not documented. Anecdotal evidence did not suggest that those whose parents professed more active support for the project benefited more than those whose parents who were not seemingly so involved, particularly in their attendance and participation during the final 10 minutes of each session. Setting individual and appropriate targets with parents and children prior to starting the study may have contributed to more investment in the project. The research design for group intervention restricted the ability to individualise targets and adapt the intervention if it appeared to be exacerbating difficulties, beyond removing the two disruptive individuals from the groups and changing their involvement in the study to that of 'Private Detective'.

Therapists

All efforts were made to ensure impartiality amongst the therapists who led the intervention sessions as well as those undertaking the six monthly reviews. Inevitably, there were some changes to staff over the period of the intervention study. The lead intervention therapist was commissioned independently for the project, working under an honorary contract for the district and part funded by Bromley PCT and the DCD Study group (an account set up from funds obtained through training and teaching programmes organised by the researcher). This ensured some continuity for all the treatment groups. The second senior therapist assisting with the 'Detective Club'

varied and involved five different therapists who had all undergone training in the CO-OP approach. It is not known whether this may have contributed to differences in treatment response of individual children although it is unlikely to have played a major role as children within each group were seen to make progress.

Lack of funding for the project resulted in the decision to undertake each six monthly review in small groups by MABC age band. Group testing was not incompatible with administration procedures and these sessions provided for a more realistic scenario in which children had to perform tasks in a peer group.

Of greater interest, were the dynamics of the parent groups which occurred at each testing point when they were required to complete the various questionnaires. Nearly all of the parents commented on how much they valued meeting parents of children with similar difficulties, some even arranging additional events in the holidays. Despite the benefits of a more organically derived group, these parents said that they would not have attended a 'support' group for families of children with DCD. Sadly, this unanticipated beneficial outcome went unmeasured. It is not known whether these parent groups contributed to a shift in expectation for their children. Although the Family Grid was incorporated at the end of the study to try and capture an element of this process, without having taken a pre-treatment gauge of parental expectation, it remains conjecture as to what advantage may have been conferred on outcome.

7.5.4 Measures

A critique of the measures used in this study highlights the fact that no direct measure of cognitive ability was undertaken. The BPVS was chosen as good estimate of verbal match and clinically expedient test of verbal ability as discussed in Section 5.6.9. There is the possibility therefore that BPVS standard scores used in this study, may have over-estimated general intellectual ability. To accommodate for this, the potential covariance of BPVS standard scores was incorporated into all statistical

equations in which group differences may have been partially explained by intellectual differences.

The outcome measures chosen for the intervention study included a mix of clinical assessment of motor difficulty, parent report of movement skills and behaviour and children's opinions of their ability and satisfaction in performing daily tasks. In view of the fact that none of these tests measured the same thing or from the same perspective, it was difficult to contrast clinician, parent and child opinion of progress. Furthermore, Law et al. (1994, p.43) have suggested that 'an increased level of insight may cause the client to rate themselves lower for an activity on reassessment'. This principle may apply equally to either the child or parent, when completing questionnaires that directly (parent DCDQ) or indirectly (child CSQ) compare skills to those of other children.

7.5.5 Non-specific effects of Intervention

As mentioned above, it is unlikely that the regime of our intervention programme rather than the specific nature of the treatment, would have been of sufficient intensity to have made an overwhelming difference to our results through involvement in the project alone. It is plausible that the children may have invested more effort in their participation in the 'Detective Club' as they had signed up to this special project whereas the 'Special Times' was introduced at home and the children may have been unaware of this aspect of the overall study. More recent critique of flaws within the original Hawthorne studies precludes further analysis of this point (Rice, 2006).

7.6 Future directions

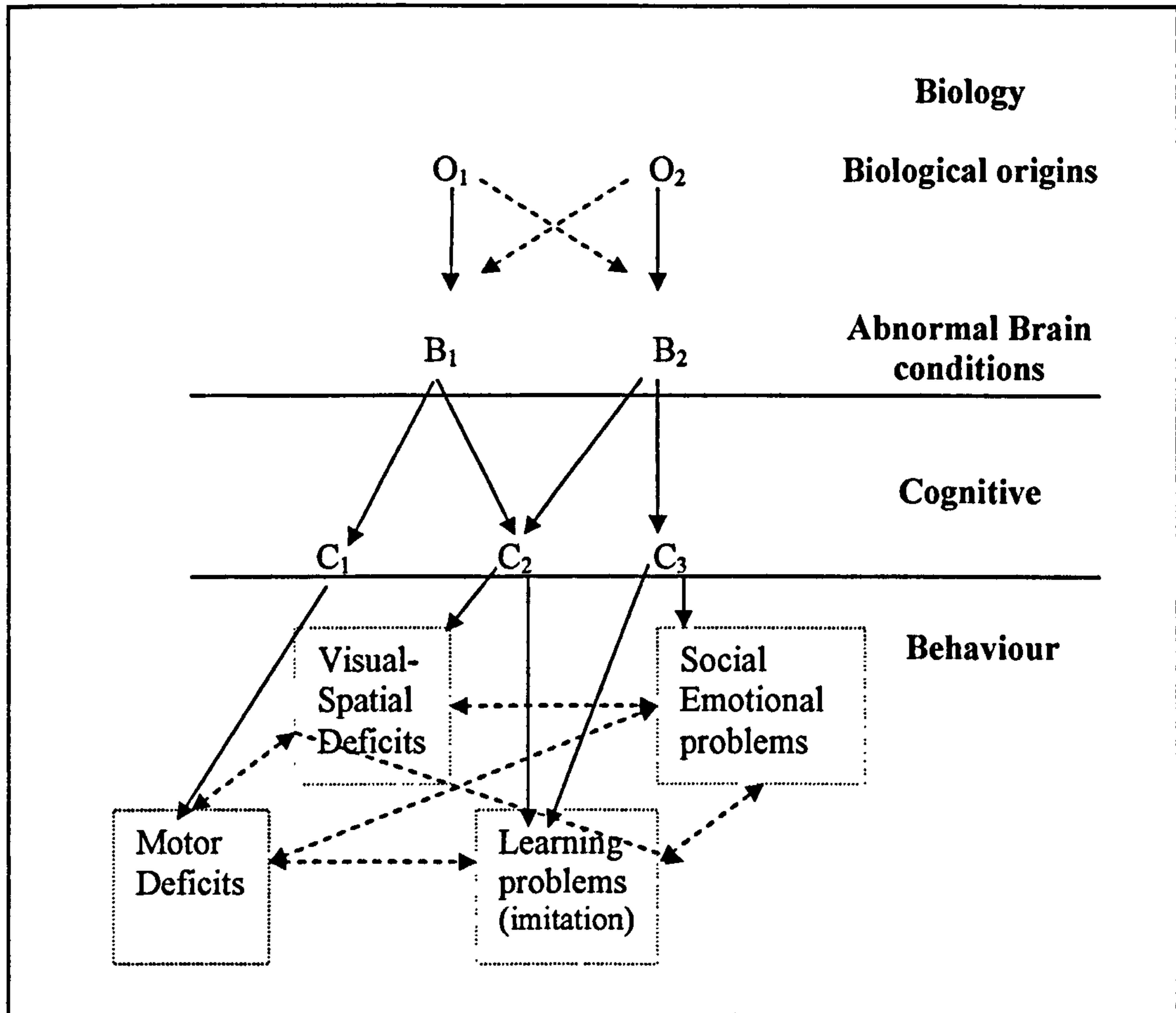
A more apposite approach for researchers to consider in order to support an understanding of the heterogeneous nature of DCD and allow for predictions of outcome, may be to analyse the interaction of strengths as well as the weaknesses of perceptual skills along with developmental and environmental factors, particularly as

multiple developmental pathways may stem from aetiological factors to behavioural presentation (Taylor et al., 2004). Morton's (2004) causal modelling approach for understanding developmental disorders provides a mechanism for exploring the complexity of these interacting factors.

In Figure 7.2 Morton's causal modelling approach outlined in chapter 3 (Figure 3.2), has been expanded to include, not only underlying aetiological factors that may contribute to the mixed presentation of motor and behaviour difficulties in DCD, but also to consider interactions of skills and/or deficits at a behaviour level. At the biological level two or more different origins may contribute to a more primary cognitive deficit (C_1) which results in poor/delayed acquisition of motor skills. The common association of visual-spatial problems and learning difficulties (particularly imitation) with DCD can be explained through interactions at a biological level as well as a cognitive level. Visual-spatial and learning problems, linked to representational understanding and imitation, could arise independently of motor difficulties (or with limited motor impairment in tasks requiring a high degree of visual spatial targeting) if only the second cognitive factor (C_2) was impaired. Although frequently co-occurring with DCD, social and emotional problems may be seen as more distinct impairments, arising from a separate cognitive variable (C_3) which may also contribute to learning and imitation problems. Learning and socio-emotional capabilities may interact at a behaviour level to exacerbate or mitigate performance of movement skills in different contexts.

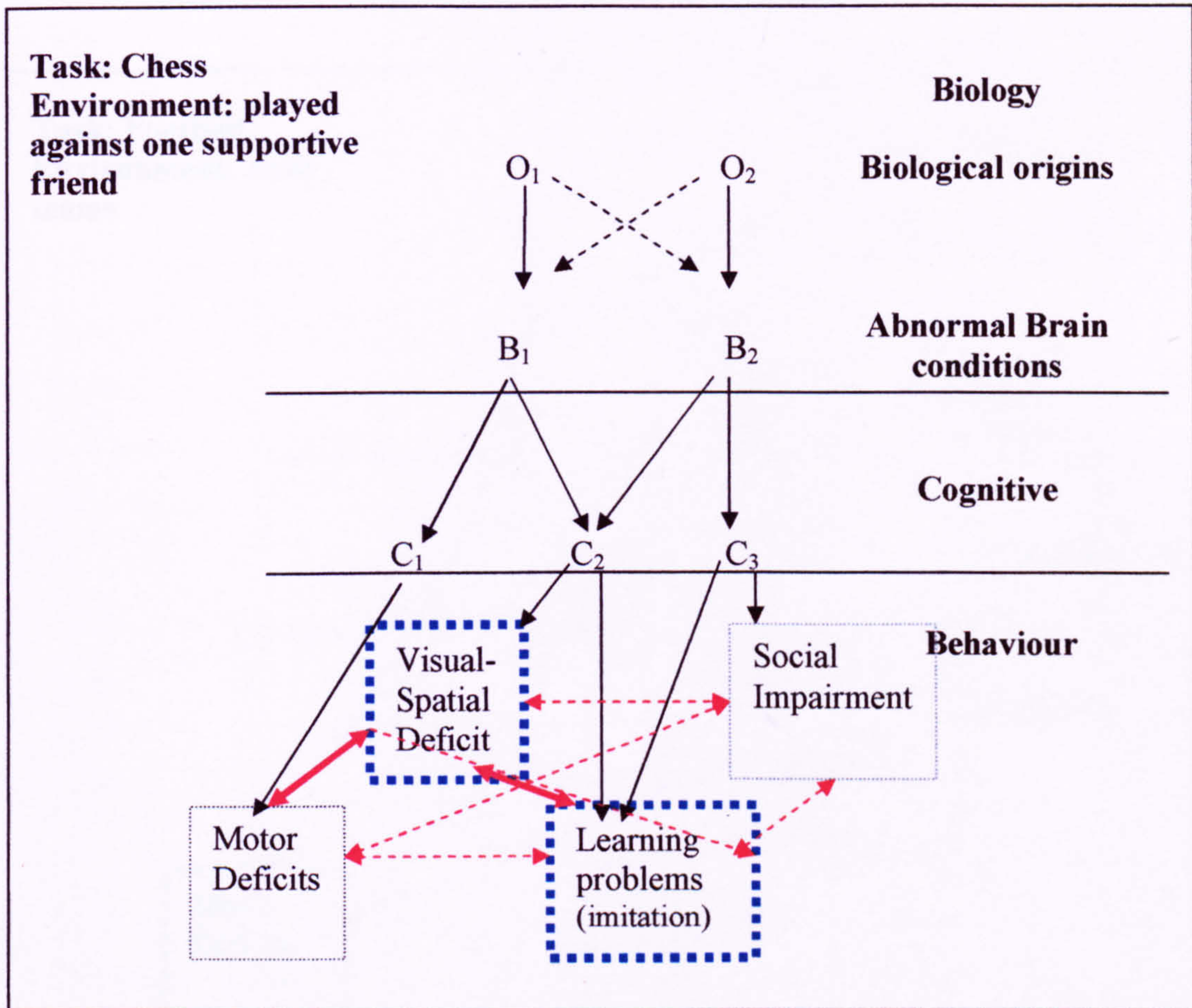
Elaborating on this model further by incorporating an ecological approach to understanding DCD (Sugden & Chambers, 2005), the environment and nature of the task can be seen to differentially shift the strength of these interactions at a behaviour level due to the demands for skills or availability of options for compensatory responses.

Figure 7.2 Causal Model of DCD (adapted from Morton, 2004)



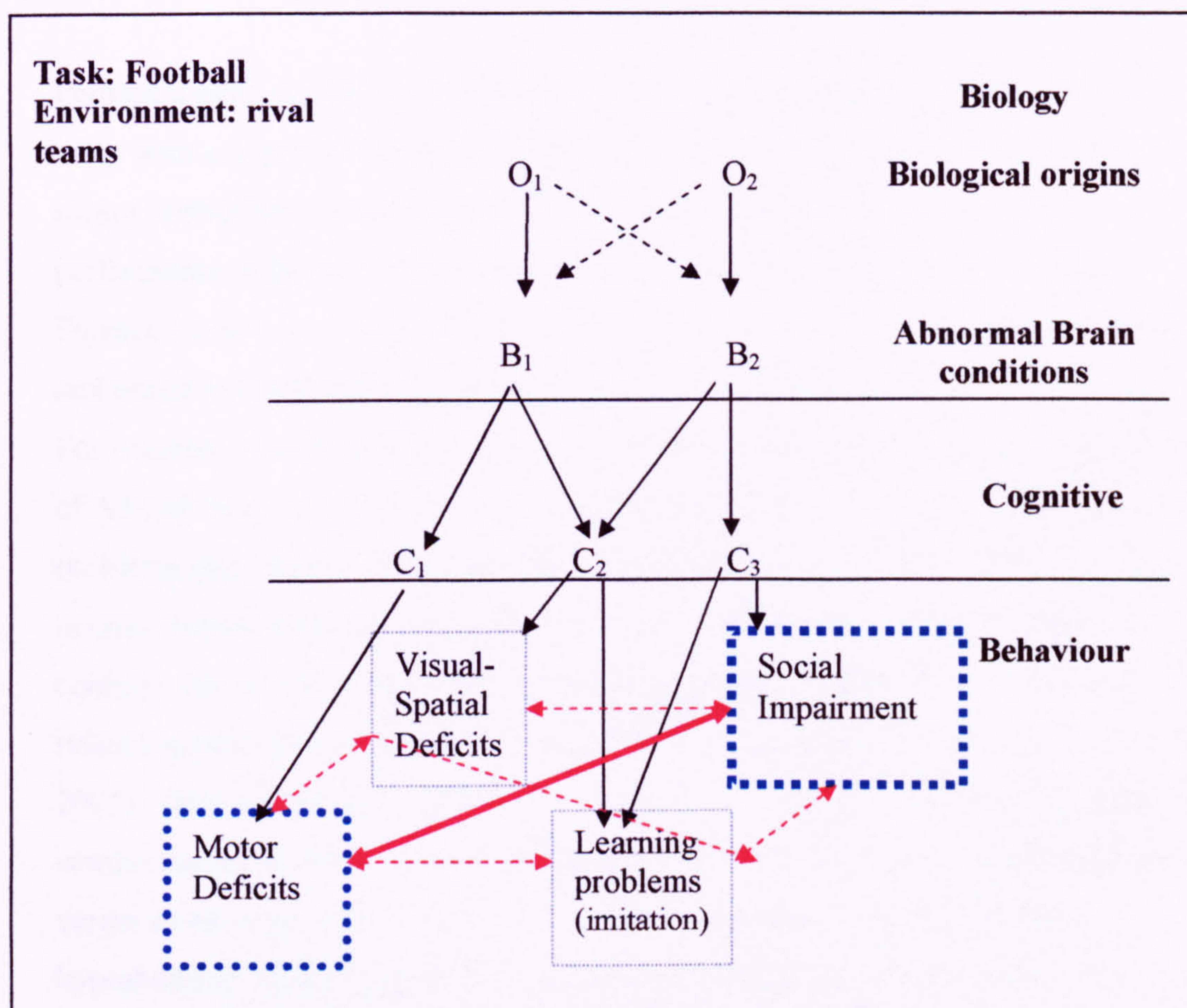
The model outlined in Figure 7.2a shows that visual-spatial skills and learning ability will be challenged more directly in a game of chess with a friend whereas the interaction between social and emotional factors and motor skill will be more predominate in a competitive game of football between rival teams as shown in Figure 7.2b.

Figure 7.2a Causal Model of DCD - Differential effects of task and environment on behaviour during a game of chess



In Figure 7.2a the biological and cognitive origins to motor deficits remain the same however, the task (in this case chess) places greater demands on visual-spatial and intellectual functioning with less requirement for fine motor accuracy.

Figure 7.2b Causal Model of DCD - Differential effects of task and environment on behaviour during a game of football



In contrast, Figure 7.2b emphasises the impact social and emotional problems may have on motor skills and vice-versa during a football match. The ecological validity of testing ball catching or kicking in a clinical setting is therefore challenged without having some mechanism for accounting for the affordances of the natural setting of the task. Netelenbos (2006) alludes to the inherent problems of clinical assessments which emphasise an impairment approach and also recommends a shift to a disability model that focuses on the environmental context of task performance. Further questions that remain, concern the constituents of a suitable outcome measure and from whose perspective.

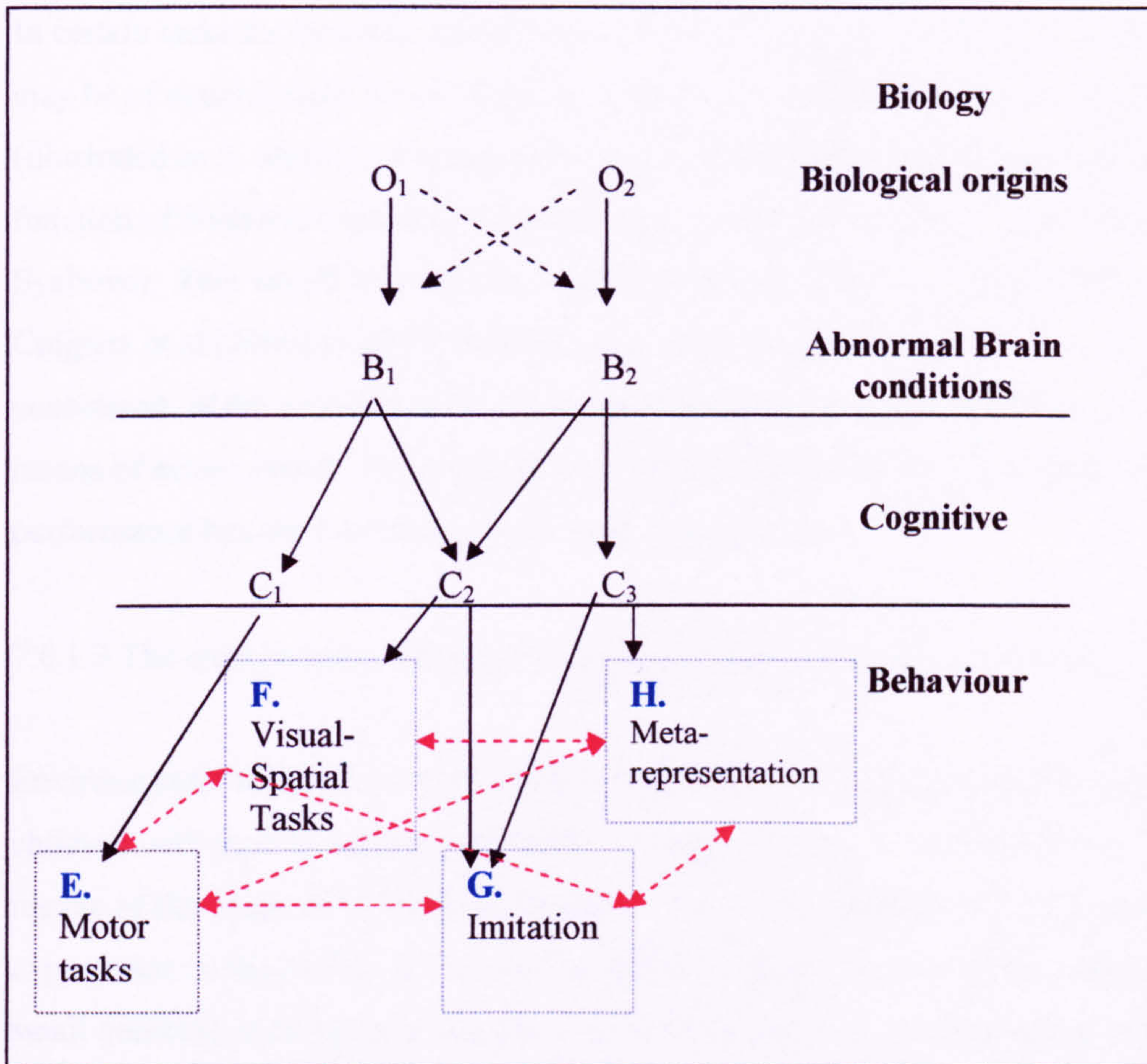
7.6.1 *Future research questions*

7.6.1.1 How to explore the potential theoretical and diagnostic implications of subtyping?

Perhaps a more credible argument for continuing investigations of subtypes is to do away with categorical distinctions and adopt a dimensional model in which the extent of overlapping skills and deficits can be mapped more directly onto performance indicators. Continuing the theme of causal modelling illustrated in Figures 7.2 and 7.2.a and b, different theories can be superimposed onto the model and tested out by changing task constraints and observing the impact on behaviour. For example, the literature has already made a link between the imitation problems of AS and those of DCD however, recent research goes further to suggest that the problems experienced by individuals with AS/ASD may be due to faulty ‘mirror neuron’ functioning (Lepage & Théoret, 2006; J.H.G. Williams et al., 2006). In contrast, the imitative deficits in DCD have been attributed to poor body schema (visual-spatial) representation (Livesey, 2001; Maruff, et al., 1999; Wilson et al., 2004). The similarities or differences between AS and DCD could be tested by comparing the ability to imitate human (meaningful and non meaningful) actions versus robot generated movements (meaningful and non meaningful). One hypothesised result would be that the imitative deficits of AS are linked to C_3 — the faulty mirror neuron system — and a discrepancy would occur between imitation of human versus robot actions. Imitative deficits of DCD would be linked to C_2 with more equal problems replicating human and non-human actions. These children would also demonstrate problems in visual-spatial tasks.

7.6.1.2 Mathematical modelling of environment, task, child interaction

The possibility exists for mathematically modelling of a developmental contingency model.

Figure 7.3 Developmental Contingency Modelling for DCD versus AS

E = Motor skill, F = Visual Spatial tasks, G = Imitation/Gesture and H = Meta-representation skills.

The equations could take various forms as outlined below, in which the task (S_1 or S_2) could be subjected to four experimental options to determine the weights of α and β under different constraints.

$$S_1 = \alpha (E * F) + \beta (G * H) \text{ and } S_2 = \alpha (G * H) + \beta (E * F)$$

where α is equivalent to 1 and $\beta \ll 1$. Or, an alternative expression

$$S_1 = E * Ff(G) + \beta H \quad \text{where } F \text{ is a function of } G$$

If the link between F and G is weak: $F = \beta_0 + \epsilon G^{<1}$

or if the between F and G is strong: $F = \beta_0 + \epsilon G^{>1}$

$\hat{\epsilon}$ = exponent

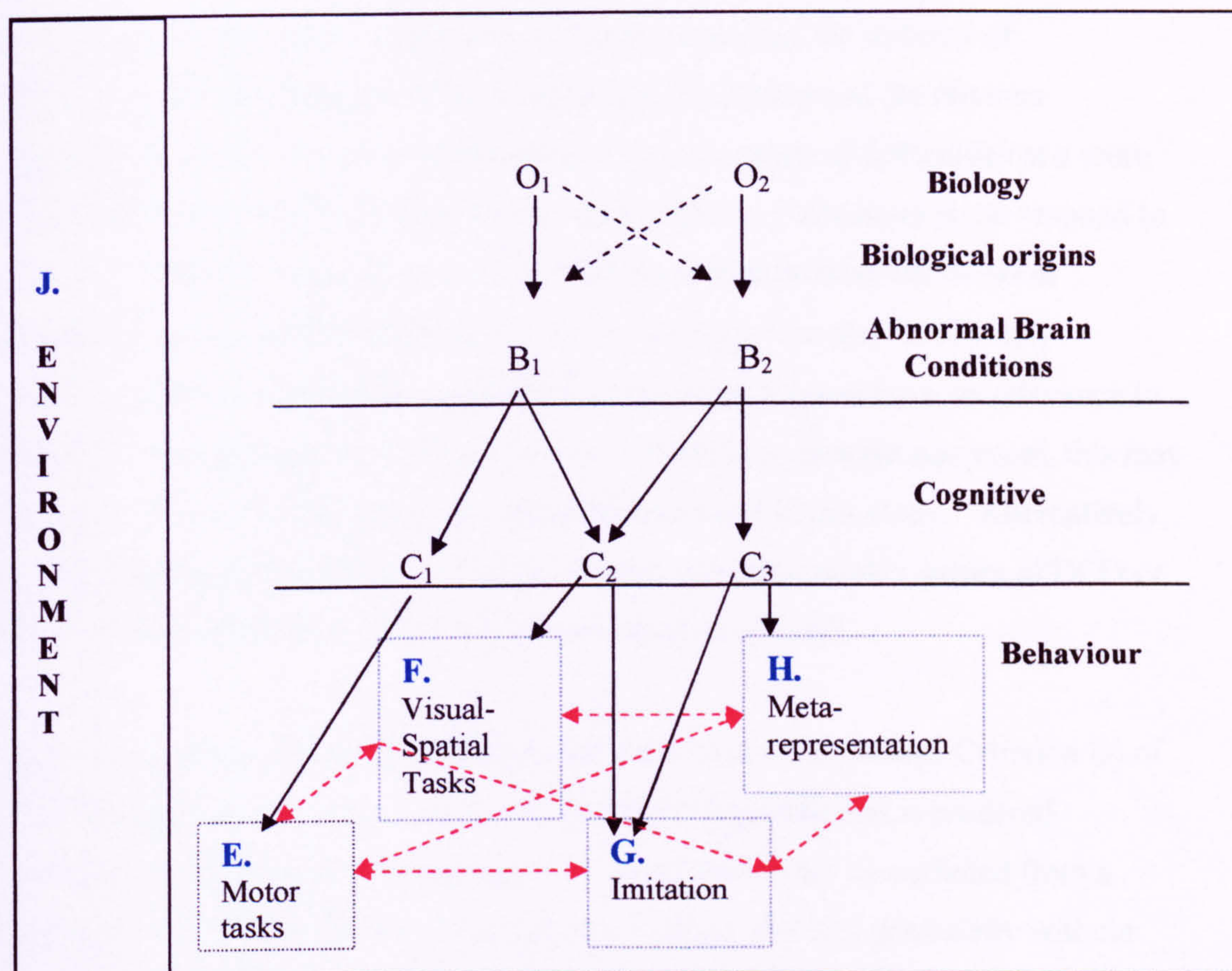
In certain tasks for example, gross motor, fine motor and visual spatial capability may be of equal weight but modified by imitative and meta-representation ability (illustrated as S_1 above). Alternatively, visual spatial skills may be a more direct function of imitative capability when learning to manipulate laboratory tools (e.g. S_2 above). This would be consistent with the computational model outlined by Cuijpers et al.(2006) in which both the goals and the means to achieve the goals are considered in the equation, with the end performance (goal) influenced by multiple means of achievement. However, in most such models, the real-life context of task performance has not been incorporated into the equation.

7.6.1.3 The environment: Influence of parental involvement/family factors

Environmental factors have been shown to contribute to developmental outcome in children with specific learning disorders (Hadders-Algra & Lindhahl, 1999). The results of this study do not indicate a direct relationship of either SES or parental expectation on the ability of any child to make progress. In view of the relatively small numbers of children in the intervention study the possible interaction between SES and parental expectation could not be explored. Further research should also include these factors along with environmental context of task performance when evaluating performance.

Reiterating the causal modelling approach outlined above, Figure 7.4 illustrates the role of the environment in supporting task performance and overall development. These environmental factors could be incorporated into a mathematical equation as illustrated above to consider the impact on performance (illustrated by including function J , the environment, as a factor).

Figure 7.4 Developmental Contingency Modelling for DCD to include environmental factors



7.6.1.4 Differential use of strategies

Although children from each cluster group were seen to make progress irrespective of the extent of their initial motor impairment, what is also of interest is whether different strategies were used, depending on the particular pattern of strengths and weaknesses. Systematic observation of videotaped intervention sessions to identify type and frequency of strategy use may be an important way forward to not only distinguish between subtypes but provide an understanding of how children can benefit from intervention (Bernie & Rodger, 2004; Sangster et al., 2005; Ward & Rodger, 2004).

7.7 Conclusions

In summary, no conclusive evidence was found supporting the stability of qualitatively distinct subtypes of movement impairment beyond the obvious suggestion that more complex children have a greater range of difficulties at a more profound level but that these children are equally likely, if not more so, to respond to treatment! Progress in motor skills following involvement in an intervention programme, was unrelated to initial severity or subtype. Ex ante results may conclude, in view of their inherent instability, that cluster types have no relevance to outcome. Although the evidence for subtypes remains somewhat equivocal, this may be as much due to weaknesses in the theories contrasted in this study. Alternatively, was the inability to identify predictor variables due to the complex nature of DCD or characteristics of the more 'top down' intervention approach?

Furthermore, it may be concluded that Criterion C (and even perhaps Criterion D) of the DCD diagnostic criteria, is so nebulous that its diagnostic fiat is rendered meaningless; particularly so if children who would otherwise be excluded from a diagnosis of DCD have similar motor profiles to those children potentially without diagnostic confounders. This assumption is consistent with the conclusions of the LCS group (2006) which recommended excluding a diagnosis of DCD only when the intellectual or psychosocial deficit can explain the extent of motor impairment.

The inability of this study to identify any specific profile of perceptual motor skills or combination of other variables to predict outcome may have been influenced by the small numbers of children from some of the clusters who were followed up in the intervention study. The indications however suggest that children with better verbal ability, particularly in the absence of more profound movement problems and an additional developmental disorder, are more likely to have a better outcome especially when involved in a cognitive based therapeutic programme. The implications of these results suggest that clinicians should focus on applying the criteria of DCD IV (with modifications recommended by the LCS, 2006) and identify; first and foremost,

whether there is a functional deficit (child/parent/teacher view) along with a motor impairment (standardised clinical assessment) as well as ensure a measure of verbal ability is undertaken and any co-morbidities identified. More comprehensive — and hence costly — assessments that include other measures of hypothesised ‘components’ of motor problems should be considered gratuitous at this stage with so little evidence substantiating any distinguishing characteristics that contribute to profile and outcome. More important is the need to offer intervention packages, to children identified as having borderline or definite motor difficulties, which focus on enabling them to develop strategies for success in performing motor tasks and facilitating participation in a range of daily activities.

And thus, we are left with a concluding sentiment (adapted from Hetherington & Parke, 1986, p. 420), reminiscent of attempts to qualify and quantify cognitive development:

“Is it possible to recognise the heterogeneity of the child’s movement skills yet still provide a meaningful profile of motor development?”

FOOTNOTES

¹ Learning disabilities is the term used in North America to refer to children who have difficulties with specific aspects of learning (APA, 1994). For clarity the term Specific Learning Disabilities will be used in this text as this is the term adopted in the UK.

² Horner's Syndrome – ipsilateral constriction of the pupil (miosis) with lid drop (ptosis).

³ Pierre Robin Syndrome (PRS) describes an association of micrognathia and upper airway obstruction caused by glossoptosis, frequently with cleft palate thought to be due to in utero mechanical constraint (high incidence of twinning). Infrequently associated anomalies may include congenital cardiac defects, central nervous system malformations or facial dysmorphia. Complications may occur of breathing, choking and feeding problems.

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APPENDIX 1 DIAGNOSTIC CRITERIA FOR CO-ORDINATION DISORDERS

<p>DSM-IV / DCD-IV-TR criteria for DCD (APA, 1994, 2000)</p>	<p>A. Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (e.g. walking crawling, sitting), dropping things, "clumsiness", poor performance in sports, or handwriting.</p> <p>B. The disturbance in Criterion A significantly interferes with academic achievement or activities of daily living.</p> <p>C. The disturbance is not due to a general medical condition (e.g. cerebral palsy, hemiplegia or muscular dystrophy) and does not meet the criteria for a Pervasive Developmental Disorder.</p> <p>D. If mental retardation is present the motor difficulties are in excess of those usually associated with it.</p>
<p>ICD-10 criteria for SD-DMF (WHO, 1992)</p>	<p>A. The child's motor coordination on fine or gross motor tasks, should be significantly below the level expected on the basis of his or her age and general intelligence. Difficulties should have been present since early in development and they should not be a direct result of any defects of vision or hearing or of any diagnosable neurological disorder.</p> <p>B. Developmental milestones may be delayed and there may be some associated speech difficulties.</p> <p>C. The young child may be awkward in general gait, being slow to learn to run, hop, and go up and down stairs. Likely to be difficulties in learning to tie shoe laces, to fasten and unfasten buttons and to throw and catch balls. Child may also be clumsy in fine and in fine and/or gross movements, tending to drop things, to stumble, to bump into obstacles and to have poor handwriting. Drawing skills are usually poor and children are often poor at jigsaw puzzles, using constructional toys, building models, ball games and drawing and understanding maps.</p> <p>D. May show 'soft' neurological signs and immaturities such as mirror movements.</p>

	<p>E. Scholastic difficulties may occur and in some cases socio-emotional problems.</p> <p>F. Often associated with some degree of impaired performance on visuo-spatial tasks.</p>
<p>London Consensus description and definition for DCD (Polatajo, Fox & Missiuna, 1995)</p>	<p>A. DCD is a chronic and usually permanent condition characterized by impairment of motor performance sufficient to produce functional performance deficits not explicable by the child's age or intellect, or by other diagnosable neurological or psychiatric disorders.</p> <p>B. DCD is expressed in movement and spatial-temporal organization problems.</p> <p>C. Persons with DCD display qualitative differences in movement from their peers.</p> <p>D. There is a high incidence of associated problems in a wide range of functions.</p>
<p>Leeds Consensus Statement (2006) – Provisos to DSM-IV-TR</p>	<p>A. The cut-off point for Criterion A should be applied to performance at or below the 5th percentile on an individually administered and culturally appropriate, norm-referenced test of general motor competence.</p> <p>B. Assessment should reflect culturally relevant developmental norms relating to activities of daily living and should include consideration of self-care, play, leisure and schoolwork (including handwriting, P.E. and tool use) and the views of the child, parents, teachers and relevant others.</p> <p>C. A conventional neurological examination should be conducted to rule out major neurological conditions (e.g. definite disorders of posture, tone, reflexes) but it is inappropriate to exclude the possibility of a dual diagnosis of DCD and other developmental disorders of behaviour and learning.</p> <p>D. Children with a measured (or presumed in the absence of intellectual testing) intellectual quotient should not be given a diagnosis of DCD.</p>

Appendix 2

**Appendix 2 Studies reporting significant overlap of additional diagnoses with DCD/motor impairment
(from Green & Baird, 2005,p99-103)**

Reference	Motor Impairment	Number of children/ Age	Psychopathology				Learning	Develop- mental Speech and Language Impairment
			Emotional	Conduct	Attention Deficit/ Hyperactivity	Social		
Cantell, Smyth & Ahonen 1994	Identified at age 5 with motor delay	106 DCD equivalent & 40 controls Age 15				Clumsy children fewer hobbies and reduced social/physi cal activities	Reduced academic ambitions	
Cermak et al., 1986	Movement ABC/TOMI	5-8 years						40% children with SLI met criteria for DCD
Gillberg & Gillberg 1989	MBD - perceptuo motor criteria	Population cohort 42 children with DAMP 13 years	75% children with motor difficulties had experienced school failure or were identified with emotional and/or behavioural problems.					
Gillberg, Gillberg & Groth, 1989	MBD perceptuo- motor criteria	Population cohort 42 children with DAMP 13 years			49% children with motor difficulties met criteria for ADHD			

Fletcher-Flinn, Elmes & Stragnell 1997	TOMI	28 DCD 7.5-9.7 years							68% reading problems 25% >2 years below 93% spelling problems 30% >2 years below Most children scored poorly on phonological processing
Green et al 2002	Movement ABC	9 SDDMF 11AS 7-10 years						Similarities between SDDMF and AS children	
Green, Baird and Sugden in preparation	Movement ABC	47 DCD children 5-11 years	70% emotional symptoms	38% conduct problems	68% attention/ activity problems			51% Peer problems	
Hellgren et al 1994	Motor - perceptual criteria	45 DAMP 16 year	40% Axis I	15.5% substance abuse 4% suicide attempt	58% Axis II inc. AS				
Hill 1998 Hill et al 1998	Movement ABC	11 DCD 19SLI 5-13 years							60% children with met criteria for DCD
Kadesjo & Gillberg, 1999b	Met criteria for DSMIV	Population study with 55 DCD 6.8 to 7.8 years		.	47% had symptoms 19% met diagnostic criteria for ADHD			7% diagnosed with Asperger's Syndrome	
Kaplan et al 1998	BOTMP or Movement	379 school aged			41%* ADHD with DCD				55% * reading

	ABC	81/379 DCD 8-18 years			* 28% ADHD and reading problems with DCD		problems with DCD	
Landgren et al. 1996	Criteria for Motor perceptual deficit defined	Birth cohort 6-7 years 63/589 children with MBD			49% ADHD with DCD (DAMP)			
Losse et al 1991	TOMI	34 motor impaired 15.1 to 17.4 yrs	82% reported to have emotional, conduct and attentional/concentration problems from school records.			47% poor social concept	71% academic problems	
O'Hare & Khalid, 2002	TOMI/ Movement ABC	23 DCD 7-10 years					Auditory problems associated with reading delay	processing associated with
Owen & McKinlay 1997	Motor deficits identified via Pegboard, buttoning bead threading and graphic tasks	16 SLI 16 controls 4-7 years						SLI children were slower on speed and accuracy tasks and more likely to have mixed hand preference
Moxley- Haegert & Ladd, 1989	Motor delay identified prior to 4 years	48 7-8 year olds			Hyperactivity associated with motor delay		motor delay associated with later reduced intellect	
Piek,	Motor co-	48 ADHD			21% had			

Pitcher & Hay 1999	ordination	boys 8.7 to 11.7 years			additional motor deficit				
Powell & Bishop 1992	Battery of fine and gross motor tasks	17/34 children with SLI 6-12 years						SLI group scored significantly worse on 7/19 motor tasks	
Rasmussen et al 2000	MBD criteria	15 year follow-up 49 meeting DCD criteria seen age 22 years	60% DCD with ADHD showed poor psycho-social outcome						
Rintala 1997	Movement ABC	76 Dev. Language impairment 6-10 years						71% children with SLI met criteria for DCD	
Robinson 1991	TOMI	9-17 years						90% children with SLI met criteria for DCD	
Schoemaker & Kalverboer, 1994	TOMI	18 6-9 years	33% STAIC					Self-report of social acceptance poor	

Sigurdsson, van Os, & Fombonne, 2002	Criteria for motor impairment met at 7 years old	Birth cohort followed up at 11 & 16 years	Childhood motor impairment high risk for anxiety in males.					
Skinner & Piek, 2001	Movement ABC and criteria for DCD met	8-10 years (n=116) DCD = 58 12-14 years (n=102) DCD = 58	Children and adolescents with DCD rated themselves as less able scholastically and athletically with lower scores for physical appearance and self worth. Anxiety was more prevalent in the adolescent group with DCD.					
Sooring-Lunsing et al., 1993	Touwens MND criteria*	Population cohort 170/346 MND			Social difficulties associated with fine-motor problems	Co-ordination problems related to school failure		
Wright-Strawderman & Watson, 1992	Learning Disabled group-motor status not measured	53 students 8-10 years	Increased risk of Depression in LD group (35.8% scored in depressed range on the CDI)					

*MND = minor neurological dysfunction identified according to Touwen (1979) measuring posture (reflexes and responses), co-ordination; fine manipulation; and presence or absence of choreiform dyskinesia

Appendix 3 – COMMON ASSESSMENTS FOR IDENTIFICATION OF COMPONENTS OF COORDINATION DISORDERS

Component	Test	Author (Year) Publisher		
Motor Performance	<ul style="list-style-type: none"> ▪ The Bruininks Oseretsky Test of Motor Proficiency ▪ Movement Assessment Battery for Children ▪ School Entry Examination ▪ McCarron Assessment of Neuromuscular Development ▪ Test of Gross Motor Development ▪ Peabody Developmental Motor Skills ▪ Pegboard Tests (Purdue/Grooved) ▪ Clinical Observations of Motor and Postural Skills 	<ul style="list-style-type: none"> ▪ Bruininks (1978) American Guidance Service ▪ Henderson & Sugden (1992) Psychological Corp. ▪ Bax & Whitmore (1987) Developmental Medicine and Child Neurology ▪ McCarron (1982) Common Market Press ▪ Ulrich (2000) Pro-ed ▪ Folio & Fewell (1983) The Riverside Publishing Company [PDMS-2 (2000)] ▪ Tiffin (1960) Lafayette Instrument Company/Lafayette Instrument Company (1997) ▪ B. Wilson et al. (1994) Therapy Skill Builders 		
	Visual-Spatial Deficits	<ul style="list-style-type: none"> ▪ Motor Free Visual Perceptual Test ▪ Test of Visual Perceptual Skills - revised ▪ Test of Visual Motor Skills - revised ▪ Matrix Analogies Test ▪ Developmental Test of Visual Motor Integration ▪ Developmental Test of Visual Perception 	<ul style="list-style-type: none"> ▪ Colarusso & Hamill (1972) Academic Therapy Pubs ▪ Gardner (1985) Psychological & Educational Pubs. ▪ Gardner (1985) Psychological & Educational Pubs. ▪ Naglieri (1989) Psychological Corporation ▪ Beery (1997) Modern Curriculum Press. ▪ Reynolds, Pearons & Voress (1993) Pro-ed. 	
		Kinesthetic-Proprioceptive Deficits	<ul style="list-style-type: none"> ▪ Kinesthetic Sensitivity Test ▪ Subtests of the Sensory Integration and Praxis Test 	<ul style="list-style-type: none"> ▪ Laszlo & Bairstow (1985b) Holt, Rinehart & Winston ▪ Ayres (1989) Western Psychological Services
			Functional Deficits	<ul style="list-style-type: none"> ▪ The School Function Assessment ▪ Developmental Coordination Disorder Questionnaire
		Attentional Deficits		<ul style="list-style-type: none"> ▪ Continuous Performance Test ▪ Test of Everyday Attention of Children
			Planning (praxis) Deficits	<ul style="list-style-type: none"> ▪ Subtests of the Sensory Integration and Praxis Test ▪ Subtests of the Miller Assessment for Preschoolers ▪ British Assessment of Dysexecutive Syndrome

Bromley Research Ethics Committee

Health Intelligence Unit
1st Floor, Templegate House
115-123 High Street
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REC Chair: Ms Carol Jones
REC Co-ordinator: Ms Janine Peters
E-mail: janine.peters@bromleyhospitals.nhs.uk
Phone: 01689 865985/Fax: 01689 865310

20th June 2006

Dido Green MSc DipCOT
Clinical Expert Paediatric Therapist
Newcomen Centre
Guy's and St Thomas's NHS Trust
St Thomas's Street
London
SE1 9RT

Dear Ms Green,

Study title: *Developmental Co-ordination Disorder – A qualitative and experimental study to explore the nature and remediation of Developmental Co-ordination Disorder*

REC reference: *LREC 631*

Protocol number: *N/A*

EudraCT number: *N/A*

Thank you for sending the progress report for the above study dated 14th February 2006 and received at this office on 8th June. The report will be reviewed by the Chair of the Research Ethics Committee and I will let you know if any further information is requested.

LREC 631	Please quote this number on all correspondence
-----------------	-------------------------------------------------------

Yours sincerely,



Janine Peters
REC Co-ordinator

NEWCOMEN CENTRE**Tel: 020 7188 4655/4629****Fax: 020 7188 4668****Email: dido.green@gstt.sthames.nhs.uk****GUY'S & ST. THOMAS' FOUNDATION TRUST****ST. THOMAS STREET****LONDON SE1 9RT****Tel: 020 7955 5000**

14 February 2006

Carol Jones
 Chairman Bromley LREC
 Health Intelligence Unit
 Maplewood
 Farnborough Hospital
 Farnborough Common
 Orpington
 Kent BR6 8ND

Dear Ms Jones

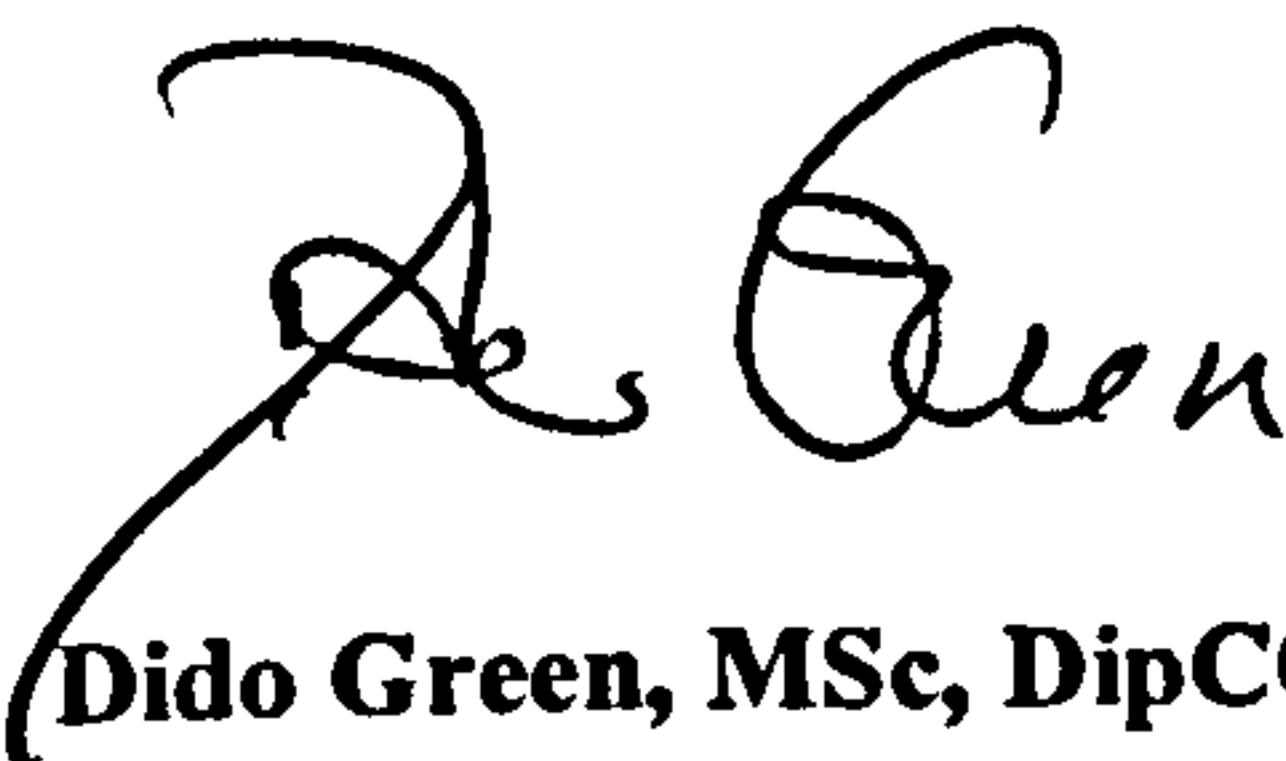
Re LREC reference 631 – DCD Treatment Efficacy study

I realise once again that time has passed and I have not updated you on the progress of this study. As of last spring (2005) we completed all aspects of intervention and follow-up testing. A provisional report of the results was presented at the VI International Conference on DCD in Trieste, Italy in May 2005. Copies of the poster and oral presentations are attached.

There is an enormous wealth of information obtained through the detailed analysis of the full sample as well as the subset of 43 children who participated in the intervention study. There were 36/43 families in the intervention study who managed to attend the final session, with nearly full data sets of all 43 children available up until the penultimate review. 67% of the children benefited from the intervention programme and there is a significant difference between the number of children (n=19) who made good progress following intervention being more than those who made progress with maturation (n=10).

More of the data will be analysed over the coming months with the hope of completing the writing up of the project by the end of the year. Should you require any further information please do not hesitate to contact me.

Yours sincerely



Dido Green, MSc, DipCOT
Clinical Expert Paediatric Occupational Therapist

Bromley Local Research Ethics Committee
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7th April 2005

Dido Green
 Newcomen Centre
 Guy's Hospital
 St Thomas Street
 London
 SE1 9RT

Dear Ms Green,

Full title of study: Developmental Coordination Disorder – A qualitative and experimental study to explore the nature and remediation of Developmental Coordination Disorder

REC reference number: LREC631/2003

Protocol number:

Amendment number: 1

Amendment date: 13/12/04

The above amendment was reviewed by a Sub-Committee of Bromley LREC.

Ethical opinion

The members of the Committee present gave a favourable ethical opinion of the amendment on the basis described in the notice of amendment form and supporting documentation.

Approved documents

The documents reviewed and approved at the meeting were:

Covering letter dated 13/12/04

Additional Measures proposed dated 13/12/04

The Young Person's Grid (Read and Davis 1999)

The Family Grid (Davis 1999)

Questions about your goals (1997)

WORD Record Form (1993)

Article from British Journal of Occupational Therapy (January 2005): Is questionnaire-based screening part of the solution to waiting lists for children with developmental coordination disorder

Membership of the Committee

The members of the Sub-Committee who reviewed the amendment were Ms Carol Jones, Chair, Dr Ian Jessiman, Vice-Chair, and Mr Niall McCrae, Expert Member.

Management approval

Before implementing the amendment, you should check with the host organisation whether it affects their approval of the research.

Statement of compliance (from 1 May 2004)

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

REC reference number: LREC 631 Please quote this number on all correspondence

Yours sincerely,



Janine Peters
Committee Administrator

Green Dido

To: Bromley LREC**Subject:** RE: LREC 631[Scanned][MESSAGE NOT SCANNED]

Dear Dido

I have been in touch with the LREC Chair, Carol Jones, who has some concerns about the additional data collection you are proposing. She would find it helpful to discuss this with you and has asked me to pass you her mobile phone number in order that you can talk to her about this. Her number is 07901 916706 and she is happy for you to call her anytime.

Please feel free to phone me if you wish.

Janine Peters

Administrator - Bromley LREC

01689 865985

Templegate

115-123 High Street

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Kent BR6 0LG

e-mail: janine.peters@bromleyhospitals.nhs.uk



Central Office for Research Ethics Committees (COREC)

NOTICE OF SUBSTANTIAL AMENDMENT

For use in the case of all research other than clinical trials of investigational medicinal products (CTIMPs). For substantial amendments to CTIMPs, please use the EU-approved notice of amendment form (Annex 2 to ENTR/CT1) at <http://eudract.emea.eu.int/document.html#guidance>.

To be completed in typescript by the Chief Investigator and submitted to the Research Ethics Committee that gave a favourable opinion of the research ("the main REC"). In the case of multi-site studies, there is no need to send copies to other RECs unless specifically required by the main REC.

Further guidance is available in section 5 of our Standard Operating Procedures available at www.corec.org.uk/applicants/help/docs/SOPs.doc.

Details of Chief Investigator:

<i>Name:</i>	Dido Green
<i>Address:</i>	Newcomen Centre, Guy's Hospital St Thomas Street London SE1 9RT
<i>Telephone:</i>	020 7188 4655
<i>E-mail:</i>	dido.green@gstt.sthames.nhs.uk
<i>Fax:</i>	020 7188 4649

Full title of study:	Developmental Coordination Disorder – A qualitative and experimental study to explore the nature and remediation of Developmental Coordination Disorder
Name of main REC:	Bromley LREC
REC reference number:	631
Date study commenced:	January 2003
Protocol reference (if applicable), current version and date:	
Amendment number and date:	Amendment 1 Date: 13.12.04

Type of amendment (indicate all that apply in bold)*(a) Amendment to information previously given on the REC application form*

Yes No

*If yes, please refer to relevant sections of the REC application in the "summary of changes" below.**(b) Amendment to the protocol*Yes No*If yes, please submit either the revised protocol with a new version number and date, highlighting changes in bold, or a document listing the changes and giving both the previous and revised text**(c) Amendment to the information sheet(s) and consent form(s) for participants, or to any other supporting documentation for the study*

Yes No

*If yes, please submit all revised documents with new version numbers and dates, highlighting new text in bold***Summary of changes***Briefly summarise the main changes proposed in this amendment. Explain the purpose of the changes and their significance for the study.**Supporting scientific information should be given (or enclosed separately) where the amendment significantly alters the research design or methodology, or could otherwise affect the scientific value of the study.*

Request for additional parent and child questionnaires to be added to final testing point in February 2005 and one additional measure of children's reading. Reason for proposed changes is due to the large numbers of parent and child reports of progress and behaviour that have been used at each of the previous 4 testing points. It is felt that some parents and children may negatively or positively report their child's or own performance differently depending on expectations. Please refer to letter of 13.01.04 for further details.

Additionally, following presentation of some of the data at the European Academy of Childhood Disability Conference in Edinburgh in October 2004, a number of questions arose around the impact of overall learning on a child's behaviour. In view of the interest in co-morbidity in childhood disorders and the interest in a possible relationship between dyslexia (reading disorder) and dyspraxia (motor planning disorder), we would like to undertake the Wechsler Objective Reading Dimensions (WORD) test and test of reading fluency which would take approximately 20 minutes. Additional psychologists in training have agreed to undertake this additional assessment.

Any other relevant information

Applicants may indicate any specific ethical issues relating to the amendment, on which the opinion of the REC is sought.

Original information that was sent to parents and children included the initial assessment and four further testing of motor (visual-motor) tests along with parent and child questions of competence, participation and satisfaction in motor and social activities. Parents have had access to the results of these assessments, when required, to support educational and developmental planning and will receive a summary of all test scores after the final data collection.

Parents and children have been and will be notified that they do not need to complete the forms if they do not wish to and are free to withdraw from the project at any time.

List of enclosed documents

Documentation of additional assessments proposed for final testing session.

Copies of:

Family Grid Questionnaire – Parent and Child

Hope Questionnaire (Snyder et al) 'Questions about your Goals'

WORD test form (original)

Declaration

- I confirm that the information in this form is accurate to the best of my knowledge and I take full responsibility for it.
- I consider that it would be reasonable for the proposed amendment to be implemented.

Signature of Chief Investigator:

D. D. Green

Print name:

D. D. GREEN

Date of submission:

21. 1. 05

Green Dido

From: Bromley LREC [bromley.lrec@bromleyhospitals.nhs.uk]
Sent: 20 January 2005 16:23
To: Green Dido
Subject: LREC Reference 631 - DCD Treatment efficacy study[Scanned]
Importance: High

Dear Dido

I am sending you this e-mail further to your letter to John Chadwick, previous Chairman of the Bromley LREC, dated 13th December.

I am sorry it has taken me some time to respond to you regarding the amendment to your study but I needed to take advice from COREC regarding the proposed changes you describe. As you may know the process for obtaining ethics committee approval for studies has changed significantly since you originally sought ethical approval for this study. Similarly, arrangements have changed for dealing with minor and substantial amendments to studies and I needed to seek advice to clarify how the LREC should deal with the matters outlined in your letter.

As it appears that your study is not yet completed, the inclusion of additional questionnaires means that you are effectively notifying the LREC of a substantial amendment to the study. Whilst your letter was very clear about what you intend to do I must also ask you to complete a Notice of Substantial Amendment form. This can be found on the COREC website but I also attach this for your convenience. Along with the completed form you will need to submit the new questionnaires and any other amended documents, such as information sheets and consent forms (if there are any). These do not need to be submitted to a full LREC meeting but can be considered by a sub-committee (which should speed the process up). I will ensure that your letter dated 13th December is also submitted to the Sub-Committee with these papers as this outlines your proposals very clearly.

Just for your information, John Chadwick stood down as LREC Chairman last year. The new Chair of Bromley LREC is Ms Carol Jones.

Please do not hesitate to contact me if you wish to discuss this or need any further advice.

Yours sincerely
Janine Peters
Administrator - Bromley LREC
01689 865985
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115-123 High Street
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e-mail: janine.peters@bromleyhospitals.nhs.uk

21/01/2005

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GUY'S & ST. THOMAS' FOUNDATION TRUST

GUY'S HOSPITAL**ST. THOMAS STREET****LONDON SE1 9RT****Tel: 020 7955 5000**

John Chadwick
 Chairman Bromley LREC
 Health Intelligence Unit
 Maplewood
 Farnborough Hospital
 Farnborough Common
 Orpington Kent BR6 8ND

13 December 2004

Dear Mr Chadwick

Re LREC reference 631 – DCD Treatment Efficacy study

Further to my letter of 7 July 2004 I would like permission to include three additional questionnaires when I meet with the families for the final review in February 2005. Whilst reviewing some of the data over the summer in preparation for papers and posters accepted for a conference in May next year, I have been aware that some of the children have done particularly well whilst others whom I would have expected to do better have not achieved as much as I had anticipated.

Following discussion with families at each 6 month review, I believe that the interaction between parents and children is particularly important in this study. Professor Hilton Davis, has introduced me to the work of George Kelly and Professor Davis's own more recently developed Family Grid. In view of the large numbers of parent and child reports used in this study, the '*Family Grid*' (Davis, 1999) and '*The Young Persons' Grid*' (Read and Davis, 1999) may be used to identify any conflicts parents may experience in defining their 'ideal' child versus their 'real' child. This checklist is based on Repertory Grid analysis following Personal Construct Theory (Kelly, 1991; Bannister & Fransella, 1986). It is hoped that this questionnaire may elicit any bias that parents or children may exert when negatively or positively reporting their child's or own (respectively) performance/change in performance as well as inquire into the way in which parents and children maintain or alter their constructs regarding people and events. In addition to, I would like to include Snyder's Child Hope Questionnaire which has been found to be useful in identifying 'resilience' (to the extent of their difficulties) in children with Attention Deficit Hyperactivity Disorder and Dyslexia. It is not known how these individual constructs may be related to real or perceived progress in motor or behavioural domains but I would like to consider whether there is any interaction effect on the main outcome measures of the study. These questionnaires would add at most 10 minutes onto the final assessment session.

Furthermore, after presentation of some of the data at the October European Academy of Childhood Disability Conference in Edinburgh, a number of questions arose around the impact of overall learning ability on children's behaviour. Despite all the assessments undertaken, I failed to assess the children's reading!. In view of the considerable interest between learning disabilities of dyslexia and

dyspraxia, it was suggested that we undertake the WORD and test of reading fluency at the final session. Dr Baird has offered to provide an additional psychology student to undertake these assessments. Timetabling these should result in each child being withdrawn from the group assessments for 20 minutes each during the two hour (+10 minutes) period and therefore a total of 30 minutes would be added to the overall assessment time.

It is my view that the families would not object to this additional data being collected. I have notified all families that I will provide a summary of the test scores their child has obtained over the past two years which would include the additional WORD test results.

Please note also the changes to Guy's and St Thomas' telephone numbers.

With thanks.

Yours sincerely



Dido Green, MSc, DipCOT
Clinical Expert Paediatric Occupational Therapist

cc: Professor Sugden, Department of Education, University of Leeds, LS2 9JT

Developmental Coordination Disorder – a qualitative and experimental study to explore the nature and remediation of Developmental Coordination Disorder – Bromley LREC 631

Additional Measures Proposed 13.12.05

1. In view of the large numbers of parent and child reports used in this study, the *'Family Grid'* (Davis, 1999) and *The Young Persons' Grid* (Read and Davis, 1999) it is proposed to use this format to identify any conflicts parents may experience in defining their 'ideal' child versus their 'real' child. This checklist is based on Repertory Grid analysis following Personal Construct Theory (Kelly, 1991; Bannister & Fransella, 1986). It is hoped that this questionnaire may elicit any bias that parents or children may exert when negatively or positively reporting of their child's or own (respectively) performance/change in performance as well as inquire into the way in which parents and children maintain or alter their constructs regarding people and events. It is not known how these individual constructs may be related to progress in motor or behavioural domains.

2. *Snyder's Child Hope Questionnaire* ('Questions About Your Goals'). This questionnaire has been found to be useful in identifying 'resilience' in children with Attention Deficit Hyperactivity Disorder and Dyslexia. This may help provide some indication as to why some children have shown very good progress despite the extent and severity of their problems whereas other children have shown less progress with relatively fewer difficulties.

3. *Wechsler Objective Reading Dimension (WORD)* to identify literacy level of children. At each testing point, children have been asked for a handwriting sample and to complete a self-perception questionnaire. Children's progress on these assessments will in part be dependent on their level of literacy. In addition, research surrounding co-morbidity of childhood disorders has suggested a considerable overlap between dyslexia and 'dyspraxia' (motor planning problems). Obtaining further information regarding this factor will support understanding of the nature of coordination disorders – a key purpose of this study.

**Bromley LREC
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LREC reference 631

Ms Dido Green
Guy's & St Thomas' NHS Trust
Newcomen Centre
Guy's Hospital
St Thomas Street SE1 9RT

14 September 2004

Dear Ms Green

Re: Developmental Coordination Disorder - A qualitative and experimental study to explore the nature and remediation of Developmental Coordination Disorder

Thank you for your letter of the 7th July 2004 enclosing a progress report, which was noted by a Sub Committee of the Bromley Local Research Ethics Committee.

I wish you well in your research endeavours.

Yours sincerely



 Ms Carol Jones
Chair of Bromley's Local Research and Ethics Committee

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John Chadwick
 Chairman Bromley LREC
 Health Intelligence Unit
 Maplewood
 Farnborough Hospital
 Farnborough Common
 Orpington Kent BR6 8ND

7 July 2004

Dear Mr Chadwick

Re LREC reference 631 – DCD Treatment Efficacy study

I fear time has passed very quickly and apologise for the delay in providing an update on our DCD Treatment study. The study has received good support from the therapy services at the Phoenix Centre and we have been fortunate through a grant from the DCD Study Group to have been able to sponsor a Specialist Paediatric Occupational Therapist, Terri Worsley, who has led all of the treatment groups with good continuity. The following points and adjustments have been made to accommodate the needs of participating children and their families:

Sample Size and Attrition

There was a slightly lower than hoped for uptake ($n=46$ as opposed to $n=50$). On discussion with families this appeared to be due predominately to the length of time of the project and some families not wishing to take the risk that they would be allocated the last treatment block. In contrast to this attrition has been less than feared with two children unable to participate from the beginning due to changes in family circumstances, another child's medical condition changed resulting in the need for alternative services and two further children had complicating psychosocial difficulties resulting in their removal from the direct treatment sessions although the families are continuing to participate in the six monthly reviews. One child was unable to complete his treatment block due to difficulties in transport to and from the venue and has since moved to Norfolk. Consequently, by the end of July, 34 children will have completed their treatment sessions with one remaining group of 7 students expected to participate from September 2004 to February 2005. However, two of these remaining students have now moved on to secondary school and their progress in acquiring motor skills with the standard programmes provided by therapy services when first diagnoses has been good. It is my feeling that their participation in the treatment block is not warranted especially in view of the absences from school that this would entail over a 20 week period. I have discussed this with the parents who are in agreement. The two students and their families are happy to continue to participate in the reviews and the liaison opportunity that this provides with the other families.

The overall sample size therefore makes this one of the biggest projects undertaken with children with DCD and the only one to monitor each child's maturational development using each child as their own control. I recognise that our numbers are slightly less than the recommended 50 subjects per group. However if the delta of 3.25 and effect size of .65 as set out in our application is adjusted to a probability of 80% (delta = 2.8) and maintaining the estimated effect size of .65 a sample of 39 students is acceptable.

$$N = 2 \left[\frac{\delta}{d} \right]^2 \quad (2.8/.65)^2 \times 2 = 36.98$$

$\delta = 3.25$ (90%)

$\delta = 2.8$ (80%)

We feel therefore that we have sufficient numbers with 37 to 39 children completing the treatment and full data on 41 children when we finish the study.

Procedures

We have been fortunate to be able to undertake the treatment sessions at the Widmore Adult Education Centre although, they just announced early closure for renovations in July! Thus the final 3 sessions for the current two groups will be undertaken at the Phoenix Centre but hope that this change of venue will not introduce yet another uncontrolled variable – this will be explored in the analysis. The majority of the reviews have been undertaken according to protocol except in 10% of cases which needed to be accommodated separately due to illness or other difficulties of attendance. There are only 2 children with missing data sets when it had not been possible to set a mutually convenient review date.

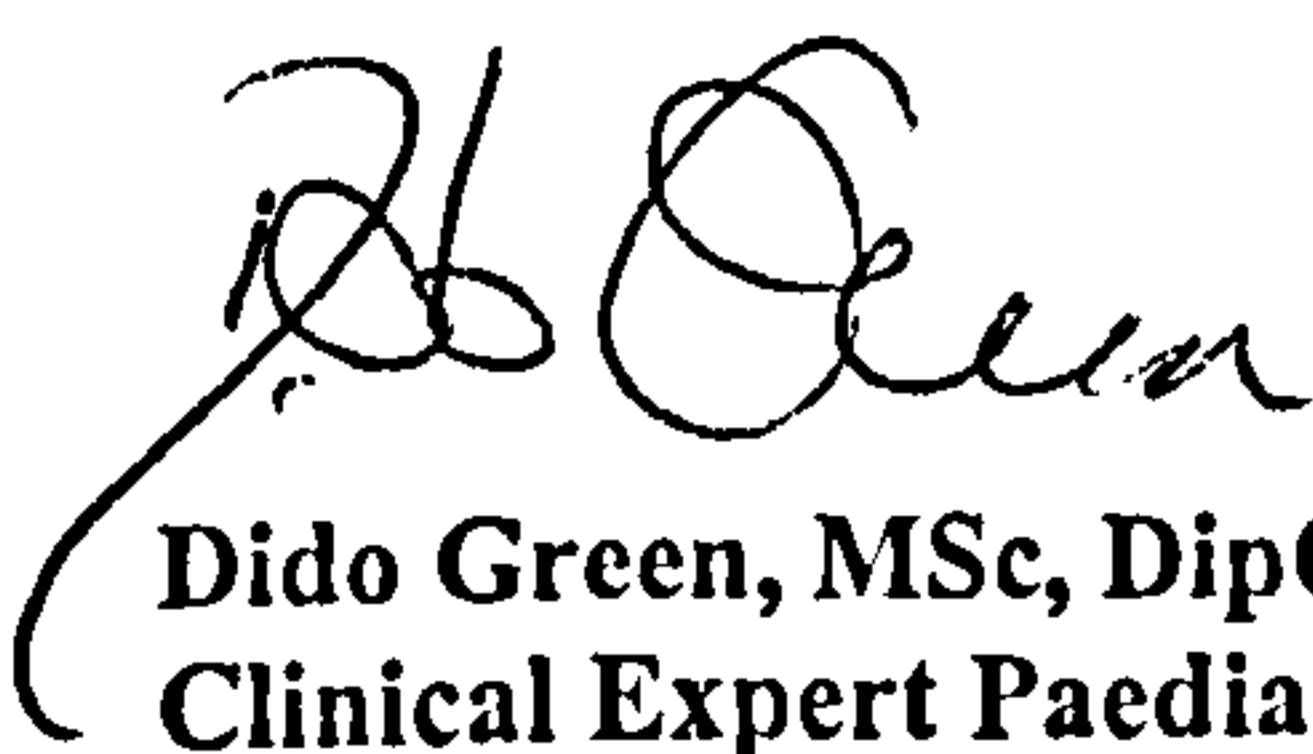
Preliminary Results

In view of the high degree of associated psychopathology identified in this group of children at the start of the study (recorded via Strengths and Difficulties Questionnaire), an article was prepared and submitted to Archives of Disease in Childhood in April and we are awaiting a response. This paper has also been accepted for presentation at the European Academy of Childhood Disorders' October Conference. Further abstracts from this project are being submitted for presentation at the DCD Six international conference in Trieste in May 2004. This will encourage early analysis of the data.

In view of the novel treatment and treatment regime being trialled here, the half way analysis of the progress of the children has been explored and is encouraging. Nearly all of the children have made good maturational progress. Those children who have completed the treatment have made greater progress not only in motor skills but also in other aspects of behaviour and performance recorded. Nearly all of the treated children met their individual targets including learning to ride a bike, tie a tie/shoelaces and roller skating.

This information provides a summary of the progress of the project. We feel confident that this study will be completed on time and are hopeful that the majority of children and their families will have benefited from participation. We are planning a party for all the families on the final session to celebrate completion of the participant phase of the project – and I am dreaming of a holiday once the analysis and writing up is finished!

Please do not hesitate to contact me should you require further details regarding the study.



Dido Green, MSc, DipCOT
Clinical Expert Paediatric Occupational Therapist

cc: Professor Sugden, Department of Education, University of Leeds, LS2 9JT

**Bromley LREC
Health Intelligence Unit
Maplewood
Farnborough Hospital
Farnborough Common
Orpington, Kent BR6 8ND
Tel: 01689 814024
Fax: 01689 814280**

LREC reference 631

Mrs Dido Green
Guy's & St Thomas' NHS Trust
Newcomen Centre
Guy's Hospital
St Thomas Street SE1 9RT

05 February 2003

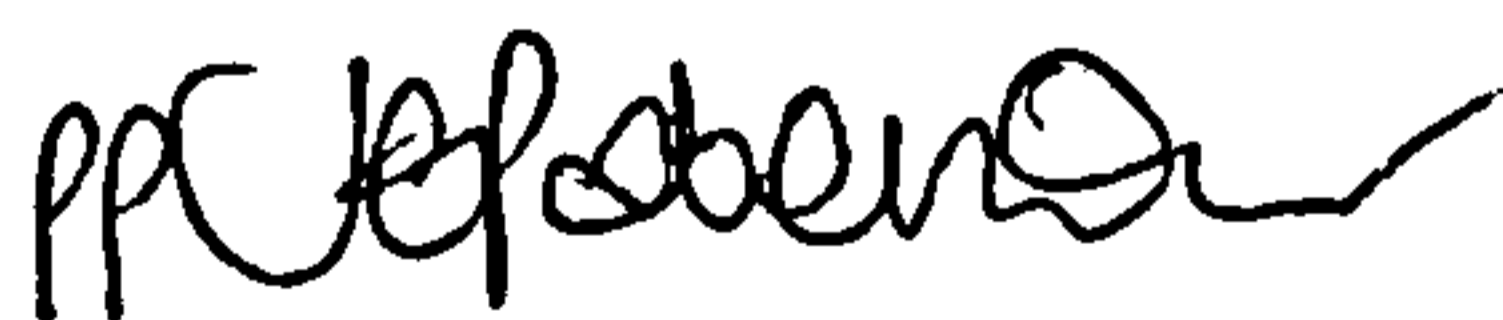
Dear Mrs Green

Re: Developmental Coordination Disorder - A qualitative and experimental study to explore the nature and remediation of Developmental Coordination Disorder

Thank you for your letter of the 16th January 2003. I am able to provide provisional ethical approval for these protocol amendments acting on Chairman's Action. This decision will be ratified by the full LREC when it meets on the 13th February 2003. You should assume that this decision is ratified unless the Committee raise any further issues in which case I will write again within one week of the full LREC meeting.

I wish you well in your research endeavours.

Yours sincerely



Mr John Chadwick
Chairman of Bromley's Local Research and Ethics Committee

Green Dido

From: Simon Jones [simon.jones@bromleyhospitals.nhs.uk]
Sent: 16 January 2003 09:43
To: Janet Paterson; Green Dido
Subject: Re: DCD treatment study LREC reference 631

Janet

I've talked to Dido and am happy with her explanation of the power calculation.

Simon

----- Original Message -----

From: <Dido.Green@gstt.sthames.nhs.uk>
To: <simon.jones@bromleyhospitals.nhs.uk>
Sent: Monday, January 13, 2003 1:11 PM
Subject: DCD treatment study LREC reference 631

> Dear Mr Jones
> Following receipt of the Bromley LREC's committee meeting in December,
I
> note that you were to contact myself to discuss the anomalies within
the
> power calculations. I am now working part-time at Guy's Hospital and
am
> even more difficult to get ahold of than usual. I apologise for that
but
> wondered whether I could address your questions via email.
>
> We are busy planning the project and I will be meeting with Tracie
Bishop,
> Head OT at the Phoenix Centre this afternoon to discuss arrangements
for
> beginning the pre-treatment assessments. Although there is some
flexibility
> in the sample size from the original cohort of children, I am hoping
that
> the any changes that errors in the power analysis will not alter the
sample
> size to much as this will have an impact on the groups we are
planning.
>
> I appreciate that you are very busy but if you did have some time
during
the
> early part of this week to email me your questions, I will try and get
these
> answered as soon as possible in order to expedite the next step of the
> project.
>
> With thanks.
> Yours sincerely
> Dido
>
>
> Dido Green, MSc, DipCOT
> Specialist Head Paediatric Occupational Therapist
> Newcomen Centre
> Guy's Hospital
> St Thomas Street
> London SE1 9RT
> tel: 020 7955 5000 x 5368
> fax:020 7955 4950
>
>

Bromley 
Primary Care Trust

Bromley LREC
Health Intelligence Unit
Maplewood
Farnborough Hospital
Farnborough Common
Orpington, Kent BR6 8ND
Tel: 01689 814024
Fax: 01689 814280

LREC reference 631
Your reference

Mrs Dido Green
Guy's & St Thomas' NHS Trust
Newcomen Centre
Guy's Hospital
St Thomas Street SE1 9RT

11 December 2002

Dear Mrs Green

Re: Developmental Coordination Disorder - A qualitative and experimental study to explore the nature and remediation of Developmental Coordination Disorder

- Thank you for your research proposal which was reviewed by the full Local Research Ethics Committee meeting held on the 5th December 2002. I am writing to confirm the Committee was able to provide ethical approval for this protocol subject to the following amendments;
- The Committee agreed that Simon Jones should contract the investigator and discuss the anomalies within the power calculations;
 - The Committee requested details of the sponsor of the study, currently only a fax number is given (p3. Item 5);
 - Details of the education course are required (p3. item 4)
 - The Committee noted that in 'The Developmental Coordination disorder Intervention Study' (DCD Project) the paragraph 'What is involved? Second to last sentence should read 'effects' not 'affects';
 - The Committee requested the letter of R & D approval from Bromley PCT;
 - Section 7 item 39 please confirm that normal NHS arrangement apply.

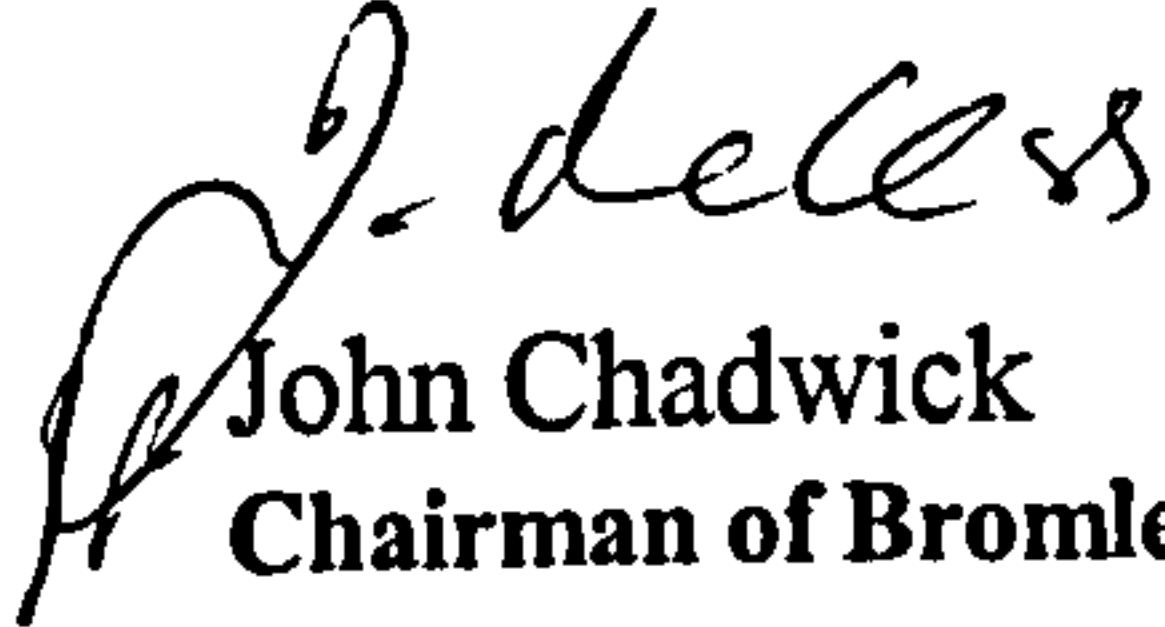
304

The role of the research ethics committee is to consider the ethical implications of all research involving Bromley NHS patients, their medical records, or Bromley NHS facilities. It is the responsibility of the investigator to advise the NHS body, under the auspices of which the research will take place, of the LREC's decision.

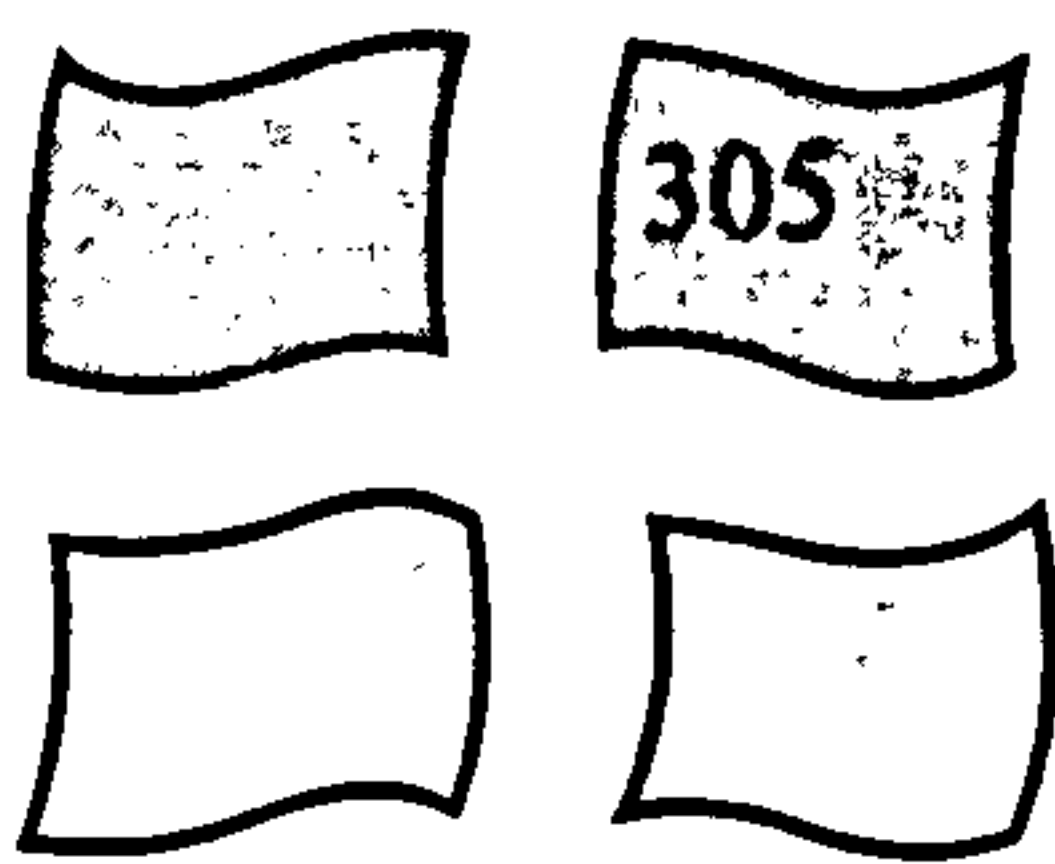
I would remind investigators that our approval is conditional. Approval may be withdrawn if the Committee review the study and are concerned about the conduct or consequences of the work. The Committee require that the investigator inform them of any changes to the protocol, or any serious adverse events during the work, and expect to receive yearly reports.

I wish you well in your research endeavours.

Yours sincerely



John Chadwick
Chairman of Bromley's Local Research and Ethics Committee



BROMLEY HEALTH

Department of Public Health

Dr J Spiby, Director

Please direct LREC correspondence to: **Bromley LREC, c/o Applied Research Unit, Pinewood Building, Farnborough Hospital, Farnborough Common, Orpington, Kent BR6 8ND**
Telephone: (01689) 814377 Fax: (01689) 814280

LREC reference 458

Mrs Dido Green
Specialist Head Paediatric Occupational Therapist
Newcomen Center
Guy's Hospital
St Thomas Street
London SE1 9RT

05 September 2000

Dear Mrs Green

Re: Developmental Co-ordination Disorder Screening Project

Thank you for your correspondence dated the 7th August 2000 and 11th August 2000. I am now able to provide provisional ethical approval for this protocol acting on Chairman's Action. This decision will be ratified by the full LREC when it meets on the 14th September 2000. You should assume that this decision is ratified unless the Committee raise any further issues in which case I will write again within one week of the full LREC meeting.

The role of the research ethics committee is to consider the ethical implications of all research involving Bromley NHS patients, their medical records, or Bromley NHS facilities. It is the responsibility of the investigator to advise the NHS body, under the auspices of which the research will take place, of the LREC's decision.

I would remind investigators that our approval is conditional. Approval may be withdrawn if the Committee review the study and are concerned about the conduct or consequences of the work. The Committee require that the investigator inform them of any changes to the protocol, or any serious adverse events during the work, and expect to be given a copy of the final research report.

I wish you well in your research endeavours.

Yours sincerely

Mr John Chadwick
Chairman of Bromley's Local Research and Ethics

Bromley Health Authority
Global House, 10 Station Approach, Hayes, Kent, BR2 7EH.
Telephone 020 8315 8315
Fax 020 8462 6767

Phoenix Children's Resource Centre
 40 Masons Hill
 Bromley
 Kent
 BR2 9JC

 Tel: 020 8466 9988
 Fax: 020 8466 8855

NHS/DCD

 16th January 2003

Dear Parent(s)/Carer(s)

The DCD Project

We are writing to ask if you would allow your child to take part in a research study being conducted in Bromley. It is a project involving the Paediatric Occupational Therapy Team at the Phoenix Centre and lecturers/researchers at the University of Leeds. The aim of the project is to expand on the work undertaken in a referral screening project which we did in Bromley over the past few years. We would like to analyse the information gathered to ascertain whether there are 'sub-types' of co-ordination deficits which affect a child's performance in daily activities and may influence his or her response to treatment. Evidence suggests that group treatment may be helpful for many children with co-ordination difficulties and we would like to invite your child to join a group of other children in a block of treatment (one hour weekly over 20 weeks). We will need to evaluate children's progress twice a year to gain information regarding children's maturation and acquisition of developmental skills. It is hoped that by combining the assessment information with intervention we will have an improved understanding of the therapy needs of children with co-ordination difficulties.

Information about the DCD Project is given on the attached sheets for you and your child to read. If you and your child are happy to take part, you should sign the enclosed consent form and return it in the pre-paid envelope provided. We hope that every child who is asked will help us with this very important work, but participation is entirely voluntary.

We think you will find the project interesting and helpful for your child.

Thank you for your help.

Yours sincerely

Dido Green
 Research Student and
 Paediatric Occupational Therapist

Professor David Sugden
 Professor of Special Needs in Education



Phoenix Children's Resource Centre
40 Masons Hill
Bromley
Kent
BR2 9JG

Tel: 020 8466 9988
Fax: 020 8466 8855

NHS/DCD

16th January 2003

Dear

The DCD Project

Would you like to help us with a new study we are doing in Bromley?

We are gathering information about children's movement skills and how to teach these so that they can be made easier to do.

Information about the DCD project is given on the attached sheet for you to read. If you would like to take part, you and your parent or carer should sign the form and return it in the envelope provided.

We think you will find the project interesting and helpful to you.

Thank you for your help.

Yours sincerely,

Dido Green
Research Student and
Paediatric Occupational Therapist

Professor David Sugden
Professor of Special Needs in
Education



Phoenix Children's Resource Centre
40 Masons Hill
Bromley
Kent
BR2 9JG

Tel: 020 8466 9988
Fax: 020 8466 8855

INFORMATION SHEET FOR CHILDREN

Hello!

We are Dido Green and David Sugden and we work at Guy's Hospital and Leeds University.

We are doing some work to help children to do things like drawing; writing; catching; throwing and we would like to ask you to help us. The study is called the **DCD Project**.

If you would like to help us we will ask you to join other children to participate in group games with instructions designed to make these and other activities easier to do. We hope it will be fun for you.

If you would like to help, please write your name on the next sheet.

Please, ask us if you want to know more.

Thank you.



Phoenix Children's Resource Centre
40 Masons Hill
Bromley
Kent
BR2 9JG

The Developmental Coordination Disorder Intervention Study (DCD Project)

Approved by the Bromley Local Research & Ethics Committee reference 631

Tel: 020 8466 9988
Fax: 020 8466 8855

What is the DCD project about?

- ◆ **To investigate the nature of children who have coordination problems and determine whether there are differing 'sub-types' within this condition which may influence the child's performance in daily activities and response to treatment.**

The evaluation of co-ordination problems currently requires considerable clinical time which limits opportunities for providing direct intervention for those children identified with DCD. It is very important to understand which assessment measures provide sufficient information regarding the characteristics of these children to improve their coordination through specific treatment programmes.

Why have we been approached?

Your child has participated in a referral screening programme at the Phoenix Centre, Bromley and was identified as having some co-ordination difficulties which may benefit from more direct intervention. We hoped that you would be interesting in helping out further with the DCD project.

What is involved?

A questionnaire is enclosed to help us determine whether your child would potentially benefit from a group intervention approach. Following this, all children in the project will be assessed prior to the treatment study beginning and at four further testing points to determine natural maturation of developmental skills in addition to change as a consequence of treatment (a total of 5 brief testing points over a two year period). Children will be randomly placed into groups of 6 to 8 children according to age bands for treatment (6-8 years and 9-10.6 years) and scheduled to receive 20 weeks of one hourly occupational therapy. All children will be given the same therapy irrespective of which treatment block they have been assigned to. Treatment blocks are anticipated to run from February to July 2003, September to January 2003, February to July 2004 and September to the following January 2005. In addition, each group of children will be requested to participate in a period of 'special time' when not involved in a treatment block to control for generalised effects of intervention. You will be asked to undertake a 20 minute activity over a 20 week period with your child (eg. listening to a story).

You and your child will also be asked to complete a short questionnaire regarding your perceptions of competence, level of participation and satisfaction in motor and social activities.



What are the possible benefits of taking part?

We hope to gather information about the nature of the problem in children with co-ordination difficulties and help to treat not only your child but other children with similar problems more effectively. All the gathered information of your child will be analysed and all the details will be available yourself and those therapists involved in your child's care.

Will my child's GP and consultant be informed about the study?

Yes, if you decide to take part in **DCD** project, we will let your doctors know.

What will happen to the information collected in the project?

The child's personal details will be kept strictly confidential, and when we publish the results there will be no way in which individual children's information can be recognised. At the end of the study, you will be informed of your child's progress and any continuing need for therapy.

Who is organising and funding the research?

The lead researcher, Dido Green, is organising the project as part of a research degree programme supervised by Professor David Sugden, Professor of Special Needs in Education at the University of Leeds. The project is supported by the Paediatric Occupational Therapy Department, Phoenix Centre, Bromley PCT.

Who has reviewed the study?

Bromley's Local Research Ethics Committee.

What happens if I do not want my child to take part in the project?

Your child's medical care will not be affected by whether you decide to take part or not, and you are free to change your mind and withdraw from the **DCD** project at any time.

What happens if I do want to take part?

You and your child should both sign the consent form and return this with the enclosed questionnaire. We shall contact you to inform you of the evaluation and treatment schedule allocated to your child. If you would like any further information, please contact the **DCD** project lead researcher Dido Green, Guy's and St Thomas' NHS Trust (telephone number 020 7955 5000 x 5368, email: dido.green@gstt.sthames.nhs.uk).

Thank you for your help

Phoenix Children's Resource Centre
40 Masons Hill
Bromley
Kent
BR2 9JG

**Developmental Coordination Disorder Intervention Study
(DCD Project)
CONSENT FORM**

Tel: 020 8466 9988
Fax: 020 8466 8855

Name of Lead Researcher: Dido Green

Study number:

NB Three copies should be made, for (1) parent/guardian

Child's Identifier number:

(2) researcher, (3) hospital notes

Child's Name.....

Please initial box

YES I would like my child to take part in the DCD Project

• I have read the Parent Information Sheet and had the opportunity to ask questions.

• I understand that more information is available.

• I understand that our participation is voluntary and we are free to withdraw at any time, without giving any reason and without my child's medical care or legal rights being affected.

• I understand that sections of my child's medical notes may be looked at by the investigators *Dido Green* and *Professor David Sugden*. I give permission for these individuals to have access to my child's records.

• I agree for my child and I to take part in this project

Please initial box

NO I do not wish my child to take part in the DCD project

Name of Parent/ Guardian
(Block Capitals)

Signature _____

Date _____

Name of CHILD
(Block Capitals)

Signature _____

Date _____

Researcher: DIDO GREEN

Signature _____

Date _____

**Please return this form in the pre-paid envelope within 7 days of receipt
Thank you for your help**



The DCD Project

Welcome to the DCD Project.

This study is being undertaken to identify how effective group treatment is in helping children with coordination disorders. We also hope to investigate which factors of motor skill and individual characteristics have an impact on a child's response to treatment. At some point over the next two years, students will be joining a 'Detective Club' to help them figure out ways to do new motor skills. Parents will be invited to join us on the first, 11th and final three sessions to support a transfer into daily activities of the skills your children have acquired. The children will be provided with a membership wallet which will help us monitor their use of successful strategies.

We also need to monitor the natural development of children and therefore some of the treatment blocks have been staggered to allow us to control for this variable. In addition, some children seem to benefit from additional attention without any specific 'motor' treatment. Each group has been allocated a period of 'Special Times' which are explained in your pack. This will help us determine more specifically which aspects of the motor intervention have helped promote skills.

In your pack you should find:

- o Information regarding '*Special Times*'; (a '*Special Times*' diary is included for those who will be undertaking this during the next 6 months);
- o Map to guide you to the Widmore Adult Education Centre where sessions will be undertaken;
- An information sheet to inform us of what treatments your child has received for coordination difficulties since his/her initial Occupational Therapy assessment;
- A repeat Developmental Coordination Disorder Questionnaire investigating your perceptions of your child's current difficulties with motor control;
- A general questionnaire looking at your child's overall development.

We would like you to complete the three questionnaires and return these by the end of this first session.

Thank you for your participation and we look forward to working with you all over the next two years. Should you have any concerns or wish to talk to someone in more detail, please telephone Dido on 020 7955 5000 x 5368 or Tracie Bishop, 020 8466 9988 x 222.

Any cancellations on day of group treatment please contact Denise Djemil-Yusuf on 020-8466-9988 x. 222.

Special Times

The process of child development is very complex. Children may move in leaps and bounds or have periods where they consolidate their skills and no progress seems evident. In developmental conditions in which children find it difficult to do things as easily and as quickly as other children they may feel frustrated, and in some cases become isolated from their peer group when they fail to keep up with the advances of their classmates. At these times, children need to know they are 'Special'.

'Special Times' is designed to ensure that each child receives personalised attention to help them feel special. In order to understand how a treatment programme helps support a child acquire motor skills we need to know what aspects of treatment relate to being 'special' ^{and} that which is specific to the motor programme.

'Special Times' requires parents/carers to allocate at least 20 minutes in a week to a specific activity. These activities should be ones that the child enjoys and the parent/carer can tolerate. Ideas that spring to mind are 'listening to Go 4 It – children' radio 7:15 to 8:00 pm Sunday evenings on Radio 4, reading a story together, watching a video together or engaging in games such as lego, football, puzzles etc. This must be dedicated time during which the parent is engaged in the activity with that child ie. S/he does not do something else, undertake a phone conversations or attend to the requests of brothers and sisters (except in the case of an emergency). We need you to document how much time you spent on the activity and list the activity undertaken. Although preferable to stick to the same type of activity over the 20 week period as long as you list what you did and how long you were able to do it for, we will be able to process the information.

We know that parents are often the 'best therapists' and we wish to learn from what works at home to translate this to the clinic where we can.

Appendix 6

CO-ORDINATION SKILLS QUESTIONNAIRE - 1

We are interested in the skills you have and how you feel about doing these tasks. We would like you to circle the number that you think best matches your ability on various activities and then circle how satisfied you are with your skill level.

Name: _____

Date: _____

Group: _____

Ability Scoring:

1 = very poor
2 = poor
3 = average
4 = good
5 = very good

Satisfaction Scoring:

1 = very unhappy
2 = unhappy
3 = OK
4 = happy
5 = very happy

Tasks	Ability	Satisfaction
1. Tying shoelaces	1 2 3 4 5	1 2 3 4 5
2. Using a knife and fork during mealtimes	1 2 3 4 5	1 2 3 4 5
3. Managing paper when using the toilet	1 2 3 4 5	1 2 3 4 5
4. Catching and throwing a tennis ball and kicking a football	1 2 3 4 5	1 2 3 4 5
5. Running, jumping and skipping skills	1 2 3 4 5	1 2 3 4 5
6. Playing with Lego, scalectrix or making bead necklaces	1 2 3 4 5	1 2 3 4 5
7. Writing neatly and quickly	1 2 3 4 5	1 2 3 4 5
8. Joining others in group games such as Football or Rounders	1 2 3 4 5	1 2 3 4 5
9. Organising materials on a desk and packing a lunch box	1 2 3 4 5	1 2 3 4 5
10. Any other task, game or sport you would like to do – please state:	1 2 3 4 5	1 2 3 4 5

Thank you.

Appendix 6

CO-ORDINATION SKILLS QUESTIONNAIRE - 2

We are interested in the skills you have and how you feel about doing these tasks. We would like you to circle the number that you think best matches your ability on various activities and then circle how satisfied you are with your skill level.

Name: _____

Date: _____

Group: _____

Ability Scoring:

1 = very poor
2 = poor
3 = average
4 = good
5 = very good

Improvement Scoring:

1 = much worse
2 = worse
3 = same
4 = better
5 = much better

Tasks	Ability	Satisfaction
2. Tying shoelaces	1 2 3 4 5	1 2 3 4 5
2. Using a knife and fork during mealtimes	1 2 3 4 5	1 2 3 4 5
3. Managing paper when using the toilet	1 2 3 4 5	1 2 3 4 5
4. Catching and throwing a tennis ball and kicking a football	1 2 3 4 5	1 2 3 4 5
5. Running, jumping and skipping skills	1 2 3 4 5	1 2 3 4 5
6. Playing with Lego, scalectrix or making bead necklaces	1 2 3 4 5	1 2 3 4 5
7. Writing neatly and quickly	1 2 3 4 5	1 2 3 4 5
8. Joining others in group games such as Football or Rounders	1 2 3 4 5	1 2 3 4 5
9. Organising materials on a desk and packing a lunch box	1 2 3 4 5	1 2 3 4 5
10. Any other task, game or sport you would like to do – please state:	1 2 3 4 5	1 2 3 4 5

Thank you.

DCD Project

In order to help us understand what type of intervention is most helpful for children with DCD, we would like to know what services you have been able to access over the past six months and how helpful you think these have been.

Name of child: _____ Date: _____

Since your child's initial assessment by an Occupational Therapist at the Phoenix Children's Resource Centre:

1. Have you received further OT advice? Y N
- If so:
- a. Have you found this useful? Y N
- b. Did your child receive direct intervention? Y N
- i. Approximately how many sessions did your child receive

2. Has your child received other therapy/specialist advice to assist your child's motor development? Y N

If so: What type of therapy

Eg. Physiotherapy Remedial gymnastics Cranial-osteopathy

Other – please state: _____

- a. Have you found this useful? Y N
- b. Approximately how many sessions were undertaken

3. Are there any other sources of support/advice which you have obtained? Y N

Eg. Dyspraxia Foundation, information from the Internet, Self-help texts etc.

Please State: _____

Any other comments you would like to make regarding any changes in your child's life:

Telephone number in case of emergency:

_____ Thank you.

Appendix 8

CO-OP approach treatment group programme

7-8 years

Week	Aim	Present	Materials
1	Teaching of Global Strategy	Parents & Children	Sharpening pencils, Making sandwich
2 TG	Teaching Global Strategy	Parents & Children	Shoe laces, zips and buttons
3 TG	Feeding	Children	Knife and fork flour game Making cereal
4 TG	Ball Skills	Children	Hoop bounce Bean bag shooting Football skills
5 TG	Skipping	Children	Pre skipping skills, French skipping, group skipping and individual skipping
6 TG	Fine motor	Children	Cutting, pinch grip, activities
7 TG	Handwriting	Children	Colouring mat, Chalk boards Writing on biscuits
8 TG	Handwriting	Children	Fridge Magnets 'Consequences' Secret GPDC statement
9 TG	Organising materials and navigating environment	Children	Obstacle course/Scooter board and lunch box race sandwich making
10 TG	Joining group games	Children	Parachute, pictionary Ludo game
11 TG	Review of goals and strategies	Parents & Children	
12 CG	Children's goals		As required
13 CG	..		As required
14 CG	..		As required
15 CG	..		As required
16 CG	..		As required
17 CG	..		As required
18	CC or Consolidation	Children +/- parents	As required
19	CC or Consolidation	Children +/- parents	As required
20	Consolidation	Children and Parents	? Children to teach parents 'their' strategy doing something new?

TG = Therapist goal from referral reasons

CG = Child's goal, one per session

Appendix 8

CO-OP approach treatment group programme

10-11 years

Week	Aim	Present	Materials
1	Teaching of Global Strategy	Parents & Children	Feet hoops, Making sandwich
2 TG	Teaching Global Strategy	Parents & Children	Shoe laces and ties
3 TG	Feeding	Children	Knife and fork flour game
4 TG	Ball Skills	Children	Hoop bounce Ping pong game Football skills
5 TG	Skipping	Children	Pre skipping skills, French skipping, group skipping and individual skipping
6 TG	Fine motor	Children	Collage kits, tweezer activities
7 TG	Handwriting	Children	Post cards Chalk boards Writing on biscuits
8 TG	Handwriting	Children	Fridge Magnets 'Consequences' Secret GPDC statement
9 TG	Organising materials and navigating environment	Children	Obstacle course/Scooter board and lunch box race sandwich making
10 TG	Joining group games	Children	Parachute, pictionary Dominoes./cards
11 TG	Review of goals and strategies	Parents & Children	
12 CG	Children's goals		As required
13 CG	**		As required
14 CG	**		As required
15 CG	**		As required
16 CG	**		As required
17 CG	**		As required
18	CC or Consolidation	Children +/- parents	As required
19	CC or Consolidation	Children +/- parents	As required
20	Consolidation	Children and Parents	? Children to teach parents 'their' strategy doing something new?

TG = Therapist Goals from Referral reasons

CG = Child's Goals – one per session

Appendix 9

Standardised Discriminant Function Coefficients (Weights)*

Sensory Integration Theory Variables

	Function 1	Function 2	Function 3	Function 4
VMI Motor subtest	.366	.557	-.078	-.809
VMI Visual subtest	.085	.689	-.052	.765
COMPS Finger to Nose	.564	-.123	.873	-.004
MABC Static balance	1.022	-.106	-.320	.100

Discriminant Function Loadings*

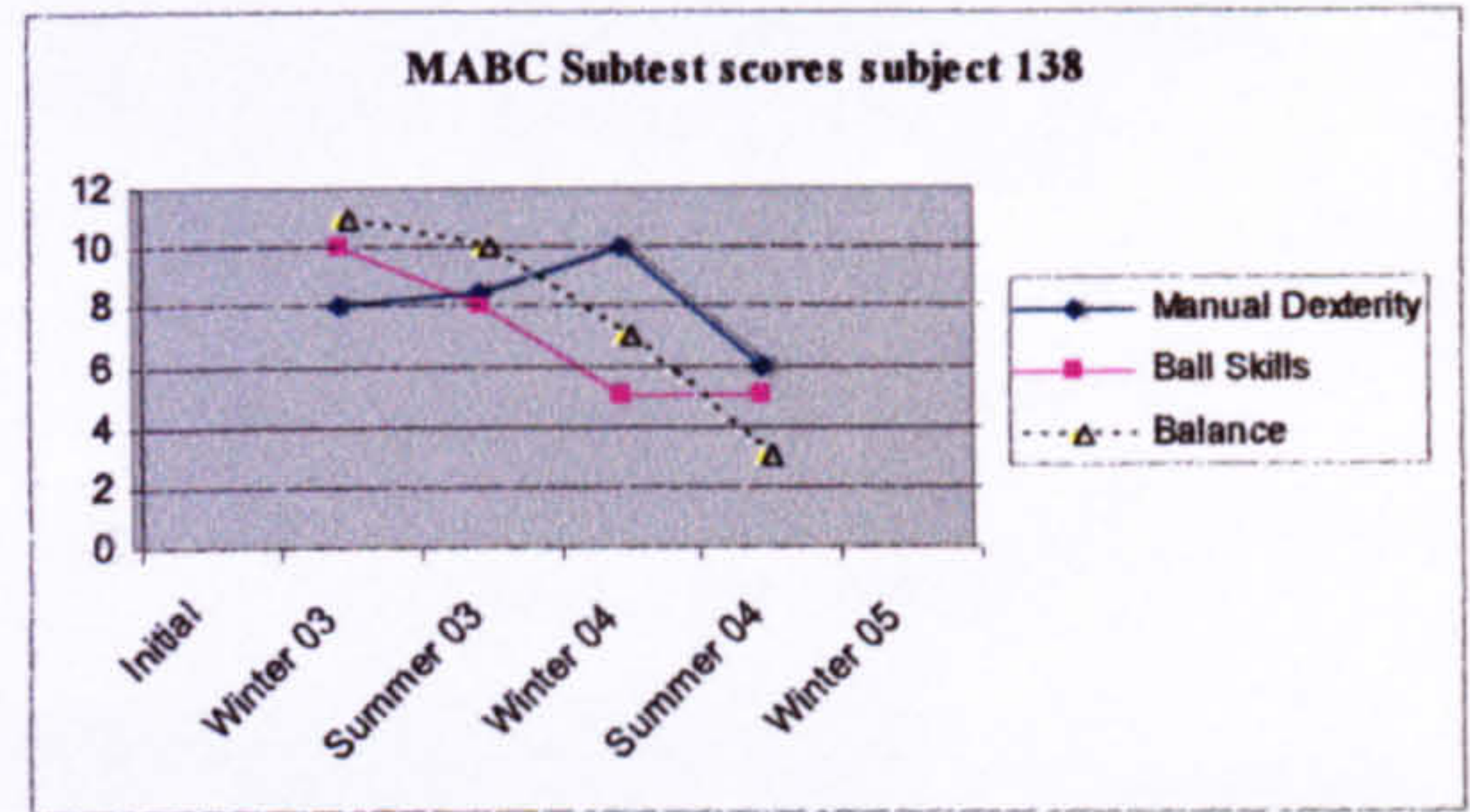
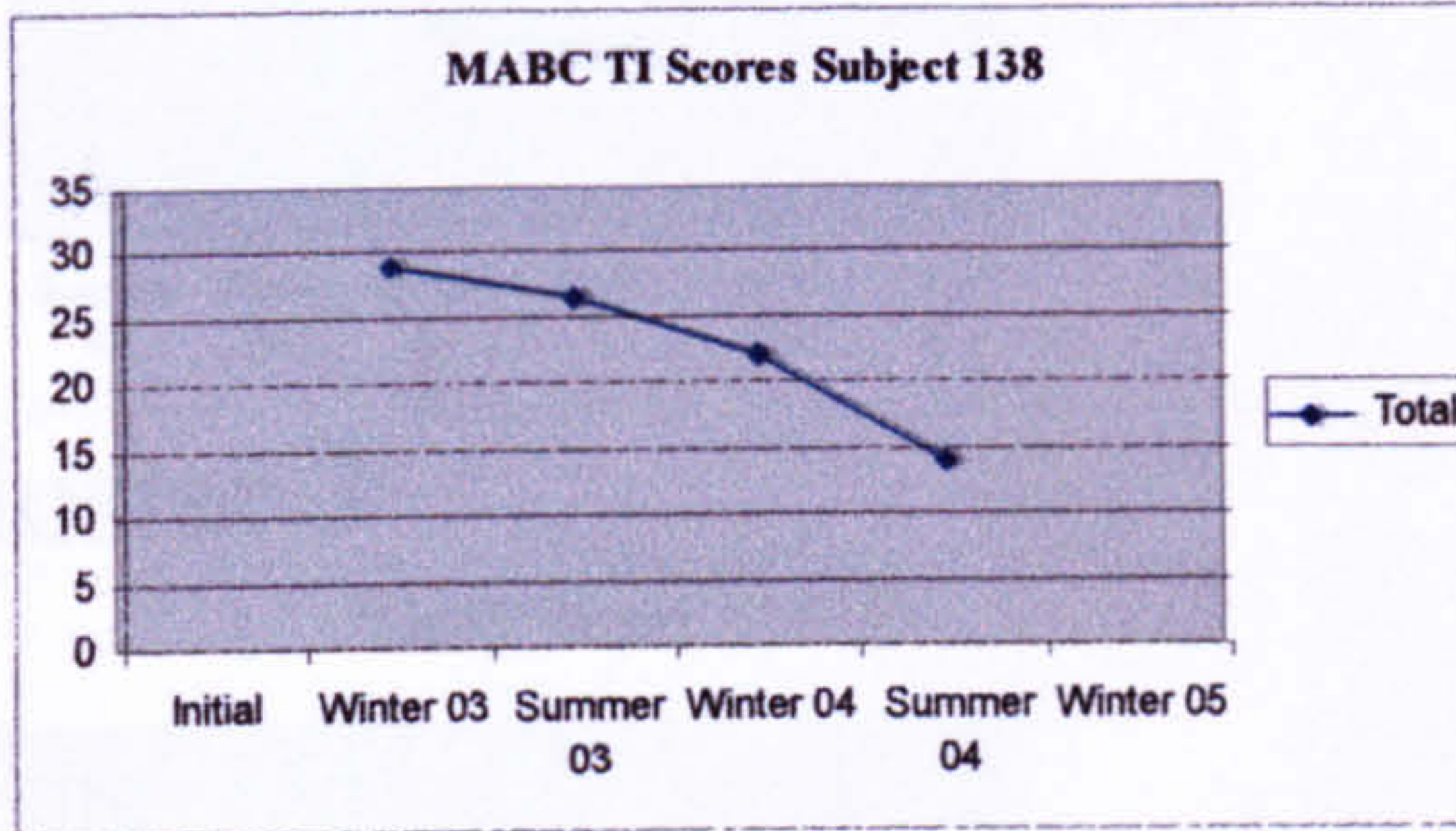
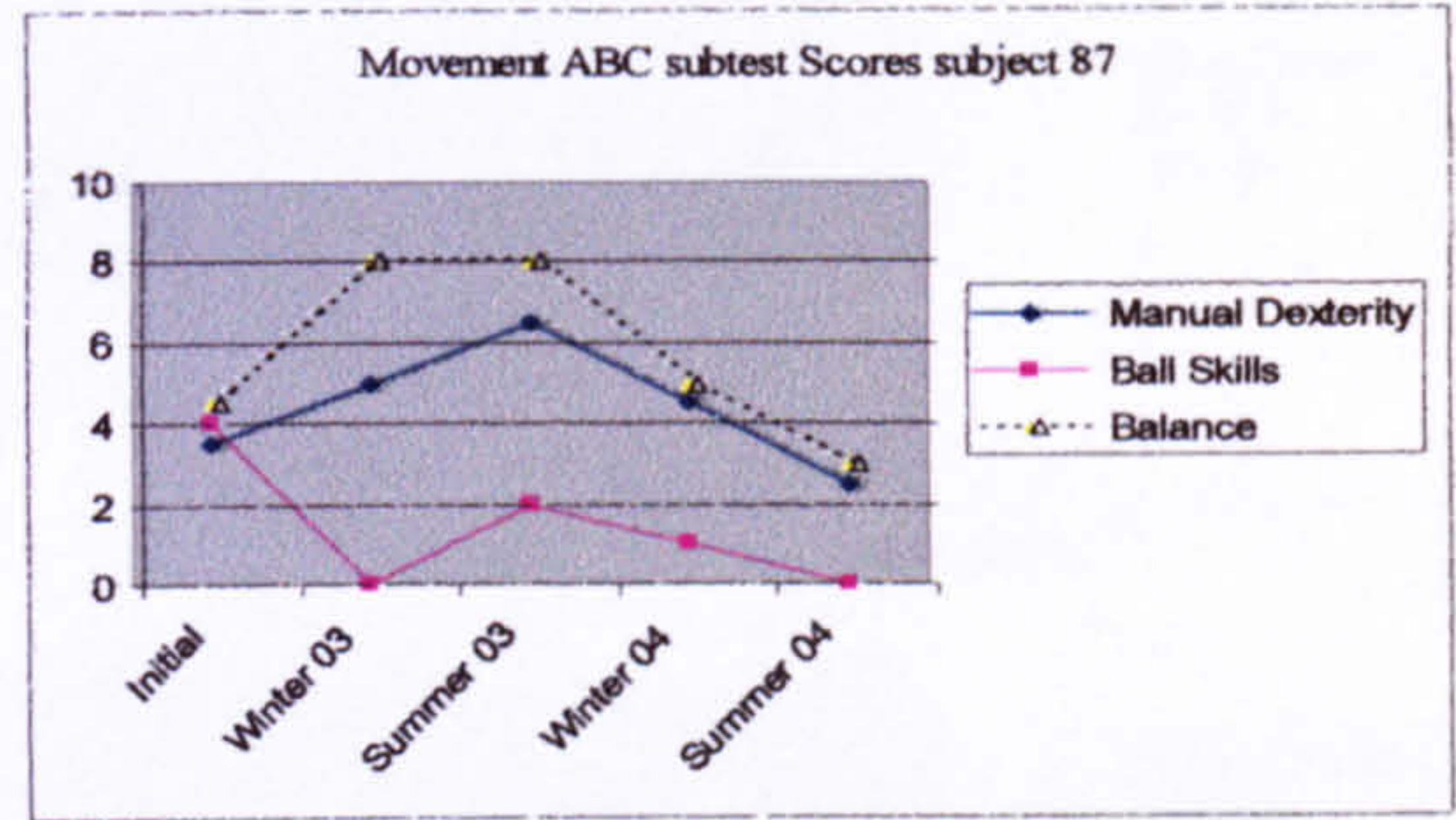
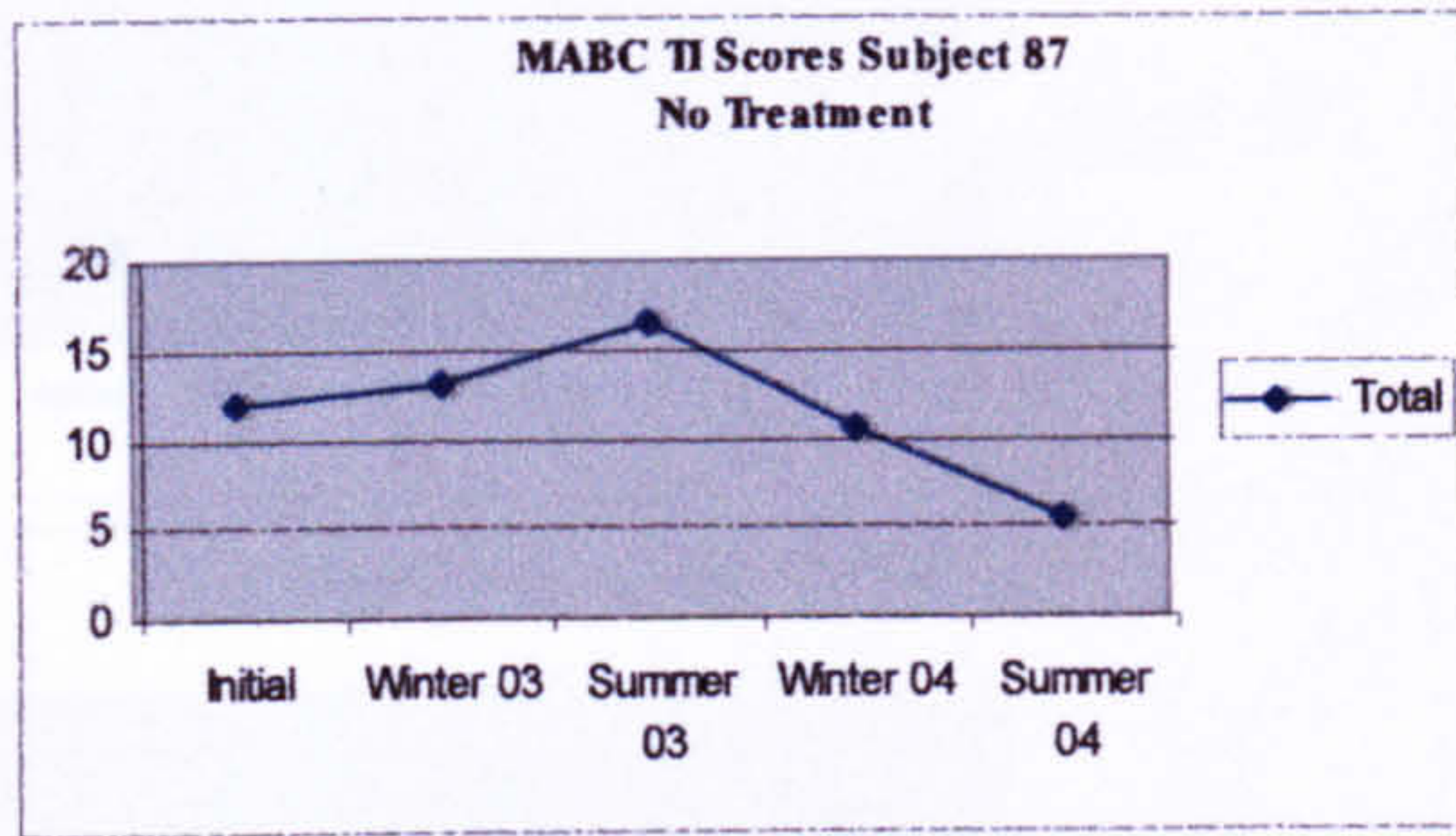
Sensory Integration Theory Variables

Z Scores	Function 1	Function 2	Function 3	Function 4
MABC Static balance	.760	-.325	-.536	.172
COMPS Prone extension	.307	.145	.251	.027
COMPS ATNR	.251	-.080	.218	-.078
Gesture Test Representational	.190	.096	.099	.083
VMI Visual subtest	.053	.812	.083	.575
VMI Motor subtest	.143	.727	.007	-.671
MAT Total score	-.124	.204	-.055	.122
COMPS Finger to Nose	.295	-.006	.955	.037
COMPS Forearm rotation	.134	.314	.430	.078
COMPS Slow Movement	.182	.208	.342	.138
COMPS Supine Flexion	.252	.008	.291	-.096
Gesture Test Non-Representation	.181	.062	.269	.095

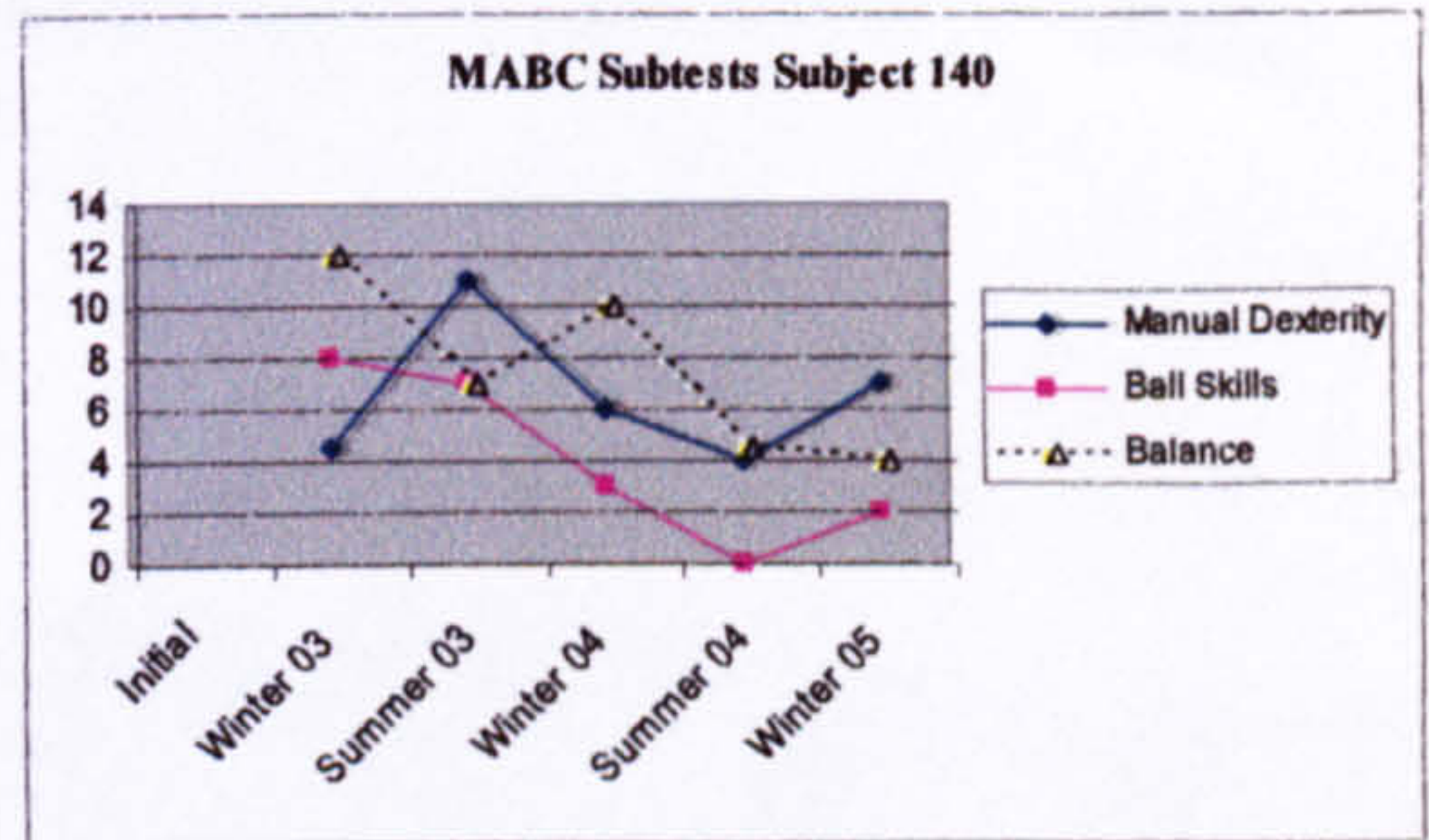
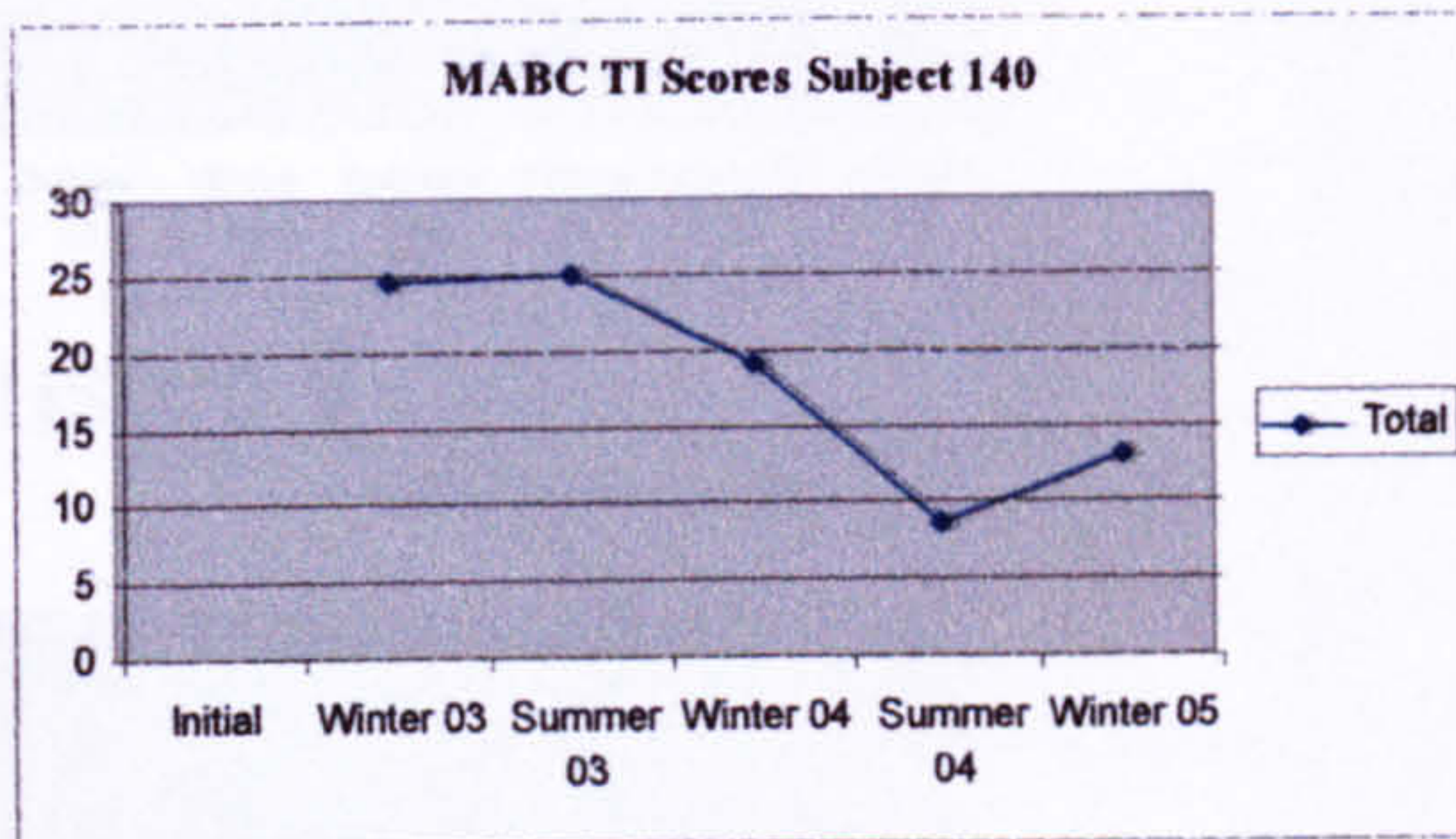
* *Weights* reflect the power (relative contribution) of independent variables to the discriminant function. *Loadings* reflect the variance that the independent variables share with the discriminant function, measuring simple linear correlations between each independent variable and the discriminant function, thus incorporate variables with a high degree of multicollinearity. Both assess the relative contribution of each independent variable to the discriminant function (Hair et al., 1992, p.106-107)

Appendix 10 Figures of variability of motor performance by cluster over time
Children who had no treatment

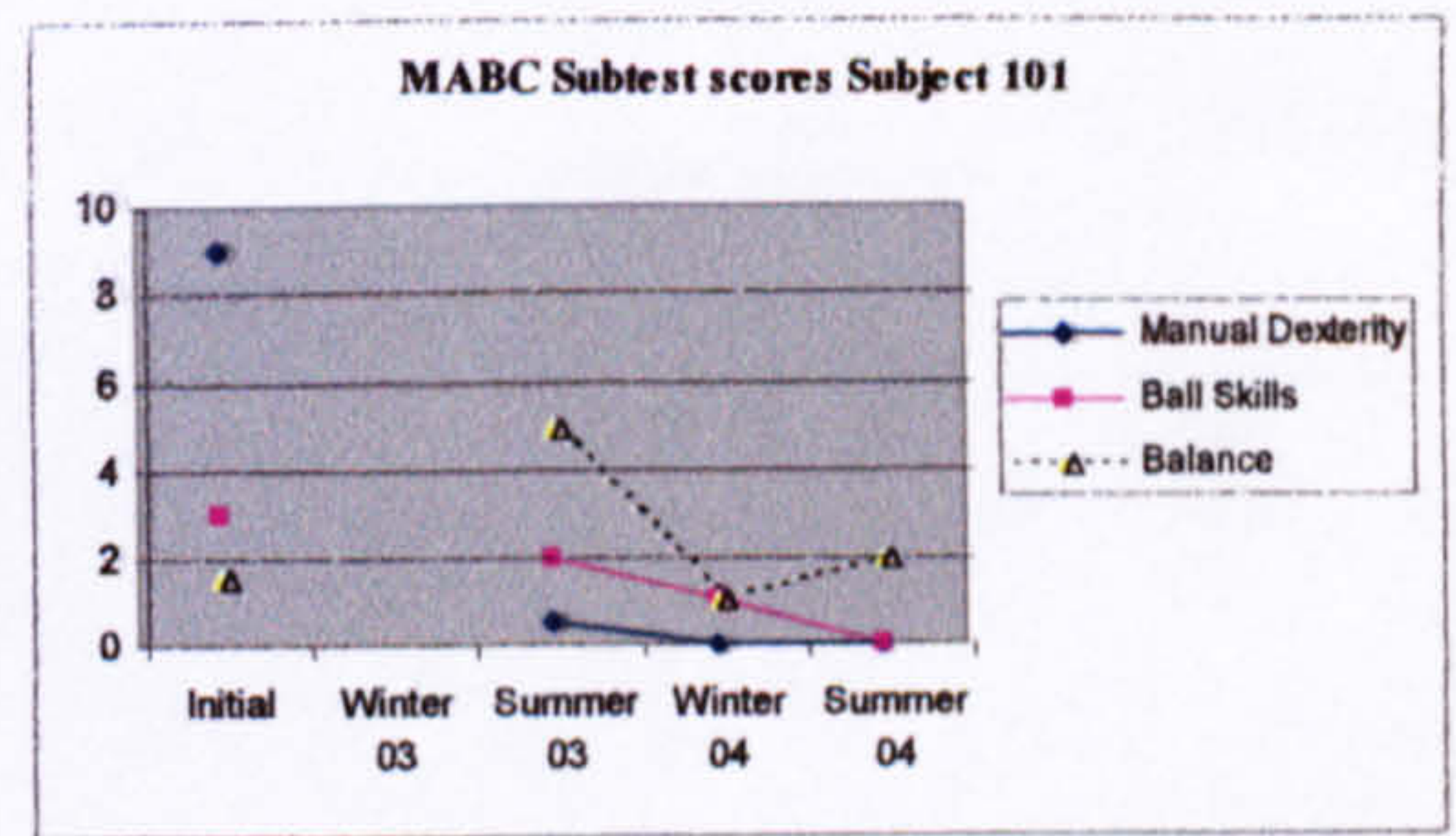
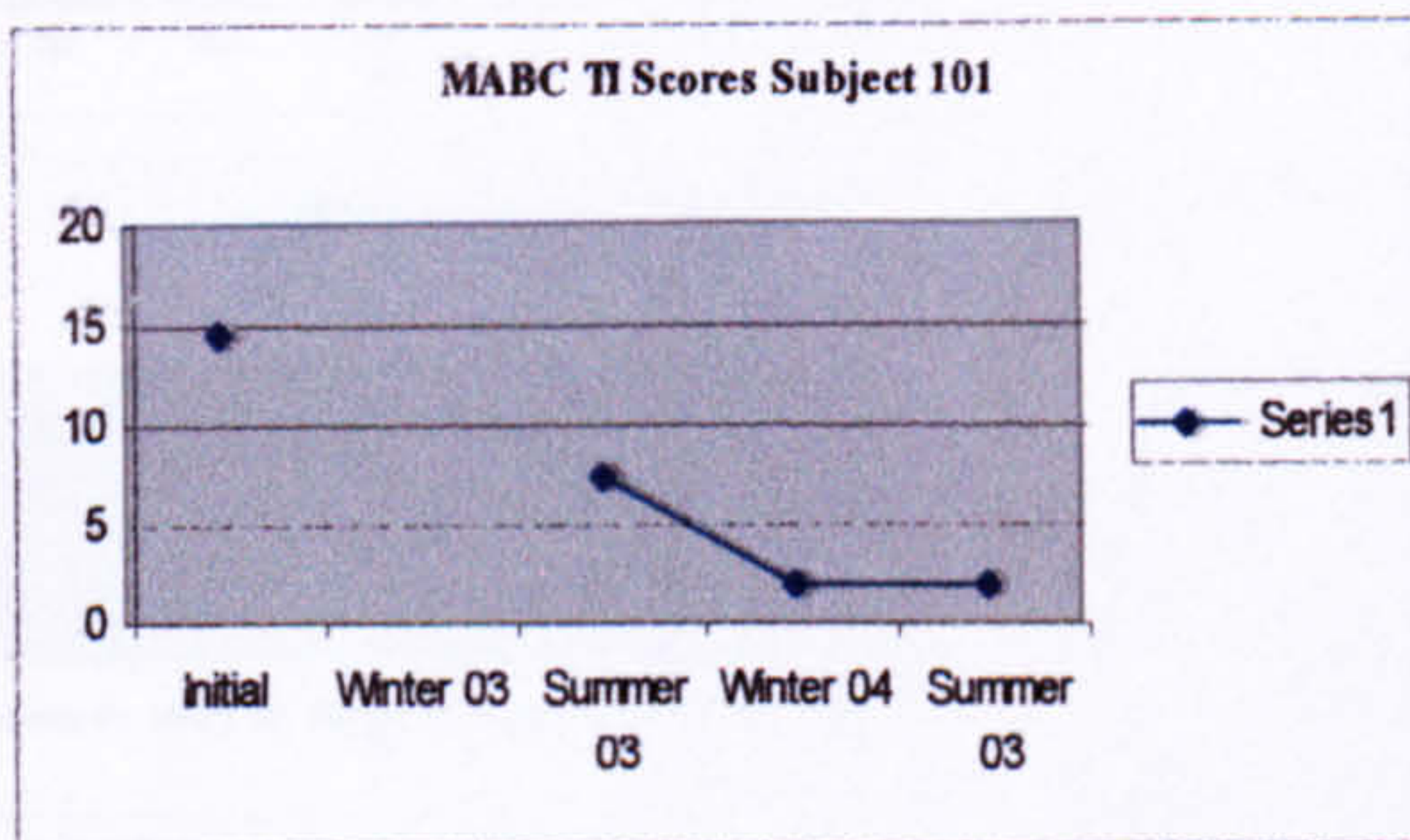
Cluster 1



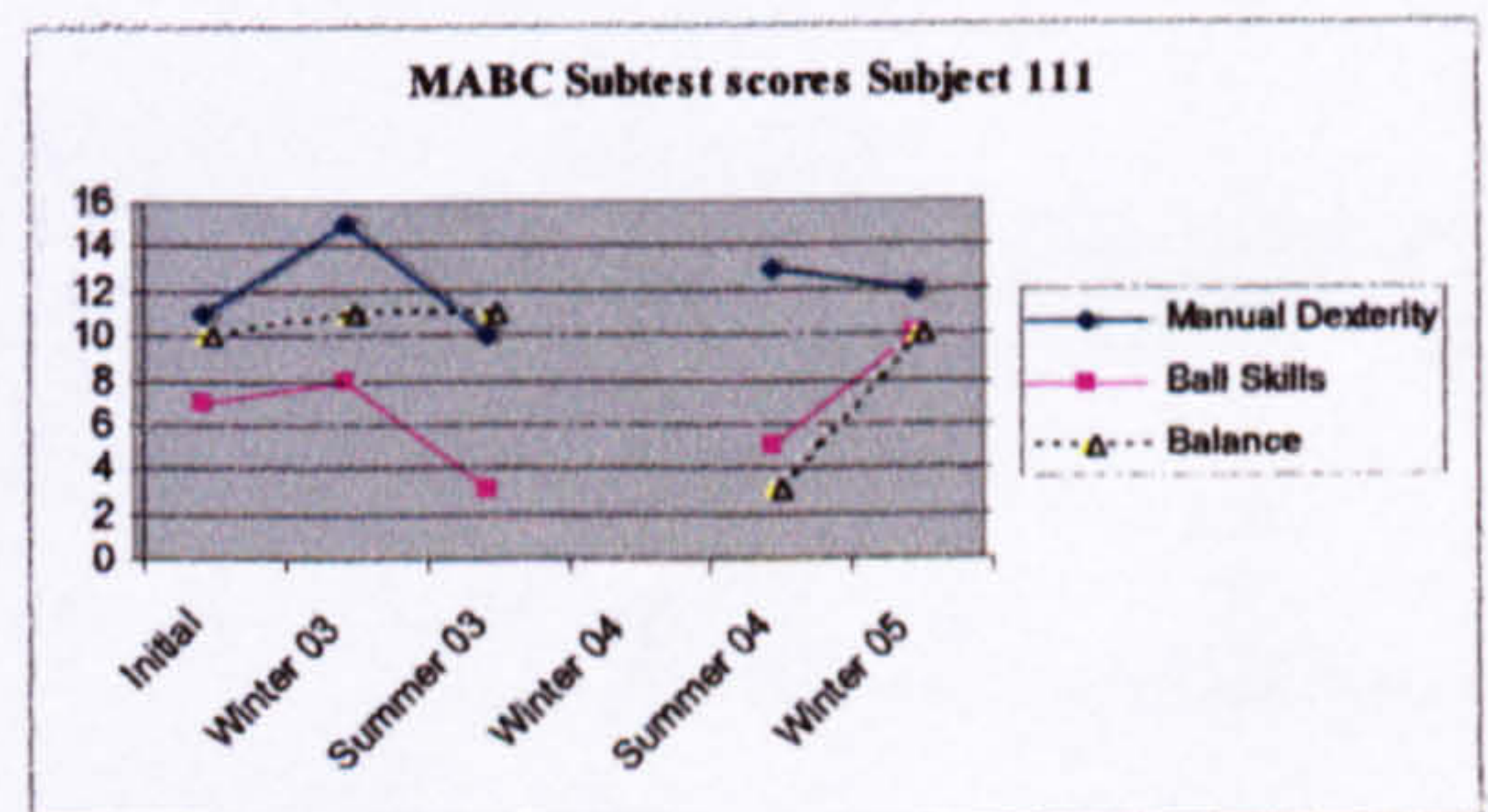
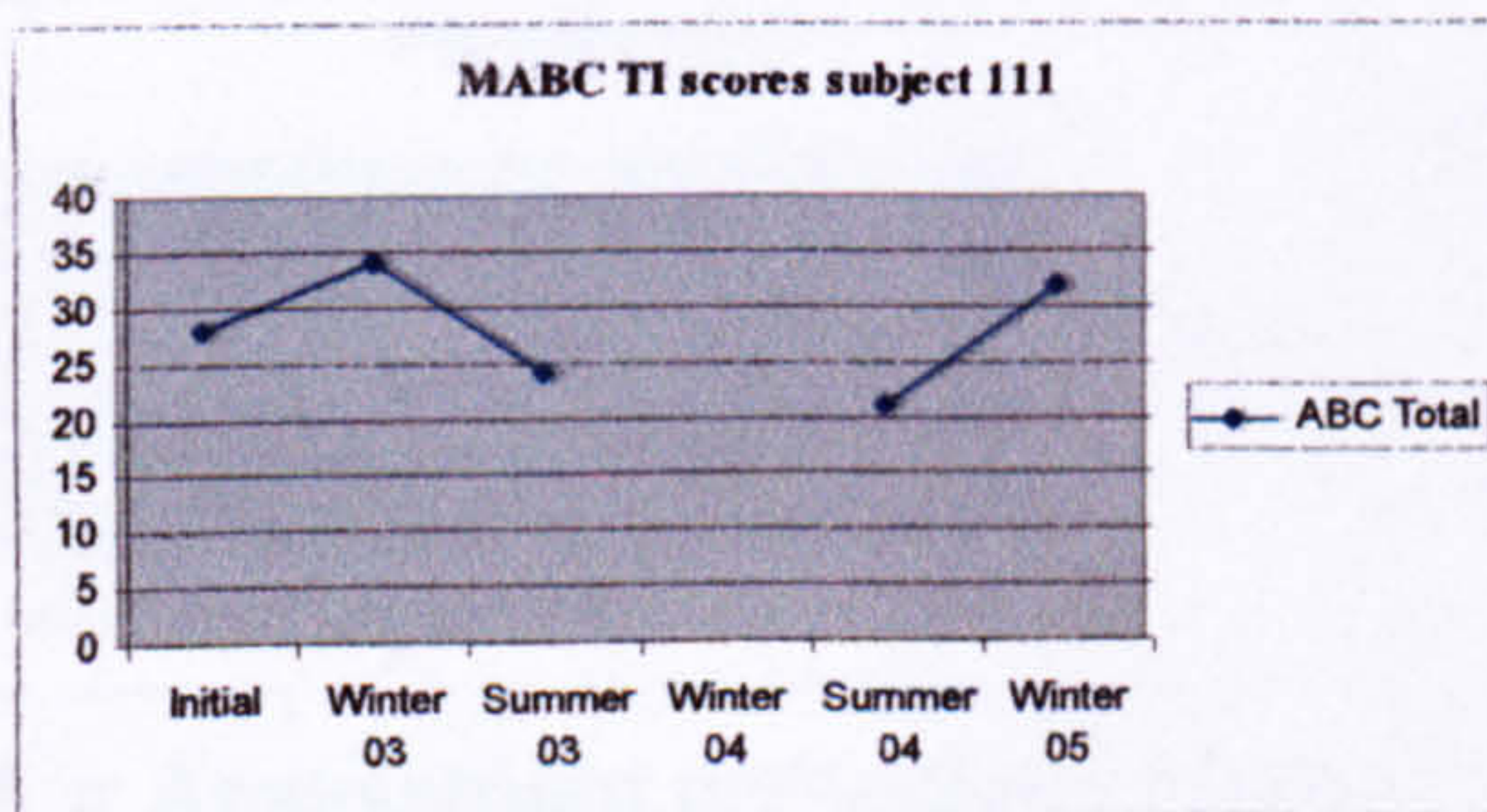
Cluster 3



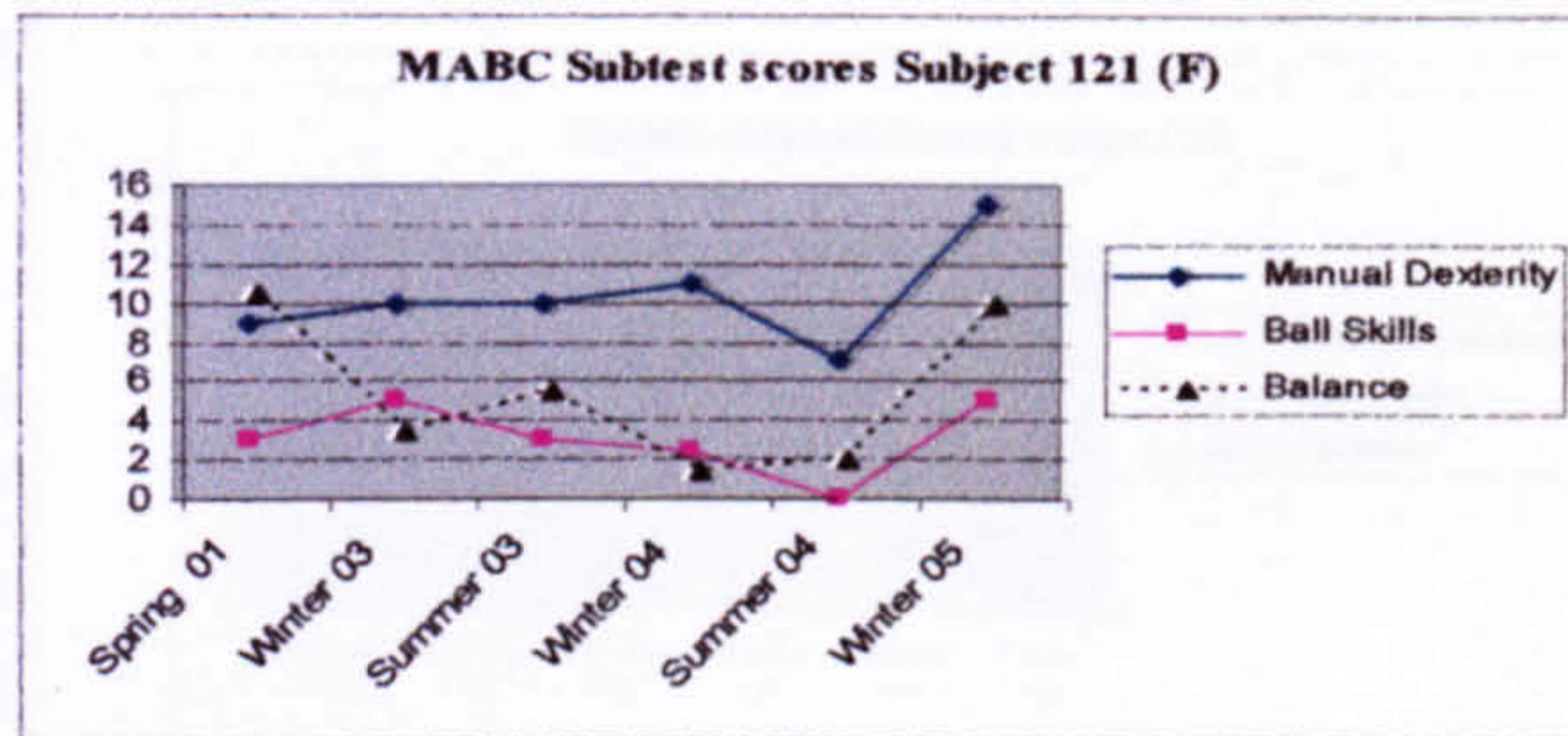
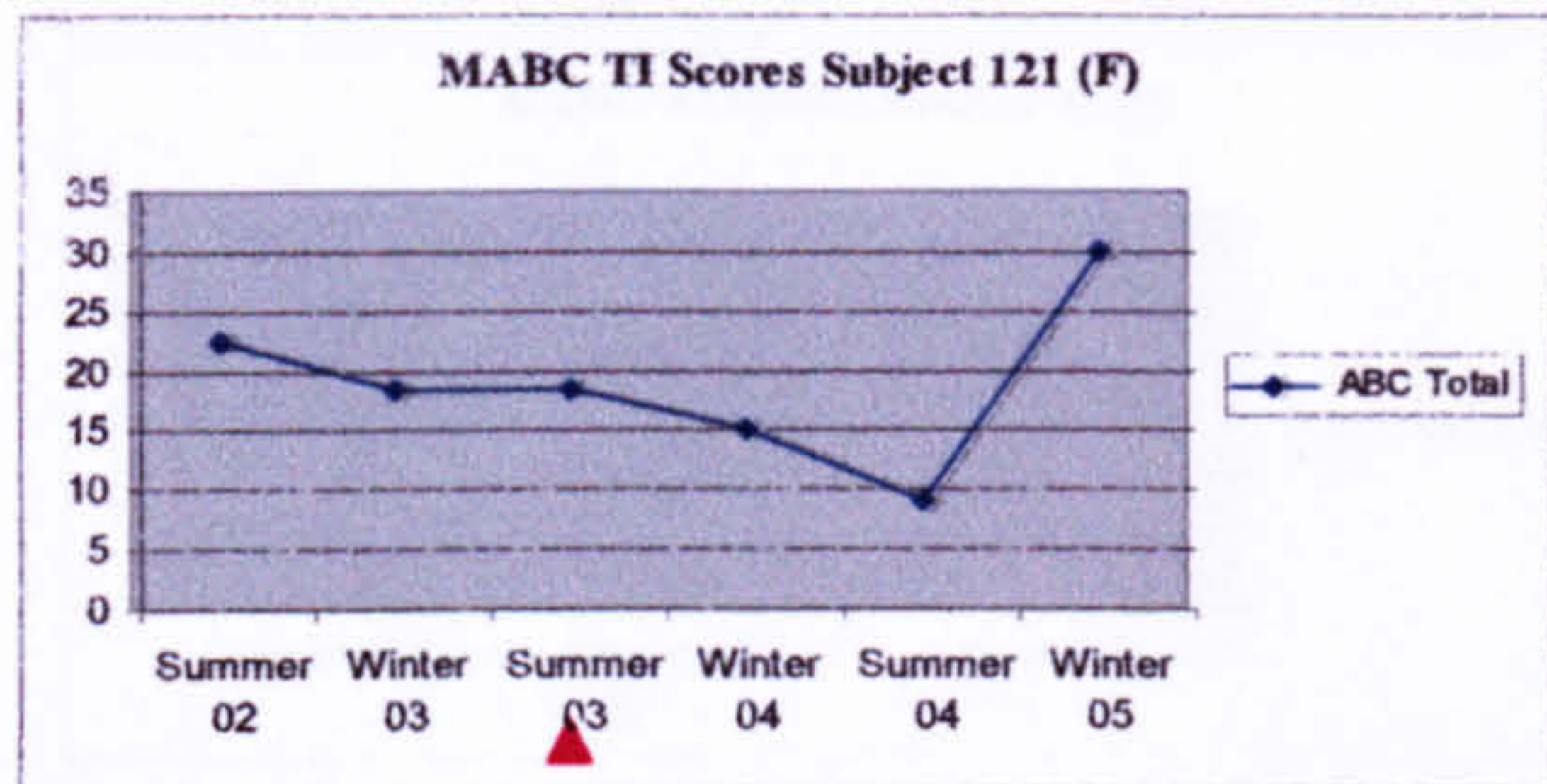
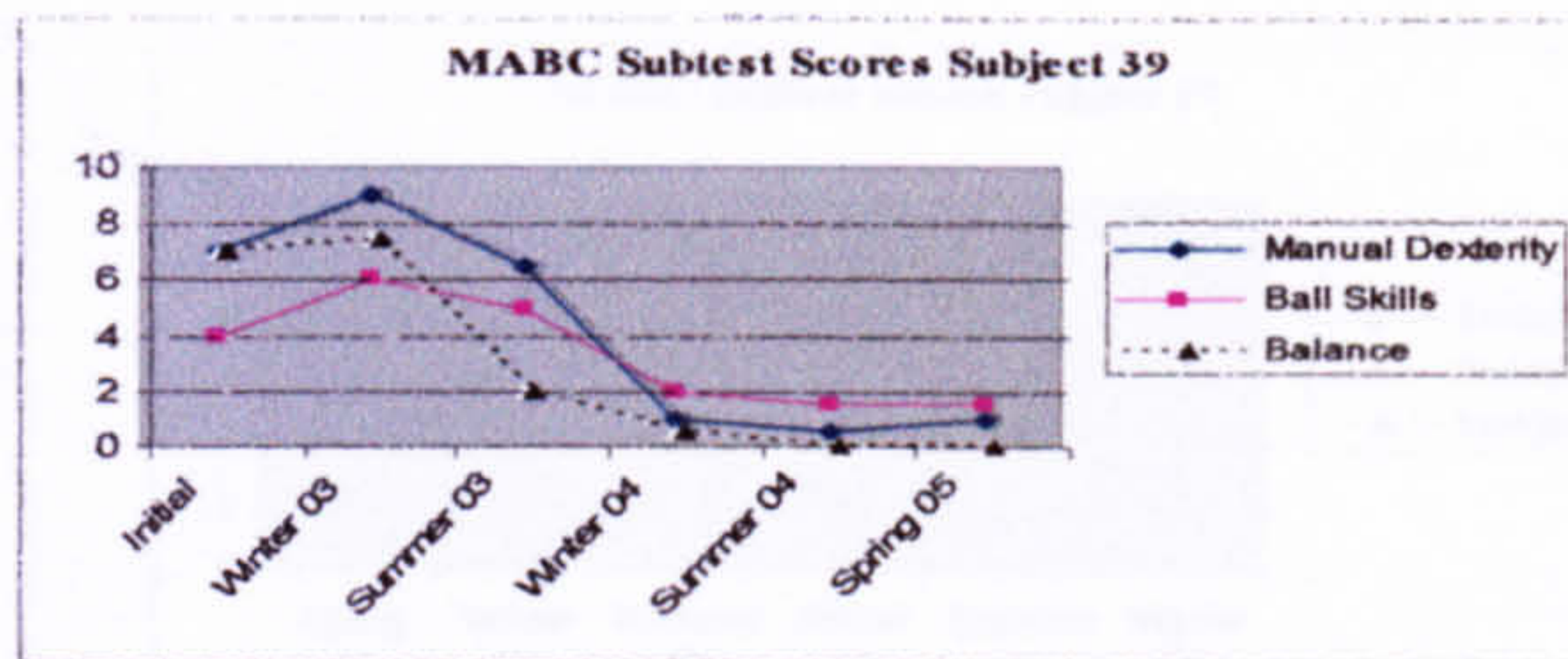
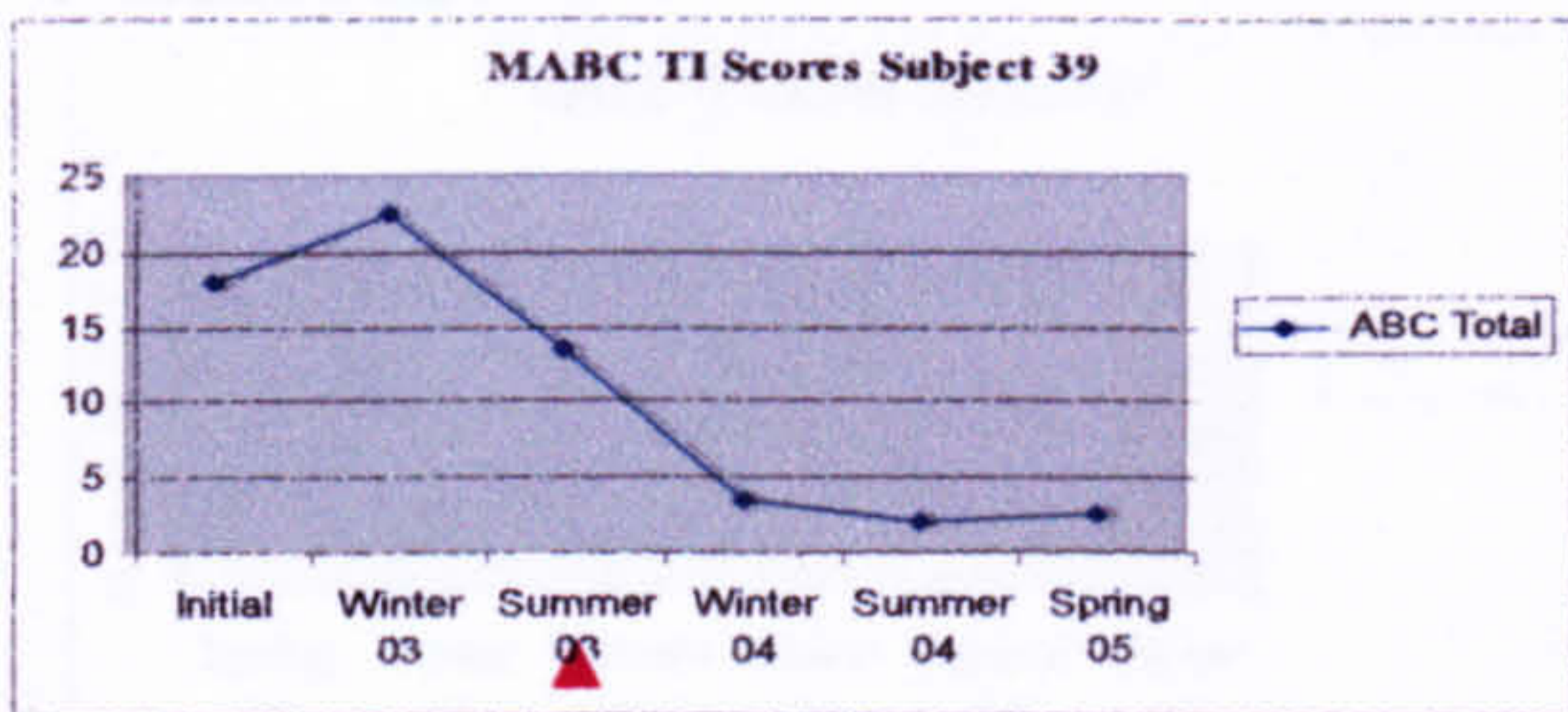
Cluster 4



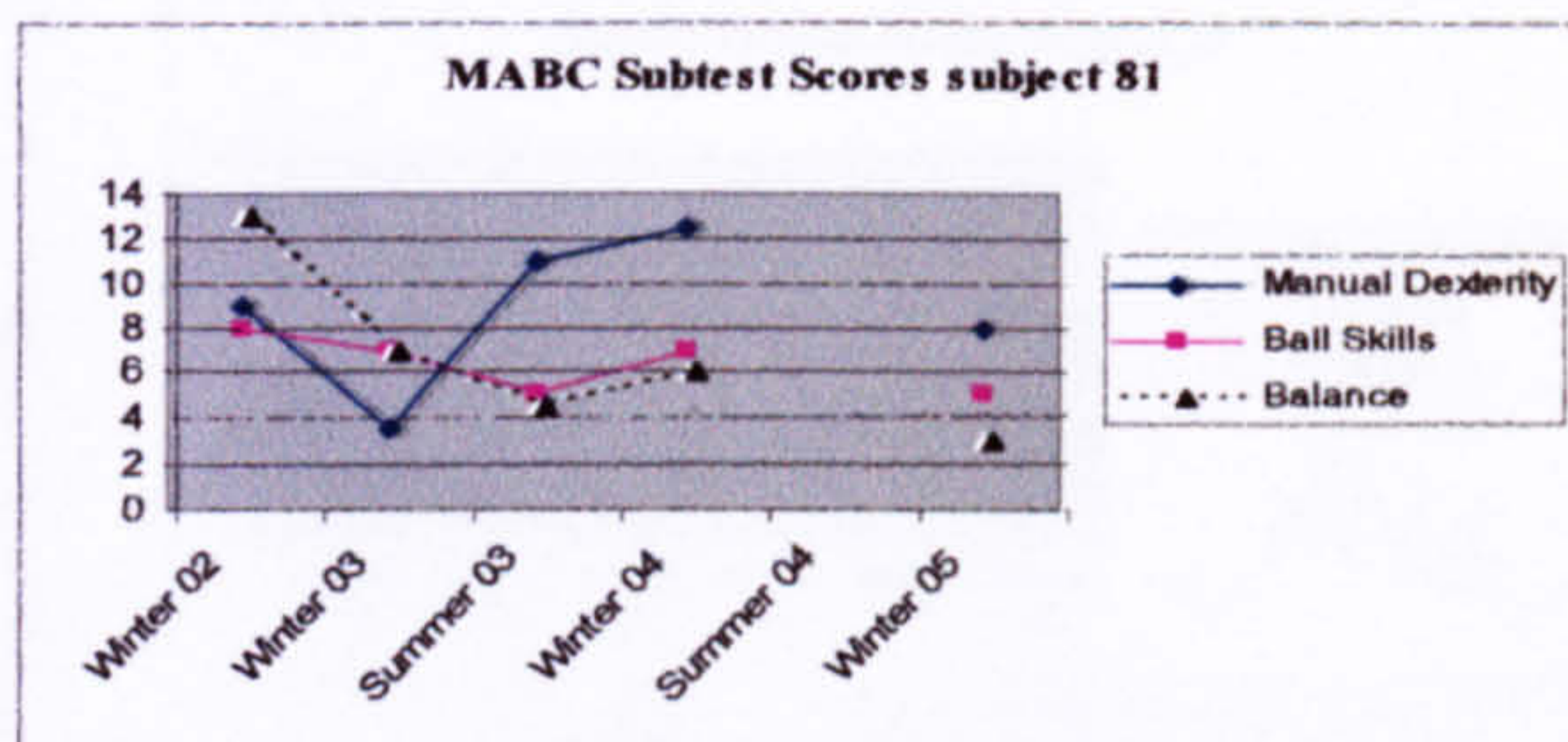
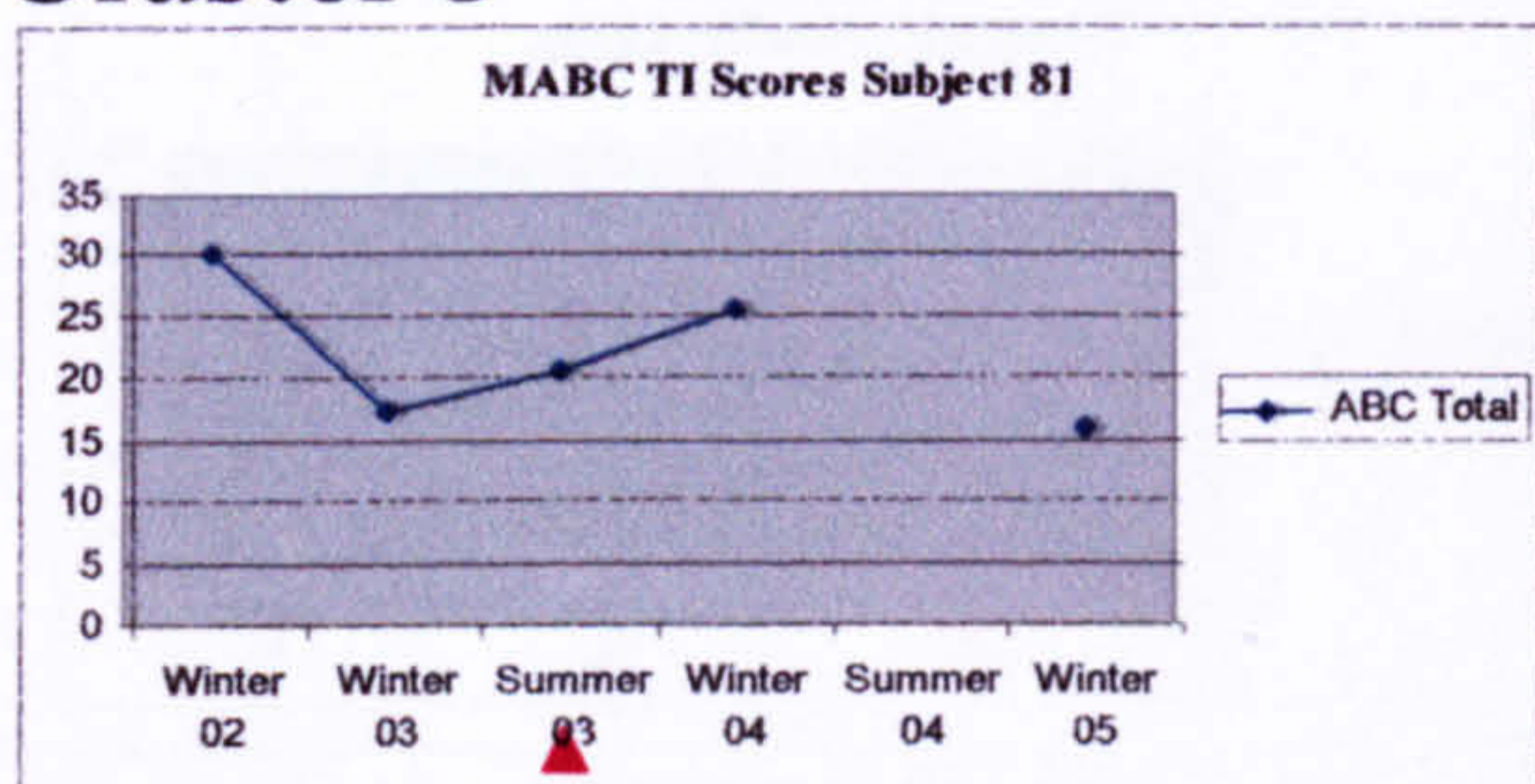
Cluster 5



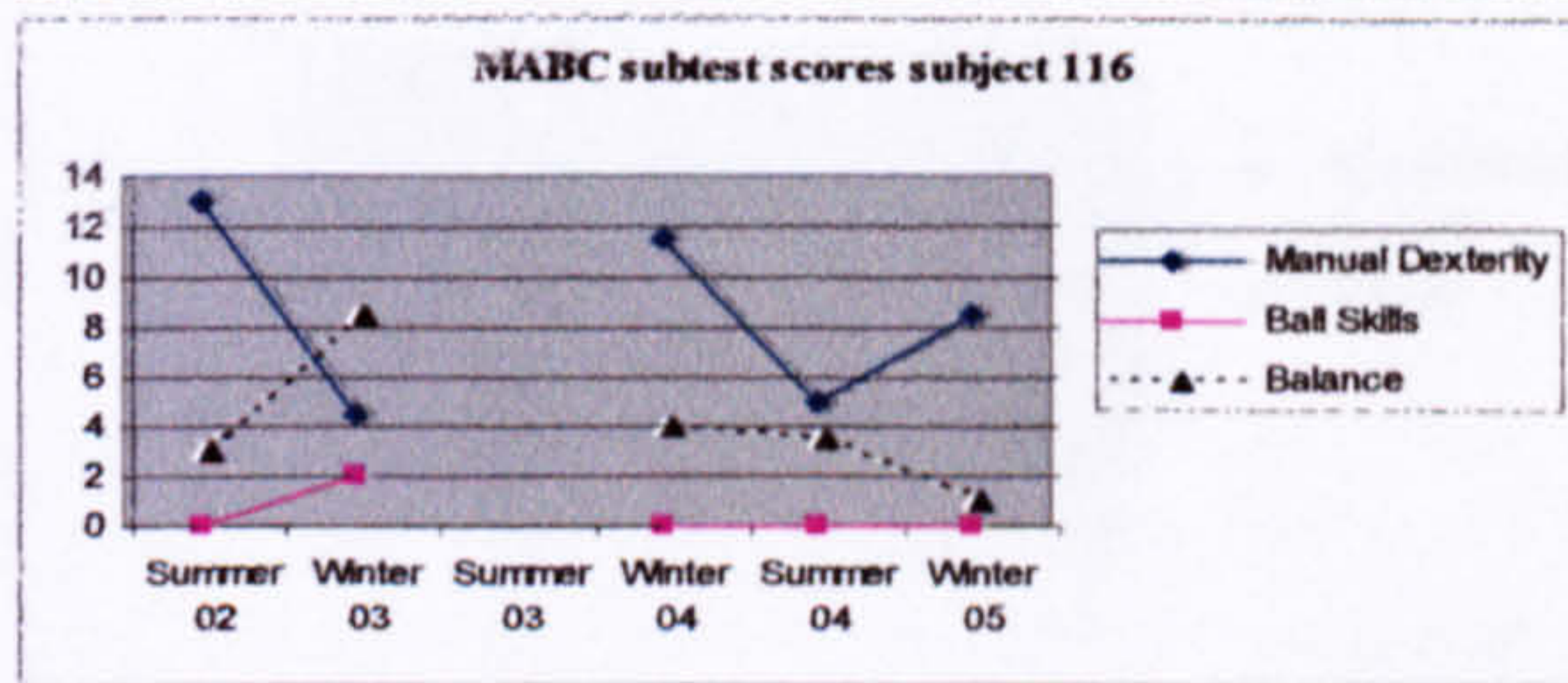
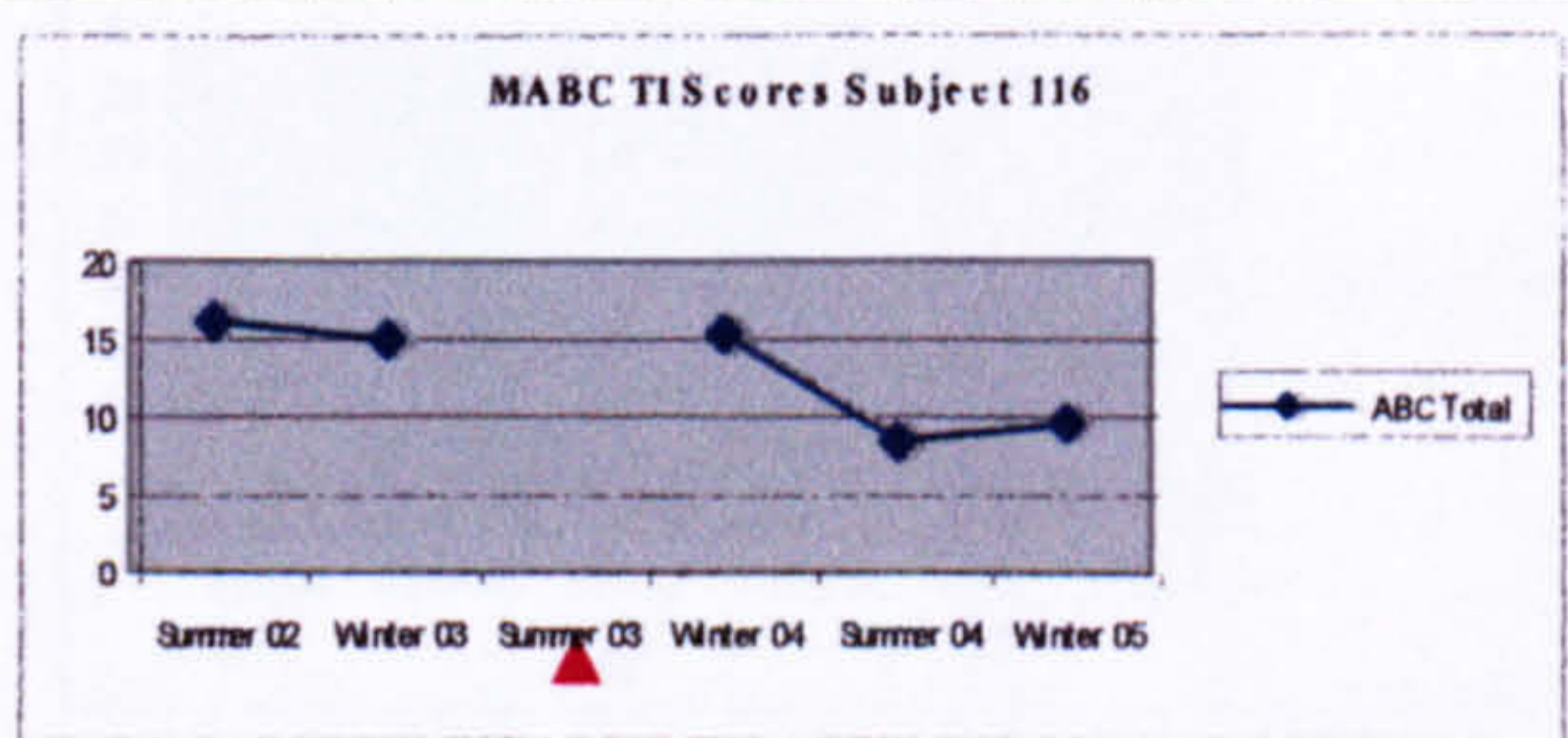
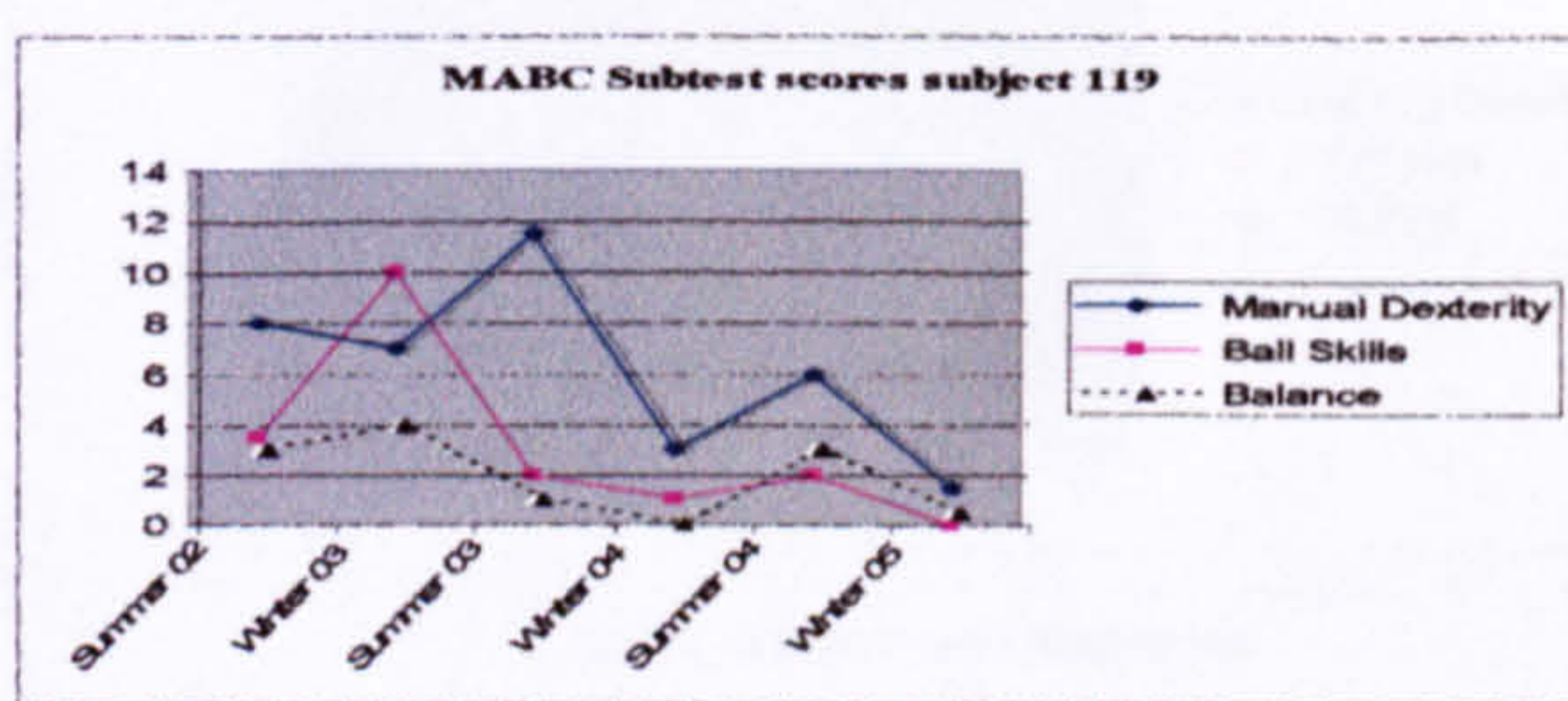
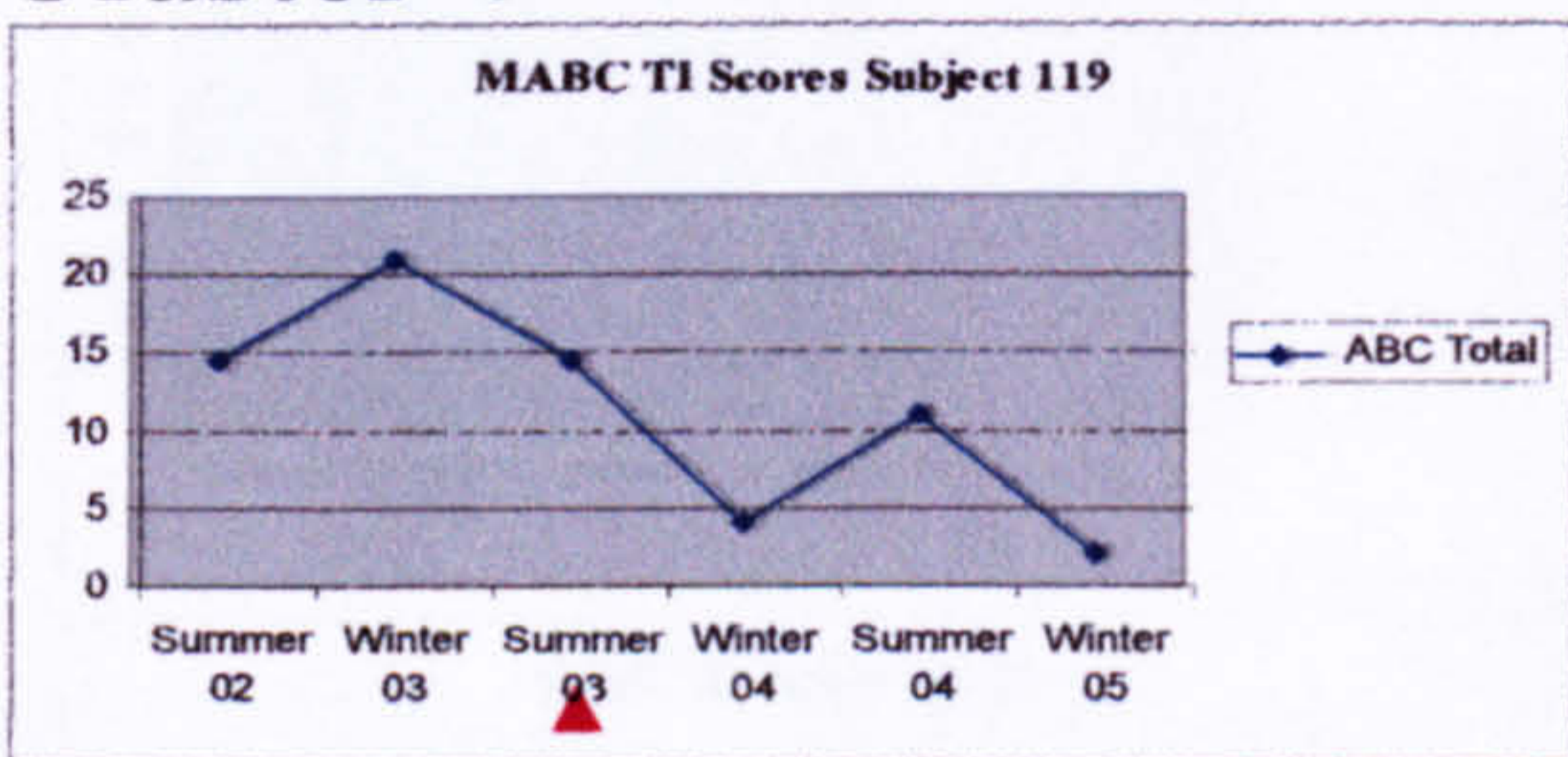
Cluster 1



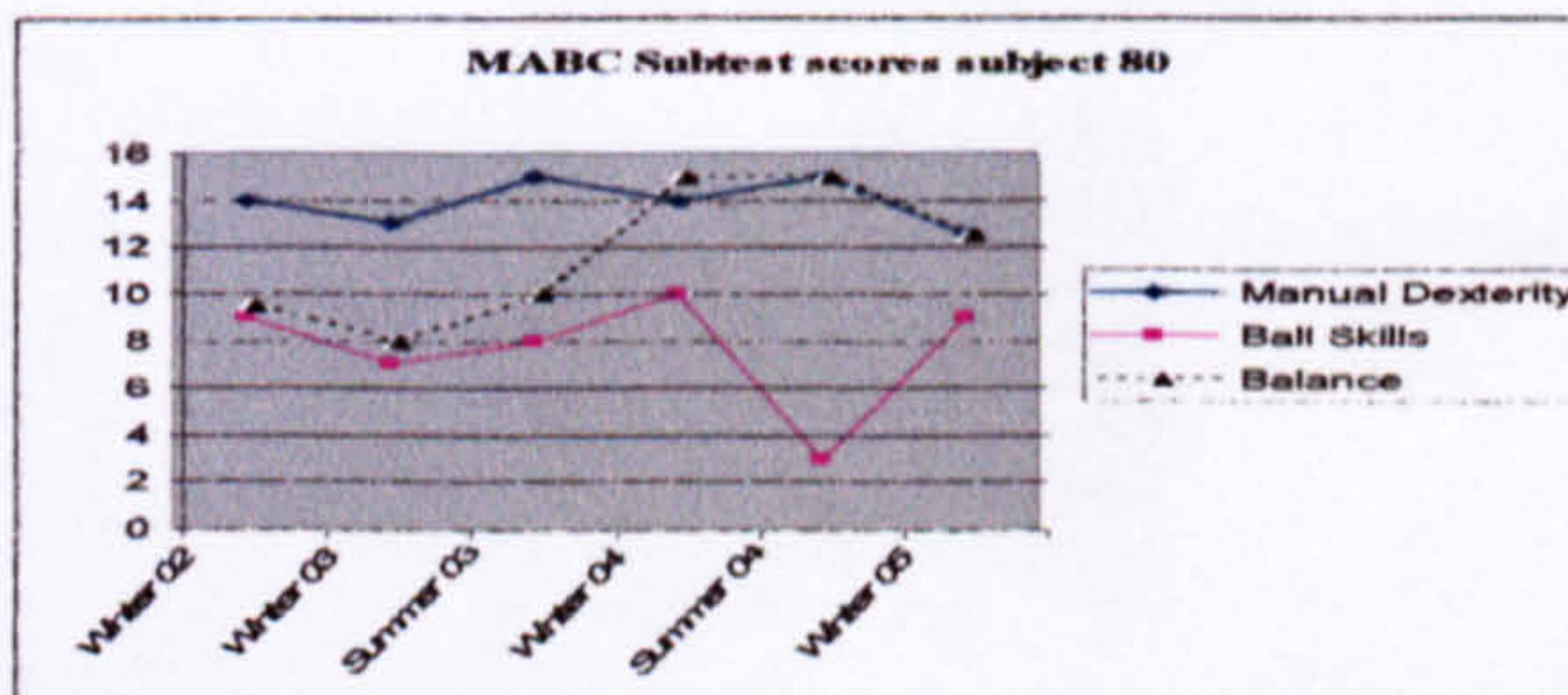
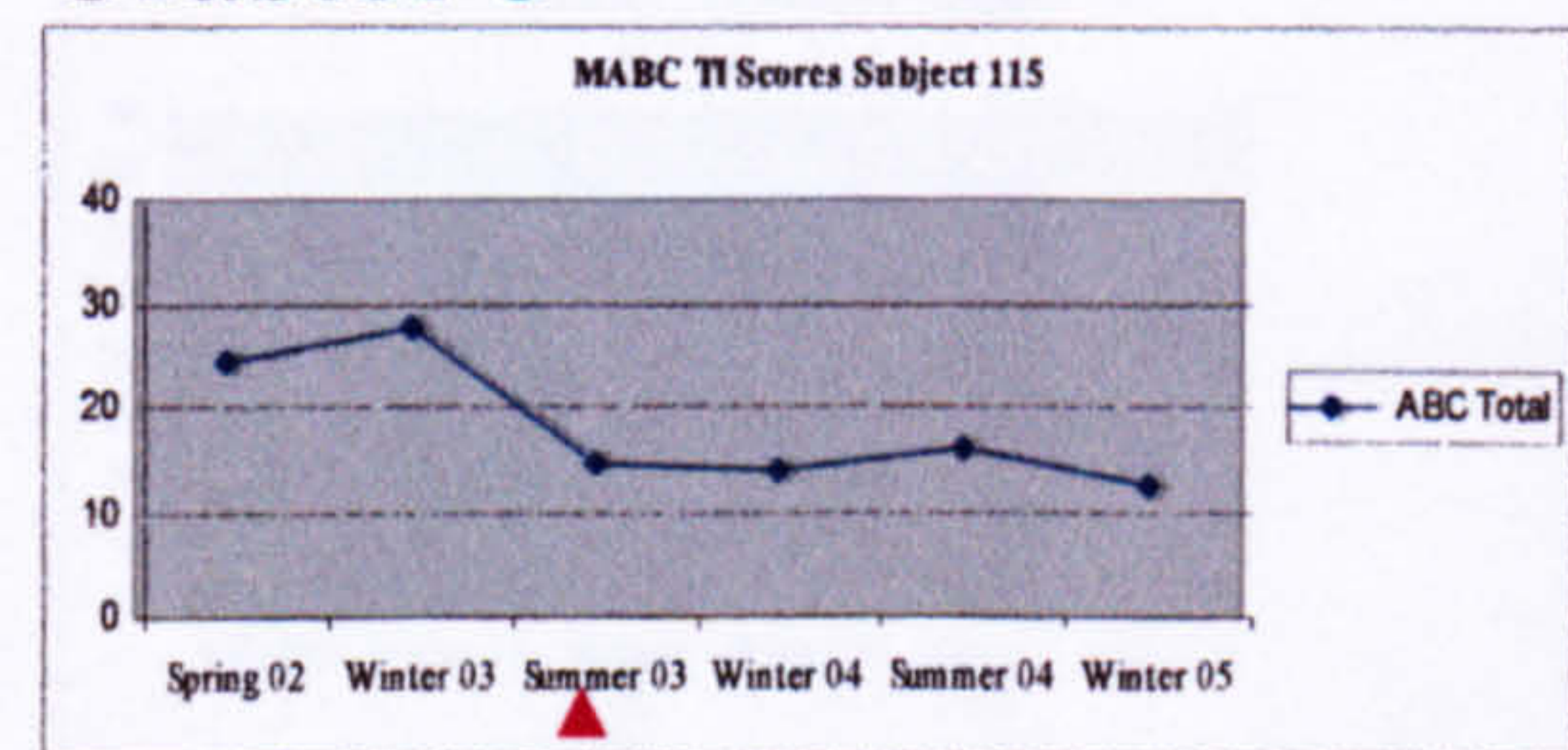
Cluster 3



Cluster 4



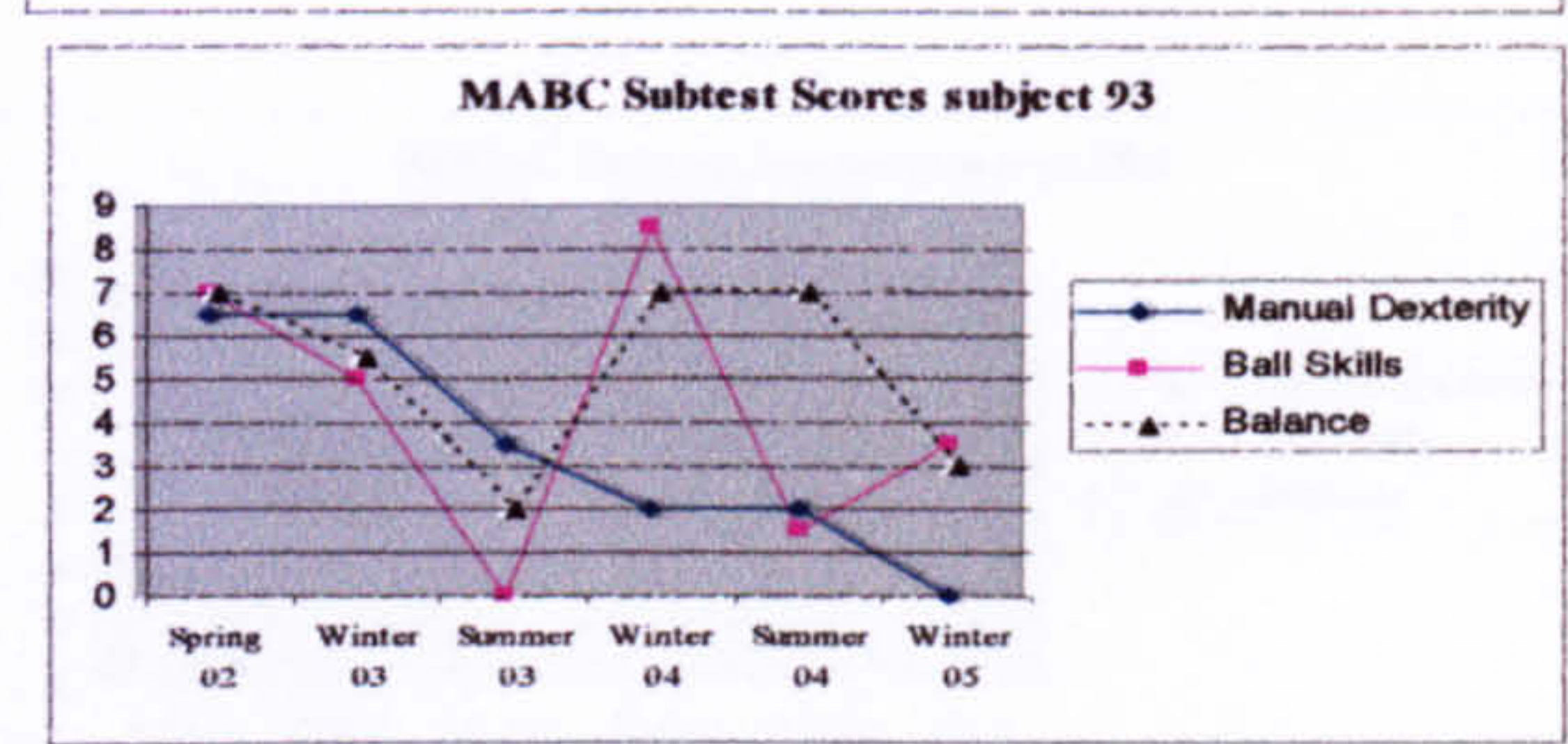
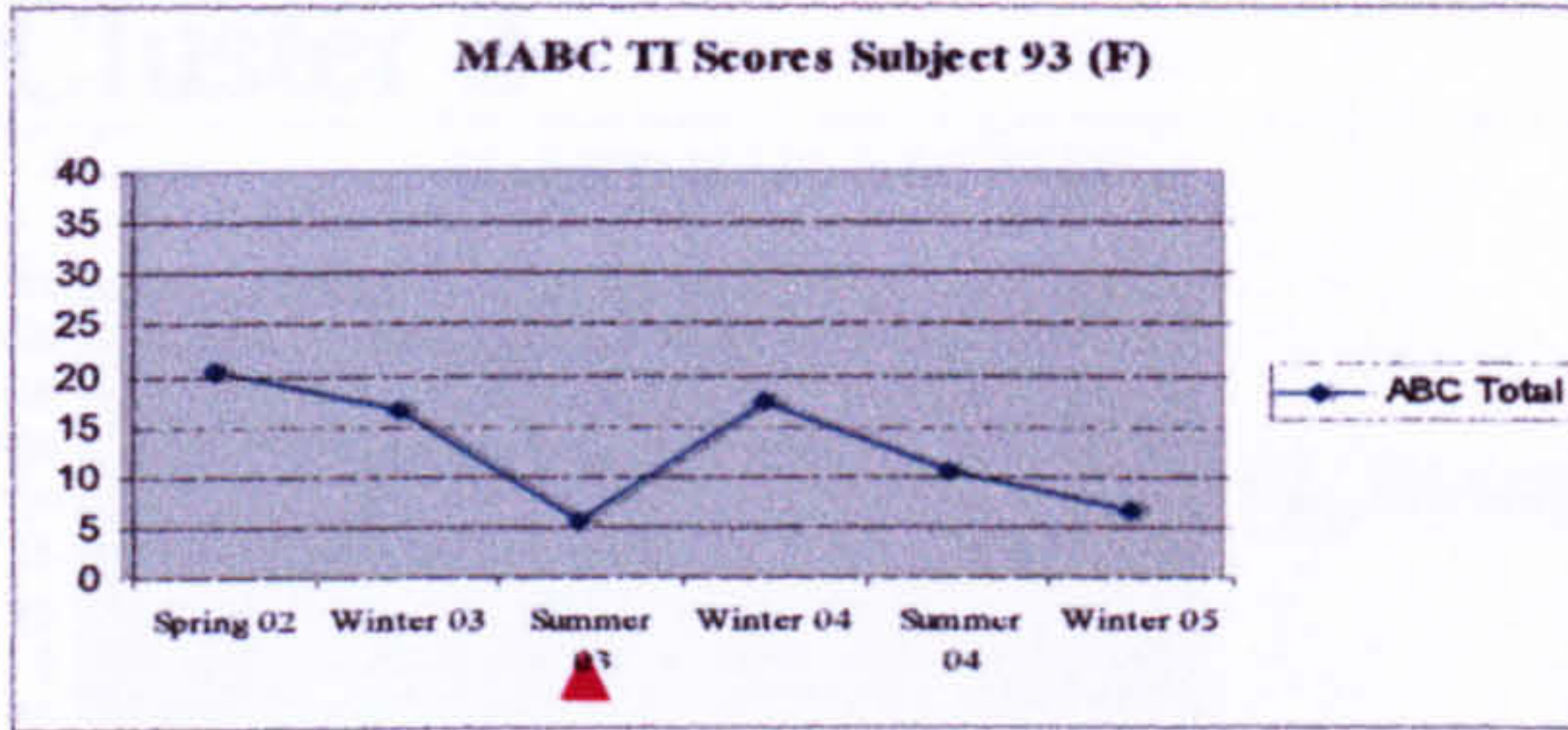
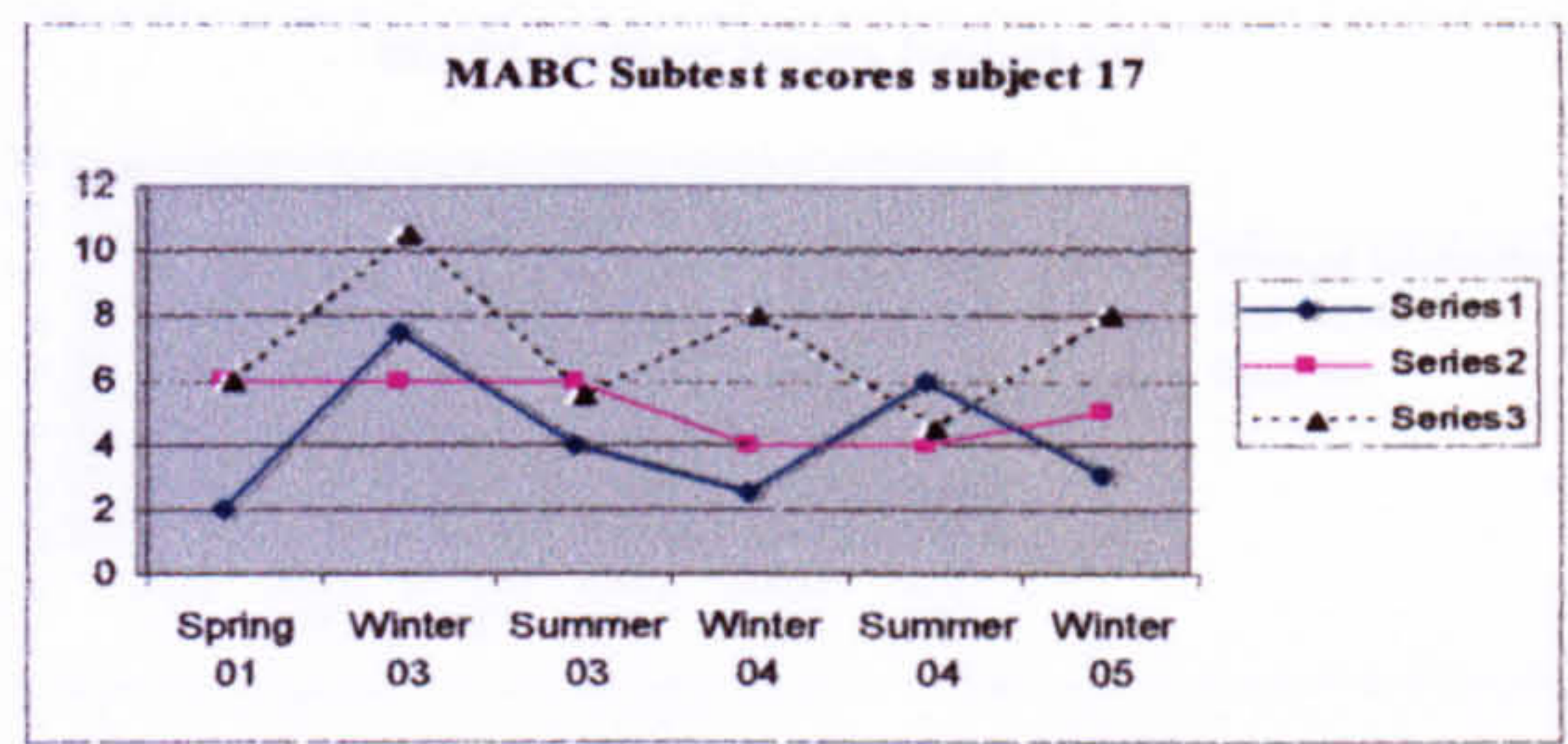
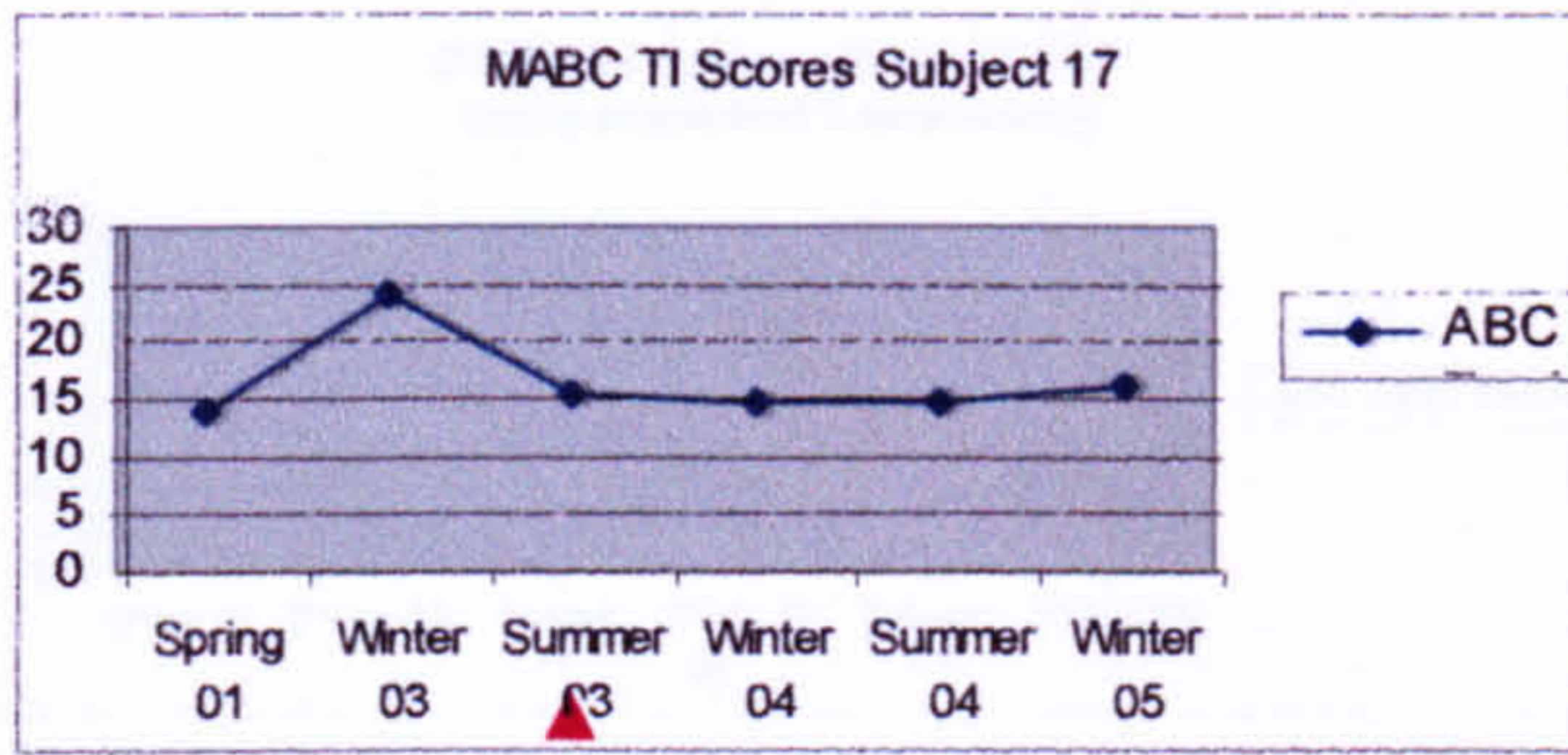
Cluster 5



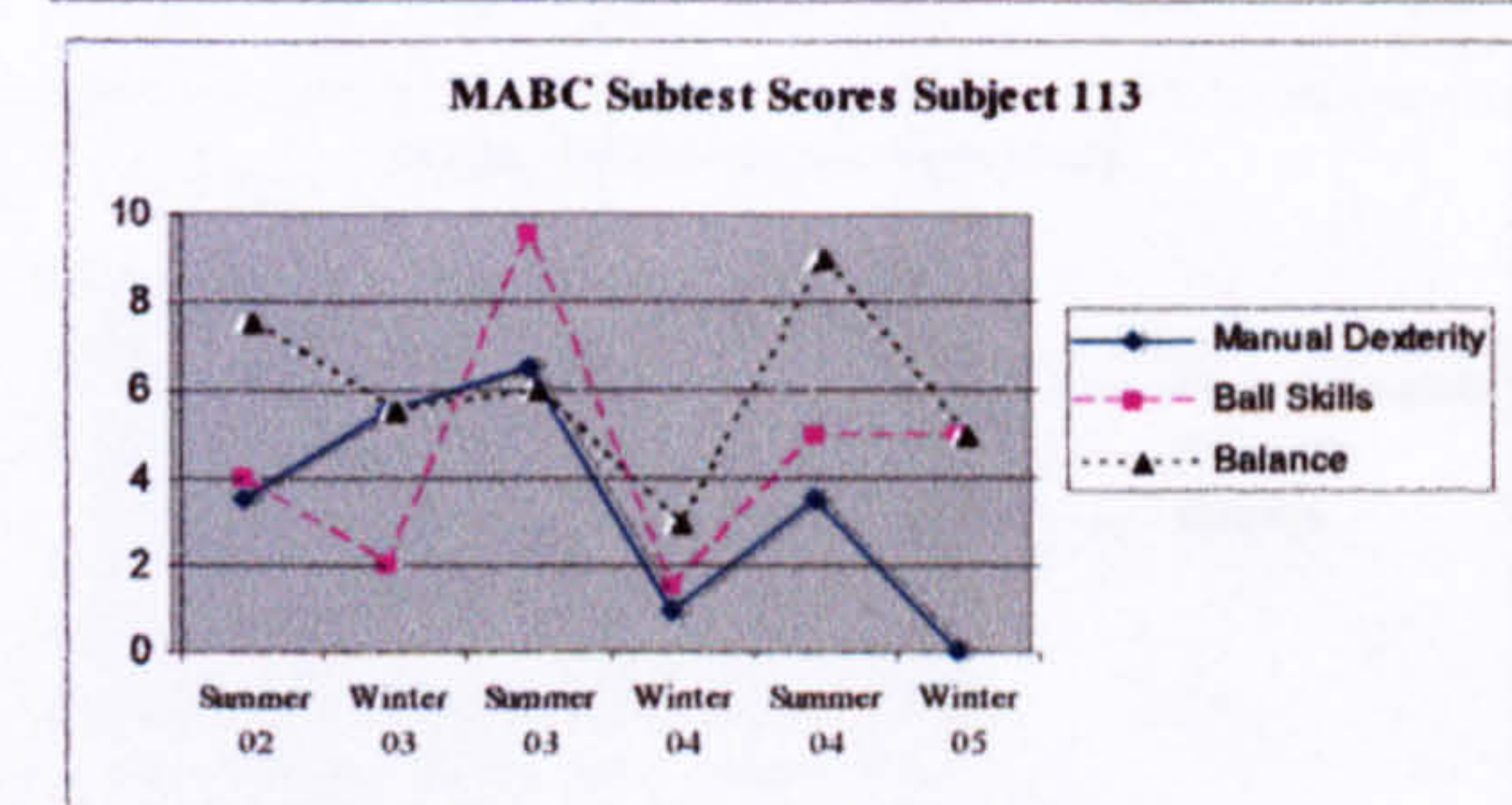
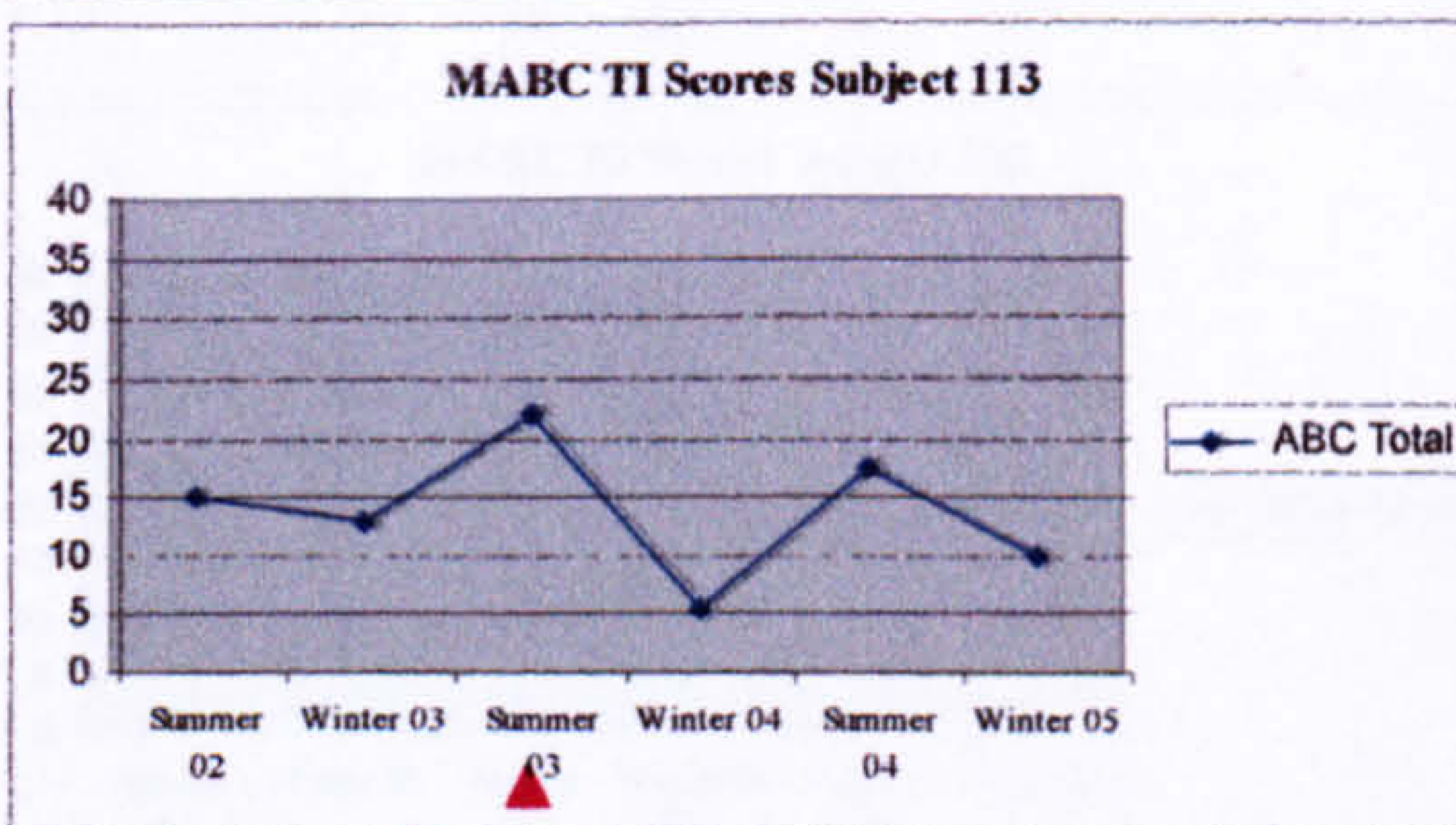
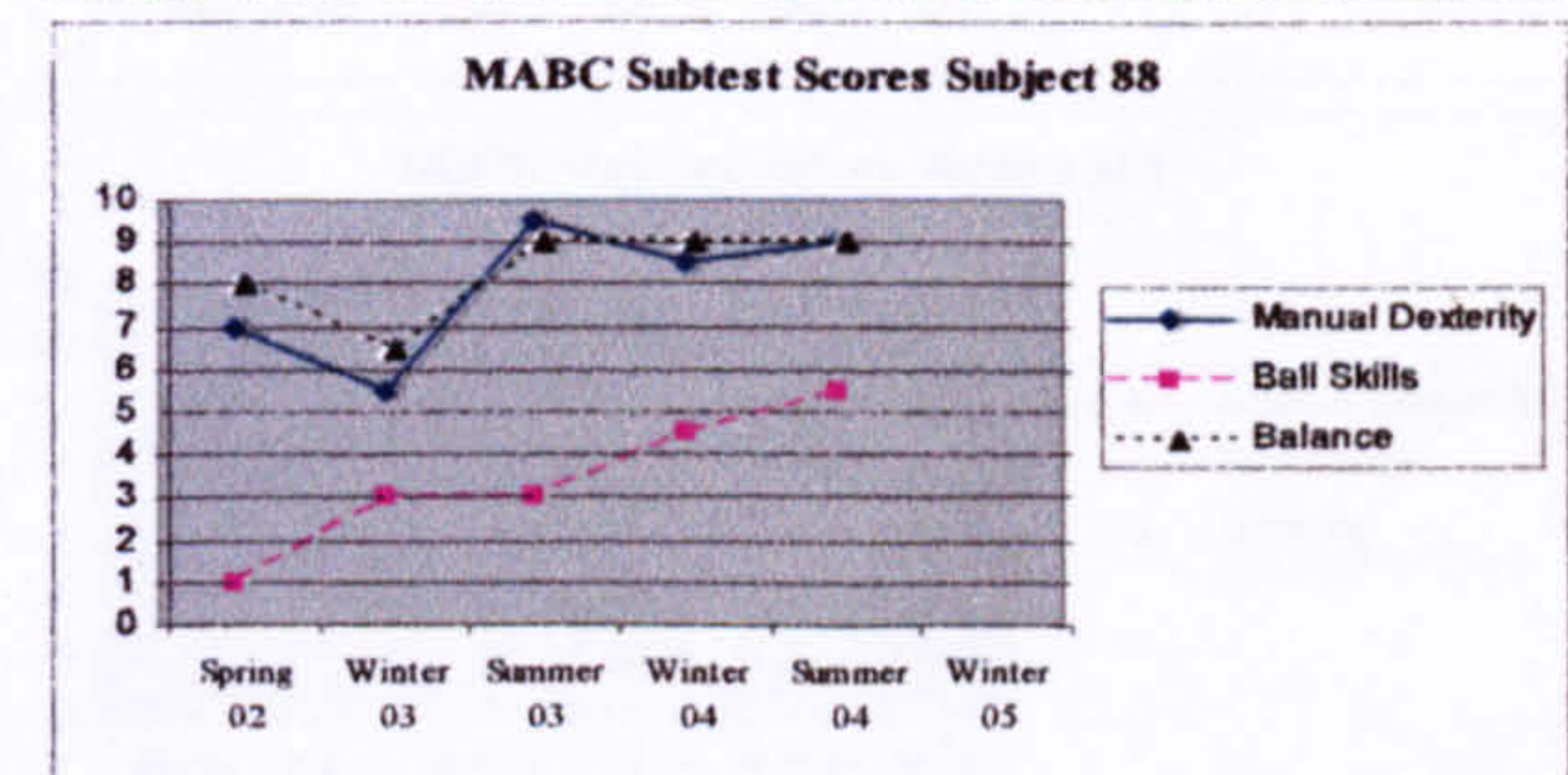
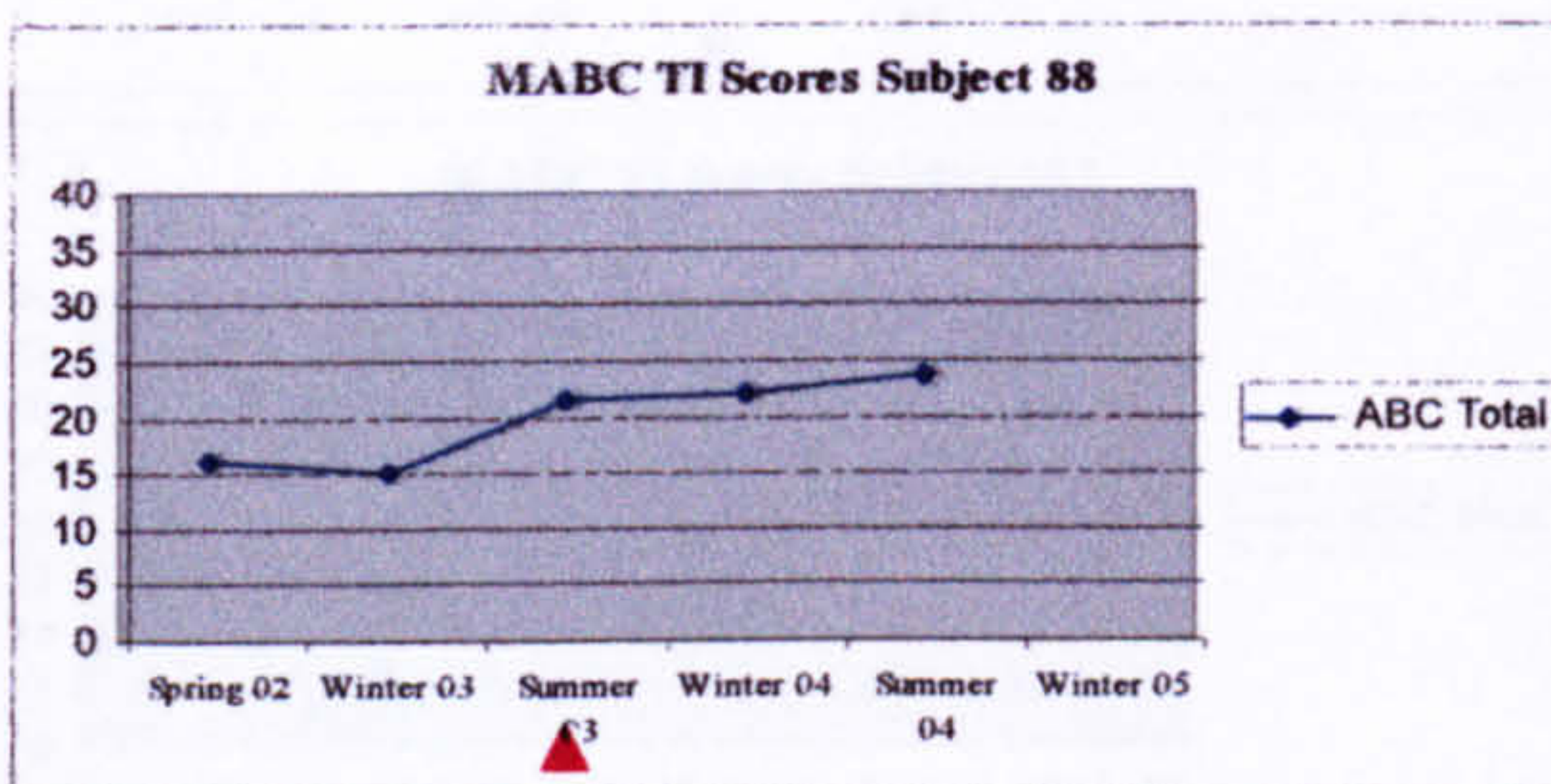
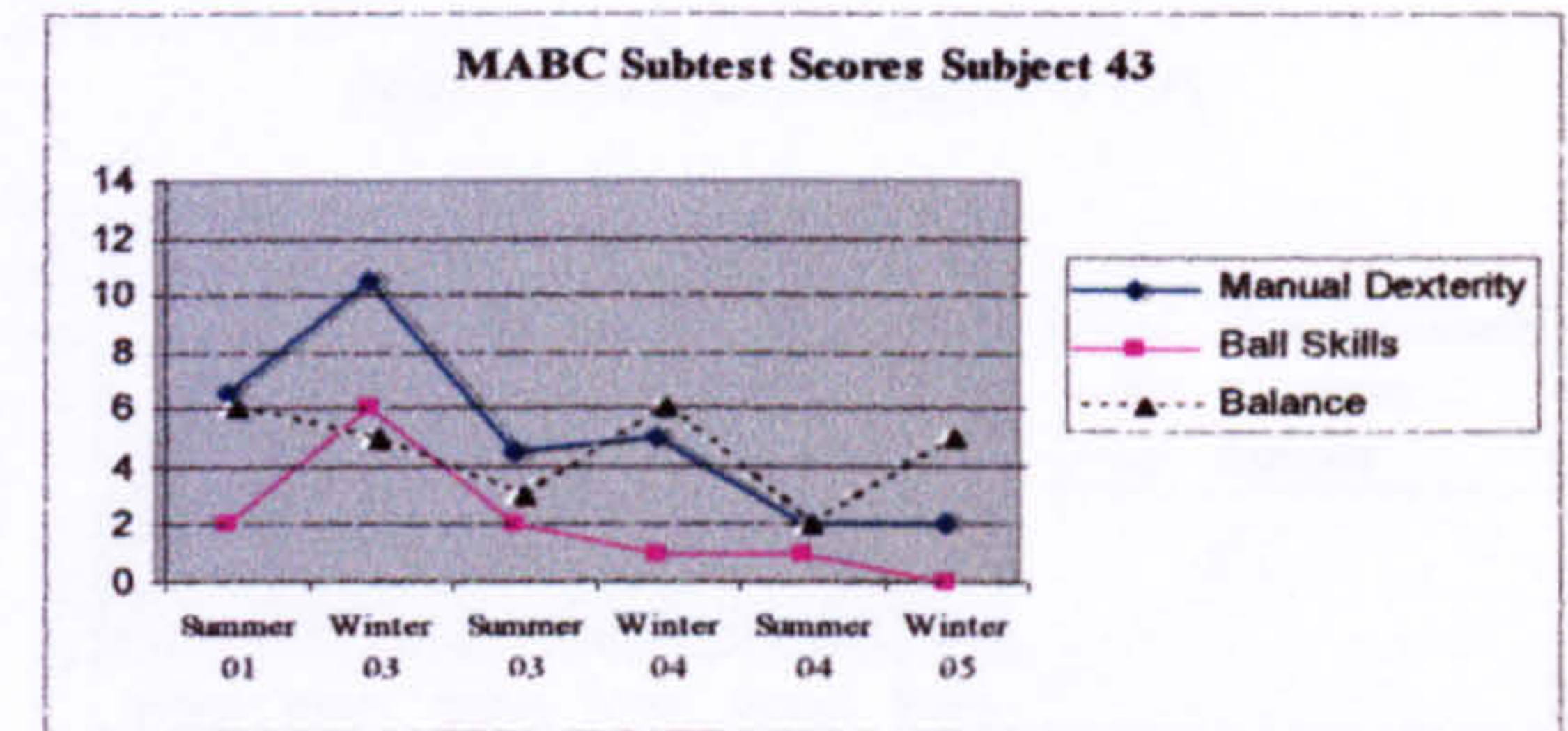
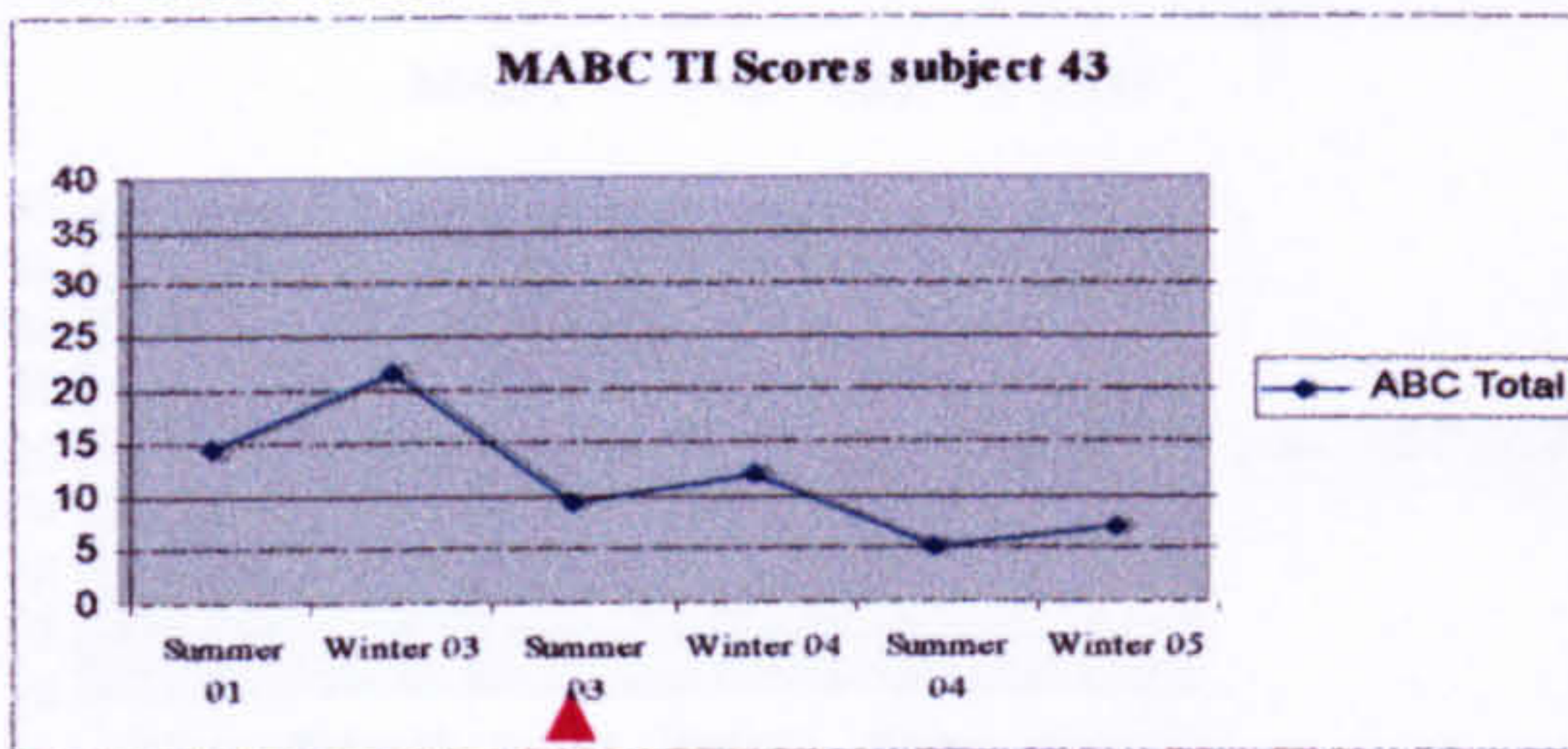
▲ = Assessment immediately following treatment

Children treated Feb to Aug 2003 – 9-11 year olds

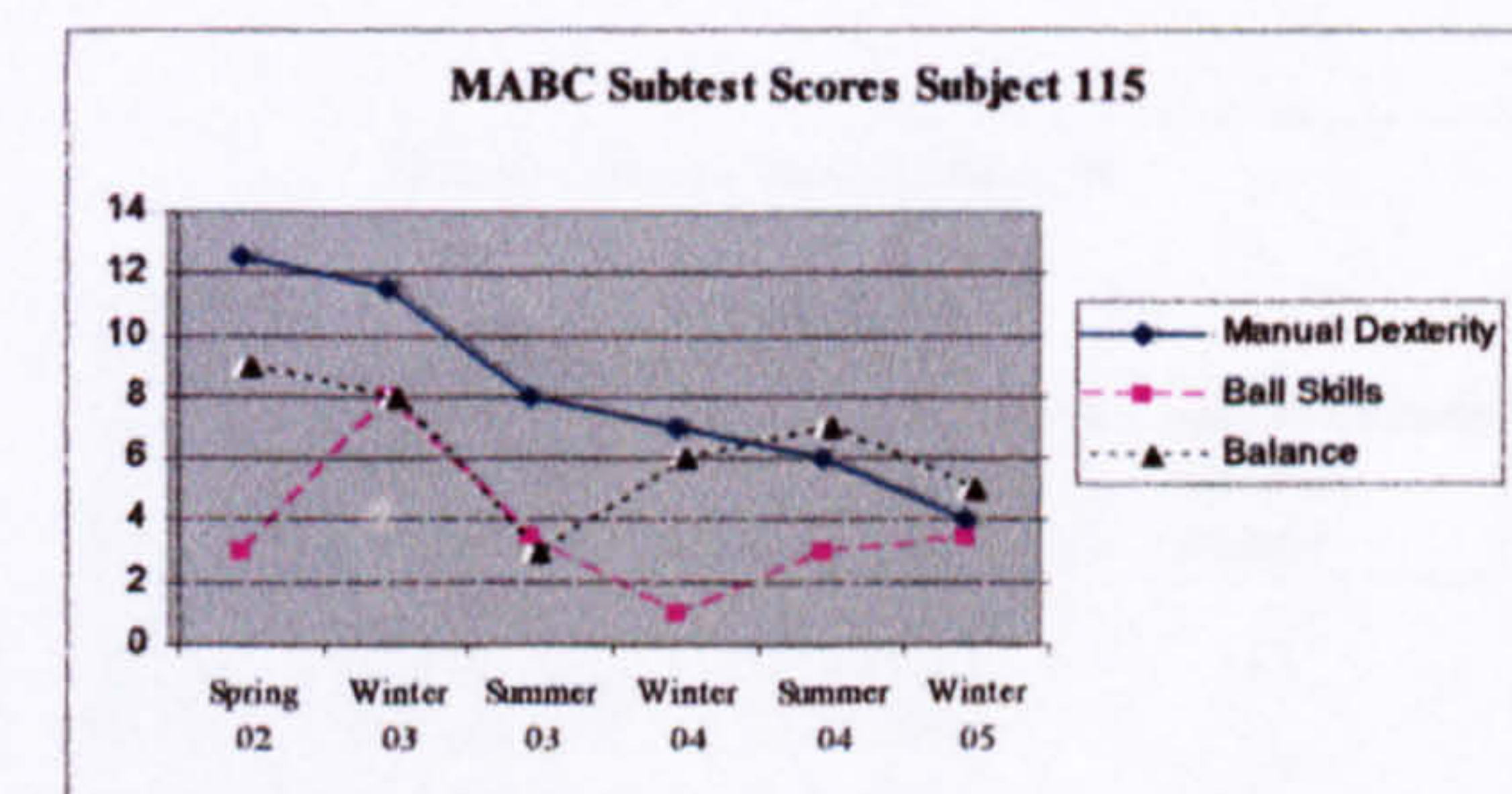
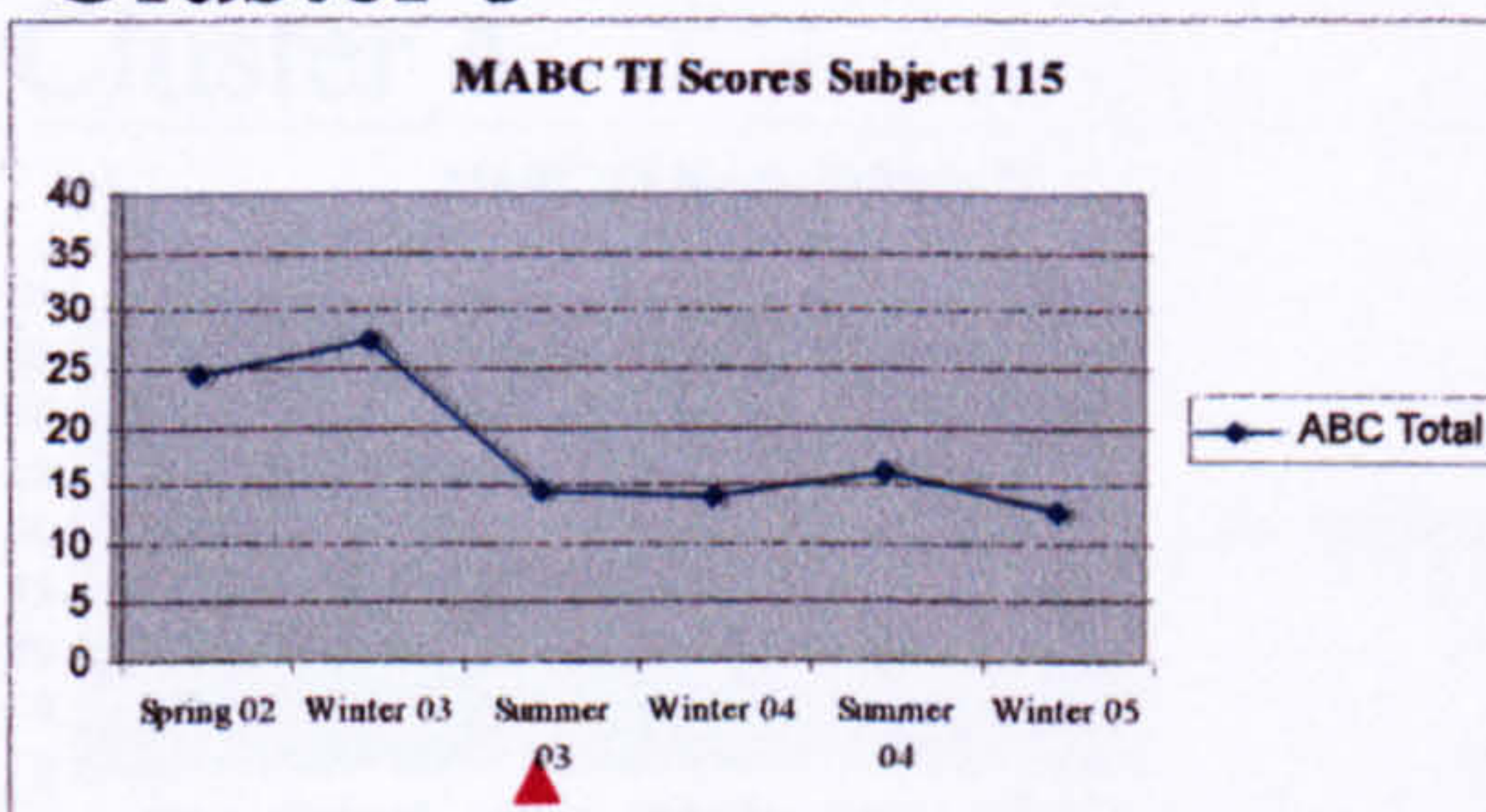
Cluster 1



Cluster 2



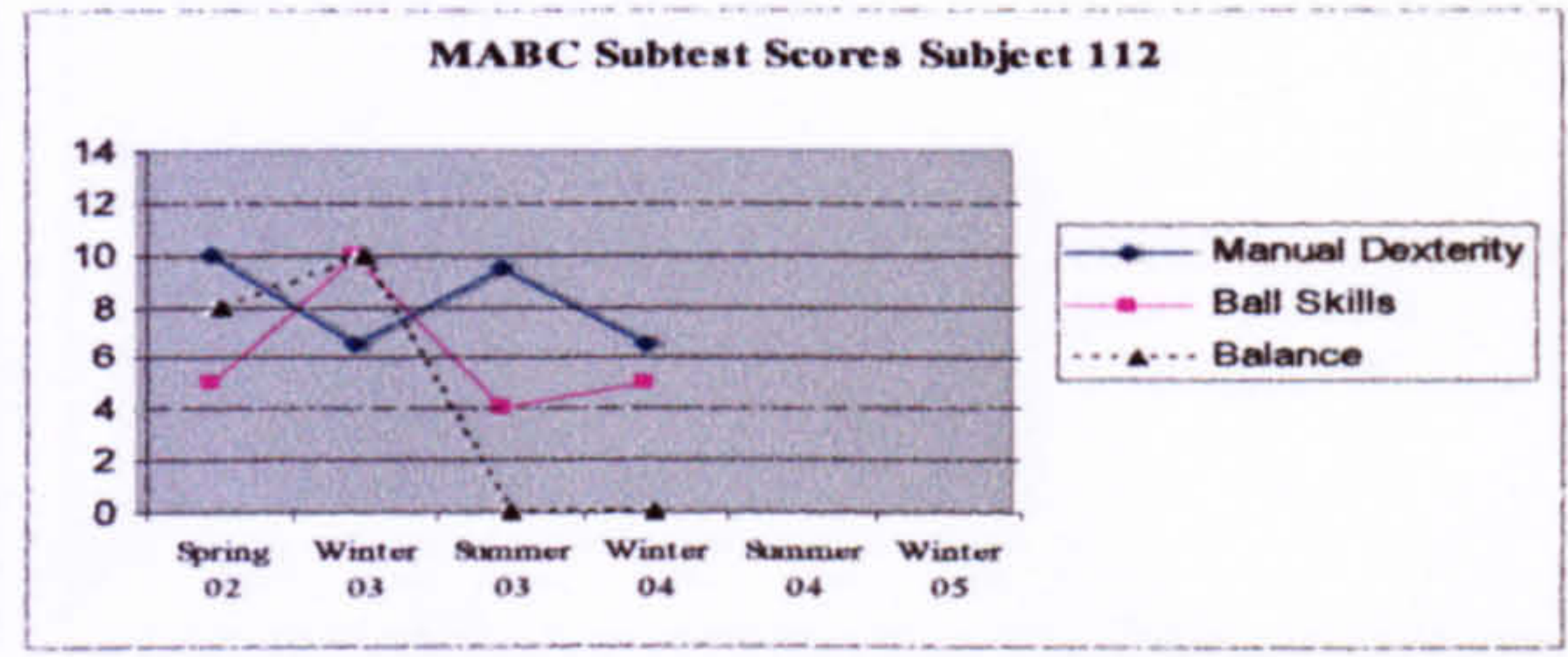
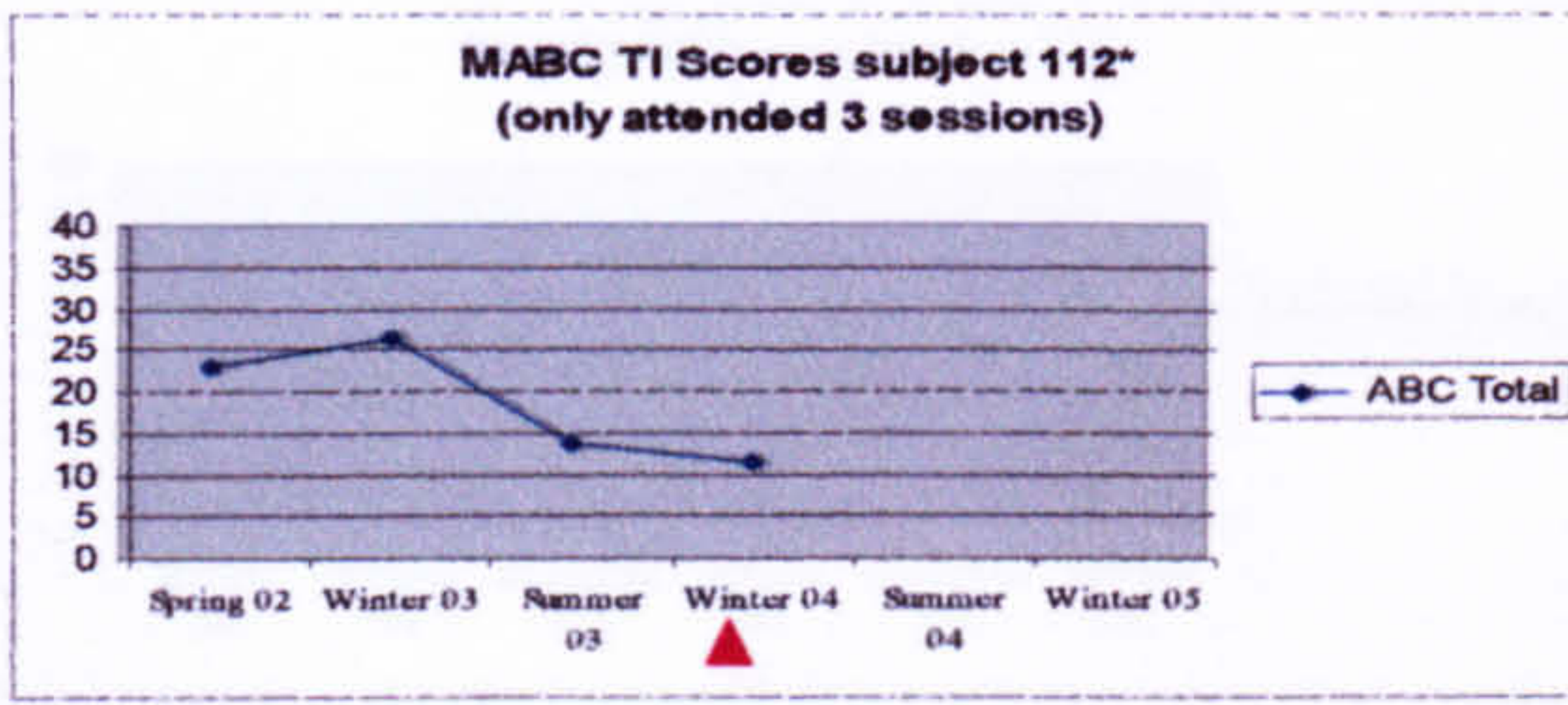
Cluster 5



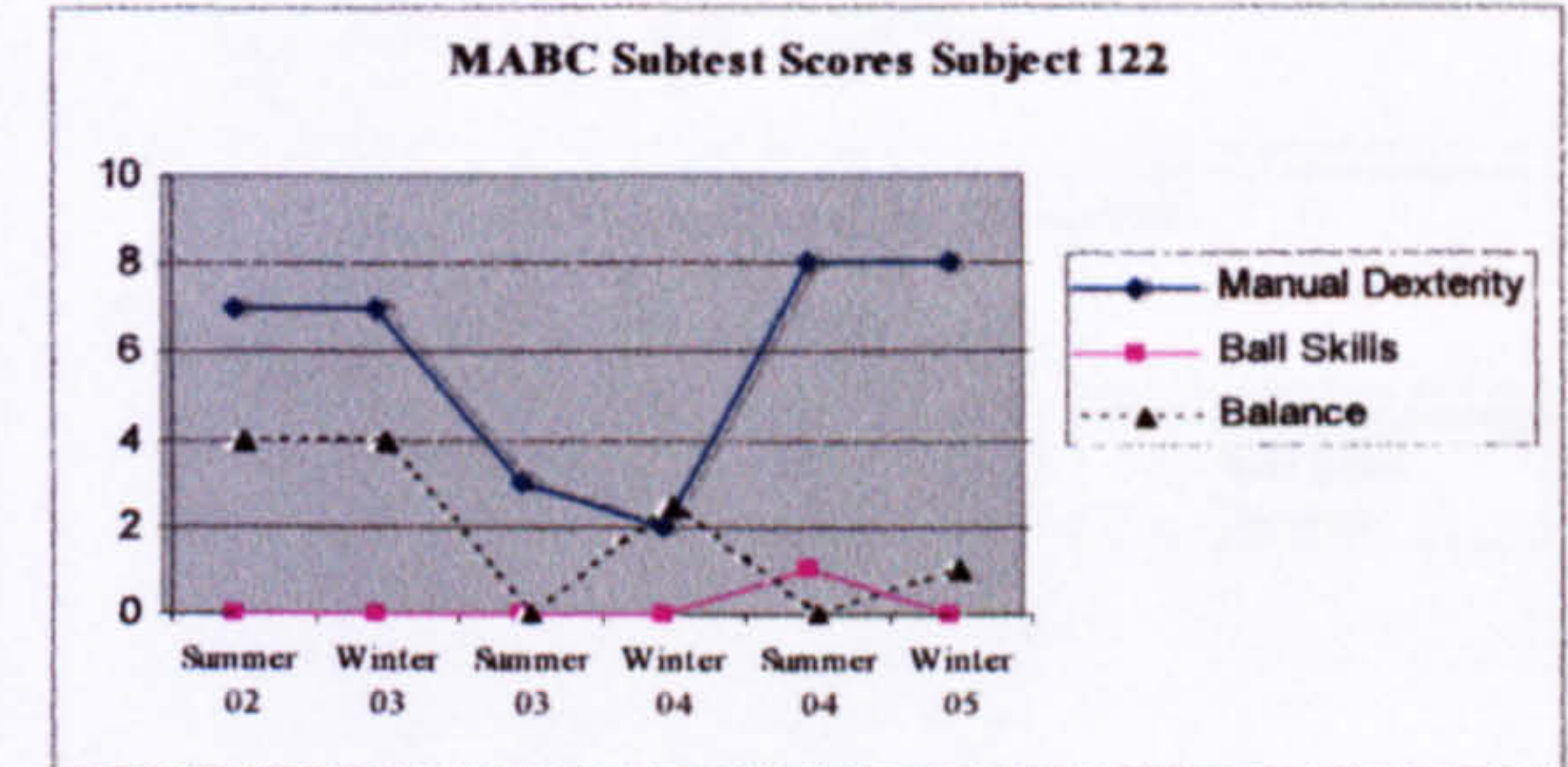
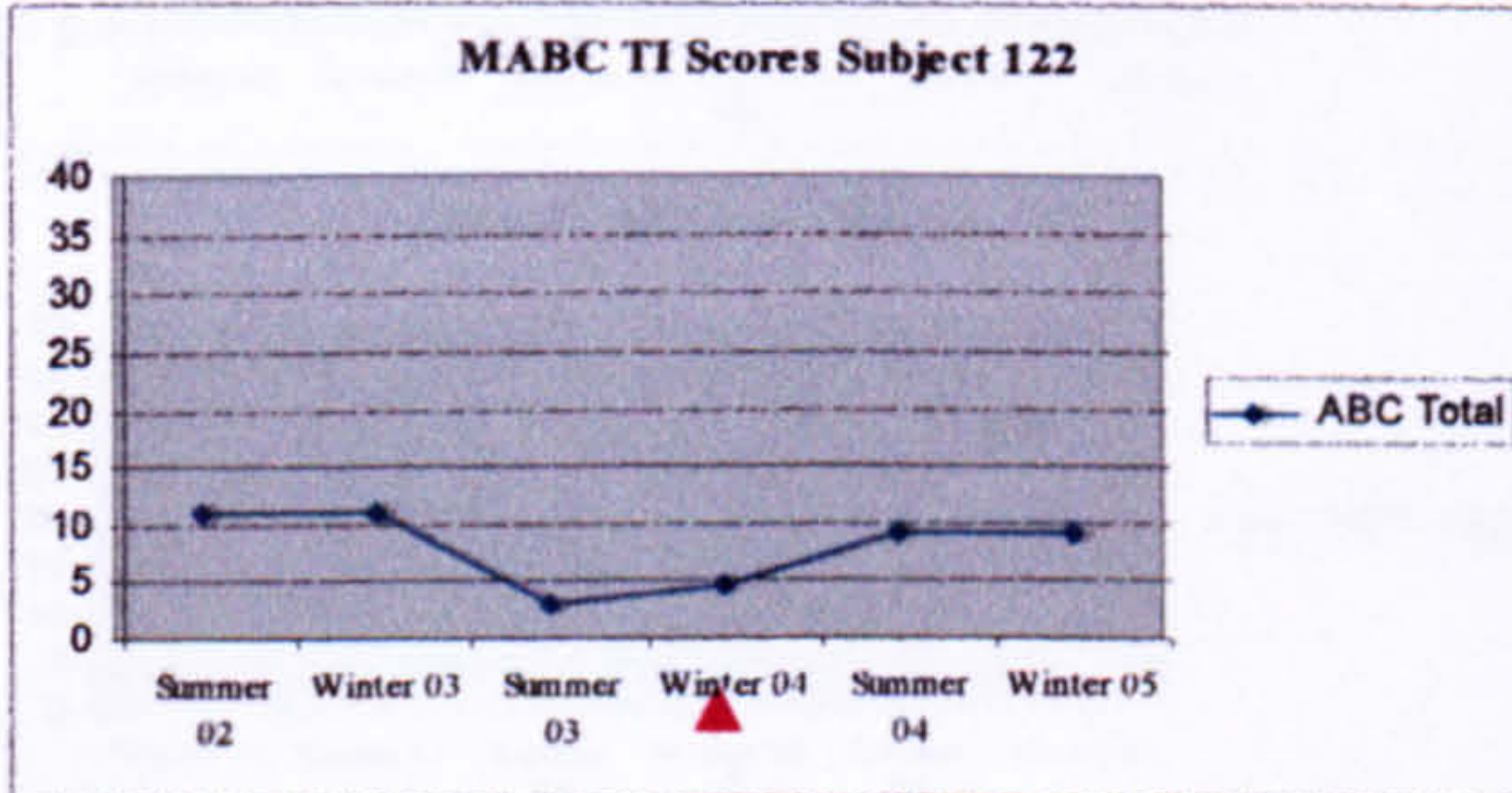
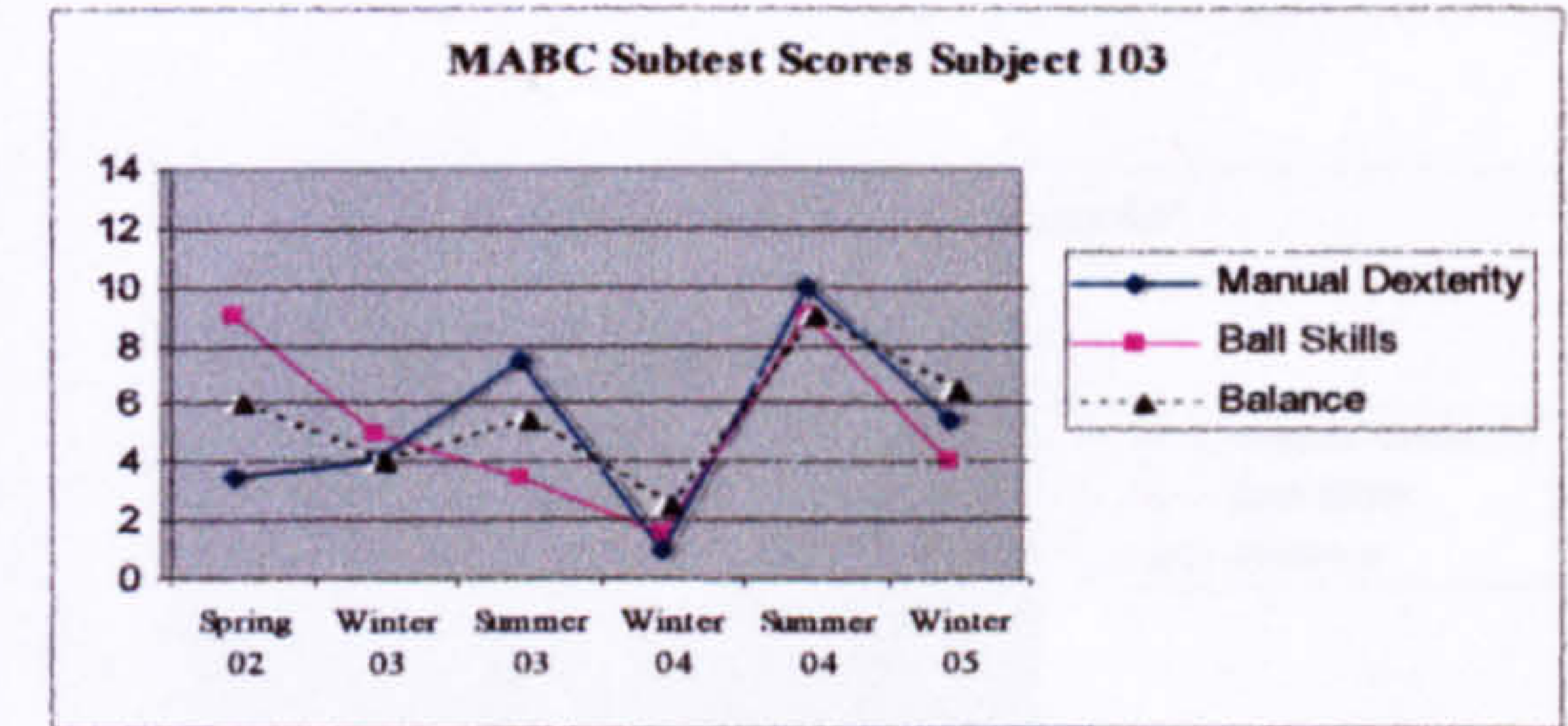
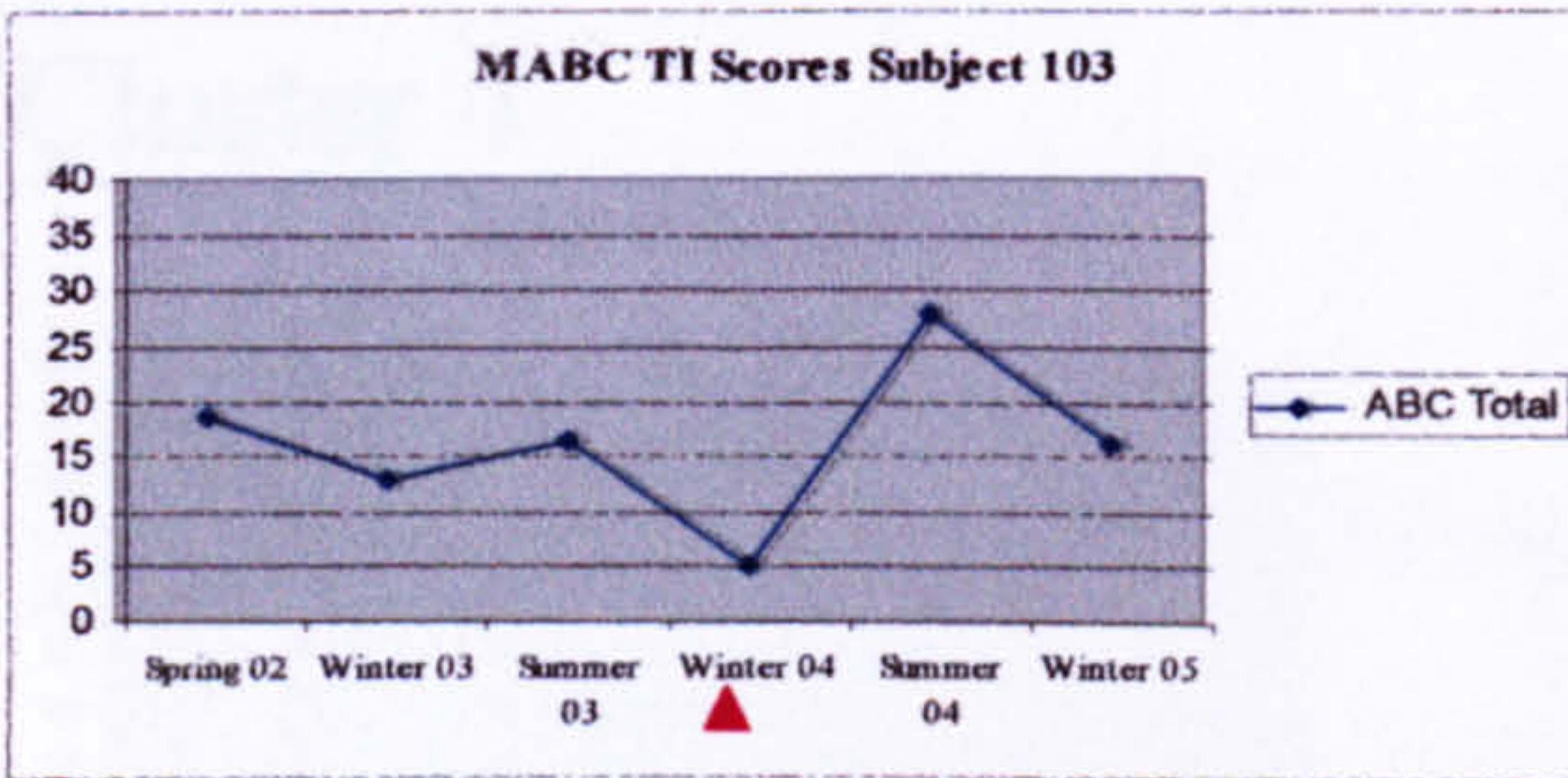
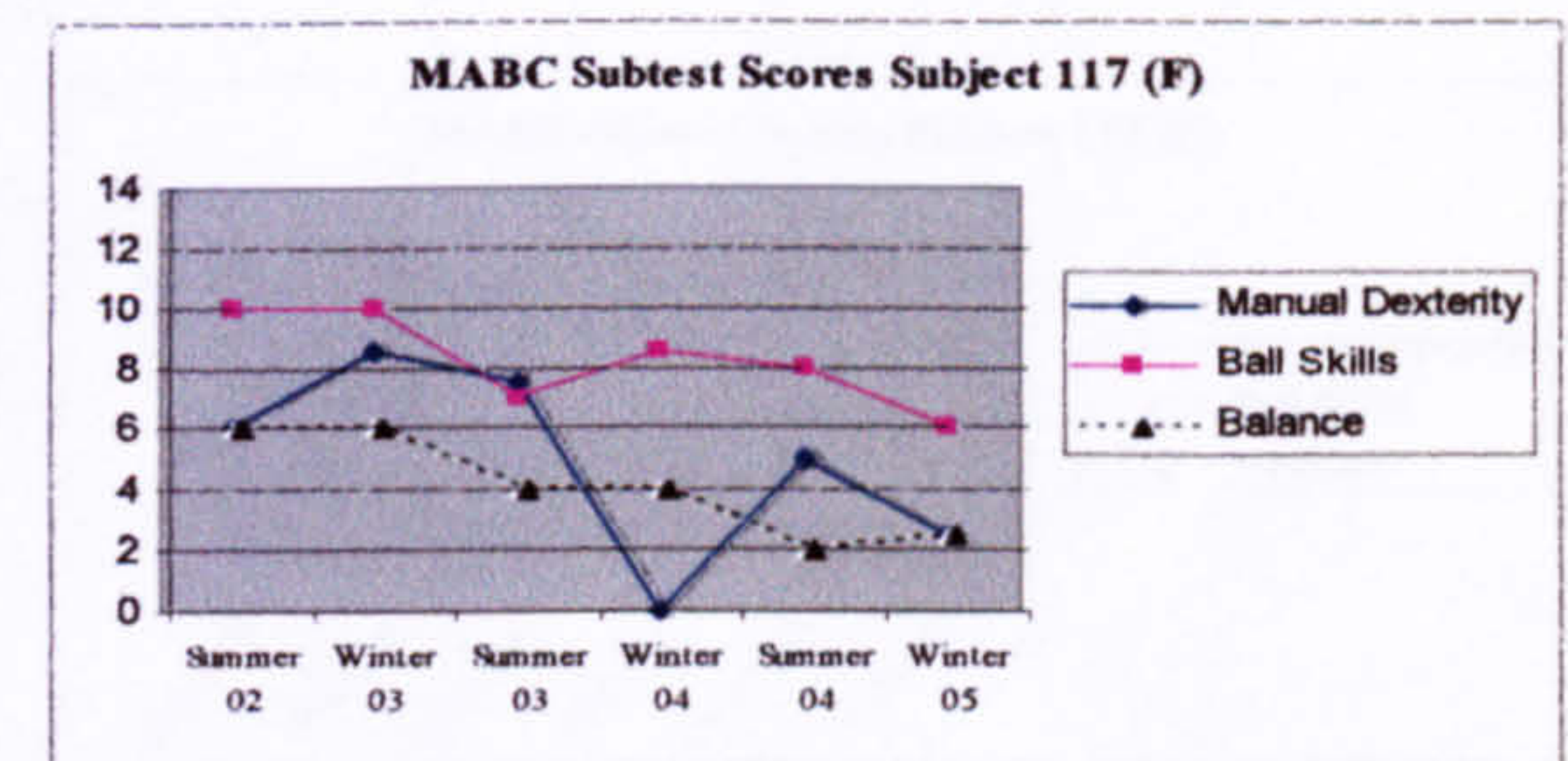
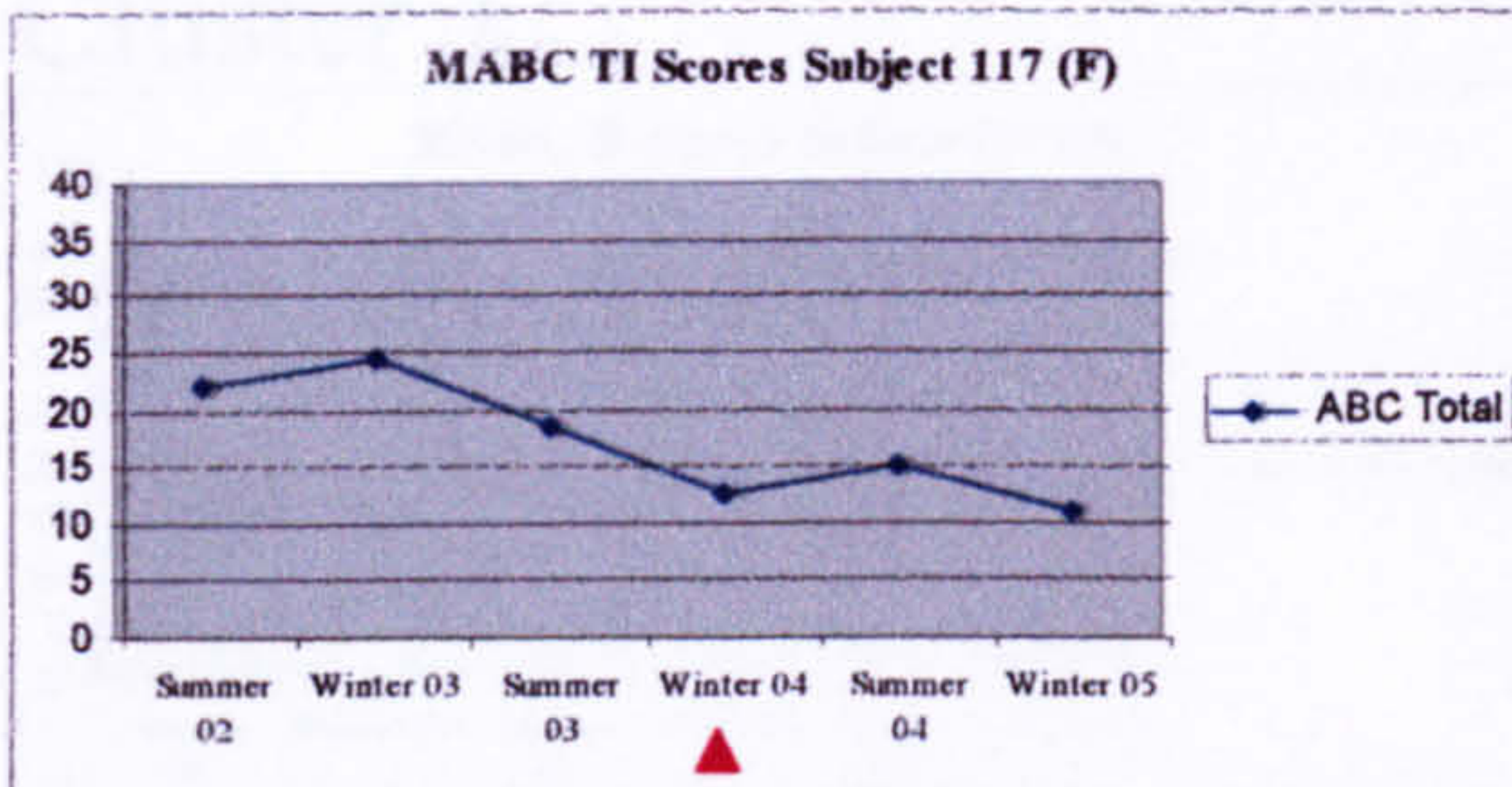
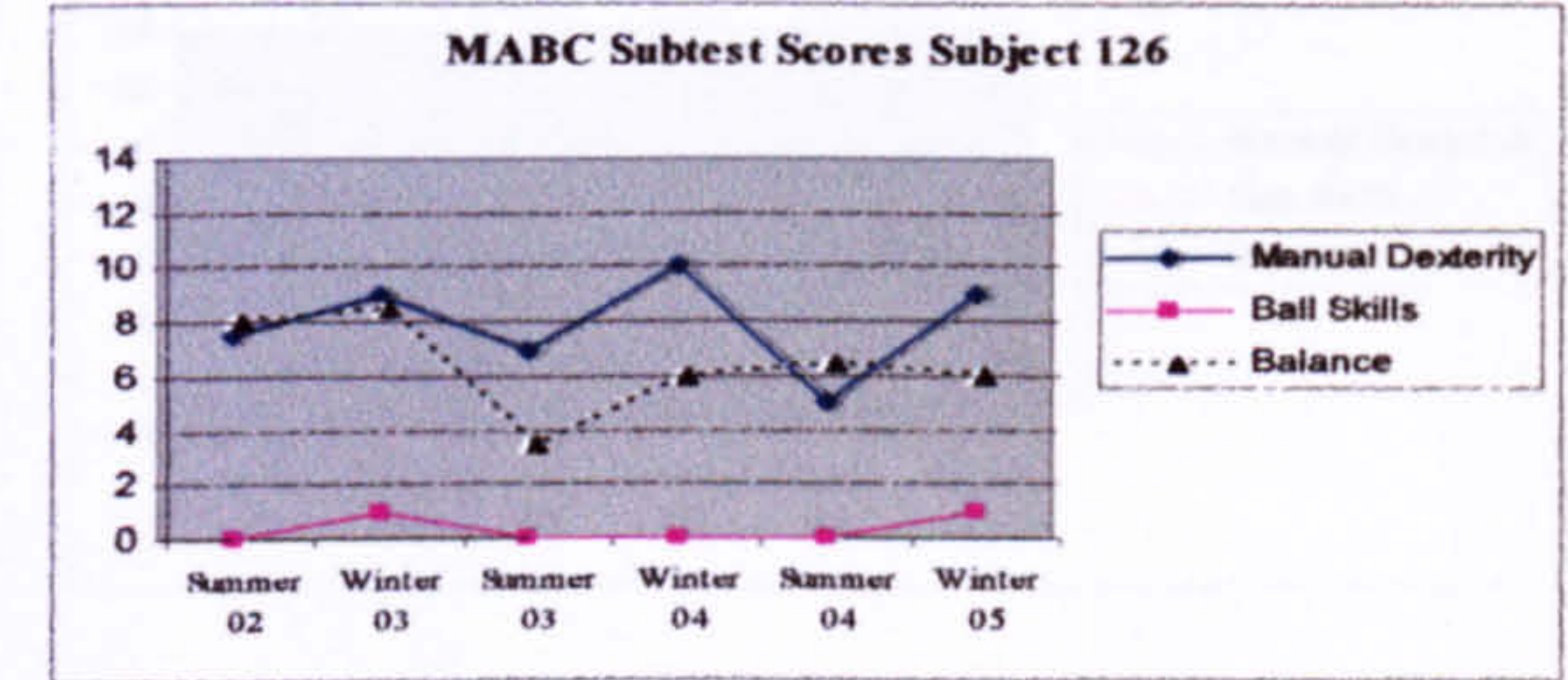
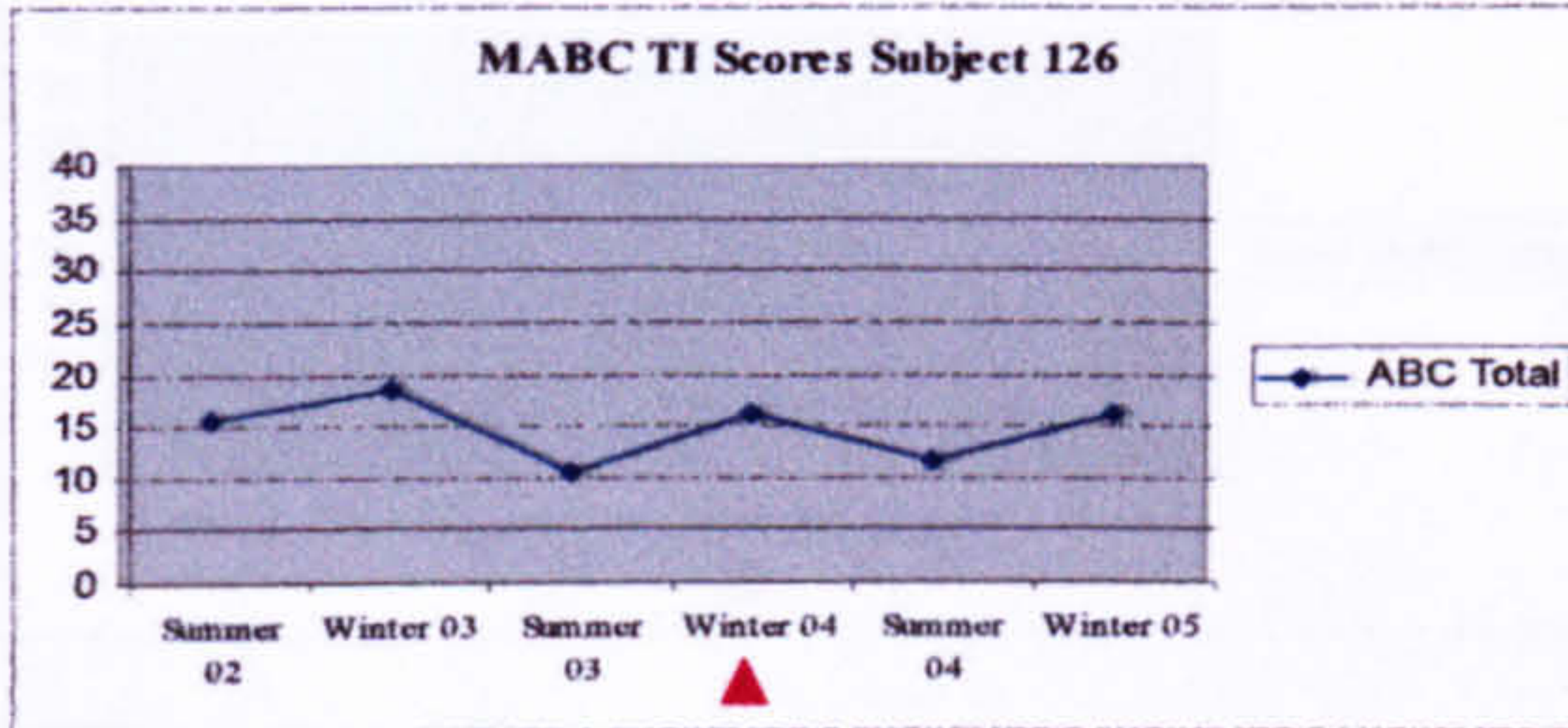
▲ = Assessment immediately following treatment

Children treated Sept 03 to Jan 04 – 6-8 year olds

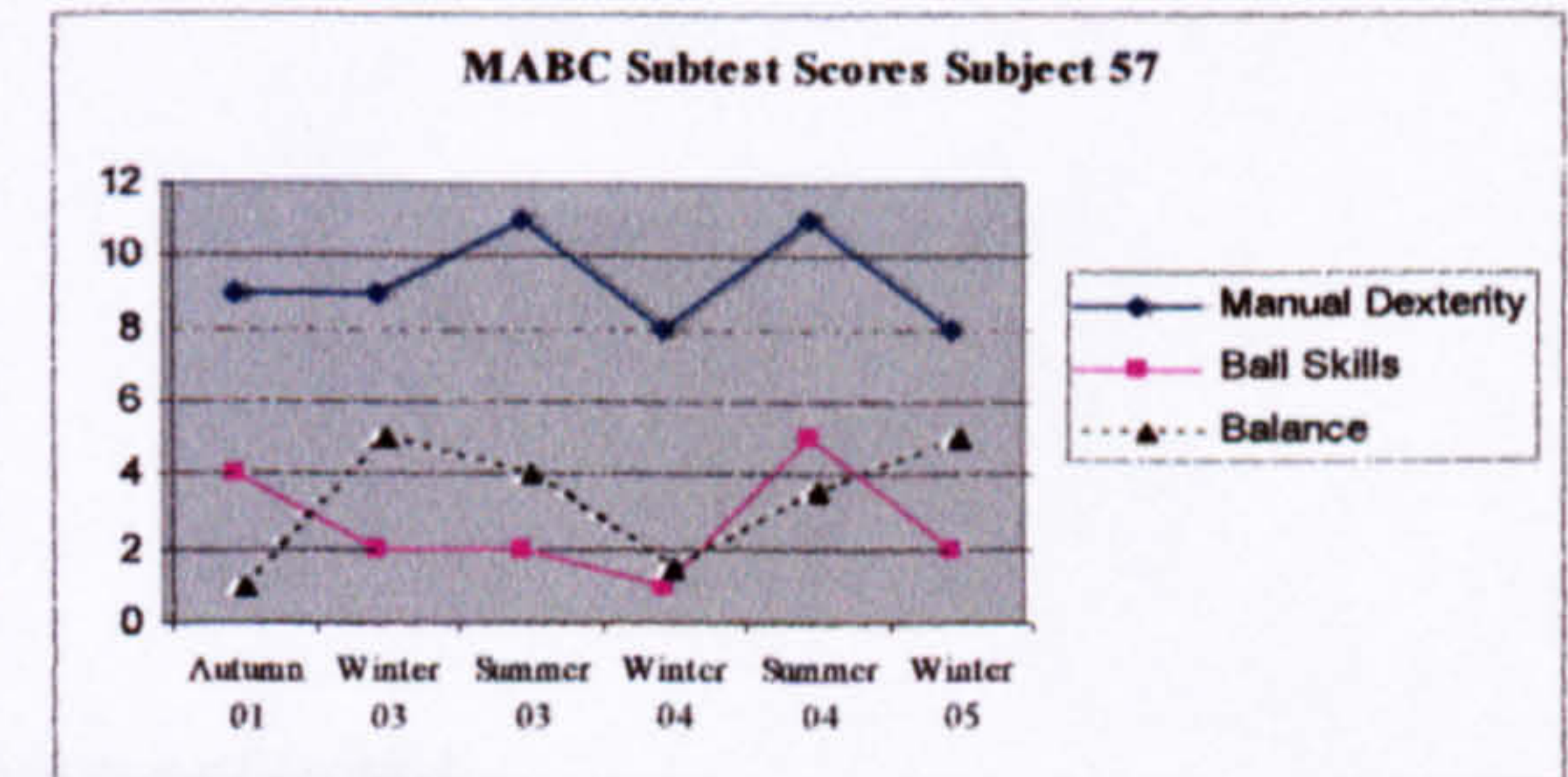
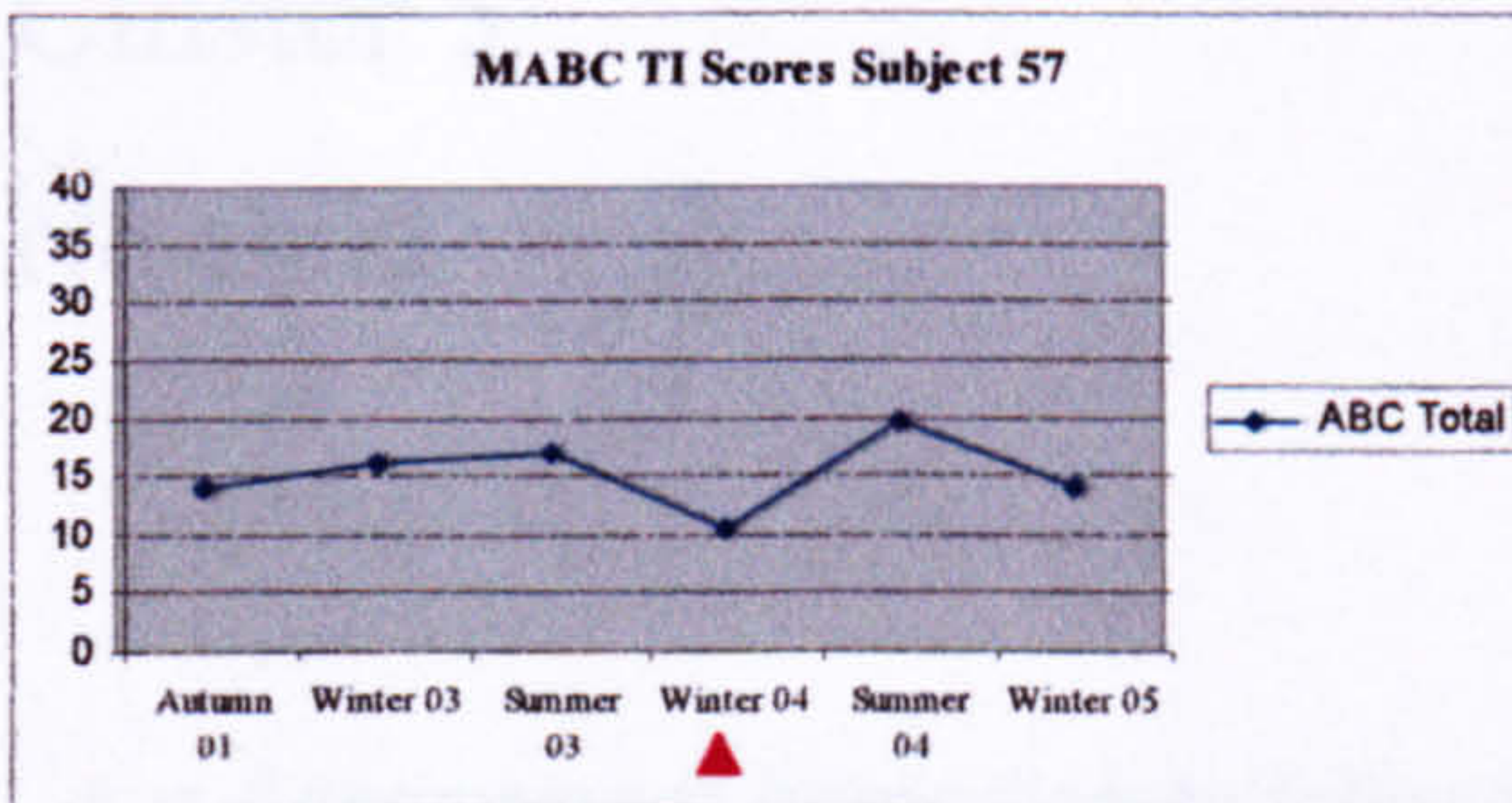
Cluster 1



Cluster 2



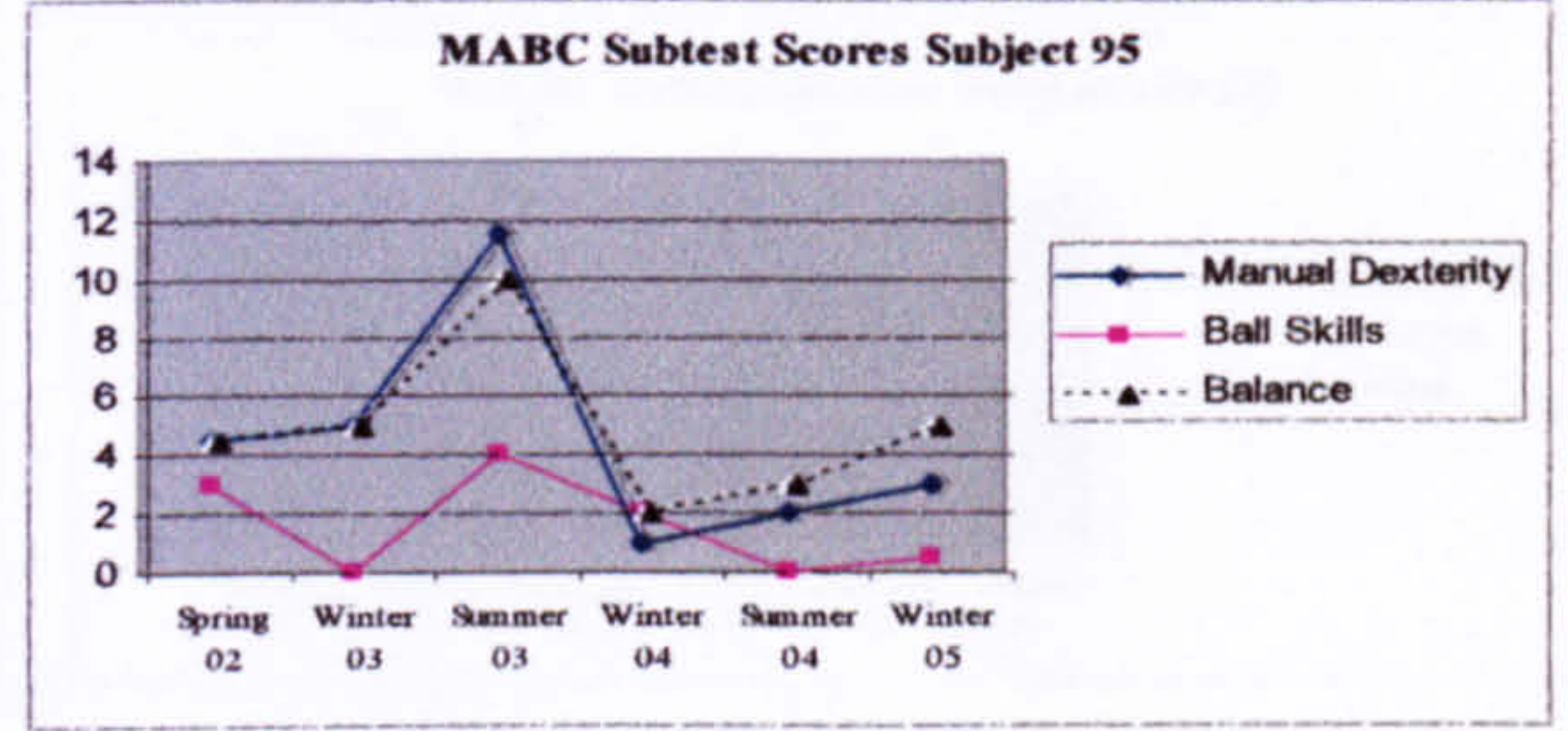
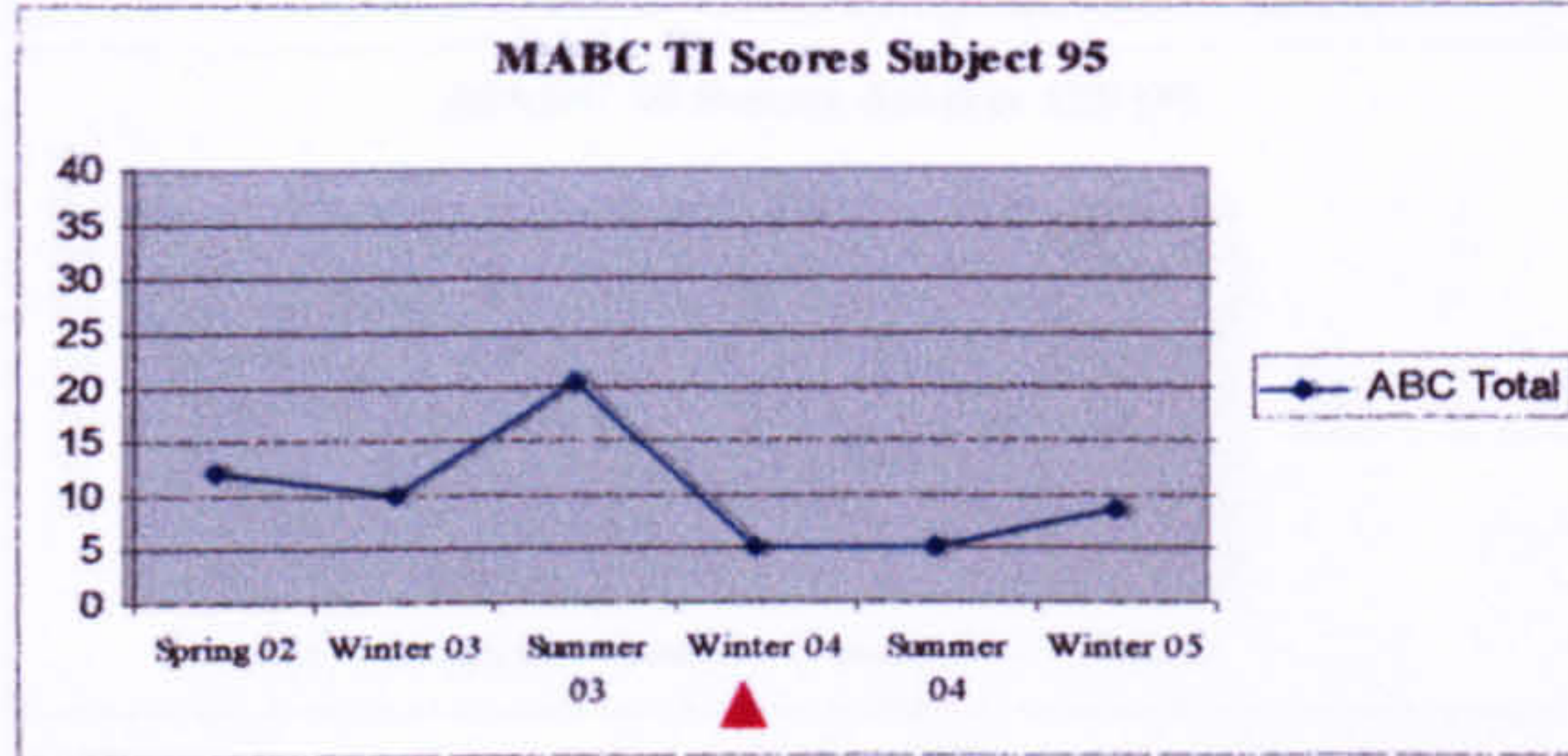
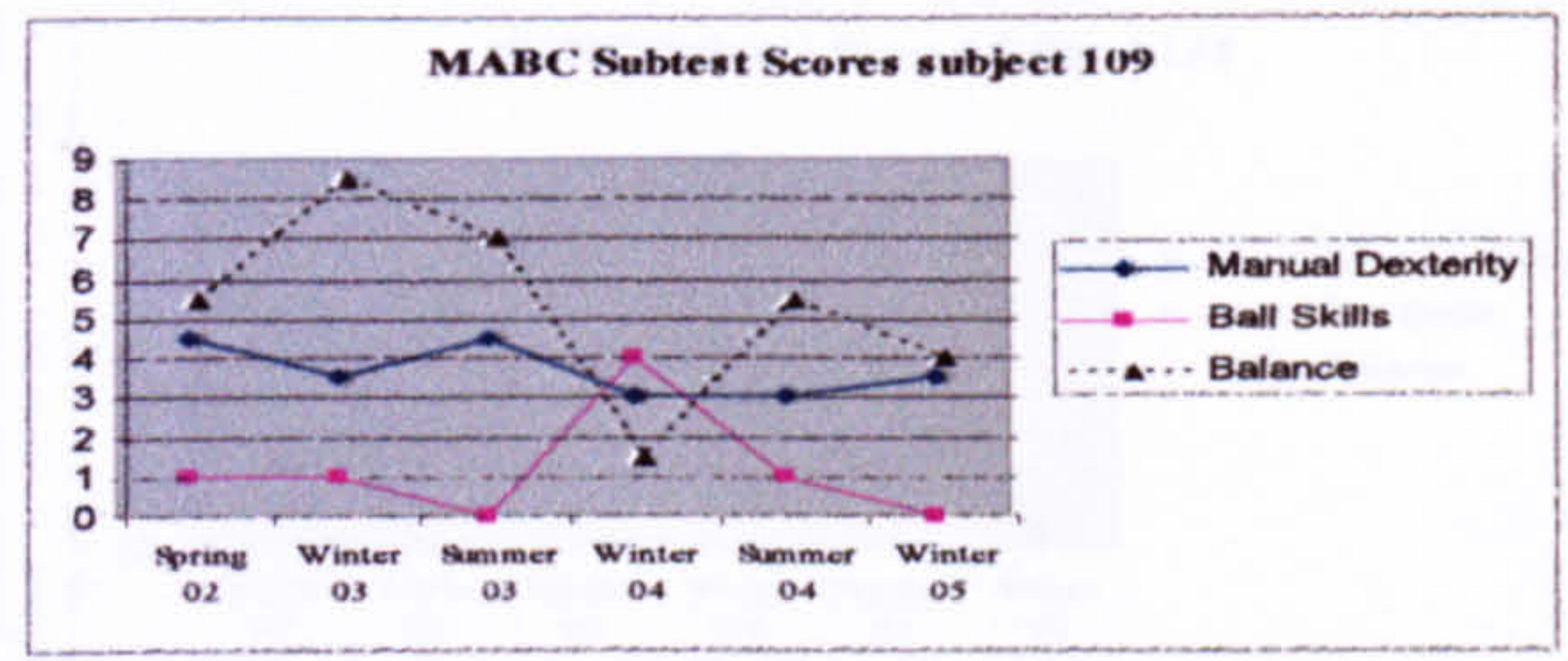
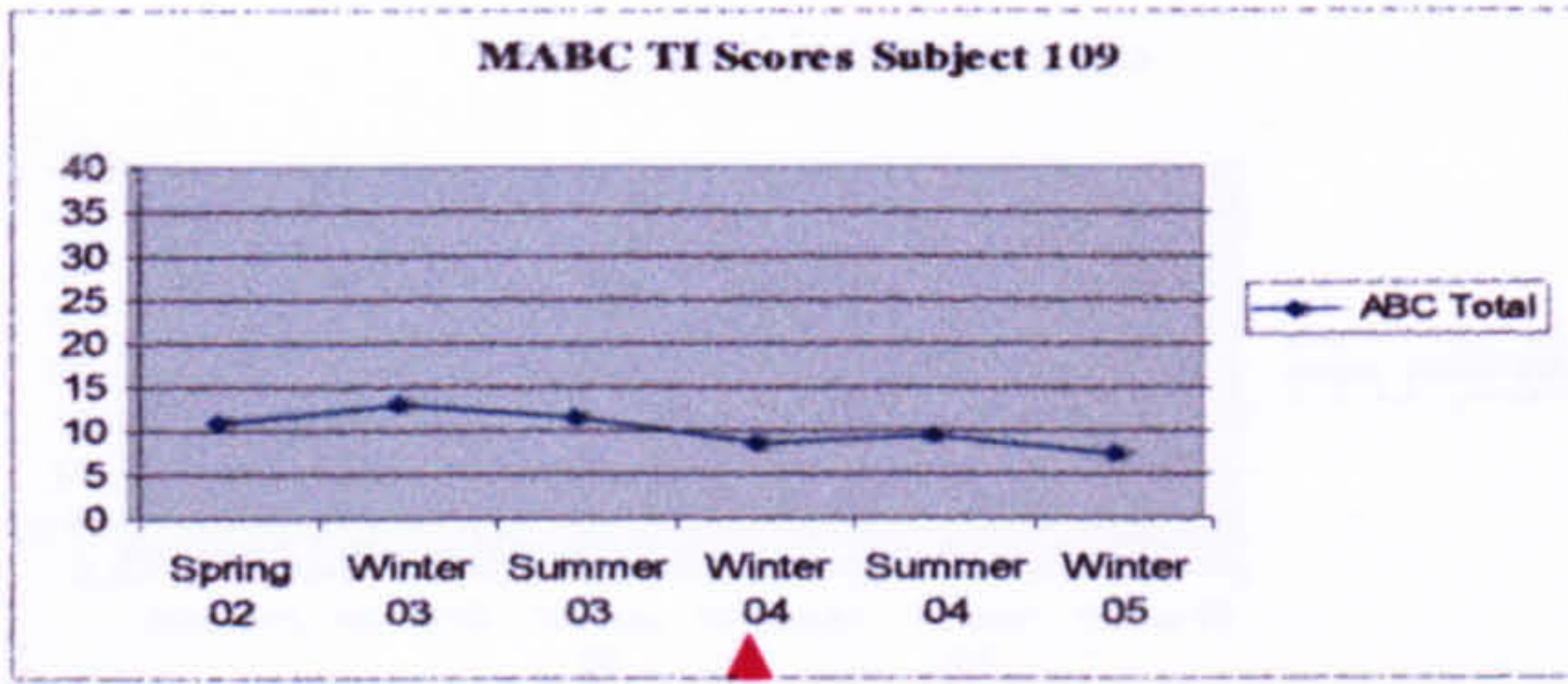
Cluster 4



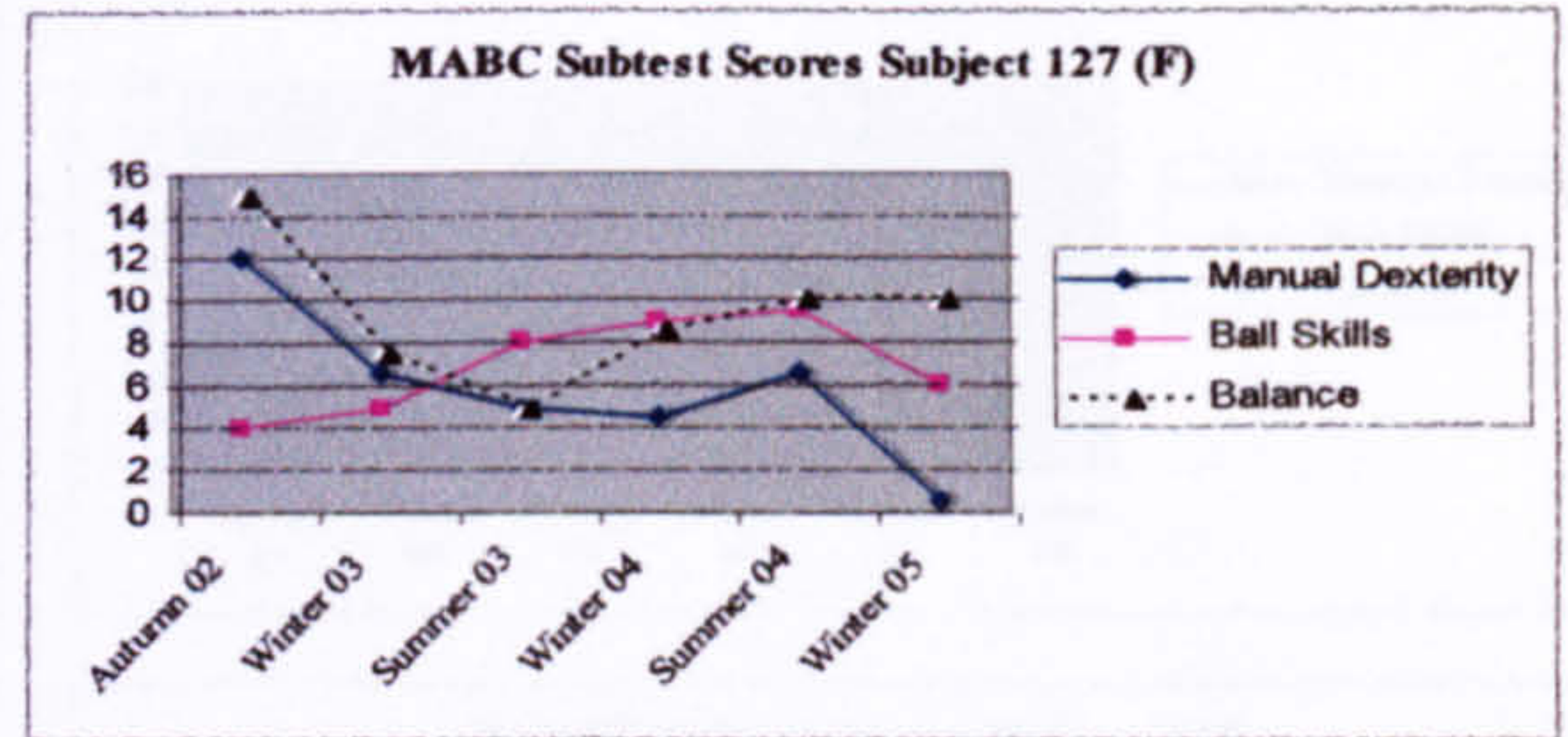
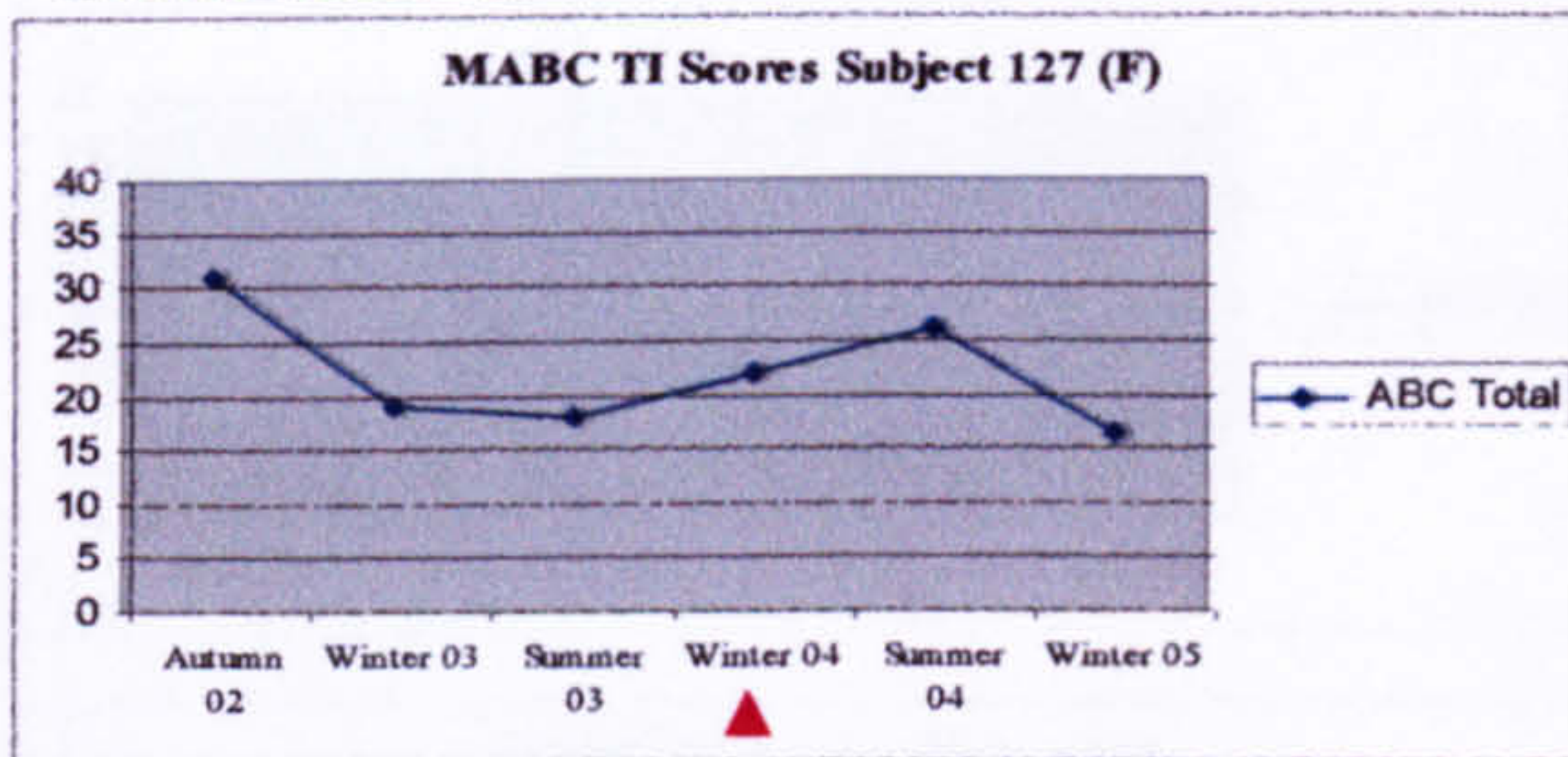
▲ = Assessment immediately following treatment

Children treated Sept 03 to Jan 04 – 9-11 year olds

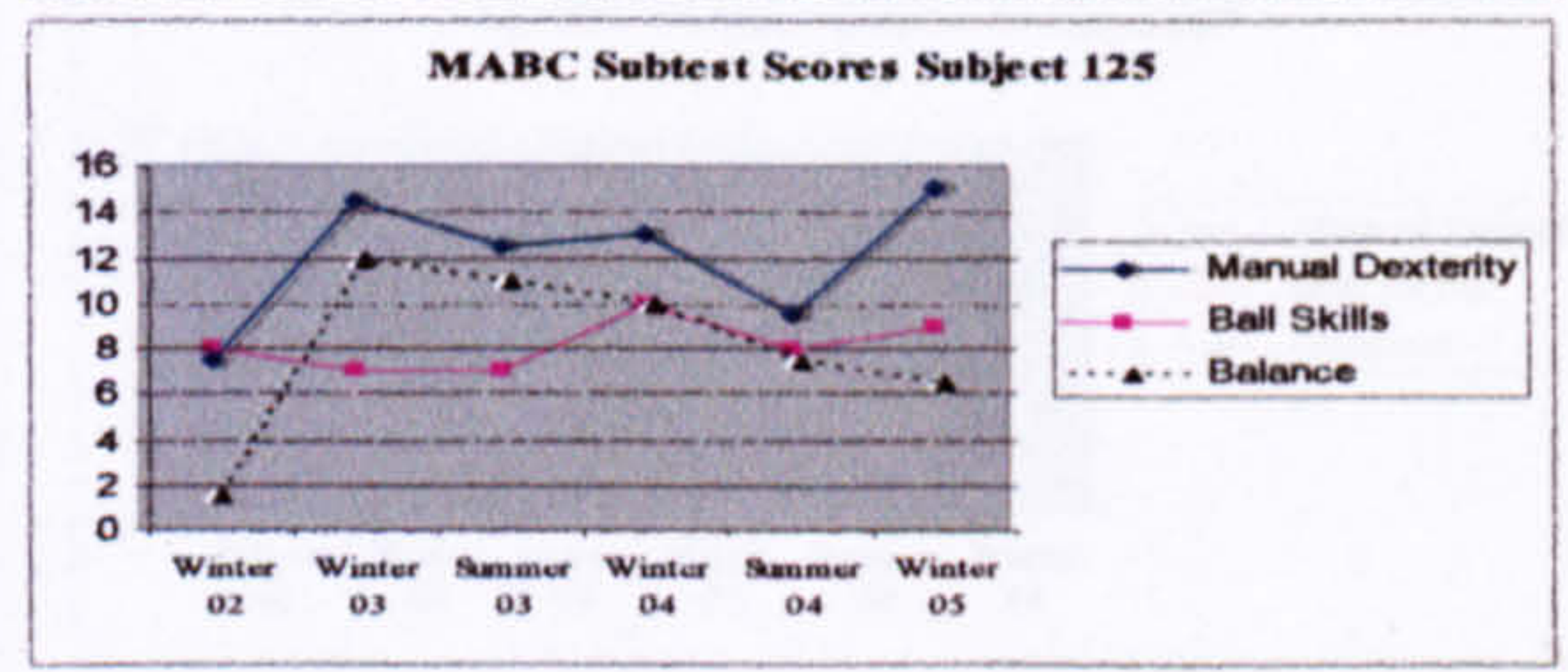
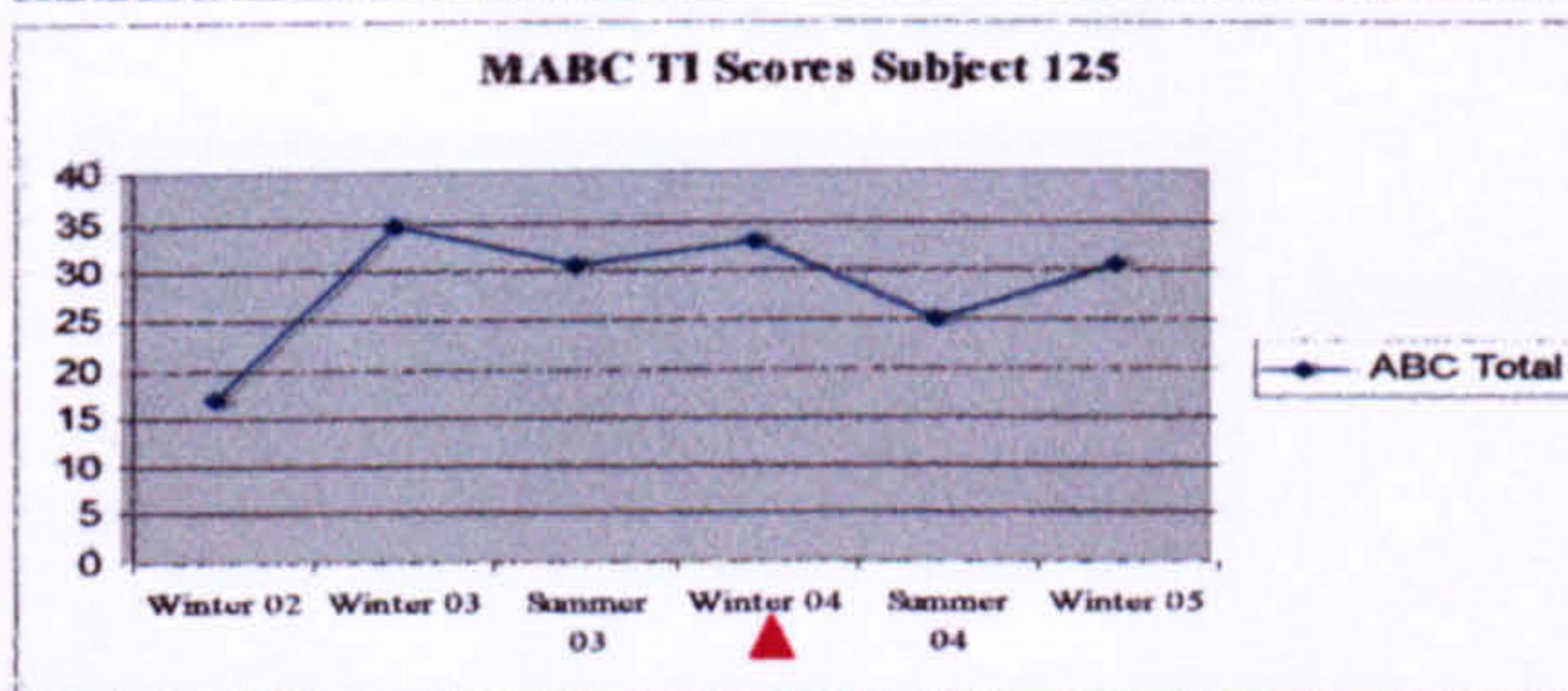
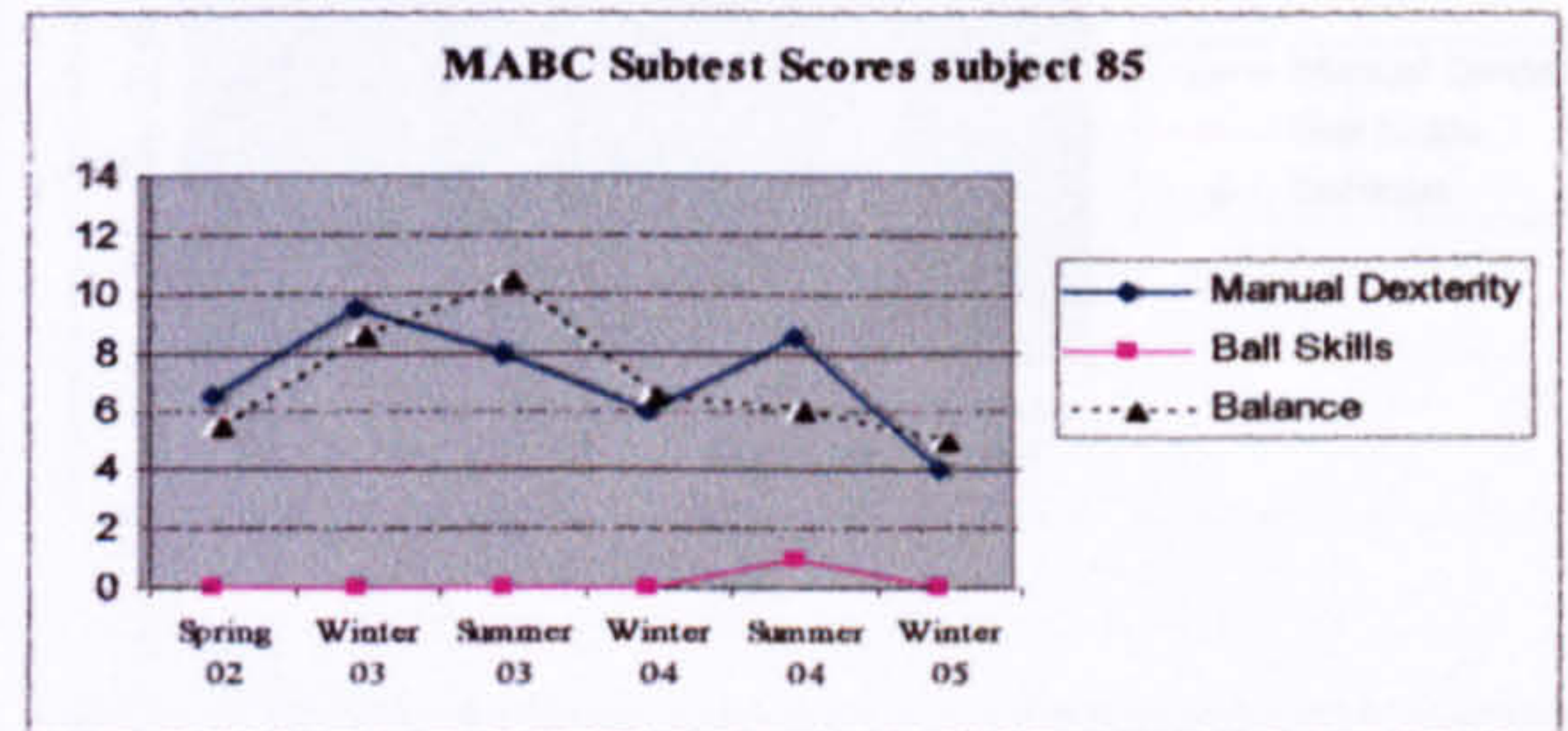
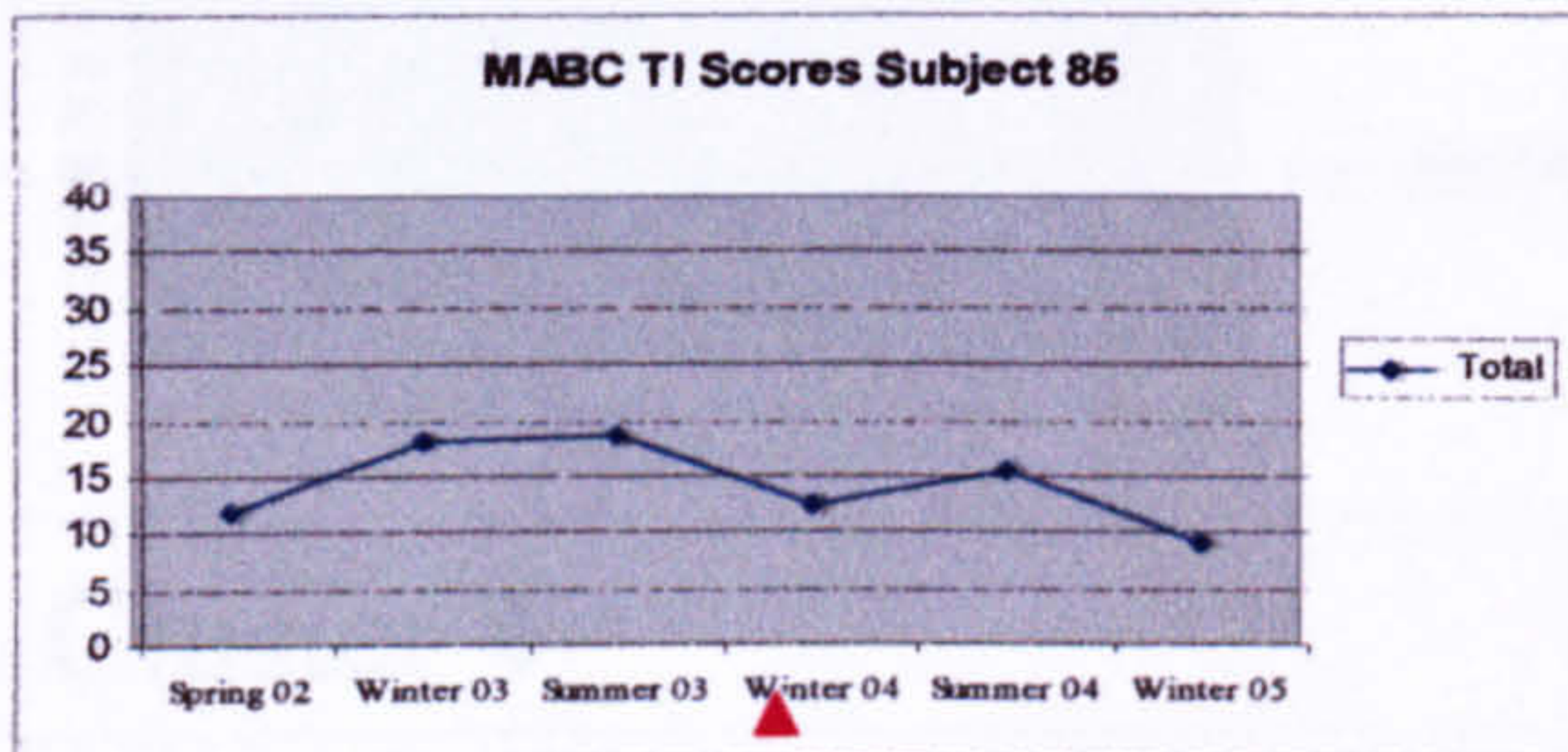
Cluster 1



Cluster 3



Cluster 4



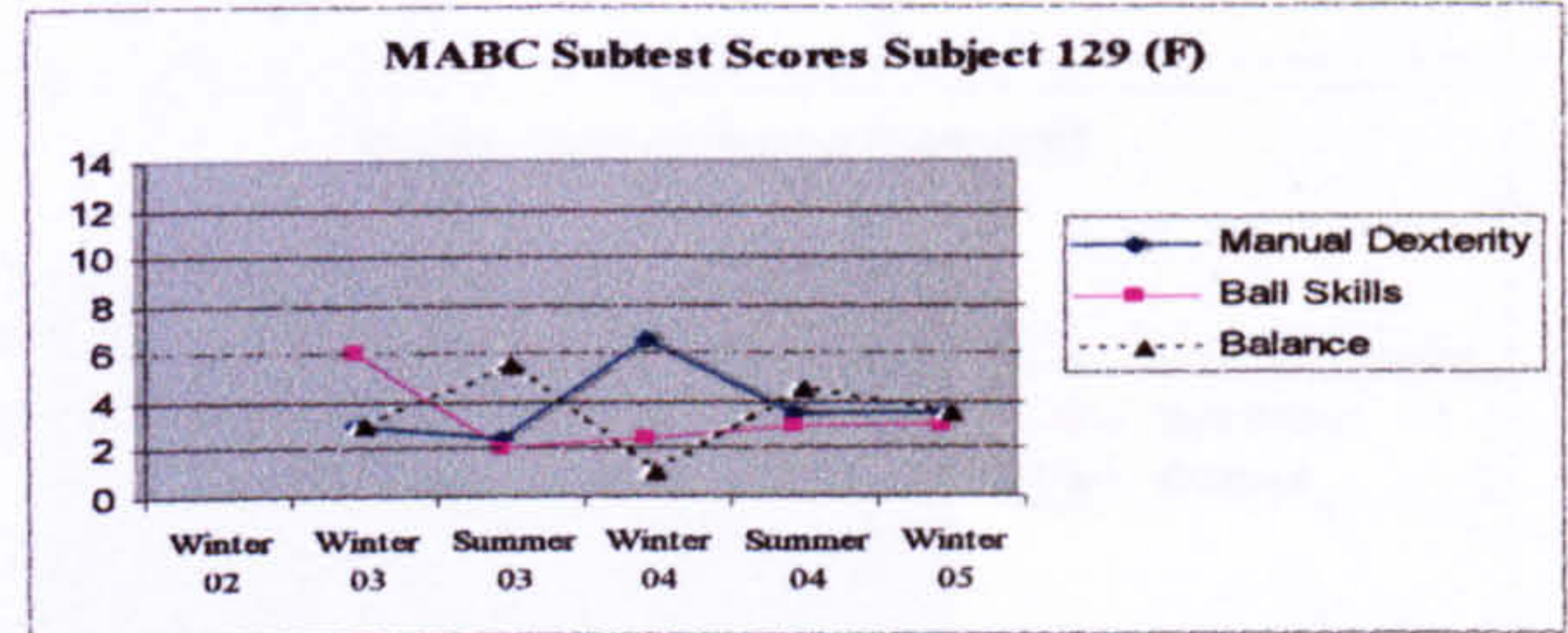
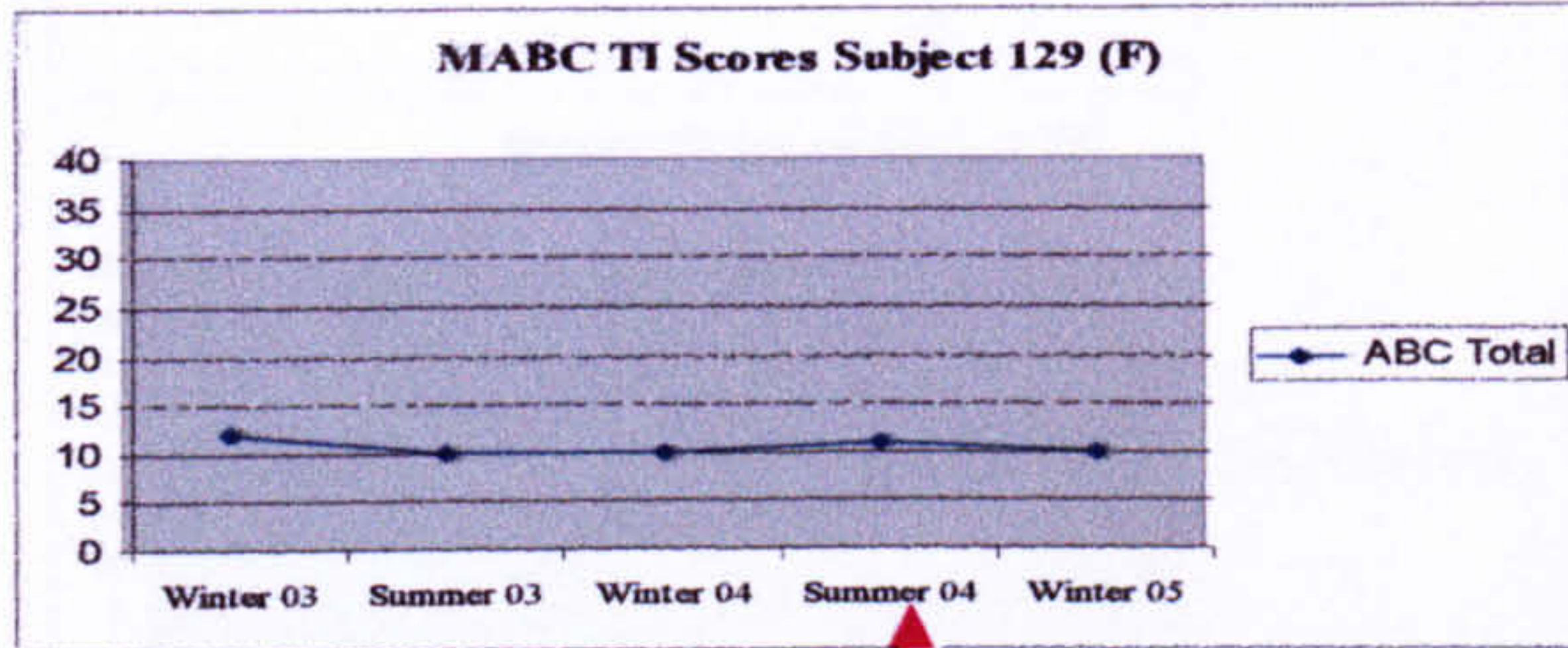
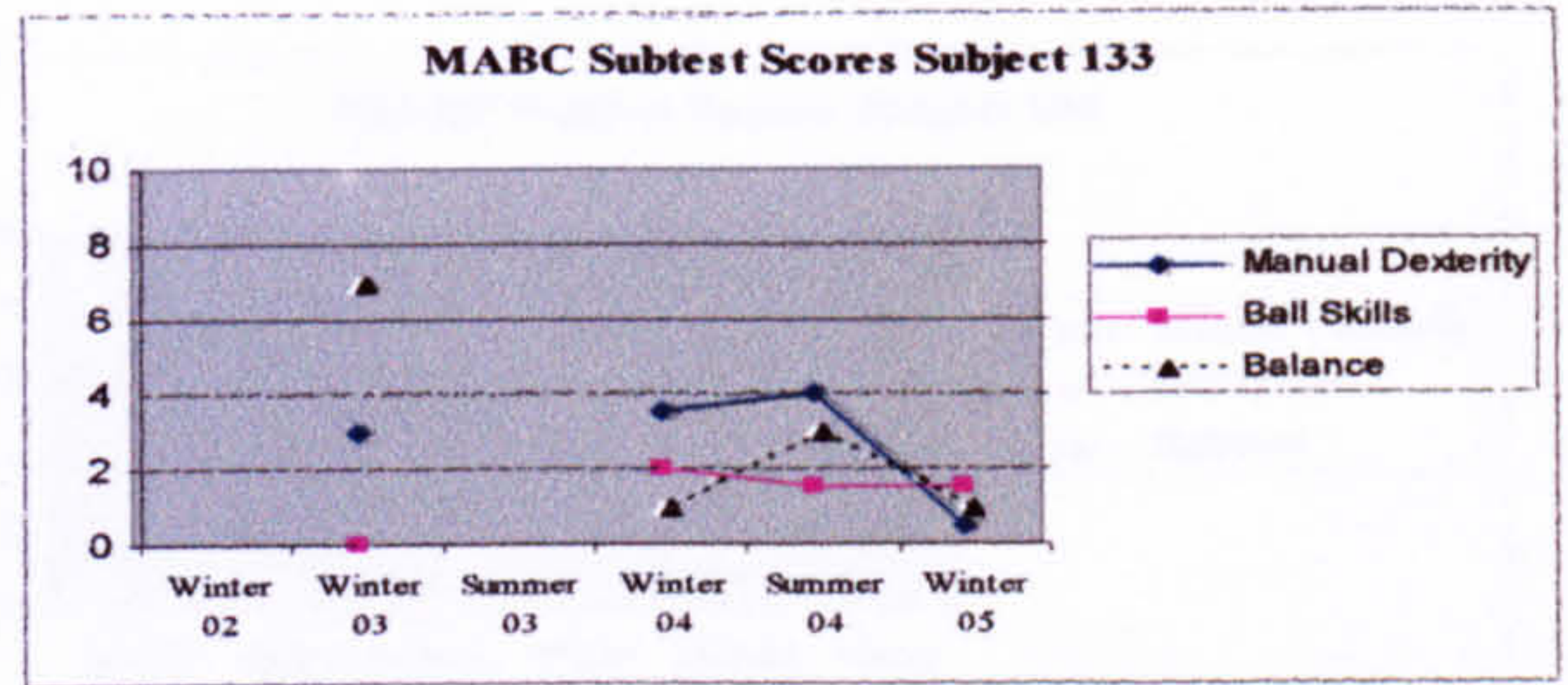
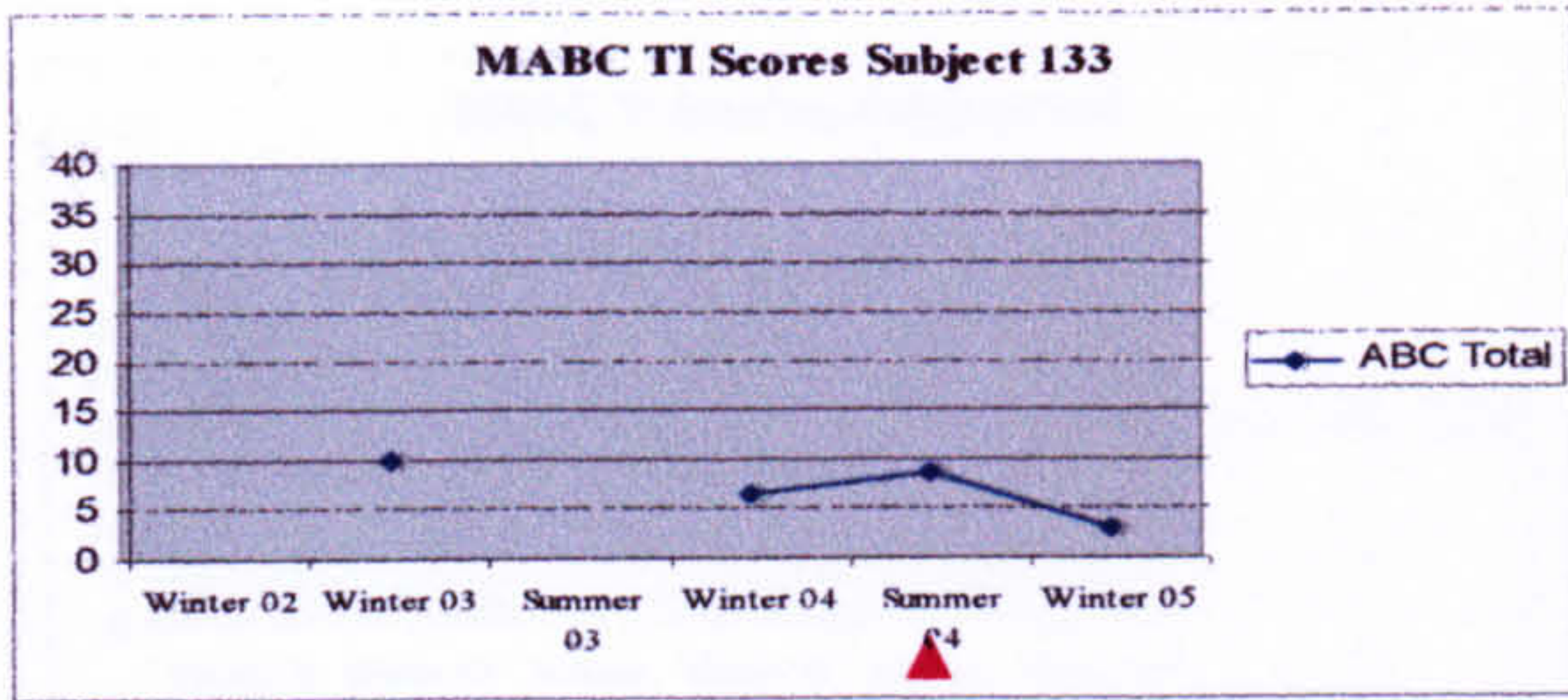
Cluster 5

No child

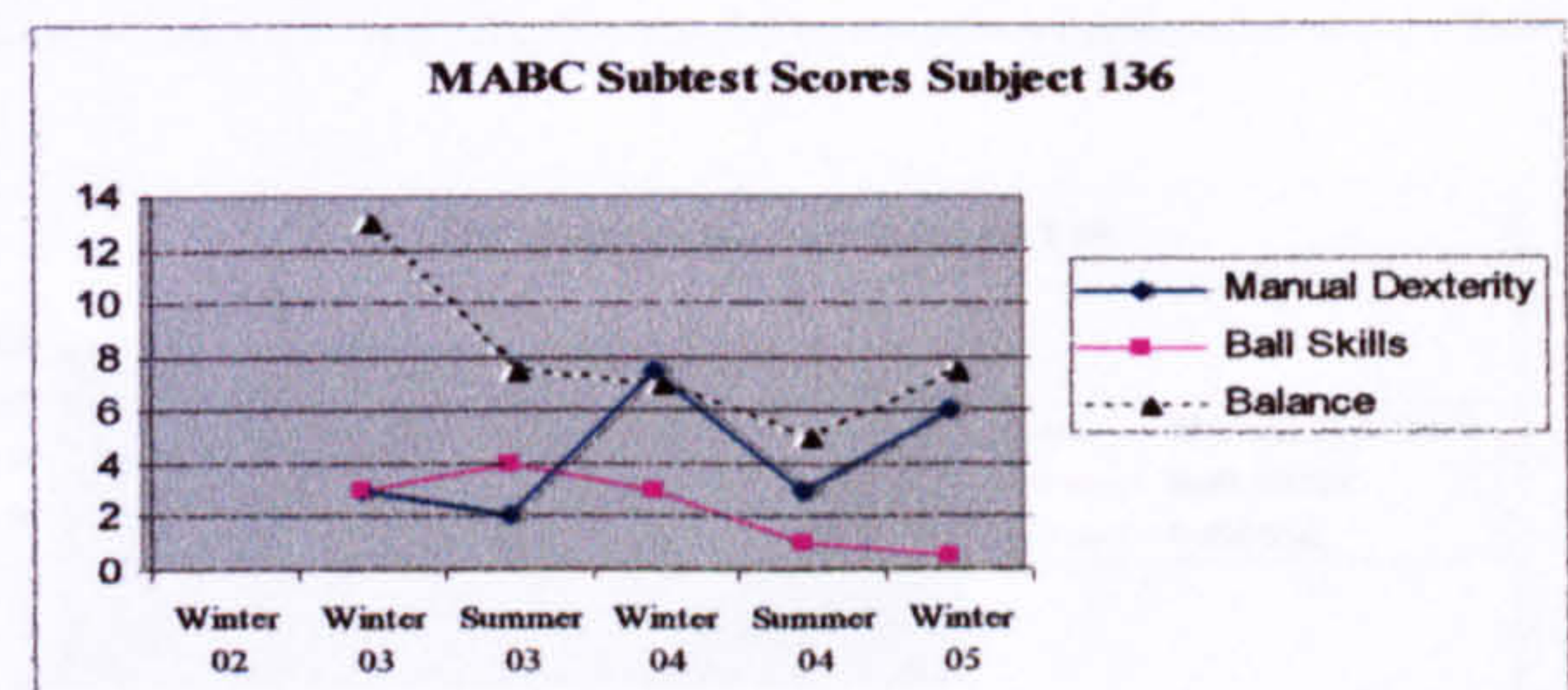
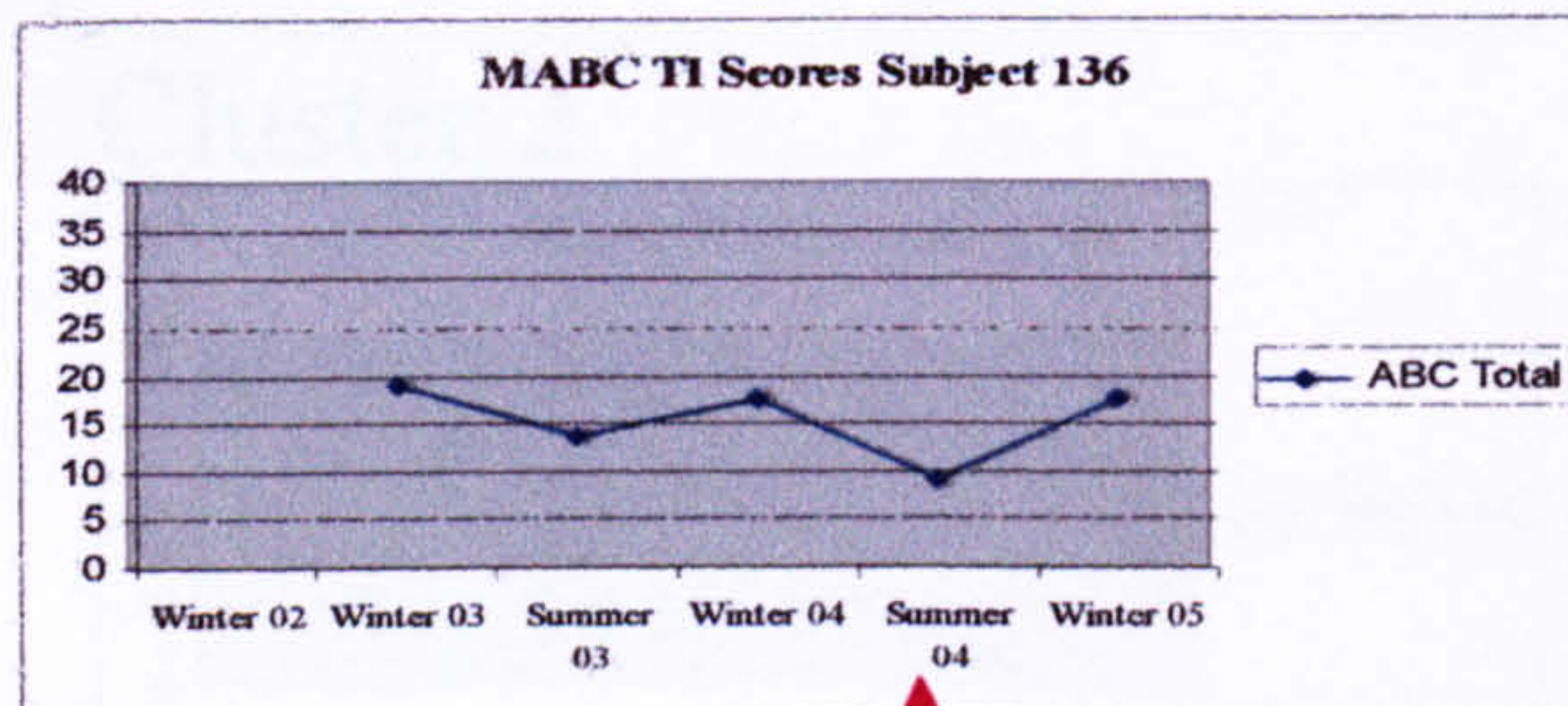
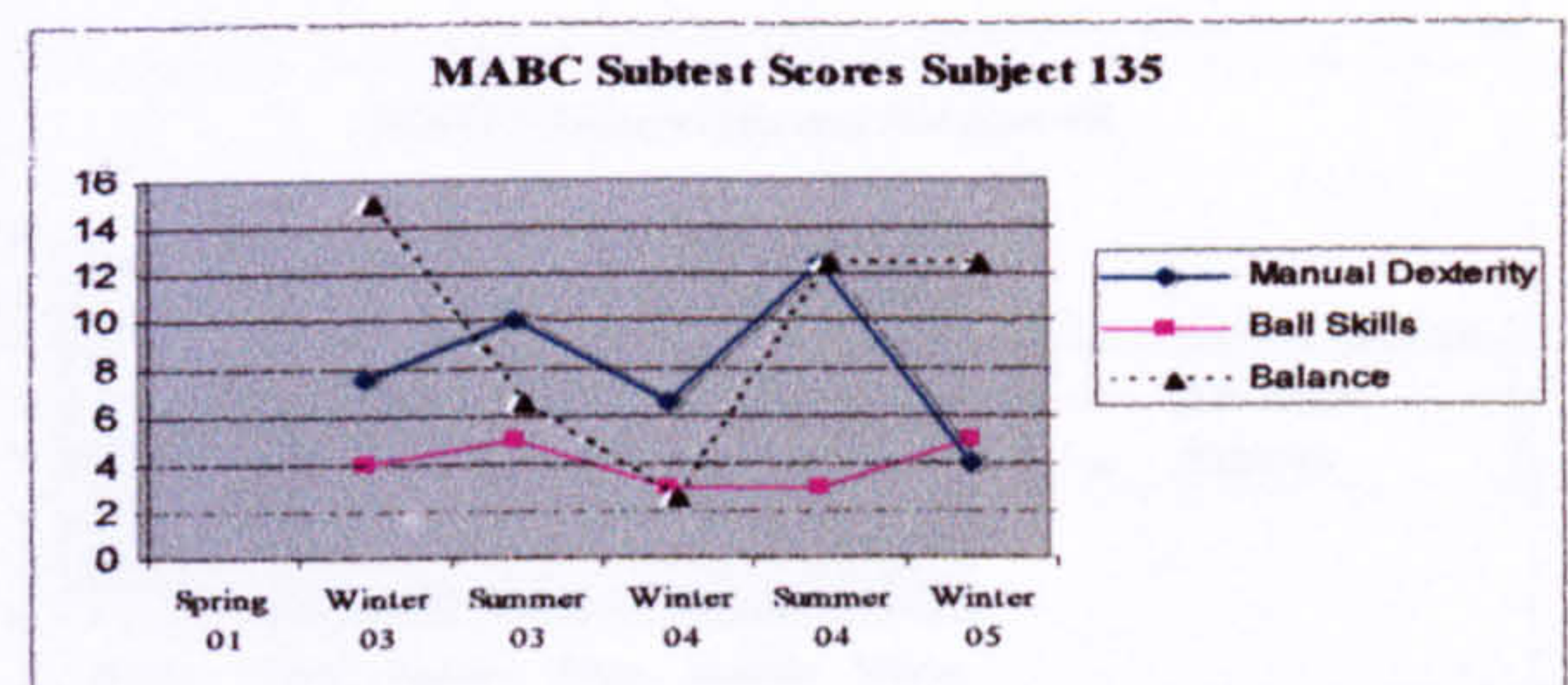
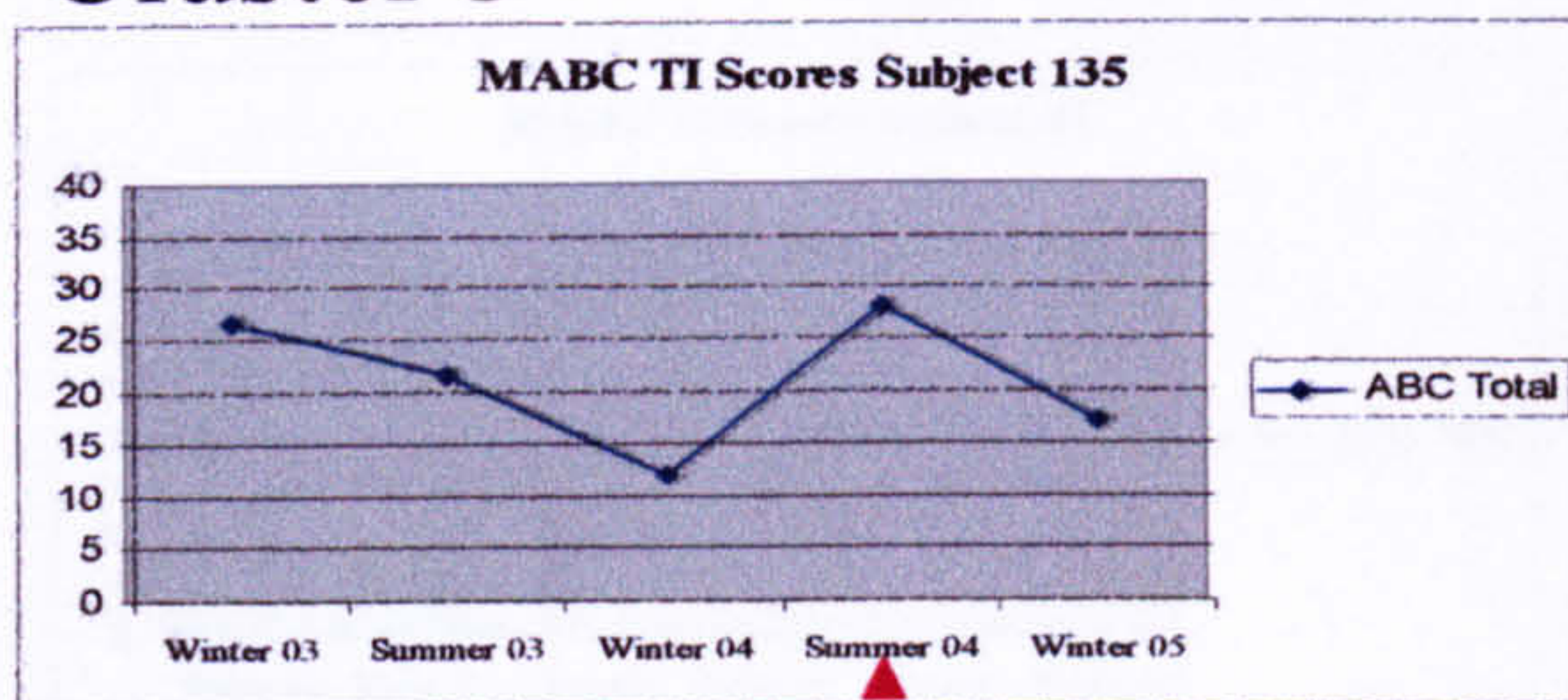
▲ = Assessment immediately following treatment

Children treated Jan to Aug 2004 – 6-8 year olds

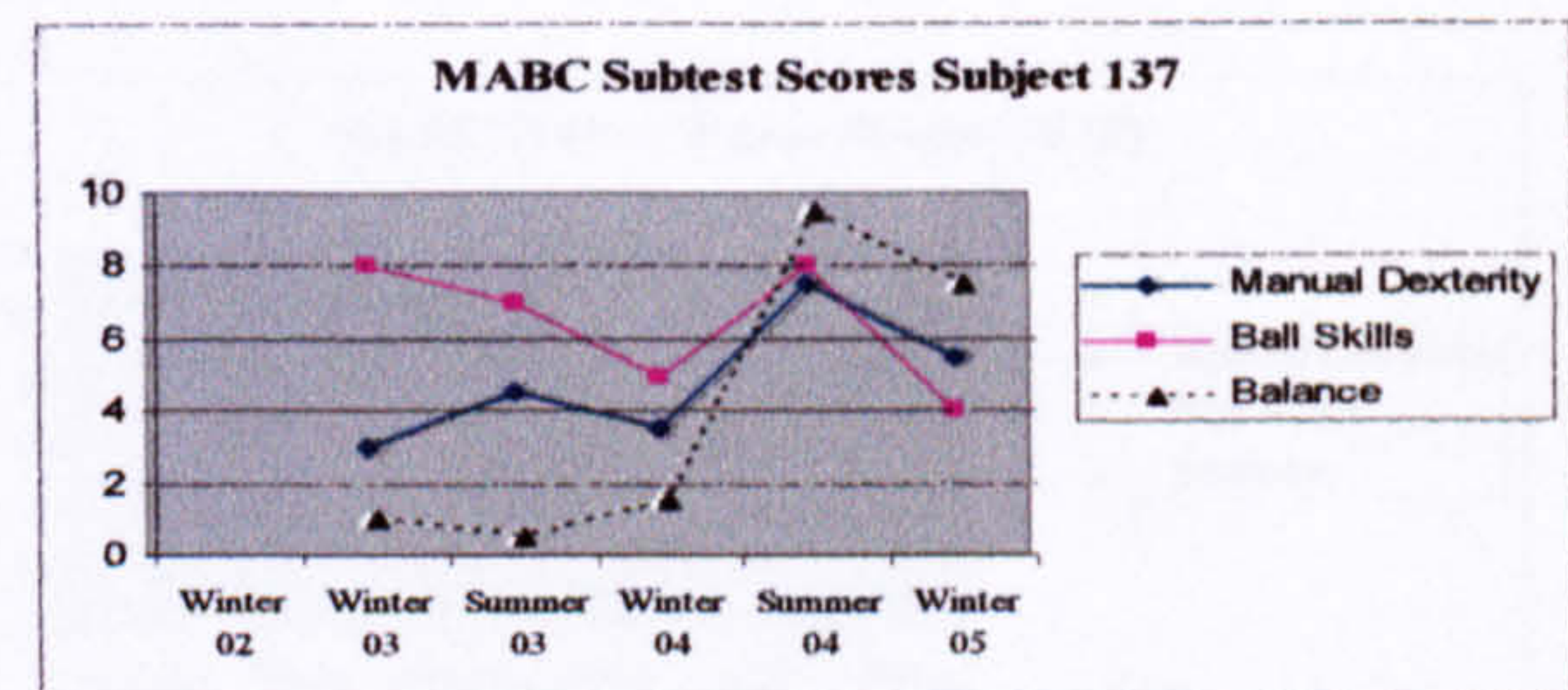
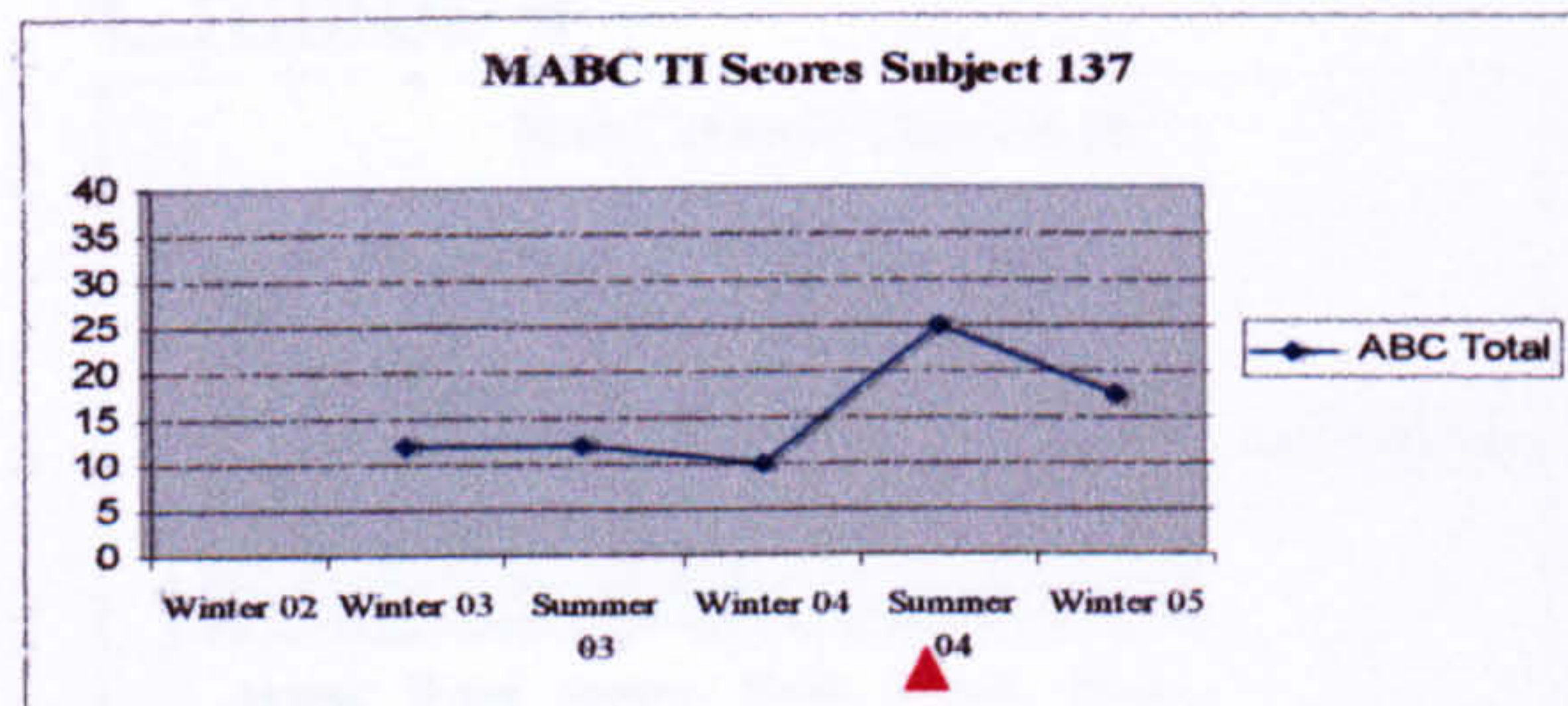
Cluster 1



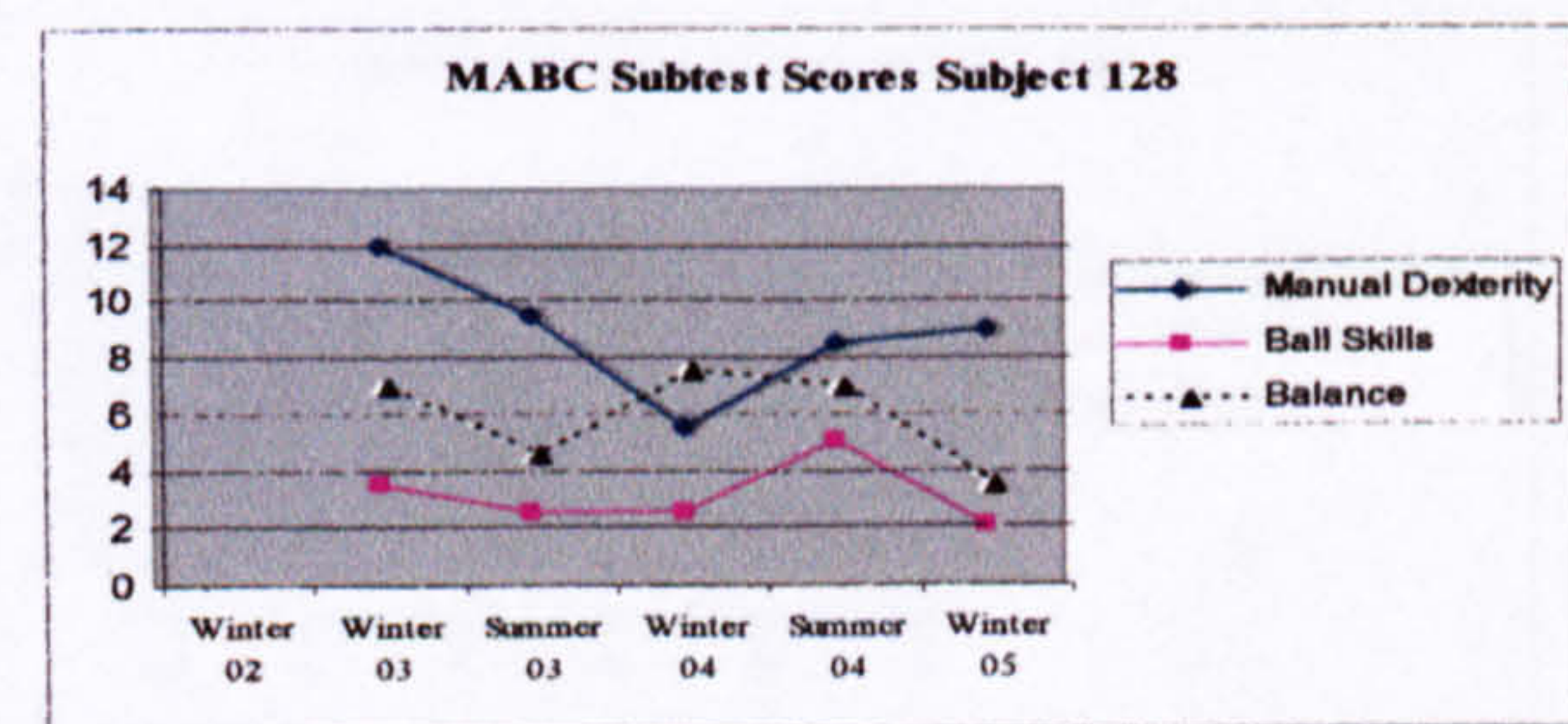
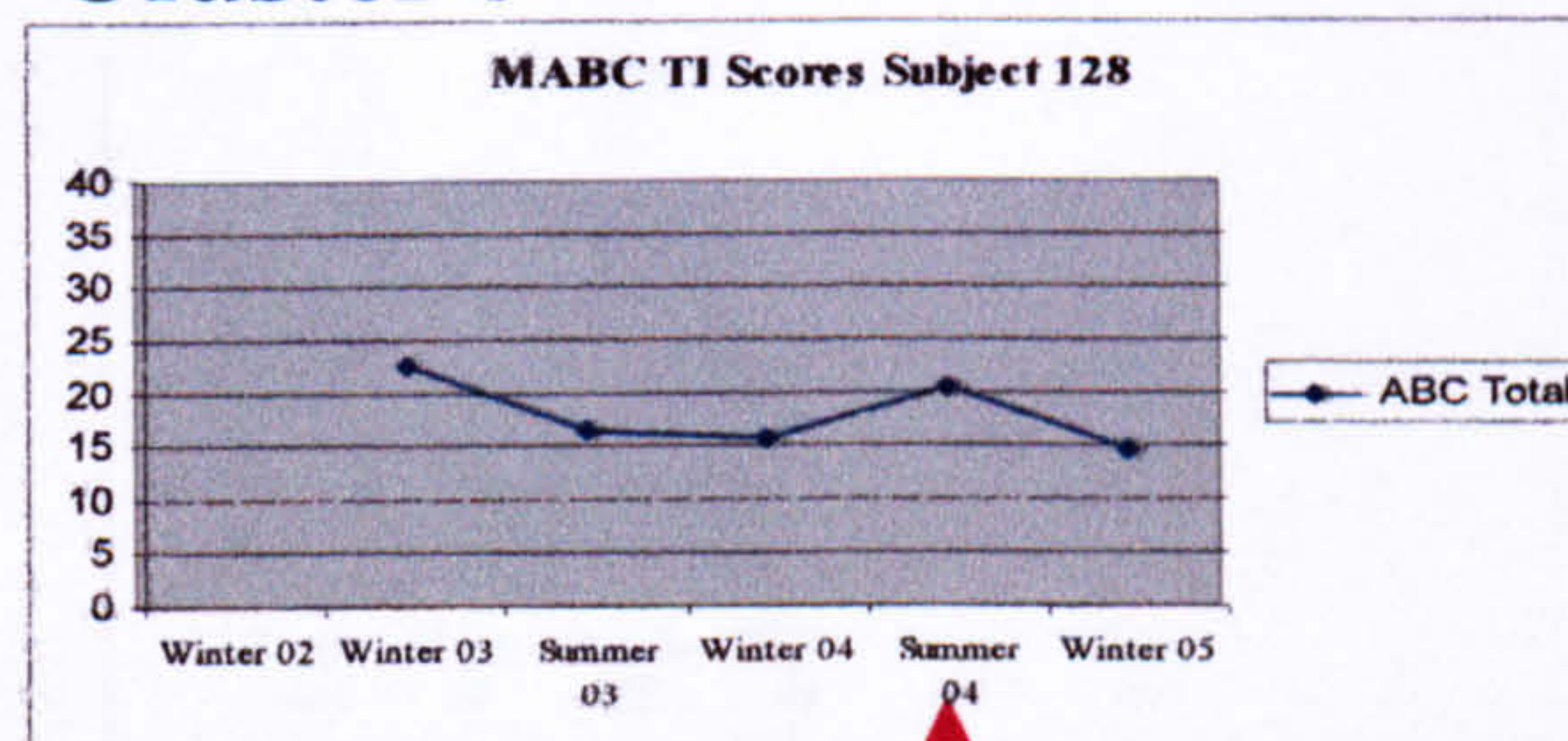
Cluster 3



Cluster 4

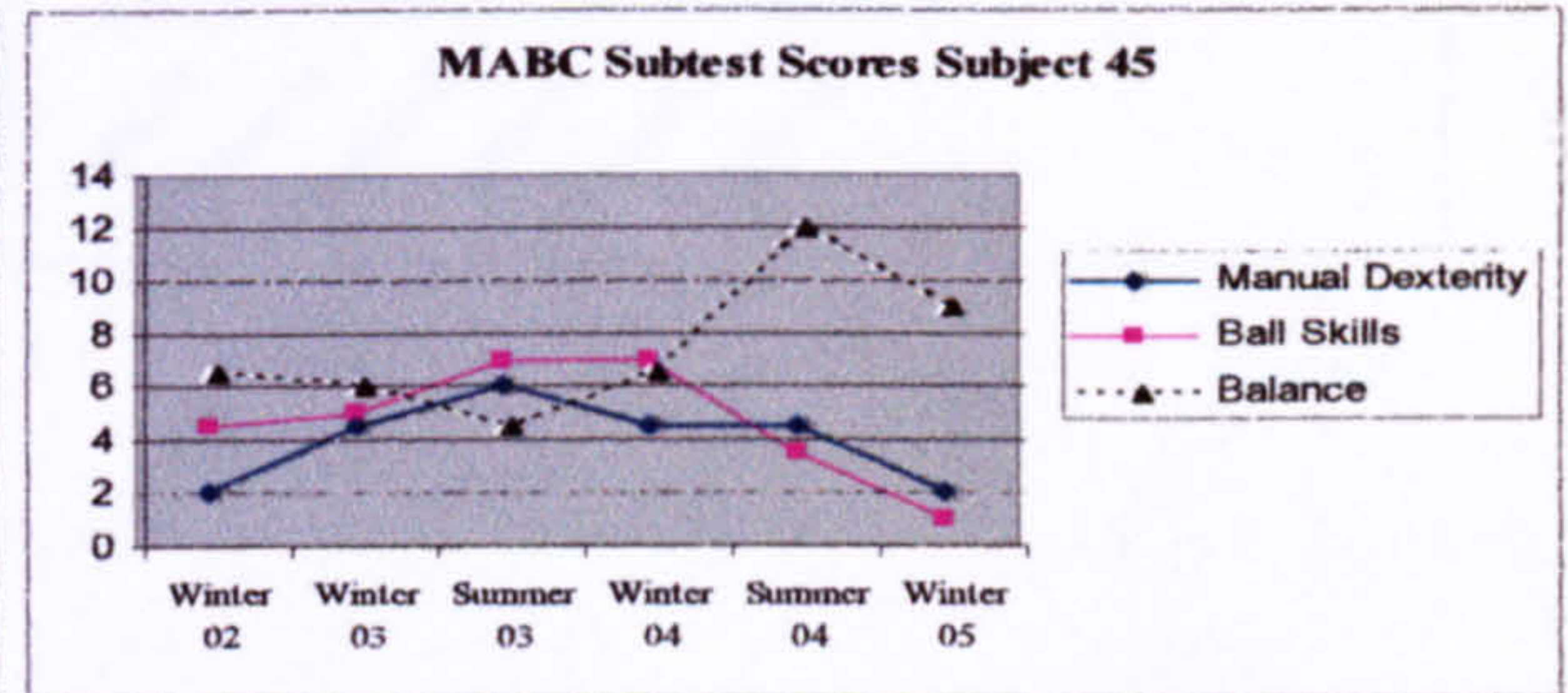
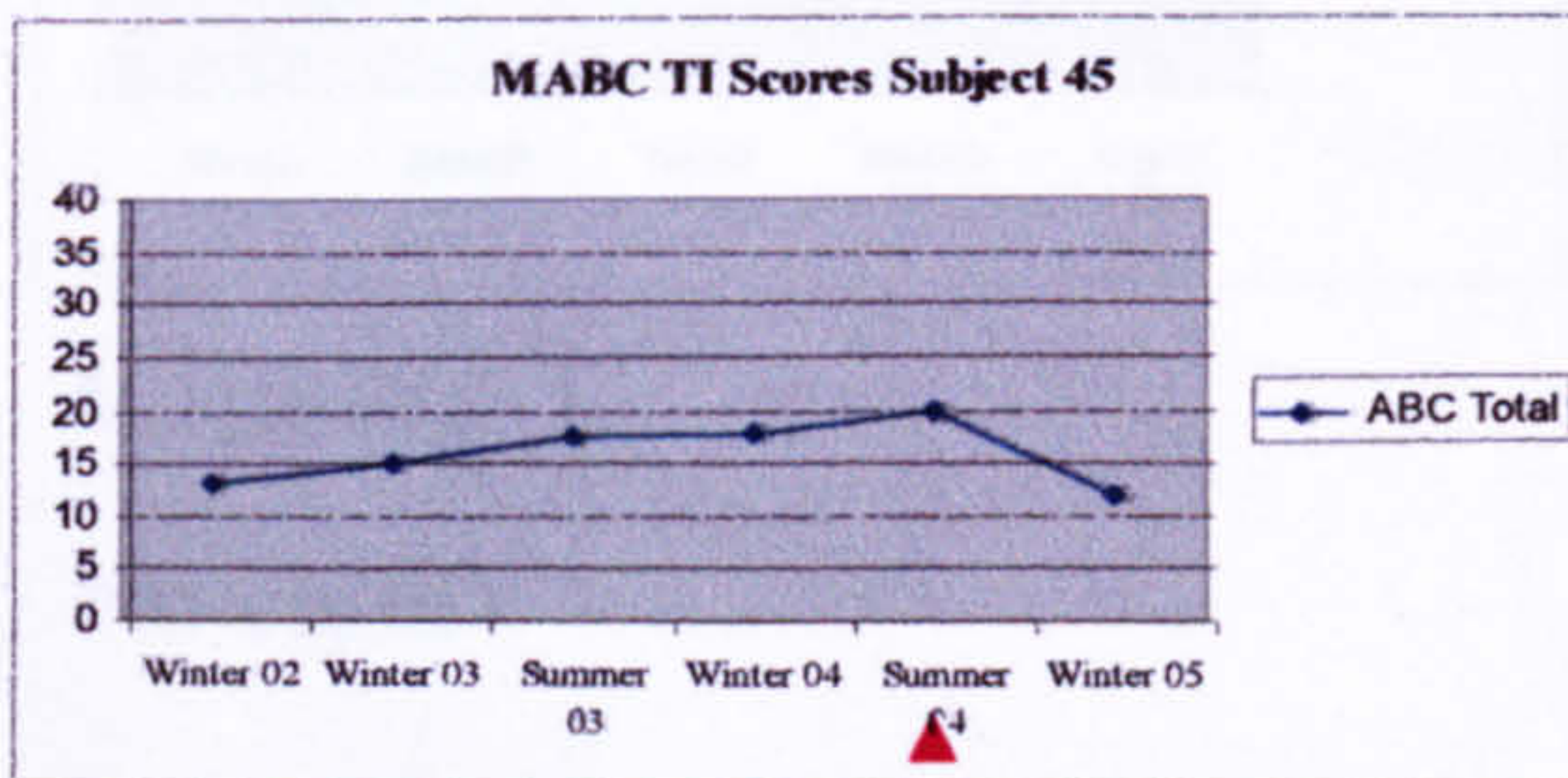
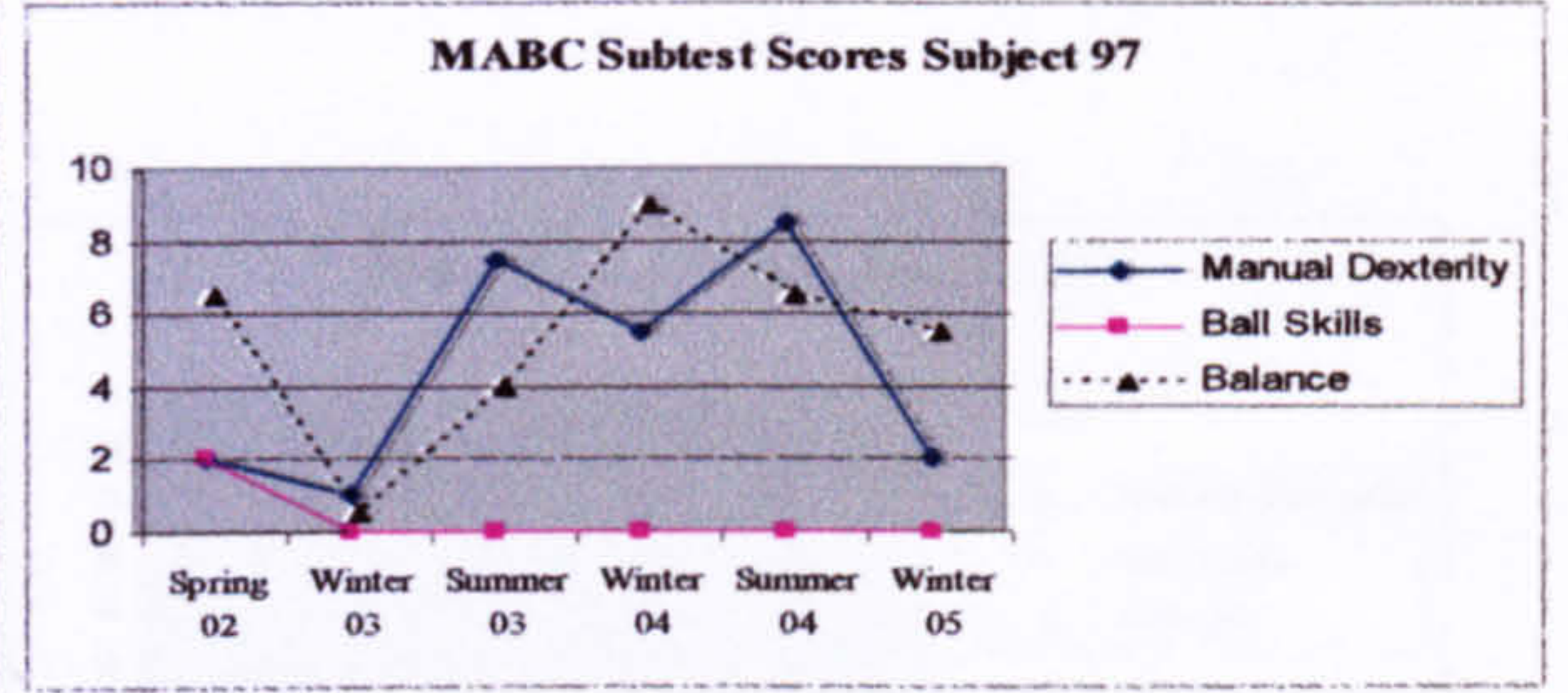
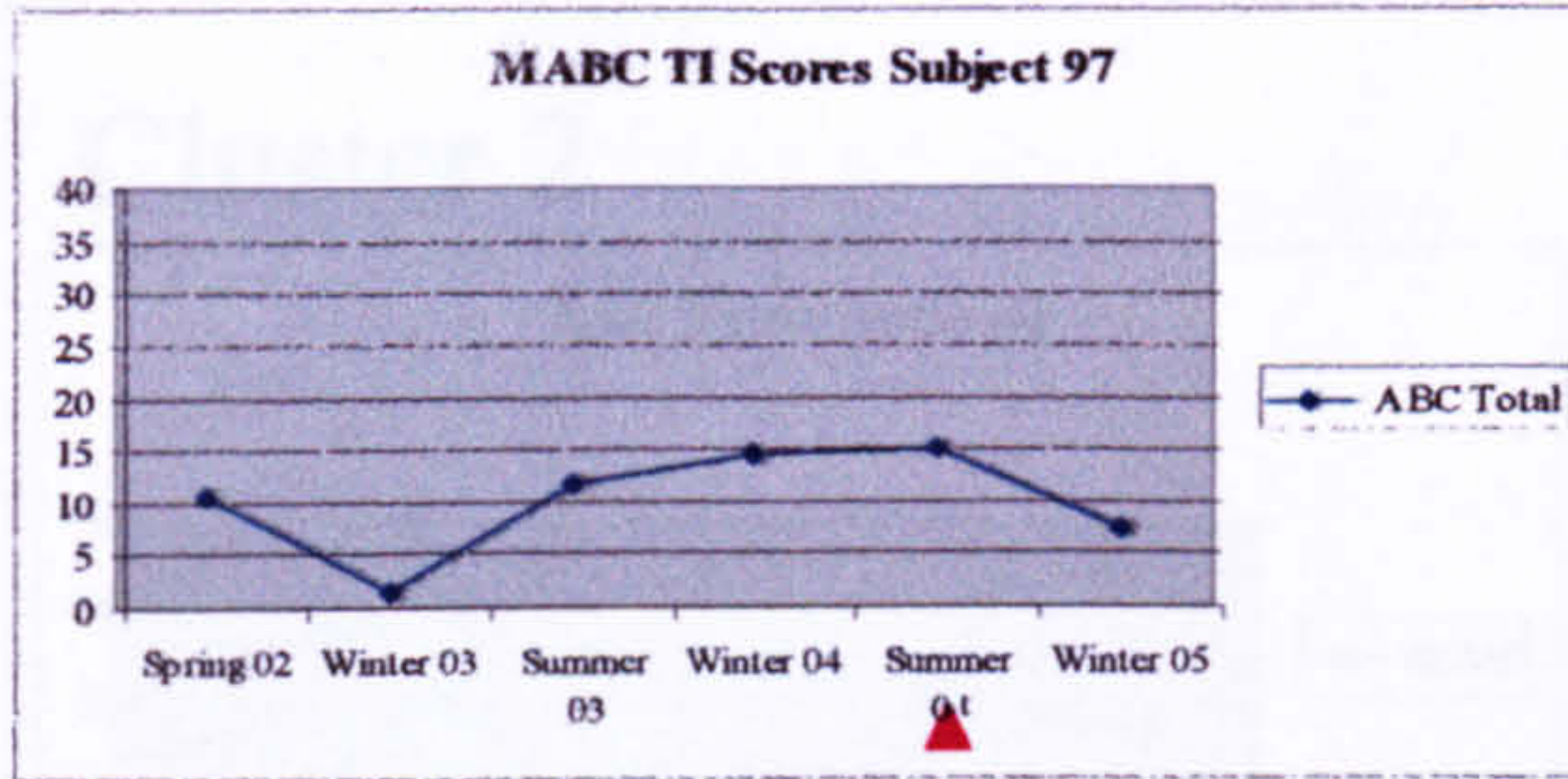
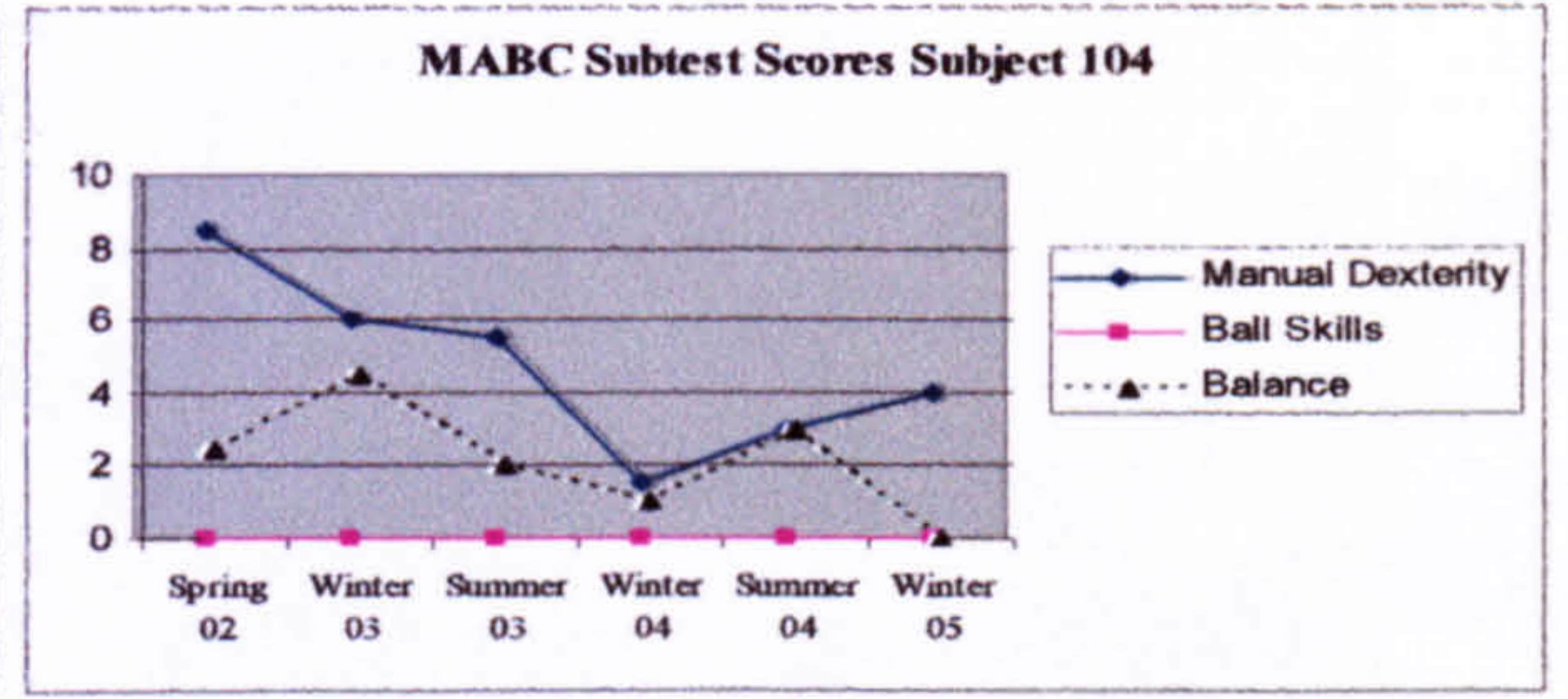
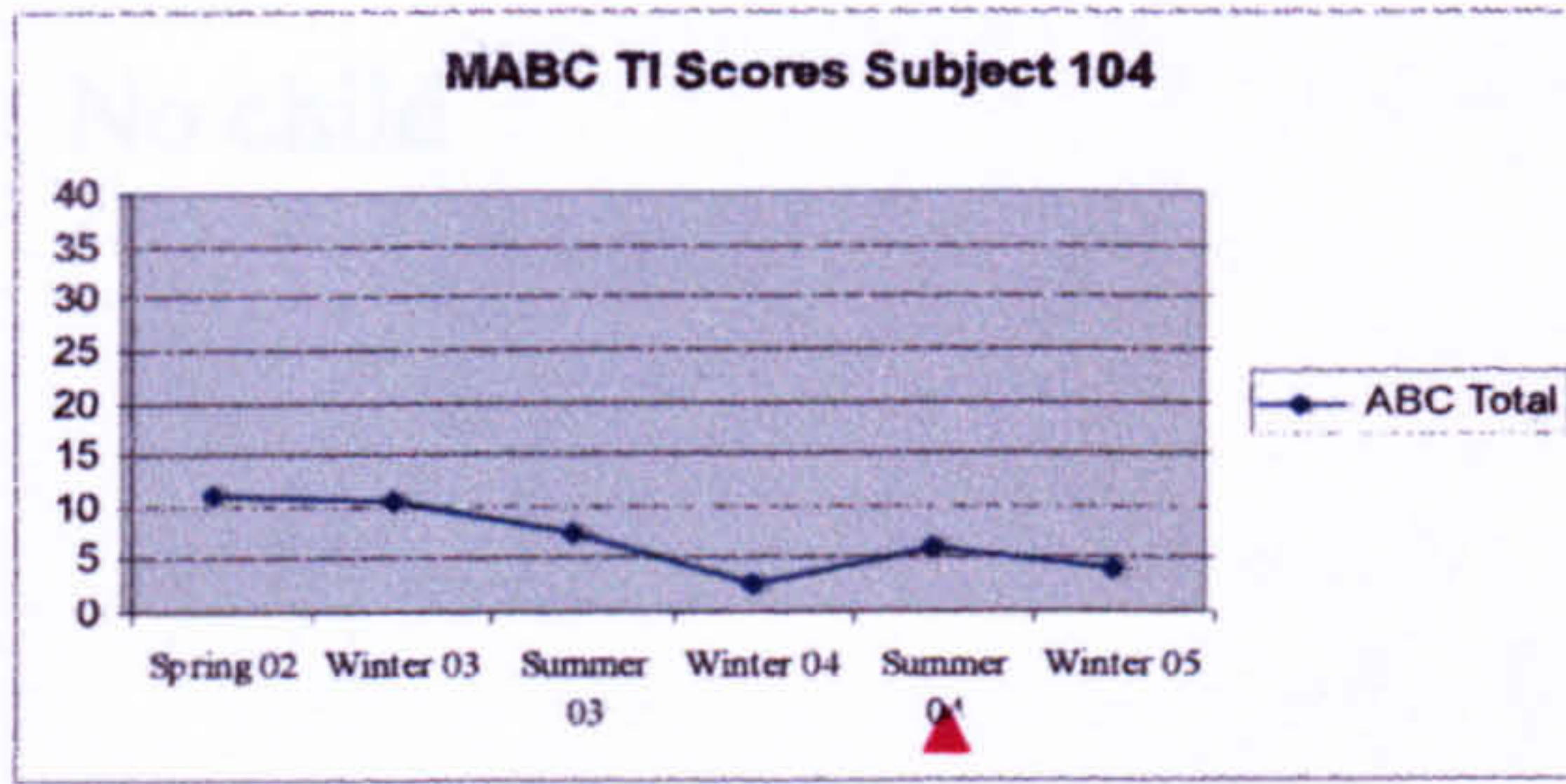


Cluster 5

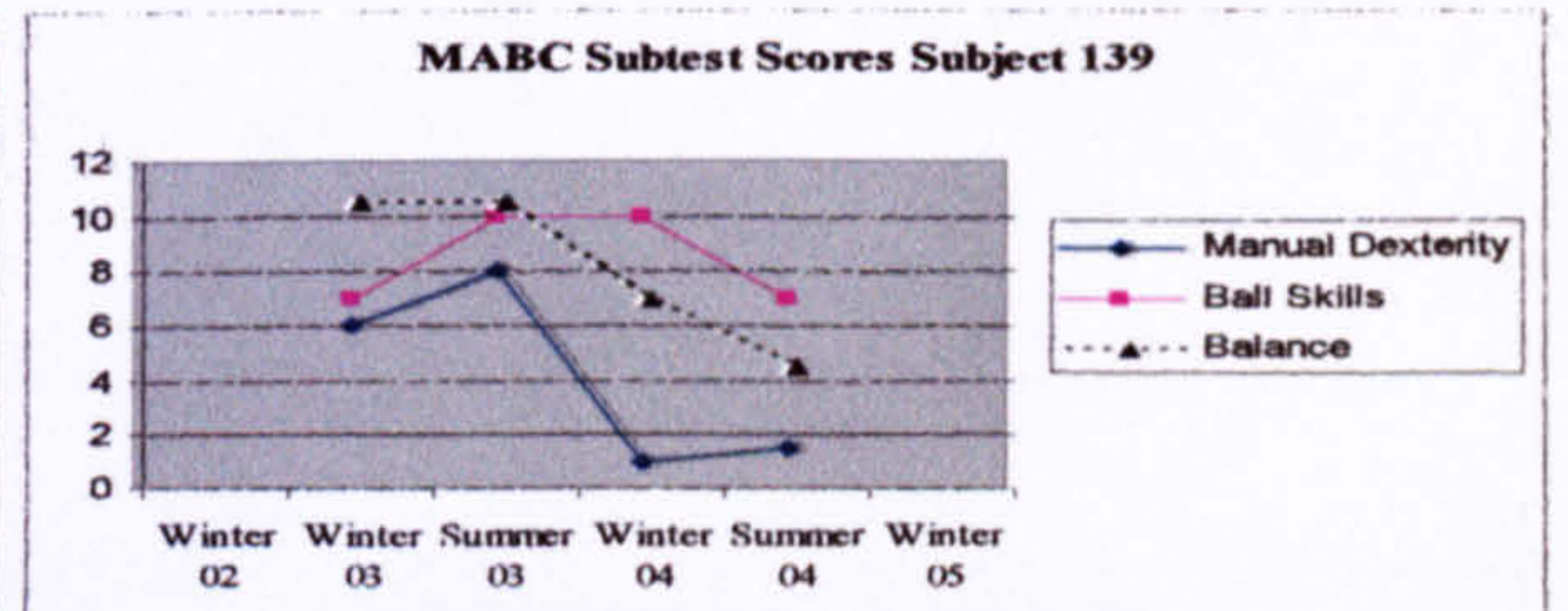
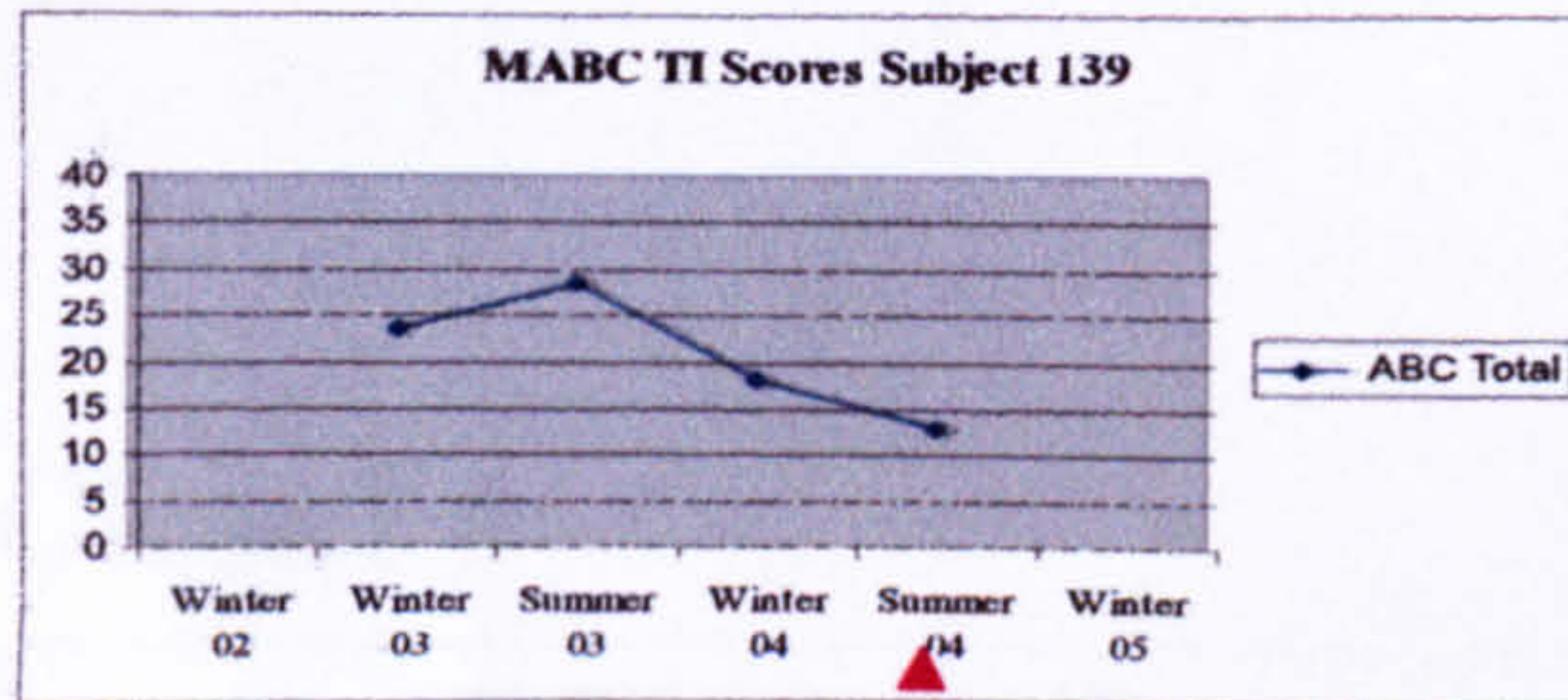


▲ = Assessment immediately following treatment

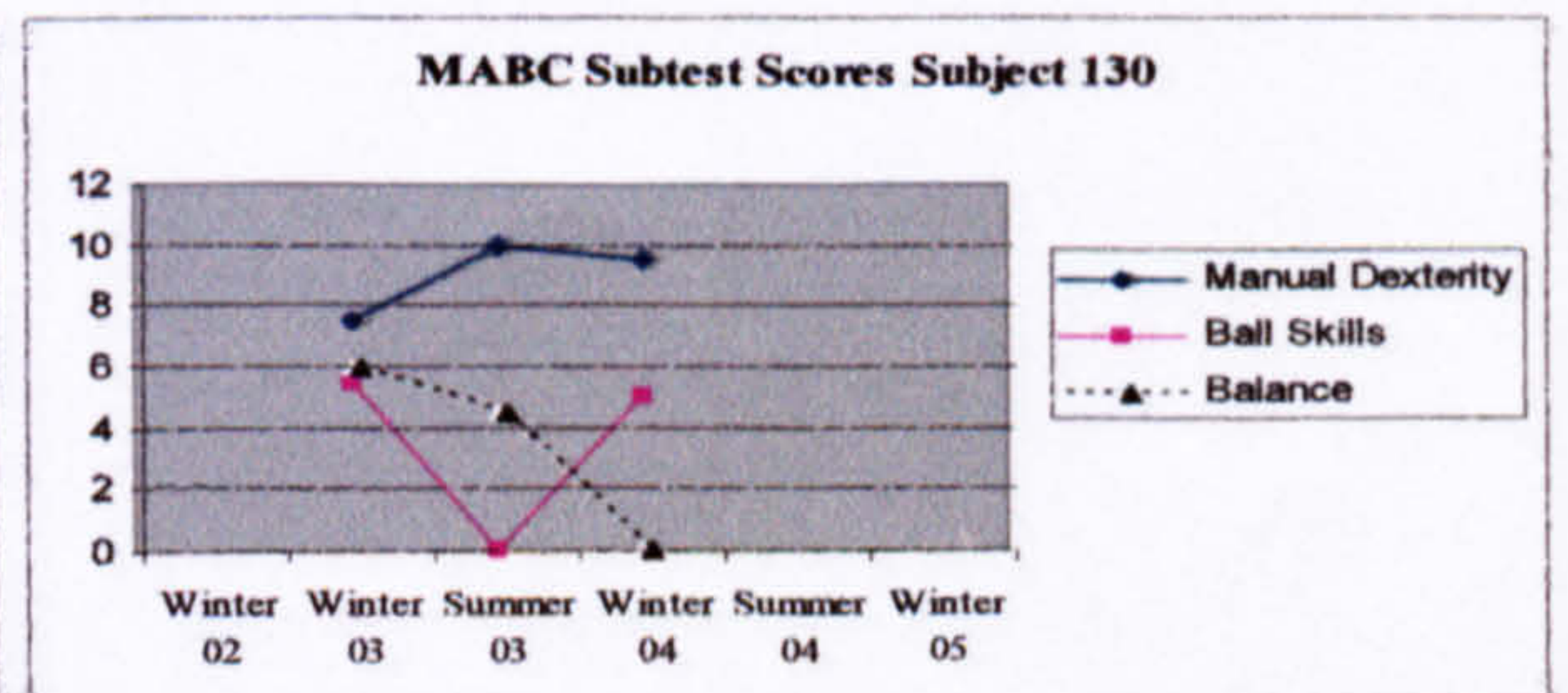
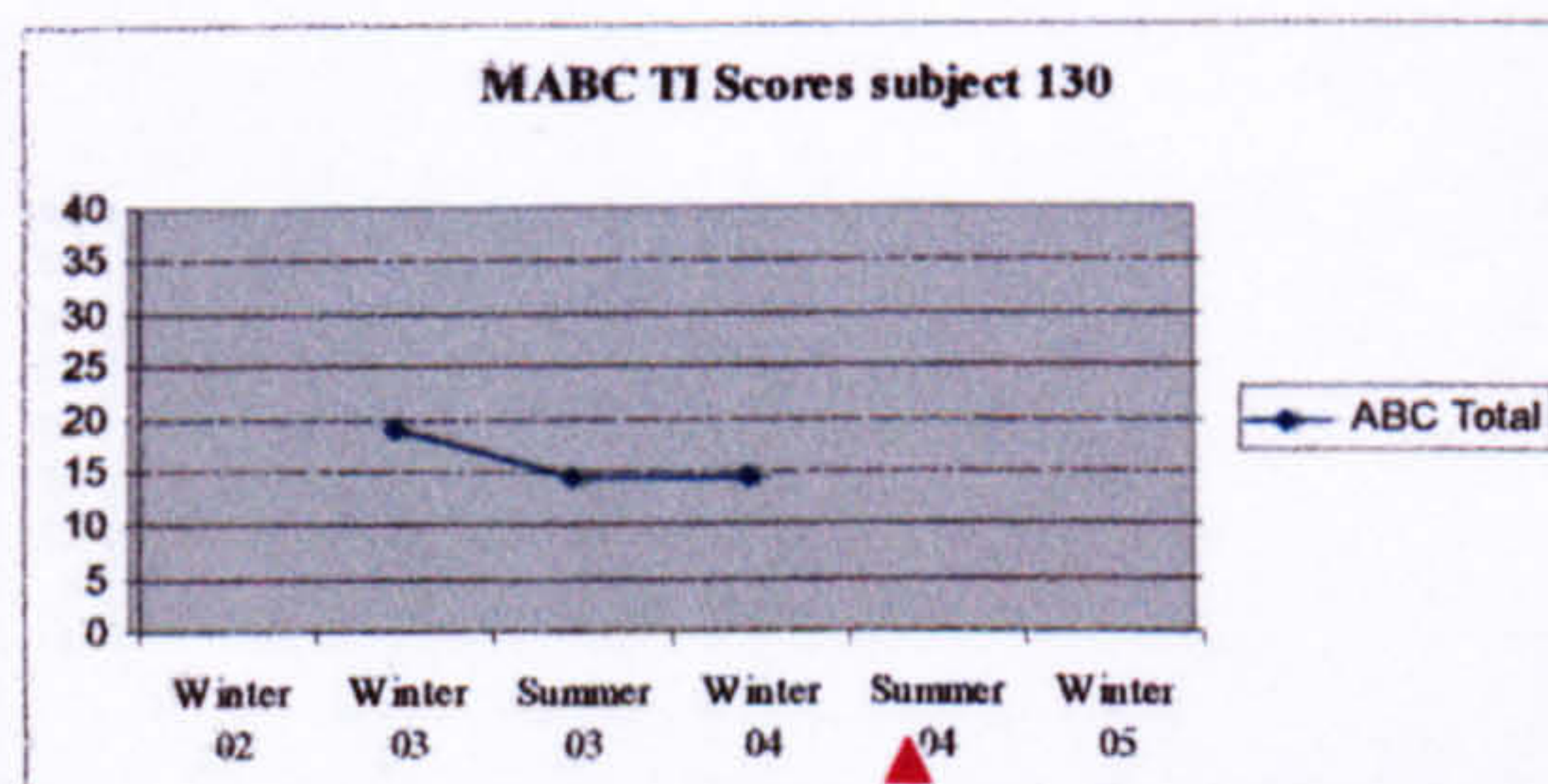
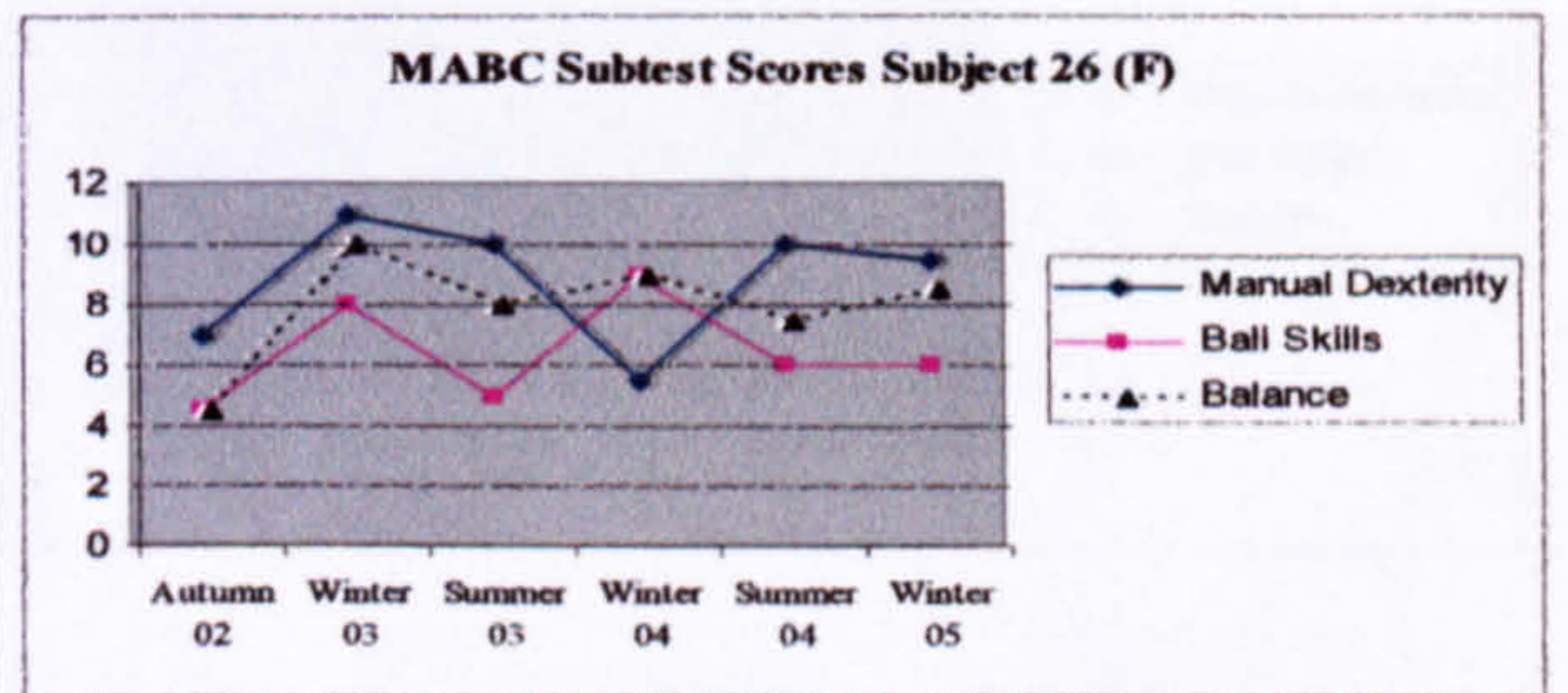
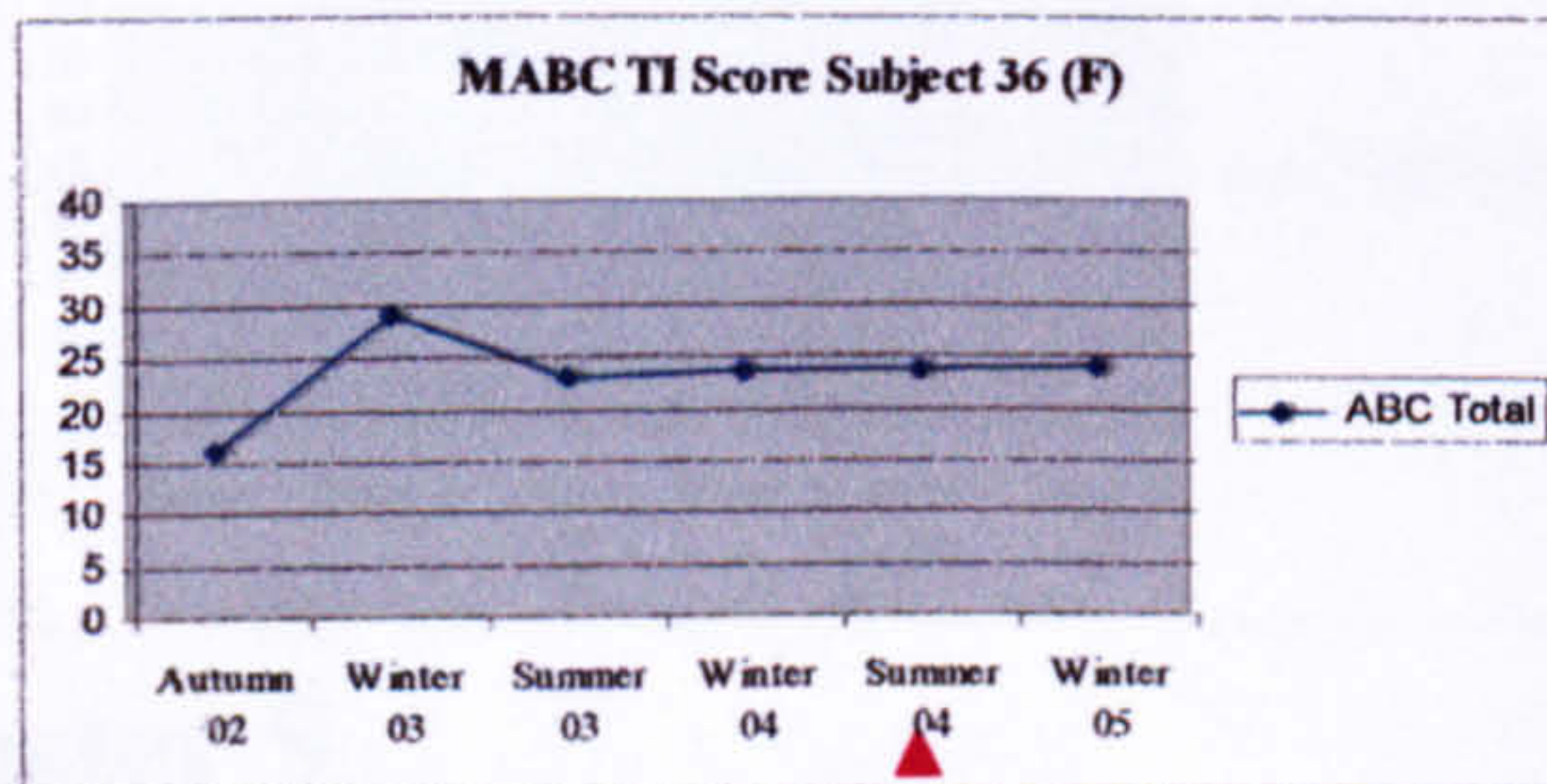
Children treated Jan to Aug 2004 – 9-11 year olds Cluster 1



Cluster 2



Cluster 4



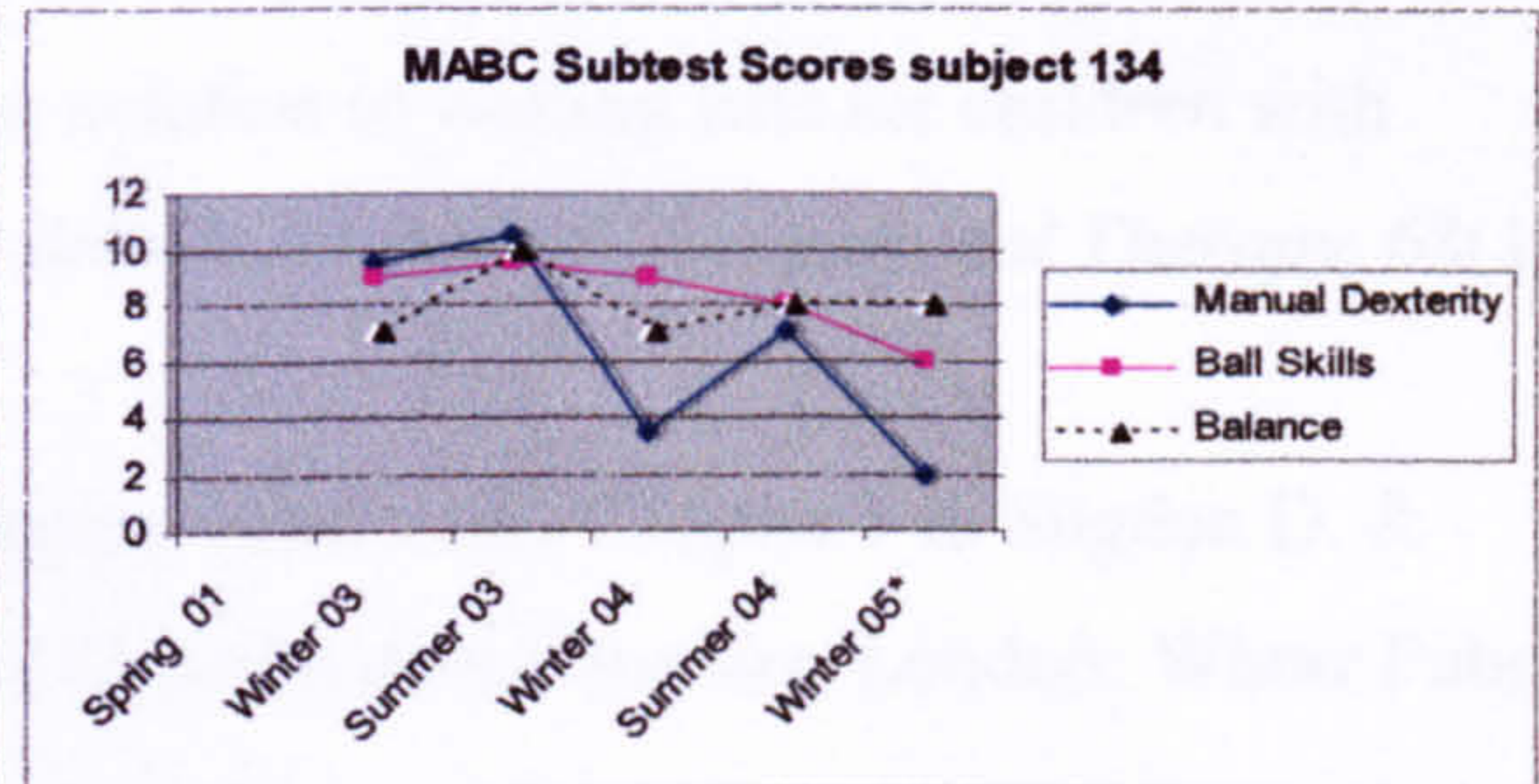
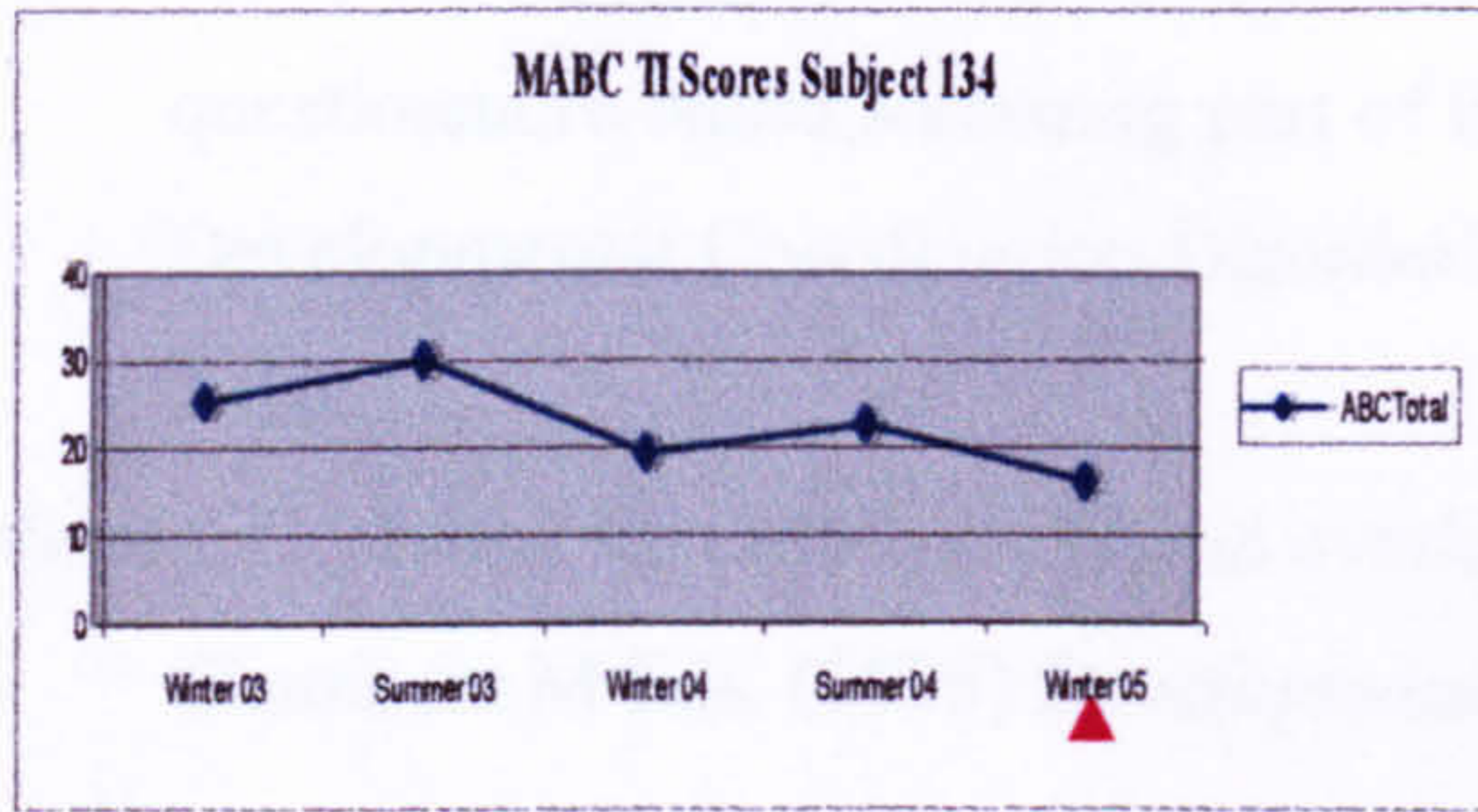
▲ = Assessment immediately following treatment

Children treated Sept 04 to Jan 05 9-11 year olds

Cluster 1

No child

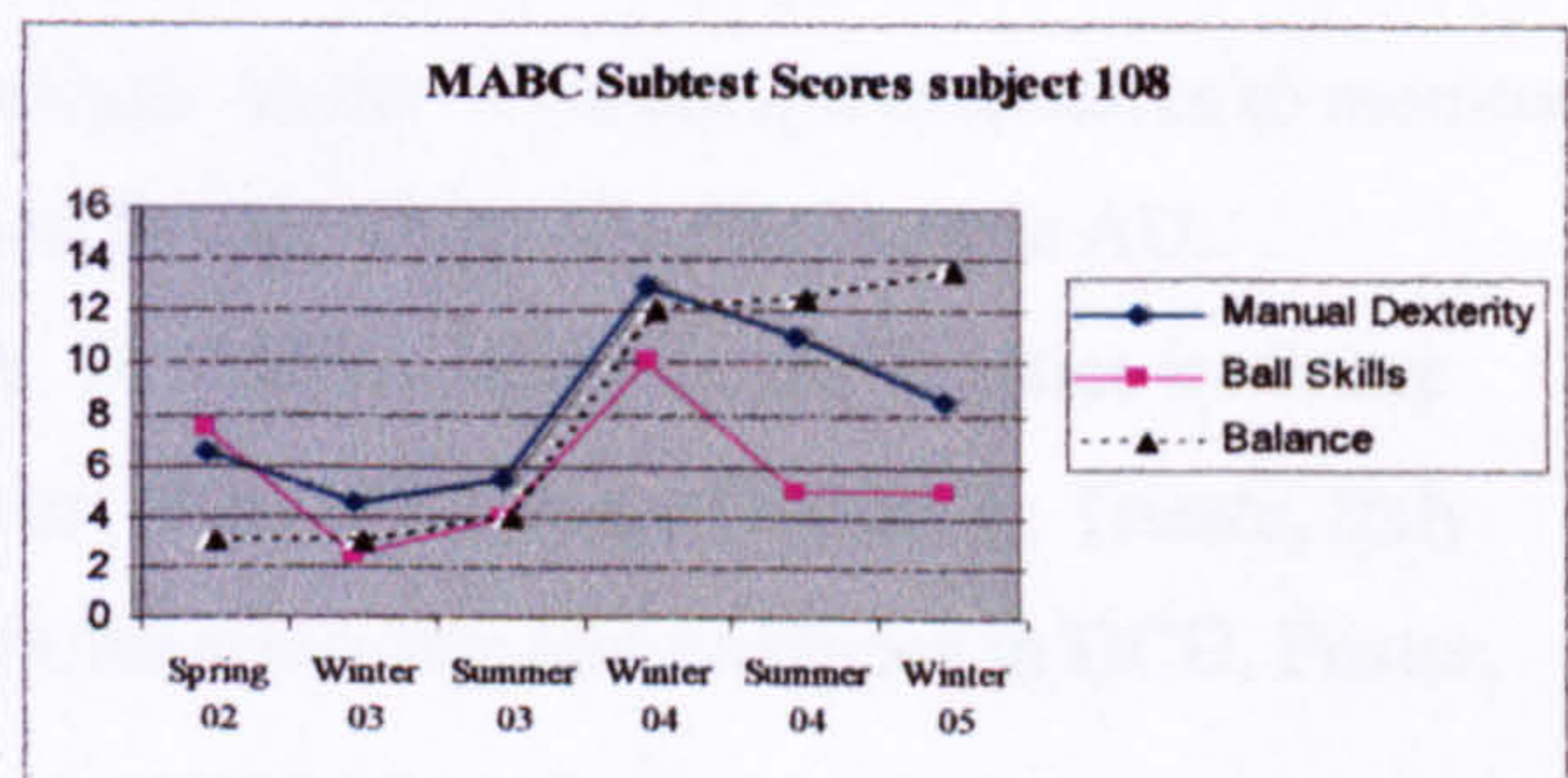
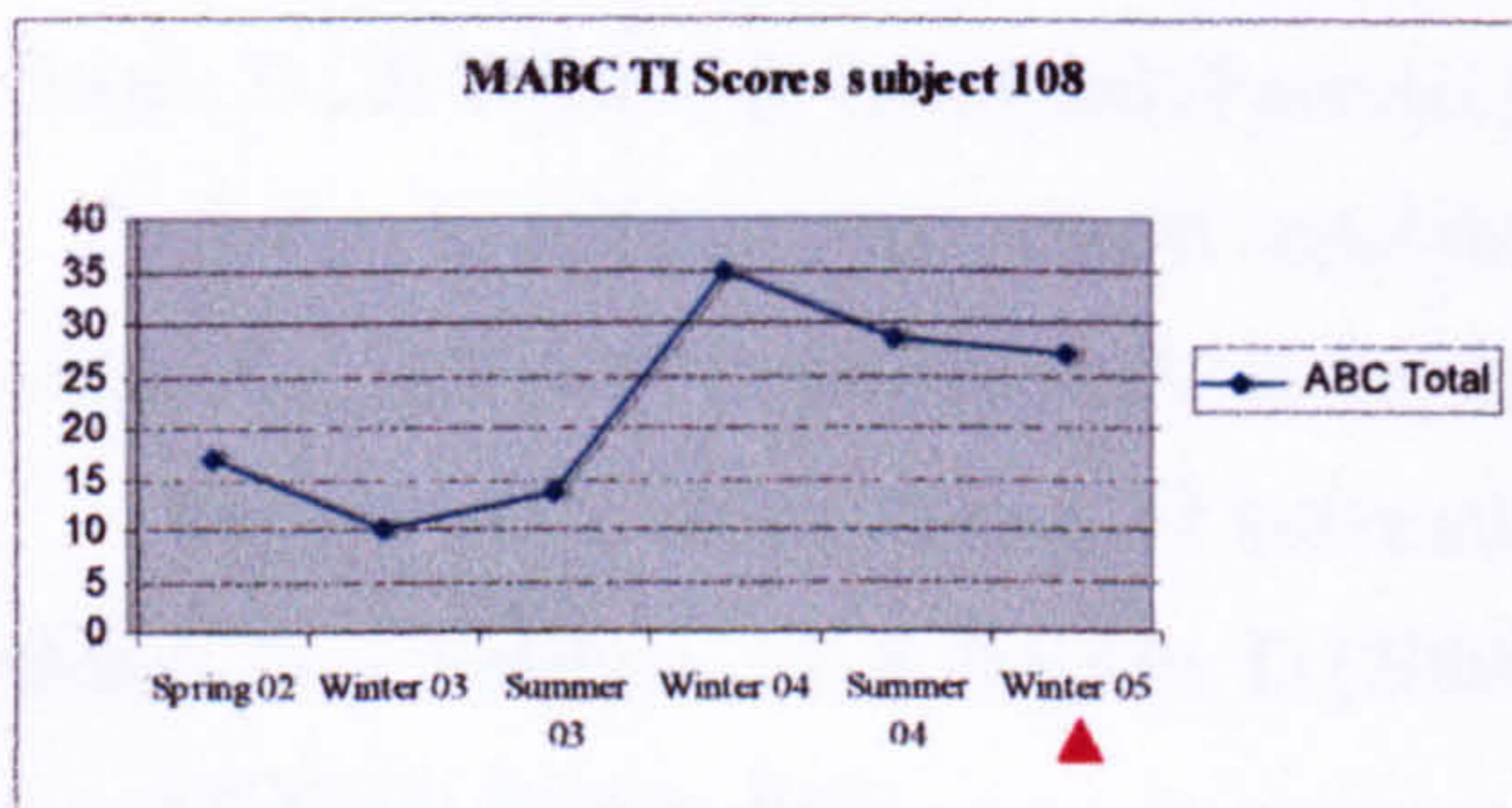
Cluster 2



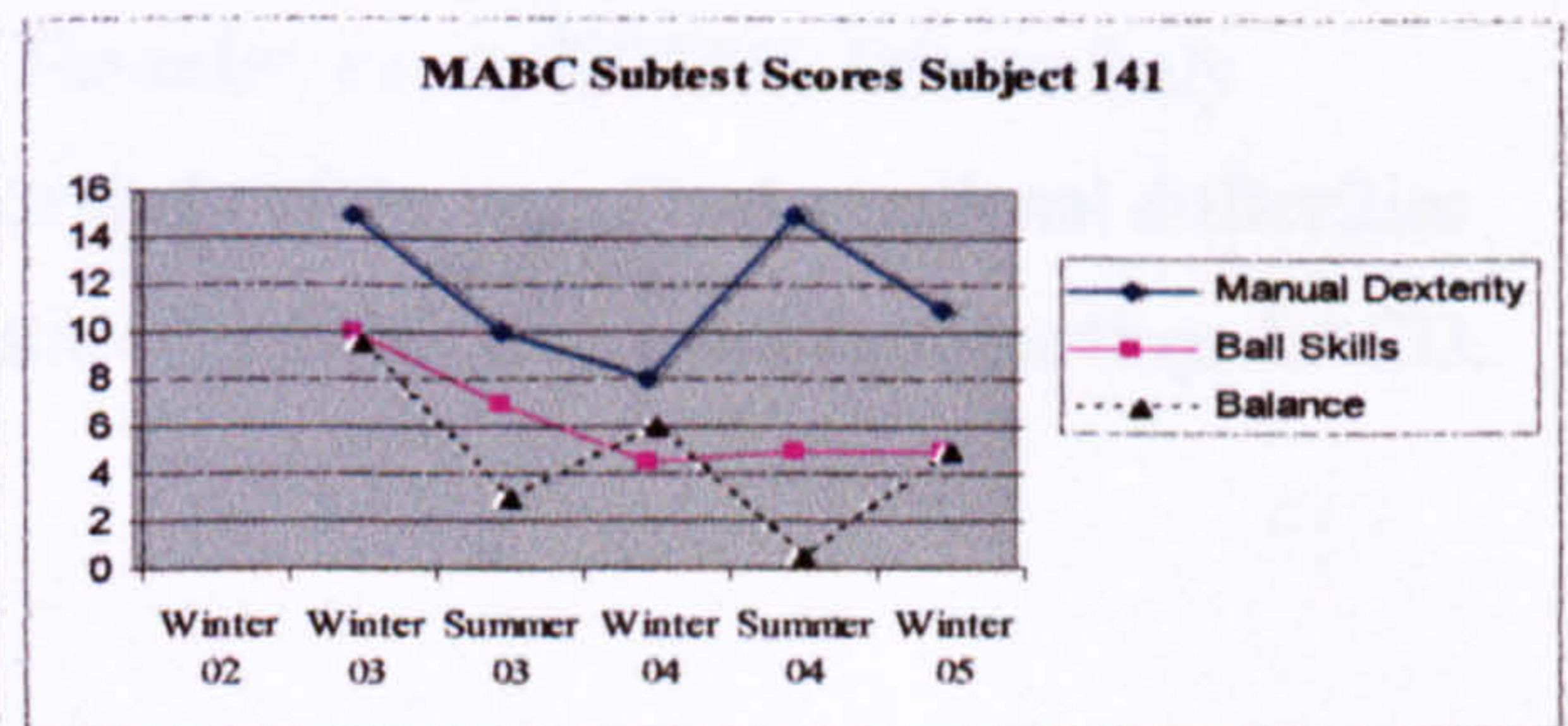
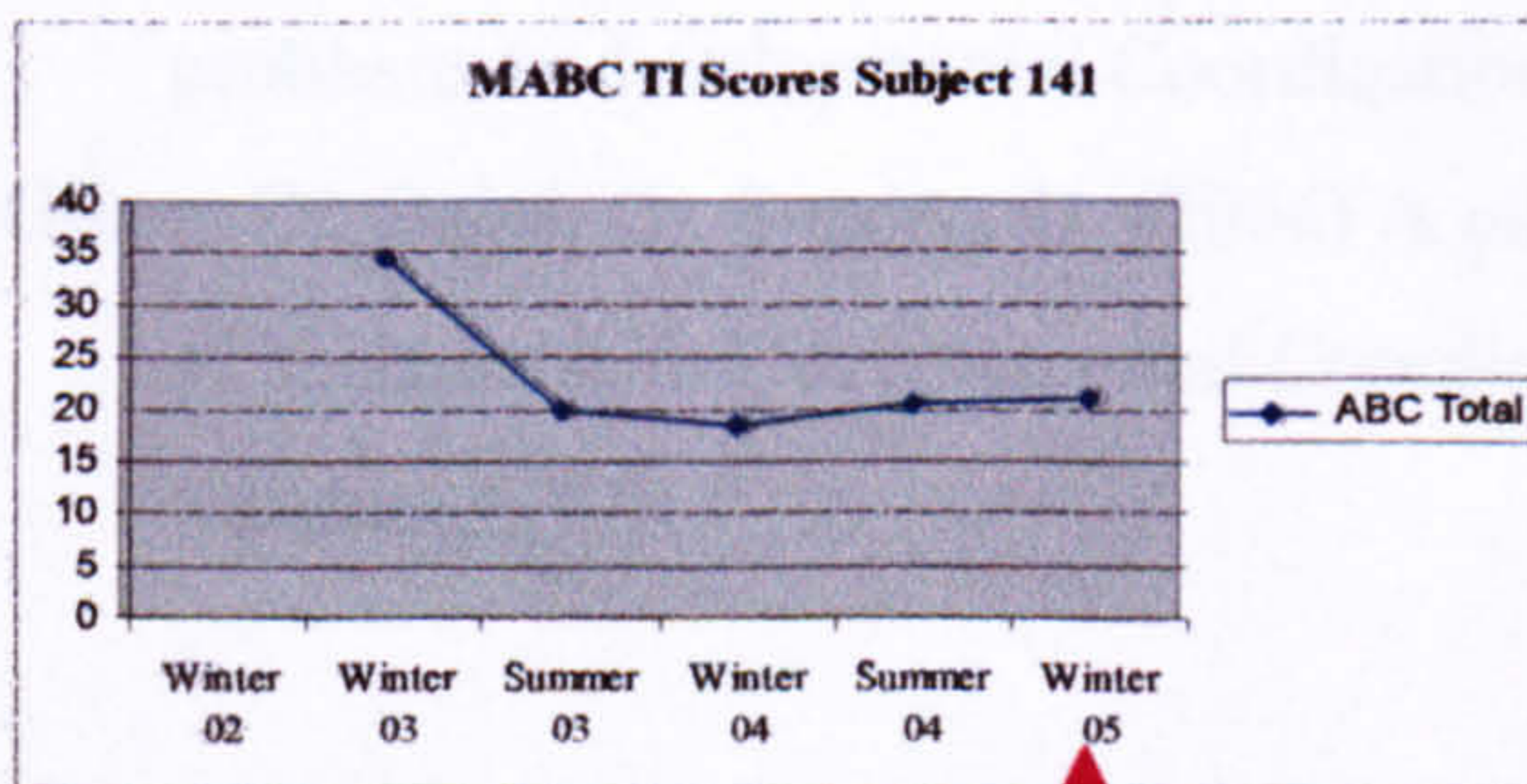
Cluster 3

No child

Cluster 4



Cluster 5



▲ = Assessment immediately following treatment

Appendix 11 - Publications and conference papers arising from study

Publications:

- Green, D., Sugden, D.A. & Baird, G. (2006) A pilot study of emotional and behavioural problems in developmental Coordination Disorder *Child Care Health and Development*, 32 (6), 741-747.
- Green, D., Bishop, T., Wilson, B., Crawford, S., Hooper, R., Kaplan, K., Baird, G. (2005) Is questionnaire-based screening part of the solution to waiting lists for children with Developmental Coordination Disorder? *British Journal of Occupational Therapy*, 68(1) 2-10.
- Green, D., Baird, G. (2005) DCD and overlapping conditions. Chapter 5 in Sugden D. & Chambers M Eds. (2005) *Developmental Coordination Disorder*. London: Whurr Pubs.

Conference Papers:

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