The Nature of Information used for Observational Learning

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Contents

Acknowledgements

I view a Ph.D. as an apprenticeship with the assumption, that when an apprentice completes their Ph.D., they should have acquired the necessary skills to enable them to balance on their own two feet. These skills, like most, require practice and some form of instruction – thankfully, my supervisory team has guided me through my apprenticeship with a confluence of complementary instructions to a level where I believe I can embrace the challenge of becoming a more skilful researcher. To my director of studies (and friend) Dr Mark Scott – thank you for your overriding support throughout my program of work. Your philosophical and pragmatic perspective on research has shaped the way I approach many challenges and at times these philosophies have kept me in some form of stability - thank you. To Professor Mark Williams thank you for offering me the apprenticeship, for opening up numerous academic opportunities and providing the impetus for driving this Ph.D. program forward when necessary - "onwards and upwards"! To Dr Nikki Hodges my theoretical mentor, I am very grateful for your continual questioning throughout my program of work – your drive and enthusiasm for answers and the meticulous nature of your work has significantly influenced my scientific thinking and it changed my life for the better! – thank you. To my friend Dr Rob Horn, thank you for showing me the ropes in the early stages, I have tried to emulate your unselfish attitude to research and the process of teamwork – thank you. To my good friend Nick Smeeton and fellow Ph.D. journeyman – all I need to say is "grazie". To my wonderful parents, thank you, I truly could not have completed this journey with out your continual support – your courage and strength is remarkable. To my sister Alison, you told me I could do it 7 years ago and I did – thank you. These pages are dedicated to my best friend Nire who is truly 'one in a million'! Thank you, SH.

Thesis Abstract

The primary aim within this thesis was to examine the constraining role of relative motion information during observational learning. Across three experiments, the kinematic content of a demonstration and task context was examined to investigate their impacts on reproduction accuracy and learning. In the final experiment, relative motion was examined as an informational variable for facilitating the processes of coordination and control. The data from the first three experiments showed that when adults and children were tasked with imitating a model, the resulting movement pattern was more affected by task constraints rather than the demonstration. Making relative motion salient within a point-light model did not facilitate observers' movement reproduction accuracy. In fact, children observing a point-light model were less accurate than children who viewed a video model (although this was mediated by conceptual training). Relative motion information was directly examined in Experiments 2 and 3. The data showed that relative motion information is not necessary for reproducing intra-limb coordination when end-point information is available. Although the subsequent presentation of a full body model, following only endpoint information, did not change the coordination parameters of the movement in both experiments, it did facilitate the scaling of the movement in Experiment 3. Participants improved their accuracy when partial end-point information preceded the introduction of the full body display. In Experiment 4 it was shown that demonstrations helped to scale a previously practiced movement, facilitating the attainment of the distance-related goal. Relative motion information is not essential for constraining intra-limb coordination when end-point information and suitable task constraints are available and the role of demonstrations is not limited to the acquisition of coordination (cf. Scully & Newell, 1985).

Chapter 1

The nature of observational motor learning

It is unlikely that Kenny Daglish (football – Celtic/Liverpool and Scotland), Marco van Basten (football – Ajax/AC Milan and Netherlands), Martina Navratilova (Tennis - Czech Republic) and Mike Hailwood (motorcycle racing – England) amongst others, were born to be sporting champions. Their ability to control the human body through highly coordinated behaviours was certainly not a function of genetically pre-determined codes or maps. However, there is evidence that some features/aspects of motor behaviour might be a result of pre-determined genetic milestones. Gessell (1946) and McGraw (1943), early maturational theorists specialising in motor development proposed that phylogenetic activities, (i.e., those that are indigenous to species such as walking and standing in humans) are primarily a result of such in-built structures. More recently, however, there has been considerable debate about the mechanisms responsible for these basic abilities, with greater emphasis being placed on interactions between the environment and the person (e.g., Thelan & Clark, 1991).

Unlike these phylogenetic activities, there are many motor behaviours that do not serve a basic function and have often evolved for enjoyment. These are termed ontogenetic and are peculiar to environmental influences and lead to the development of skills that are learnt through practice and experience. The motor skills required of an expert soccer player, for example to accurately propel a ball under varying external conditions, have been shown to be the result of many hours of deliberate and effortful practice (see Ericsson, Krampe, & Tesch-Romer, 1993; Helsen, Hodges, & Starkes, 1998). Although the total amount of practice is an extremely important variable underpinning the development of expert behaviour, the quality of the practice, including such factors as feedback, instructions and demonstrations, play a highly significant role in the development of motor skills.

To become an expert performer the learner has to start somewhere, and that somewhere is on the lowest rung of the motor skill ladder characterised as being in the early stage of motor learning. Many theorists from different conceptual backgrounds describe the journey 'on becoming skilful' as a progression of stages (Adams, 1971; Bernstein, 1967; Fitts & Posner, 1964; Gentile, 1972; Newell, 1985; Schmidt, 1975). Fitts and Posner's (1964) three-stage model of motor learning (one of the most widely cited in skill acquisition theory) has as its fundamental premise that in early skill acquisition, the learner cognitively controls the action through a conscious step-by-step process. During this stage, Fitts and Posner and others have proposed that the learner is challenged with 'getting an idea of the movement', that is an understanding or the general movement pattern or topology that describes a to-be-learnt motor skill (see Gentile, 1972; Newell, 1985). As skill acquisition progresses it is proposed that the learner passes through this initial *cognitive stage* to an *associative stage* where the need for conscious control diminishes and the learner begins a process of refinement (or controlling/parameterising, see Newell, 1985). With extended practice, performance reaches a proposed *autonomous stage* where conscious attentional control is not required. Fitts and Posner's ideas were primarily based upon anecdotal evidence and the acquisition of skills which placed little demand on the motor system. In addition, there was little guidance as to how the three-stage approach could be formally tested. Since this time there have been two theories of motor control and learning which while at least implicitly embracing the ideas of Fitts and Posner, have provided more testable predictions and hence evidence for the nature of the motor skill acquisition process. The theories of Adams (1971, closed-loop theory) and Schmidt (1975, schema theory) are briefly discussed below in terms of their contribution to our current understanding of motor learning generally and observational learning more specifically. Moreover, there has been a shift in thinking away from the cognitive accounts of motor learning towards the idea that stable behaviour patterns, that over time, evolve through the exploration and interaction of intrinsic (biological) and extrinsic (augmented) information sources (see Newell, 1986; Newell & Vaillancourt, 2001; Newell, Mayer-Kress & Liu, 2001).

Motor Learning: Brief Theoretical Background

In skill acquisition, a distinction has been made between performance and learning. Performance is defined as observable behaviour, such as hitting a tennis ball, catching a rugby ball or writing your name. Learning is defined as internal cognitive phenomena that cannot be observed and is defined as a relatively permanent change in behaviour (see Magill, 2004; Schmidt & Lee, 1999). A fundamental aspect to the cognitive theories of skill acquisition (e.g., Adams, 1971; Fitts & Posner, 1964; Schmidt, 1975) is that with practice and extended performance the learner develops cognitive representations of actions. Early motor learning theorists saw these representations as stored structures (or motor programs, see Keele, 1968) that contained all the information necessary to control and execute the entire movement from central control (stored programs within memory) without the influence of peripheral feedback. However, the motor program viewpoint was somewhat extreme because such a view only accounted for a limited number of open-loop movements. Based on this limited account of motor learning researchers began to ask questions that related to how learning and movement control operated in conjunction with sensory feedback processes (see Schmidt, 1975; Adams, 1971).

Adams (1971) proposed a two-state representational model for motor learning. Accordingly, these traces have different motor and memory functions where a *memory trace* is responsible for selecting and initiating the movement and a *perceptual trace* performs a reference-of-correctness role. The *perceptual trace* is developed through practice and is based on the sensory consequences of the action. The learner develops skilled behaviour by carrying out multiple, typically self-paced movements to a target location and through comparisons of self-produced feedback with actual performance error (knowledge of results), the strength of the perceptual trace is established. The development of these two independent memory mechanisms has been examined and verified in a number of experiments (see Adams & Goetz, 1973; Newell, 1974; Schmidt & White, 1972). The main criticism of Adams's theory is that it only accounts for slow, self-paced movements and that the memory representations that develop are formed uniquely for every movement (i.e., a one-to-one mapping structure for recall and recognition). By laying down a separate trace for every movement the learner is challenged with storing an innumerable amount of traces within the central nervous system (see Magill, 2004; Newell, 1991; Schmidt & Lee, 1999). Moreover, in a one-to-one mapping system there is the implicit problem of producing novel movements, that is, how can a motor program be responsible for the production of a novel movement?

Although important to the development of motor learning theory, the closed-loop theory was relatively short lived with some of its limitations (i.e., storage and novelty) being addressed by his student, Schmidt (1975) in his schema theory of motor learning. Similar to the closed-loop theory, Schmidt also distinguished two memory mechanisms for *recall* and *recognition* but additionally incorporated the idea of schemata. A schema is a rule that represents the <u>general</u> relationships between variables as opposed to the absolute relations seen in Adams's one-to-one mapping system (see Schmidt, 1975). By applying a generalised schema rule to motor control and learning he reduced the cognitive representational demands on the memory system and developed principles to form new motor behaviours. Like Adams's *memory trace* and *perceptual trace* the *recall* and *recognition* schema are developed as a function of practice and experience (Schmidt, 1975). The *recall* schema is based on the actual outcome and response specifications, and the *recognition* schema based on the relations between the initial conditions of the movement, the sensory consequences of the movement and actual outcome. An important feature of Schmidt's schema theory is the generalised motor program (GMP). The GMP allows the learner to formulate new movements (within a certain class of actions) by making specific calculations based on the parameters of the recall schema. The process of selecting these motor programs to satisfy particular goals and/or refining motor actions is facilitated if learners engage in variable practice (e.g., practice putting a golf ball to different target distances compared to one distance, see Shapiro & Schmidt, 1982). Although Schmidt addressed the limitations of the closed-loop theory, he has been criticised for not explaining the nature and development of the representation, how the learner performs the first response before a schema exists (see Kugler, Kelso, & Turvey, 1980; Newell, 1991).

The conceptual ideas of the 'degrees of freedom problem' (Bernstein, 1967) influenced the way some researchers approach skill acquisition from a dynamical systems, synergetics or ecological perspective. Bernstein (1967) proposed that through practice performers learn to coordinate independently an increasing number of degrees of freedom (e.g., joint configurations, muscles, motor units). This process is reflected in the search for an optimal coordination solution. Through learning, this process has been characterised by an initial freezing (reducing) of the many biomechanical degrees of freedom involved in a movement, such as by locking joint angles so that the system operates as a single unit. As skill progresses the learner begins to release the restrictions on the system until its conversion to a controllable system (see Kugler et al., 1980), or in other words the learner masters a large number of redundant degrees of freedom (see Bernstein, 1967; Newell & Vaillancourt, 2001; Newell & van Emmerick, 1989). The 'degrees of freedom problem' has prompted a shift on how motor control and coordination is conceptualised and influenced Kugler et al.'s (1980) and later Newell's (1985) ideas of coodination, control and skill.

The distinction between coordination, control and skill was formulated by Kugler et al. (1980). Coordination is the function that constrains the potentially free variables into a behavioural unit. Control is the process by which certain values are assigned to the variables in the behavioural unit in order to refine or parameterise the function and skill requires the optimal values to be assigned to the controlled variables. In terms of motor learning Newell (1985) made specific proposals as to the concept of coordination, control and skill. He suggested that motor learning does not progress through separate stages but reflects an embedded hierarchy of coordination, control and skill (see Bernstein, 1967). This implies that in the early period of motor learning the learner is primarily concerned with acquiring an appropriate (optimal) set of topological characteristics of the body and limbs. Newell (1985) based this proposal on research evidence taken from the perception of biological motion (see Johannson, 1973). According to Johansson, the topological properties of an action as characterised by the relative motions of the limbs, that is the motion of individual elements of the configuration relative to each other, specify the perception of a given activity (e.g., throwing or somersault). Therefore, for the acquisition of coordination, the learner needs to adopt the appropriate relative motion characteristics of the to-be-learnt action. Practice is then necessary for refinement or scaling of the relative motions with optimal scaling reflecting skilled performance (Newell, 1985).

The theories of motor control and learning which have been influenced by Bernstein (such as dynamical systems theory, synergetics and ecological perception) have been characterised by their reluctance to discuss motor control and learning in terms of cognitive representations and stages. Skill acquisition is seen as a process of searching for the optimal solution to the motor problem (see Haken, 1977; Kelso, 1995; Newell, 1985, 1986). The search for an optimal coordination solution is governed by a mutual interaction between the properties of the learner and the environment or in other words a perception-action coupling (see Gibson, 1966, 1979; Shaw & Alley, 1985). Newell (1989) discussed this search as one in which the learner explores a perceptual motor workspace which is specific for the task /motor problem. The perceptual motor workspace is the interface (bi-directional link) between the information contained in the environment (optic array; energy flows fields) and the human organism (Newell, 1989). Based on this interaction motor learning evolves through a search for equilibrium regions or attractors (order parameter(s), see Haken, 1977; Haken, Kelso, & Bunz, 1985) that describe the qualitative feature of the movement dynamics (at a macrolevel a movement topology is constrained). Skilled behaviour is determined when the learner is able to resourcefully solve the movement coordination problem based on the *pick-up* and utilisation of task relevant information from the organism-environment interaction (see Gibson, 1966; Newell, 1996; Jacobs, Michaels, & Runeson, 2001). Similar to the research undertaken to examine the cognitive structures that control motor control and learning (Adams, 1971; Schmidt, 1975), research from a dynamical/ecological viewpoint has been directed at understanding and explaining the nature of the variables that 'organise' the coordination function, such as biological sub-systems, muscle units, limbs (for example Huys, Daffertshofer, & Beek, 2004).

In terms of the skill acquisition process, the main research focus within this thesis (chapters 2, 3, 4) will be directed at questions relating to the early stage of motor learning, with particular attention to the acquisition of a new movement pattern (see Gentile, 1972; Newell, 1985). Because ontogenetic motor skills cannot be accounted for by hard-wired neural constraints (see Newell, 1991; Newell, Kugler, van Emmerick, & McDonald, 1989), their acquisition is likely to be highly influenced by augmented information sources (see Hodges & Franks, 2004) and /or the interaction of informational constraints between the perceiver and the environment (see Newell, 1986). As stated, a fundamental concern with cognitive accounts of motor control and learning (i.e., Adams, 1971; Schmidt, 1975) is that they do not account for the formation and execution of novel movements. However, there has been evidence to suggest that the initial development of a motor program (or schemata) is formed via observational mechanisms (Adams, 1986; Blandin, Lhuisset, & Proteau, 1999; Blandin & Proteau, 2000). Also a possible solution to the problem of acquiring a new coordination pattern (see Newell, 1985) is through modelling strategies where learners attempt to imitate a model displaying the desired topological properties of the to-be-learnt action (Newell, 1985).

Imitation and Observational Learning

Imitation

Observational learning is suggested to be one method for developing the mechanisms that promote skill acquisition, such as the formation of motor schemas

(Blandin, et al., 1999; Blandin & Proteau, 2000) and/or directly constraining the acquisition of a new coordination function (Newell, 1985; Scully & Newell, 1985). The process of imitating underpins observational learning (see Williams, Davids, & Williams, 1999) and implies a specific causal relationship between observation of a feature of a model's body movement and the execution (copying that feature) by the observer of that same movement (Heyes, 2001). The mechanisms that drive imitation are still not fully understood but recent behavioural and neuroscience evidence is beginning to provide some light (e.g., di Pelligrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Wohlschläger, Gattis & Bekkering, 2003).

The common view about how perception and action are mediated during imitation is through a direct matching mechanism that compares the perceived information with the perceptual response (see Gray, Neisser, Shapiro, & Kouns, 1991; Vogt, 1995, 1996). For example, evidence form infant research indicates that early facial imitation is controlled by 'active intermodel mapping' (AIM) (Meltzoff & Moore, 1977, 1983). The central notion to AIM is a matching-to-target process whereby the model is the target and the self-generated movements performed by an infant initiate proprioceptive feedback which the infant compares to the visual target (model) during the imitation process (see Meltzoff & Moore, 1977, 1983). Recent AIM work has extended the simple tongue protrusion findings to show that infants can imitate novel tongue protrusions (that need more complex proprioceptive monitoring, i.e., AIM) and that they can recall the imitated action 24 hours later (Meltzoff & Moore, 2002).

Although the postulations of a close perception-action (direct-mapping) link have been primarily based on behavioural data (see Al-Abood, Davids, & Bennett, 2001; Gray, Neisser, Shapiro, & Kouns, 1991; Vogt, 1995, 1996) there is neuroscience evidence that provides strong support for this postulation. For example, neurophysiological evidence indicates that certain neurons within the macaque's pre-motor cortex (area F5) fire during both imitation and execution and are called 'mirror neurons' (Pelligrino et al., 1992). Since this demonstration in monkeys there has been evidence from brain imaging studies in humans which show the human brain to have similar clusters of neurons located in Broca's region of the cerebral cortex (homologous with area F5; e.g., Rizzolatti, Fadiga, Matelli, Bettinardi, Paulesu, Perani, & Fazio, 1996). Moreover, using a transcranial magnetic stimulation (TMS) technique Fadiga, Fogassi, Pavesi and Rizzolatti (1995) showed that the pattern of muscle excitation evoked through TMS during action observation was similar to the pattern of muscle contraction during action execution. Although these findings indicate that a mirror system exists it is still unclear if humans initiate their imitated actions based on compatible mirror neurons. However, such a system may explain how learners acquiring new skills might be able to transform the observed act into action, without the need to refer to hypothesised abstract structures.

So far the underlying imitation mechanisms have been related to a direct-matching mechanism but other researchers offer an alternative interpretation of imitation based on a process of cognitively decomposing the perceived information into a hierarchy goals (see Bekkering, Wohlschläger, & Gattis, 2000; Wohlschläger, Gattis, & Bekkering, 2003). Bekkering and colleagues argued that the AIM theory and more direct mapping theories (mirror neurons) do not account for the consistent errors shown by observers when imitating. For example, when children are asked to copy a model who touches their left ear with their right hand consistent imitation errors are seen whereby the children touch the correct ear with the wrong hand (see

Wohlschläger et al., 2003 for similar findings with adults). Therefore, instead of a direct mapping mechanism or one that compares the target response with proprioceptive feedback (where the error would eventually be detected and corrected), the mechanism is based on a hierarchy of goals (Bekkering et al., 2000). During goal-directed imitation behaviours are not directly replicated but decomposed into a hierarchy of constituent goals not elements of motor parts (e.g., ear) (see Bekkering et al., 2000). Once these goals have been decomposed the reconstruction process which controls the reproduction of a motor pattern is governed by the resource constraints of the observer. For example, when resources are limited (as seen in young children), a more simplified version of the original action will be reproduced, typically one that contains the dominant goal(s) (e.g., the ear not the arm movement).

These empirical data (and theories) offer important insights into the complex nature of imitation and researchers are beginning to link the observed act to the neural mechanisms that directly execute the imitated act (Rizzolatti, et al., 1996). Although imitation is the fundamental mechanism, observational learning is a more relevant concept for investigating skill acquisition. The concept of observational learning necessitates some measure of long-term change in behaviour (Adams, 1986; Bandura, 1977; Schmidt, 1975). Moreover, imitation performance has been typically assessed through dichotomous frequency variables such as if the desired behaviour was present or not (e.g., Meltzoff & Moore, 1977; Wohlschläger, et al., 2003). Whereas observational learning, with a specific emphasis towards skill acquisition and hence typically an older age group, has been examined using specific measures of movement quality (such as form analysis and more recently, 3D kinematic analysis) and goal attainment (such as outcome success). Because learning is directional, and changes across time, it is measured against a criterion goal, whether this is replication of the action or attainment of a particular outcome (in cases when the two can be separated).

Observational Learning

Information processing mechanisms associated with observational learning.

Early behaviourist accounts of observational learning (such as Miller & Dollard's, 1941 Social Learning and Imitation theory) were deemed inappropriate as learning models because they did not take into account or explain the (cognitive) mediating factors within the organism. In particular they failed to explain the mechanisms that transposed the observed behaviour into a new behaviour (pattern matching mechanism) and did not examine reproduction of the observed behaviour at a later time point when the model was not present (see Bandura, 1971). Sheffield (1961) proposed a Systematic Representational Theory that was a step forward in terms of the conceptual nature of the cognitive mechanisms associated with observational learning. Based on learning complex human motor skills (e.g., mechanical assembly tasks) Sheffield proposed that a cognitive-representation of the action is formulated through processes of association and contiguity. This cognitive representation acts as a 'blueprint' (or plan) that guides the recall and subsequent assembly of the motor skill. Although Sheffield's cognitive symbolic theory preceded the work of Bandura, Bandura's Social Learning Theory (1977, later revised to Social Cognitive Theory, 1986) has been the framework generally used to examine observational learning (see McCullagh & Weiss, 2001). Bandura (1977, 1986) incorporated cognitive representation ideas, but developed mechanisms that accounted for the acquisition and modification of behaviour (see McCullagh & Weiss, 2001; Williams, Davids, & Williams, 1999). Bandura proposed that observed behaviour is stored in a representational format, which is then activated through internal processes to mediate overt behaviour. These internal processes work together to govern observational learning and are characterised as four sub-processes; attention, retention, production, and motivation.

Attention represents the first sub-process where the observer perceives significant features of the modelled display. This subporcess is critical to the acquisition of new behaviour because unless the information is attended to, the observer will not learn from the observed action (Bandura, 1977). Attention is a selective mechanism that is influenced by model and observer's characteristics. The complexity, discriminability and saliency of the modelled action control the observers' attention to specific sources of information and thus mediate observational learning. According to Bandura, the cognitive capability of the observer, arousal level and functional value of the perceptual information affect the pick-up of sensory information. He hypothesised that observers pay closer attention to models that possess symbols reflecting status, are older and highly skilled (e.g., McCullagh, 1986; Lirgg & Feltz, 1991). The provision of supplementary verbal cues is also suggested to facilitate the pick-up of specific features from the display if the action is complex. For example, Carroll and Bandura (1990) found that sequence and timing cues associated with the components of a to-be-learnt action aided learning (see also Janelle, Champenoy, Coombs, & Mousseau, 2003). Moreover, these attentional cues are important for young children as they have difficulty allocating attention to specific details of the stimulus (see Weiss, 1983; Weiss & Klint, 1987) such that as many task-irrelevant cues as task-relevant cues are imitated (Yando, Seitz, & Zigler, 1978).

The mechanisms of attention are rendered redundant unless the selected information is cognitively retained (remembered) in a symbolic representation (Bandura, 1977). The process of forming a representation is presumed to occur via a verbal or visual system, whereby the sensory stimulation activates sensations of the observed act and through repeated exposure retrievable images of the performance are possible (Bandura, 1977). For example, as a function of repeated exposures to certain stimuli a visual representation is formed and the mere reference (verbal label) to the action will activate a mental visual image of the act (see Annett, 1985). Visual imagery plays a significant role in encoding stimuli in early motor development when the verbal skills or repertoire of young children is under-developed, especially when the to-be-learnt action is complex and difficult to represent verbally (Bandura, 1986; Cadopi, Chatillon, & Baldy, 1995). The positive effects of cognitive strategies such as imagery on observational learning have provided support for the importance of cognition in the observational motor learning process (see Gerst, 1971; Jeffrey, 1976).

The second representational system used during the operation of retaining stimuli is verbal coding. Bandura (1977, 1986) indicated that humans learn and retain certain skills, for example organising a series of left and right arm movements, by encoding the stimuli into verbal codes (e.g., LRLRRLLLR). Although this method of encoding is suggested to account for how quickly humans learn skills (Bandura, 1977) it has been proposed that only certain types of motor tasks are likely to be amenable to these verbal encoding strategies (see Hodges & Franks, 2001; 2004; McCullagh & Weiss, 2001). Tasks that place demands on memory rather than motor ability, involving multiple stages or sequencing, such as a series of arm movements (Carroll & Bandura, 1982, 1985) or a gymnastic floor routine (McCullagh, Stiehl, & Weiss, 1990; Weiss & Klint, 1987) are more likely to be retained through such coding strategies. Moreover, due to age-related differences in the ability of children to spontaneously implement adult like verbal coding strategies, young children only benefit during these verbally-amenable tasks when coding strategies are provided to them (see Gallagher &

Thomas, 1986; Weiss, 1983). This organisation process retains the information as a representation of the act. In addition to organising the stimuli into visual or verbal codes the performer either mentally and physically rehearses the act to aid memory and recall (Bandura, 1977). For example, during skill acquisition the process of rehearsal is carried out by physically practising the act (Carroll & Bandura, 1985) or if physical re-enactment is not possible the learner performs mental rehearsal such as imagery (see Hall, Moore, Annett, & Rogers, 1997). Both of these strategies increases the proficiency and retention of the act (Jeffrey, 1976). After a period of practice in which these retention processes have been in operation a relatively accurate cognitive representation of the observed act is formed and acts as criterion reference (see Carroll & Bandura, 1982, 1985, 1987). This references serves as the internal model for response production and response correction when the model is not present (Bandura, 1986) similar to the traces proposed by Adams and Schmidt, although no distinction is made between the reference and initiation mechanism (see McCullagh & Weiss, 2001).

According to Bandura (1986), behavioural reproduction is a process of converting the representation into appropriate actions. Effective motor reproduction is achieved by organising the response according to spatial and temporal characteristics of the model. The response is selected and organised cognitively and incorporates a common conception-matching mechanism wherein feedback from the imitated action is compared against the cognitive representation (similar to the recognition schema, proposed by Schmidt, 1975). Based on the comparison between the imitated act and the representation, modifications to overt performance are made. Thus, within Bandura's model, this conception-matching mechanism, and the subsequent use of feedback and covert rehearsal techniques to modify movements, can only happen when an appropriate representation has been developed.

Carroll and Bandura (1982, 1985, 1987, 1990) investigated the spatial and temporal nature of the cognitive representation of action through a series of experiments. They required participants to learn separate arm and hand postures using hand held paddles with specific arm movements being made during the transition between postures (i.e., the end paddle positions). Through various performance measures (i.e., a pictorial arrangement recognition test and reproduction accuracy) and manipulation of visual feedback, they concluded that the more accurate the cognitive representation, the more accurate was the reproduction of the modelled action. They found that visual feedback pertaining to the learner's own imitated movement was not useful in early practice, only later in practice. Because feedback provided little basis for error detection or correction in early practice, this finding indicates that an adequate representation was not present in order that the movement could be modified based on visual feedback (yet see, Hodges, Chua & Franks, 2003). A further test of this cognitive representation was carried out based on the hypothesis that the development of the representation would be facilitated if learners were exposed to more demonstrations (Carroll & Bandura, 1990). As predicted, eight presentations yielded more accurate cognitive representation than two (as assessed through recognition measures) and reproductions were more accurate following more demonstrations.

Concerns with Bandura's social learning theory.

There is little doubt that Bandura's (1986) social cognitive theory is the most comprehensive explanation of the observational learning process (Williams, Davids, & Williams, 1999). Yet, despite its undoubted impact on developing our understanding of the cognitive processes in operation during observational learning or what is also referred to as modelling it has received some theoretical criticism. For example, the representation has been criticised as lacking detail in terms of its architecture, that is where does the representation reside? What is its structural analog in the brain? Further, the theory was primarily based on social aspects of learning, which are differentiated from purely motor learning (for a review see Horn & Williams, 2004; McCullagh & Weiss, 2001; Williams, Davids, & Williams, 1999). With the advancements in neuroscience, the theoretical concerns relating to the cognitive structure and mechanics of the representation during imitation and learning are being addressed, although maybe not from Banduran perspective and also with only a minor emphasis on action rather than perception (due to technical limits is performing while scanning the brain). Other areas of concern relate to the type of task utilised to address various observational learning questions, the measurement techniques and most notably, the lack of critical detail associated with the attentional processes are detailed in following sections.

An important constraint on observational learning and imitation is that the to-be-learnt action must be novel (Bryne & Russon, 1998), and if the action is not, then the information conveyed in a demonstration is likely to be redundant (Newell, 1981). Based on this notion some researchers have questioned the effectiveness of movement demonstrations because the actions that have generally been investigated tend not to lend themselves well to observational learning experimentation (see Newell, 1981; Whiting, 1984; Williams, et al., 1999). For example, tasks such as ball rolling (Burwitz, 1975), ladder climbing (Landers & Landers, 1973), computer tracking (Pollock & Lee, 1992) and barrier knock down movements (Blandin & Proteau, 2000) are relatively simplistic in nature. Because the movement form involved in achieving the task goal is generally simplistic or familiar (i.e., an arm movement), it is almost certainly within the learners' perceptual-motor repertoire such that there is not much to be acquired or picked up from a demonstration (Whiting, 1984). Although motor or key pressing sequencing tasks allow the examination of cognitive processes involved in observational learning (for example Weiss & Klint, 1983), the motor elements of the to-be-remembered motor series may already be in the learner's repertoire and therefore the task becomes primarily cognitive in nature as opposed to motoric learning.

A second concern is that while relatively objective pictorial arrangement tests have been employed in a few experiments to examine the efficacy of a memory representation and hence the perceptual process, observational learning has typically been measured through outcome measures, such as target accuracy or movement duration. These outcome measures may indicate that a group who observed a model was more accurate than a control group at a particular task, but these data do not indicate how the learner executed the action in order to attain the task goal. Without comparing the learner's movement against the model, the learner might have attained the task goal based on the pick up of general strategy information (Burwitz, 1975), the emulation of a thrown object (Tomasello, Kruger, & Ratner, 1993), or past experience. Only through measurement of the process is it possible to make inferences as to imitation of a model (see Horn & Williams, 2004). Outcome measures alone prevent a clear understanding of the observational learning process with respect to what was imitated (i.e., was the movement similar to the observed model?) and in fact may render the informational quality of the model redundant (Horn, et al., 2002). Based on this shortcoming there has been a call for a more detailed kinematic analysis of the learners' imitated action, and how this action compares to the criterion model (see Scully & Newell, 1985; Williams, et al., 1999).

To date, the aspect of Bandura's (1977, 1986) theory which has received most criticism is the lack of detail associated with attentional sub-process (Scully & Newell, 1985; Whiting, Bijlard, & den Binker, 1987; Williams, 1985). Although he acknowledged that accurate perception of the model's spatial and temporal features was critical during observational learning, no suggestion was offered as to the relevant features of the observed action that might be extracted to construct the representation. In fact, Bandura proposed that all of the model's spatial and temporal characteristics were encoded within the representation. Whiting and den Brinker (1982) also drew attention to the lack of understanding centred on the specific form of the movement representation. They differentiated the representation as being an 'image of the act' and 'image of achievement' (Whiting & den Brinker, 1982). Of particular importance to the question(s) being posed within the present thesis is Whiting and den Brinker's (1982) notion 'image of the act'. They suggested that the 'image of the act' is a representation containing the appropriate specifications to develop the essential form of the desired movement pattern (a qualitative representation) in order to tackle a specific motor problem (see Whiting & den Brinker, 1982). In line with Bernstein (1967) they postulated that the representation only contains the information required to develop the shape of the movement (topological properties), not the pattern of muscular activity that produces the movement form. However, the precise nature of the 'image of the act' was highlighted as an area 'open' to question because the specific details of its topological structure are unknown and this shortcoming formed the backdrop to some of their later research (see Whiting, Bijlard, & den Binker, 1987). With this question in mind, and in reference to Bandura's social learning model, the lack of elaboration concerning the attentional process and the 'image of the act' prevents a clear understanding of what information is required for the acquisition of a new movement pattern. Access to this type of movement information is especially important when prescribing augmented pre-practice information to learners in the early stages of motor skill acquisition where the learner is primarily concerned with acquiring the movement pattern (topological shape) of the to-be-learnt motor skill (see Gentile, 1972; Newell, 1985).

Scully and Newell (1985) provided the most significant criticism of the information processing accounts of observational learning (i.e., Bandura, 1986; Sheffield, 1961). They argued that Bandura merely focused on understanding *how* the process of observational learning occurs without elaborating on *what* cues are picked up by the performer to inform motor learning. Bandura focused on the attention process with respect to the functional value of the model, its salience and distinctiveness. These attentional characteristics affect *how* the learner attends to the model and consequently *how* the extracted information is cognitively processed. With this in mind, Scully and Newell proposed that understanding the specific nature of the spatial-temporal cues used by a learner when acquiring a new coordinated action is crucial for facilitating the skill acquisition process. An answer to this question was fundamental to the development of their '*visual perception perspective to observational learning*'.

The nature of visual information used for observational learning.

The visual perception perspective to observational learning was proposed by Scully and Newell (1985). They integrated the area of direct perception (Gibson, 1950, 1979) and visual perception of motion (e.g., Cutting & Profitt, 1982; Johansson, 1971) with Newell's (1985) model of coordination, control and skill (see also Kugler, Kelso, & Turvey, 1980, 1982). Because Bandura's attentional sub-process lacked critical detail in specifying what temporal and spatial characteristics needed to attended to, Scully and Newell believed that using principles of motion perception they could make recommendations for the use of movement demonstrations for facilitating the early stage of motor learning.

Traditional concepts of observational learning (Bandura, 1977; Sheffield, 1961) were based on indirect processing principles whereby movement information was perceived via epistemic mediation (i.e., relating to knowledge). Scully and Newell (1985), in contrast, formulated the principles of observational learning based upon the ideas of direct-perception proposed by Gibson (1950, 1979). Gibson argued that theorists should focus on *what* there is to be perceived in the environment rather than *how* information is perceived. Gibson rejected Helmholtz's notion that information processing (epistemic mediation) is required to translate the incoming environmental information, instead believing that the image itself contains all the information needed for three-dimensional perception. Gibson termed the information contained in the environment as 'gradients' and 'higher-order variables' (or invariants) that are a consequence of the observer-environment interaction (i.e., mutual interdependency). Moreover, he applied these principles to moving patterns, such that the information was deemed as stimulus flow (within the optic array) as opposed to stimulus images. Based on these direct perception principles visual perception researchers have since examined the perception of biological (Johansson, 1971) and non-biological motion (Cutting & Profitt, 1982) to determine what perceptual invariants the visual system decodes from optical flow.

Using a point-light technique (i.e., points of light attached to major joint centres of the human body or lights that simulate the hub and rim of a virtual wheel) researchers have investigated dynamic motion perception (see Cutting & Profitt, 1982; Johansson, 1971). Three types of motion have been reported to be available through perception. Absolute motion describes the motion of a single element in a configuration relative to the perceiver; common motion describes the motion common to all elements in the configuration relative to the perceiver; relative motion is motion of all the elements in the configuration relative to each other (see Cutting & Profitt, 1982; Johansson, 1973, 1975). Data from mechanical motion and biological motion research indicates that the visual system prioritises relative motion information during the perception of an activity (see Bruce, Green & Georgeson, 1996 for a review). The mechanism that deciphers the three motion components and specifies the characteristics of the objects in motion (e.g., points of light displaying a rolling wheel) is still unclear. However, it is generally accepted that the perception of moving lights follows a common-motion-first principle whereby the common motions of the display are abstracted first leaving a residual of relative motion that defines the objects in motion (Cutting & Profitt, 1982; Johansson, 1973).

The main theoretical backdrop (and resultant predictions) used by Scully and Newell to develop the visual perception perspective of observational learning was the research by Johansson (1971, 1973, 1975) who first theorised about biological motion. Using the point-light technique (Marey, 1895, 1972) Johansson sought to examine the mechanics of the visual system when perceiving biological motion displays. He attached points of light to the major joint centres of human actors and filmed them walking in a dark room. In the film that results, all information about the contour of the human are removed such that what is left is a dozen or so lights attached the human actor. When these static displays are shown to observers they are unable to identify the stimuli and in fact report that they are a meaningless jumble of lights (Johansson, 1975). However, and importantly, once the actor moves (dynamic display) a person (biological motion) is immediately perceived within as little as 100 ms of film (see Johansson, 1975). Humans viewing point-light displays can also identify gender (e.g., Barclay, Cutting, & Kozlowski, 1978; Mather & Murdoch, 1994), friends (Cutting & Kozlowski, 1977), different animal species (Mather & West, 1993) and aesthetic quality from gymnastics (Scully, 1986). This perceptual sensitivity extends to the perception of underlying dynamics, such as the weight of a lifted object (e.g., Runeson & Frykolm, 1981, 1983) and develops as young as three-five months old (see Bertenthal, Profitt, & Cutting, 1984; Booth, Bertenthal, & Pinto, 2002).

Johansson (1971, 1973) considered the perception of biological motion in these displays as being consistent with perceptual vector analysis (i.e., a hierarchy, and similar to the common-motion-first principle). For example, when an actor walks across the visual display in a horizontal direction all the points of light move in a common motion to the observer. Although these individual lights such as the knee and ankle contain common motion they also inter-relate to each other thus displaying slight undulatory motions. These undulatory motions within the dynamic configuration can be resolved by perceiving the individual relative motions of certain lights of the display as rigid limb segments (i.e., interpreting the structure as rigid connections). Therefore, human activities are identifiable by the specific relative kinematic pattern peculiar to that activity. There appears to be consistent evidence from biological and non-biological research that relative motion is a key variable in the hierarchy of visual motion perception (see Cutting & Profitt, 1982; Johansson, 1973).

The problem for a learner of motor skills appears to be one of coordinating the many degrees of freedom to learn a particular coordination pattern that defines the to-be-learnt motor skill (see Newell, 1985). Because activities are defined by the topological properties of the relative motions of the body and limbs, Scully and Newell (1985) proposed that the crucial information conveyed within a demonstration should be the topological properties of the activity. Therefore, the use of demonstrations at the early stage of skill acquisition should enable the learner to observe the important relationships between the body and limbs, namely the relative motions. They estimate that the influence of relative motion information is greatest in the early stage of learning, and when a learner approximates the model's relative motion pattern within 'certain bandwidths', this is considered to indicate that the action has been modelled. Once the learner has acquired the relative motion pattern they are then required to scale (parameterise) the 'coordination function' up or down, depending on the amount of force required. Although Scully and Newell (1985) recognised that scaling related information is available within a model's kinematic movement pattern (Runeson & Frykolm, 1981, 1983) they suggested that only through physical practice would optimal parameterisation of the coordiantion function be determined.

Research Relating to the Visual Perception Perspective

In observational learning research the visual perception perspective has typically been examined through indirect manipulations of relative motion, whereby point-light display (PLD) models have been compared to video models, as detailed below. There has also been considerable variability in the type of tasks used to assess the role of relative motion information in observational learning (e.g., either goal- or non goal-directed actions), such that it has been difficult to decipher the actual role of the demonstration in the learning process. Moreover, although there have been attempts to determine what other information within motion display demonstrations might aid this process, and when, there has been a lack of systematic evaluation of these two questions. A detailed review of research relating to the visual perception perspective are provided in chapters 2, 3, 4 and 5, therefore a brief outline of research is provided here in order to develop the research questions examined in the current thesis.

Examining relative motion information

Point-light versus video models.

As stated, Scully and Newell (1985) proposed that the crucial information conveyed to the learner during movement observation is the topological characteristics pertaining to the relative motion of the activity. In order to test this proposal researchers have typically compared point-light versus video models (see Al-Abood et al., 2001; Horn et al., 2002, in press). The use of point-light models has been based on the prediction that because all non-essential structural information is removed from a point-light display the perception of relative motion is facilitated (Runeson, 1984) and thus so is skill acquisition. However, only Scully and Carnegie (1998) have found learning benefits for participants acquiring a gymnastic action after viewing a point-light compared to video model. Whereas other researchers have found no difference for participants learning a dart throwing action (Al-Abood et al., 2001) and a soccer kicking action (Horn et al., 2002, in press). A possible reason for this disparity was the type of action and task used in these learning experiments. These experimental paradigms differed with respect to whether task had outcome goal (i.e., hit a target) and/or the action required the integration of information across limbs (i.e., multi-limb action). It is possible that benefits in imitation through the watching of PLDs are only realised for tasks that are more complex in nature (i.e., multi limb actions) and where the action itself is the only goal of the task.

Although point-light demonstrations have only facilitated skill acquisition in adults in relatively complex movement tasks there is reason to believe that this technique might benefit children. Yando, Seitz and Zeiger (1978) found that children focused on as many irrelevant as relevant task cues during movement observation that required the children to imitate a model's strategy. In situations where the to-be-imitated action is complex providing point-light displays might help to effectively constrain perception to the critical sources of relative motion information and hence shape movements for young children in the early stages of motor learning. Moreover, because young children have difficulty processing complex movements (unless aided with the provision adult like learning strategies, see, Weiss & Klint, 1987) removing all non-essential information is likely to reduce the processing demands associated with imitating these actions. Despite these predictions, the empirical evidence for the role of point-light stimuli facilitating the pick-up of relative motion information in children is also equally unclear. Williams (1989) found that video and point-light demonstrations were equally effective in encouraging 12-year-old children to imitate a dart throwing action. However, Romack and Briggs (1998) found that 6 year-old children learning to bounce a basketball were significantly less accurate at imitating the model's pattern of movement after viewing a point-light display. A plausible rationale for the observed difficulties in imitation is that the six-year children's lack of motor experience and familiarity with the basketball task negatively influenced their perception of the required motion from a point-light model (see Sparrow et al., 2001). However, the poor reproduction performance could have been associated with a combination of the task being outcome related (see next section titled 'task constraints') and presented in point-light format. For example, this combination may have exceeded the limited processing resources of the young children such that a more simple version of task was executed based on the goal of bouncing the ball as opposed to imitating the model's movement (see Bekkering et al., 2000).

Task constraints.

An additional variable that has been reported to affect the efficacy of point-light and video demonstrations has been whether the to-be-learnt motor task requires both imitation and the attainment of an outcome goal. For example, Horn et al. (2002) found that observers executed a kicking technique during a soccer chipping task that was guided by error information rather than the observed model's movement pattern. However, only when the model was the primary constraining source of information (i.e., vision of the ball's trajectory was occluded at foot-ball contact) did observers imitate the model's movement form (Horn et al., in press).

Children's imitation performance has also been shown to be goal-directed. Bekkering, Wohlschläger, and Gattis (2000) proposed that goal-directed imitation is mediated by a hierarchy of selected goals, these being the goal of the action as opposed to the means (i.e., the effector) that led to the goal. Bekkering et al. (2000) argued that if the observer's resources are constrained or limited, as with young children, the observer is more likely to reproduce a simplified version of the act, that is, one that contains the dominant goal.

These effects show that when imitation is coupled with the challenge of attaining a specific outcome goal the efficacy of a movement demonstration (and thus relative motion information) is downplayed in importance. Therefore, it is important to consider other task constraints, in addition to the demonstration and relative motion information in determining what has been imitated (see Newell, 1986). A specific movement pattern might be a consequence of trying to attain a task outcome rather than the performer extracting and using relative motion information (see also Hodges & Franks, 2001). While Newell (1986) discussed the impact of various task constraints on practice, there has not been a systematic attempt to isolate and determine the relative importance of these variables during observational learning. Comparisons across children and adults will help identify how individual differences in cognitive and motor ability, in addition to task familiarity impact on the use of these various information sources and task constraints.

Finally, researchers have concluded that relative motion information constrains the reproduction of a to-be-imitated action based on the similarity of the observer's imitated movement or coordination pattern to that of a criterion model (Al-Abood et al., 2001; Scully & Carnegie, 1998). Just because the movements are similar, however, does not mean that relative motion was extracted and used to shape the imitated movement. For example, the movement may have been a consequence of additional outcome constraints (Horn et al., 2002) or another source of kinematic information inherent within the model's movement pattern which acted to constrain the resulting movement pattern (for example velocity or displacement of the movement end-point). Therefore, there is need to directly manipulate (through the systematic removal of relative motion information, see chapter 3 and 4) relative motion information under various task conditions to examine its importance for the acquisition of a new coordination pattern.

Toward a Program of Research: Aims of the Thesis

The primary aim within this thesis is to examine the constraining role of relative motion information during observational learning. Moreover, across the first three experiments (see chapters, 2, 3, 4) an additional aim is to examine how the information content of a demonstration and task context impacts on reproduction accuracy. The task will be manipulated to examine how target-outcome related variables mediate the effectiveness of demonstrations. To directly examine relative motion information, this information will be manipulated in Experiments 2 and 3 through demonstration occlusion techniques. Finally, to understand how demonstrations generally and relative motion more specifically affects both the acquisition of coordination and the scaling of this action, in chapter 5, comparisons are made across different 'stages' of practice which are designed to tap into these different processes of coordination and control (see Newell, 1985).

General methodology

(i) Point-light models.

Across the first three experiments PLDs will be used to assess how demonstration influence the acquisition of a relatively novel crown-green bowling action (Chapters 2 and 4) and a left-footed football kicking action (Chapter 3). PLDs will be used because of the ease with which they allow modification of information (Chapters 3 and 4) and also be provided to further examine their potential benefit in aiding attention processes in observational learning amongst children (Chapter 2).

(ii) Task context.

In Experiments 1, 2 and 3 (Chapter 2, 3 and 4) the task context is directly manipulated to examine how variables pertaining to outcome goals mediate the effectiveness of demonstrations in both adults and children.

(iii) Occlusion techniques.

The nature of relative motion information has typically been examined by indirectly manipulating relative motion through the presentation of point-light models (see Al-Abood et al. 2001; Horn et al. 2002; Scully & Carnegie, 1998). If observers benefit from point-light compared to video models, evidenced through closer approximation of the model's relative motion pattern, this does not support the conclusion that relative motion information was extracted and used to constrain the imitated movement pattern (see Chapter 2). As stated, a reproduced movement pattern may be a consequence of the constraints of the task (Newell, 1986), or another source of kinematic information inherent within the model's movement topology. Therefore, through the systematic removal of sources of relative motion information it is possible to make some more definite conclusions as to the importance of relative motion information in observational learning (see Chapters 3 and 4).

(iv) Practice.

In Chapter 5 the level of practice a performer receives will be manipulated to understand how demonstrations affect the control (parameterisation) aspect of the embedded hierarchy of coordination and control (see Newell, 1985). Observers will again be instructed to reproduce a relatively novel crown-green bowling action as used in Chapters 2 and 4.

Chapter 2

The efficacy of demonstrations in teaching children an unfamiliar movement skill: the effects of object-orientated actions and point-light demonstrations

Abstract

In three experiments (a, b, c) the question of what information is perceived and used for reproduction under different task constraints is examined. In Experiment 1a, adult and child participants were instructed to imitate a video demonstration of a model performing a bowling action with or without a ball. It was predicted that participants with a ball would focus on achieving a successful outcome instead of imitating the model's movement pattern. Both age groups imitated the action more accurately without a ball, and in general the adults were more accurate than the children. In Experiment 1b, adults and children were shown a video or point-light (PL) bowling action. It was predicted that the removal of non-essential, structural information via a PL display would facilitate reproduction of the bowling action compared to a video demonstration, particularly for children. Contrary to predictions, no differences were found across displays for the adults. The children in the PL group were poorer at reproducing the action than the children in the video group. It was suggested that the novel PL display and action hindered the children's ability to provide conceptual mediation between this information and their action. In Experiment 1c, a child PL group was provided with conceptual PL training, which was shown to facilitate movement reproduction in comparison to PL only, but not in comparison to video. These results show that children are able to perceive and use relative motion information from a display after some general training, and that the effectiveness of demonstrations for both adults and children needs to be judged relative to the task context.

In the early stages of skill acquisition the objective is to develop a new movement pattern. Gentile (1972) has referred to this stage as 'getting an idea of the movement' or acquiring an explicit reference of the movement's shape and structure. Newell (1985) made similar proposals by suggesting that early in acquisition the learner has to assemble body parts into a functional unit (i.e., coordination). One way to acquire this movement pattern is to copy another person's behaviour. This imitation process implies a specific causal relationship between observation of the person's body movements and replication of this behaviour by the observer (i.e., "learning to do an act from seeing it done", Thorndike, 1898, p.50). While there is substantial evidence that demonstrations can be an effective means of conveying information to learners, the question of what information is perceived and used for reproduction under different task constraints remains unanswered. This question is examined in the following program of experiments where young children and adults are required to watch and imitate an unfamiliar movement skill.

Scully and Newell (1985) proposed that the crucial information conveyed to the learner during movement observation is the topological characteristics pertaining to the relative motion of the activity (i.e., the motion of all elements in a configuration relative to each other). They predicted that a demonstration and, hence relative motion information, would be most potent in the early stage of motor learning, what has been referred to as the coordination phase (Newell, 1985). This phase requires the learner to control their movements through the coordination of various body parts (i.e., degrees of freedom). The relative motion information contained in a display is expected to facilitate coordination and constrain the degrees of freedom in an effective way in order to solve the motor problem.

These proposals have been tested by a number of authors mainly by presenting the visual information in regular video and point-light form (e.g., Al-Abood, Davids, & Bennett, 2001; Horn, Williams, & Scott, 2002; Horn, Williams, Scott, & Hodges, in press; Romack & Briggs, 1998; Scully & Carnegie, 1998). If relative motion is the only source of information necessary for the perception and subsequent reproduction of movement, point-light displays should be as effective as video. A point-light demonstration might even be the preferred method for relaying information since non-essential information is removed (Runeson, 1984), and consequently, relative motion information is made salient.

Scully and Carnegie (1998) found that participants who observed a point-light display of a gymnastic skill were more accurate at replicating angular displacement and relative timing compared to those who viewed the same skill in video format. This finding suggests that point-light displays facilitate visual attention to key features of the required movement. In contrast, Al-Abood et al. (2001) and Horn et al. (2002, in press) did not find differences between video and point-light display conditions. While Scully and Carnegie's (1998) task had no specific outcome goal and required the integration of information across limbs, the dart throw and soccer-chipping tasks employed by Al-Abood et al. (2001) and Horn et al., (2002, in press) respectively, had goals in addition to movement reproduction and required only replication of a single limb. In these tasks, therefore, the reproduced movement might be more a consequence of goal attainment rather than the demonstration per se. Moreover, if the demonstration is used, the critical information for success pertains more to end-point features of the limbs associated with goal attainment rather than whole body relative motion (for example Wohlschläger, Gattis, & Bekkering, 2003).

Although point-light demonstrations in comparison to video have only facilitated skill acquisition in adults in relatively complex movement tasks, where movement reproduction is the primary goal of the action, there is reason to believe that this technique might benefit children independent of the task. Children younger than 8 years of age have been shown to have particular difficulty in attending to sources of information which are considered critical to outcome attainment (e.g., Yando, Seitz, & Zigler, 1978) in comparison to older children. Yando et al., (1978) found that children focused on as many irrelevant as relevant task cues during movement observation that required the children to imitate a model's strategy. As such, point-light displays might help to effectively constrain perception and hence shape movements for young children in the early stages of motor learning in comparison to video demonstrations.

The empirical evidence supporting this prediction is somewhat equivocal. For example, Williams (1989) found that video and point-light demonstrations were equally effective in encouraging 12-year-old children to imitate accurate elbow flexion and extensions in a dart throwing action. In contrast, Romack and Briggs (1998) found that point-light models were worse than video models for 6 year-old children learning to bounce a basketball. The video model was more effective in facilitating movement outcome (i.e., number of consecutive bounces) and movement form (i.e., phasing between ball and hand). The developmental mechanisms mediating the perception of biological motion have been proposed to occur early in development (Bertenthal, Profitt, & Cutting, 1984; Fox & Daniel, 1982; Pavlova, Krageloch-Mann, Sokolov, & Birbaumer, 2001) and consequently, are unlikely to have acted as a constraining factor in determining the effectiveness of point-light models. An alternative proposal might be that the children's lack of motor experience and familiarity with the basketball task negatively influenced their perception of the required motion from point-lights resulting in the observed difficulties in imitation (see McCullagh & Weiss, 2001). Several researchers have proposed that the efficient processing of movement information is at least partly dependent on experience (Ferrari, 1996; Heyes, 2001; Pinto & Shiffrar, 1999), such that exposure to different action categories is necessary before specific kinematic characteristics can be identified from point-light stimuli (Sparrow et al., 2001).

While the children in the study by Williams (1989) were older than those who participated in the study by Romack and Briggs (1998), which might have affected the results, Williams (1989) also provided a period of practice that related to the dart throw and the nature of the point-light stimuli prior to testing. This practice period would perhaps have been sufficient to develop the knowledge required to identify key information from the display and help children label and form an accurate representation of the action. Similarly, Scully and Carnegie (1998) provided pre-training in their gymnastic task and found benefits of point-light displays in comparison to video. In situations where the motor skill to be learnt is novel or unfamiliar, it may be difficult for a child to attach a phrase or word (i.e., label) to the action which subsequently mediates the association between sensory input (demonstration) and motor output (reproduction) (see Heyes, 2001). This difficulty is likely to be compounded when the displays are presented in point-light rather than video format.

If point-light and video demonstrations are equally effective in encouraging motor skill acquisition, or point-light displays are better, this finding does not necessarily lead to the conclusion that relative motion is the critical constraining source of information underlying movement reproduction (cf. Scully & Newell, 1985). While there is little doubt that relative motion can be perceived and minimised (at least by adults), it is less obvious whether this information is actually used for movement reproduction. An individual's previous experience will mediate what is seen and reproduced and the nature of the task will also dictate a specific response (see Byrne & Russon, 1998). A specific movement pattern might be a consequence of trying to attain a task outcome rather than the performer extracting and using relative motion information. While Newell (1986) has discussed the impact of various task constraints on practice, there has not been a systematic attempt to isolate the independent contributions of these variables. For example, when an outcome component is added to the task of watching and replicating a movement, one question concerns how the two sources of constraining 'information' are differentially weighted. Comparisons across children and adults will help identify whether individual differences in age and subsequent experience with the action impact on the differential use of various information sources and task constraints. Since young children have been shown to process information less effectively than adults (Chi, 1976, 1977) and have difficulty attending to multiple sources of information (Yando et al., 1978), young children might show a greater departure from the model's movement pattern compared to adults, when challenged with reproducing a movement pattern and achieving an outcome goal.

Bekkering, Wohlschläger, and Gattis (2000) proposed that goal directed imitation is mediated by a hierarchy of selected goals, these typically being the goal of the action as opposed to the means (i.e., the effector[s]) that led to the goal. This proposal was confirmed through an experiment showing that children replicated the goal of action when watching a model (i.e., touch the correct ear) rather than the means of achieving that goal (i.e., moving the correct arm to touch the correct arm).

Bekkering et al. (2000) argued that if the observer's resources were constrained or limited, as with young children, the observer is more likely to reproduce a simplified version of the act; one that contains the dominant goal(s). A similar effect has been observed with adult learners when imitation is coupled with the challenge of attaining a specific outcome goal. Horn et al. (2002) found that observers adopted a technique during a kicking action that was primarily guided by error information rather than movement demonstrations. Only when the model was the primary constraining source of information (i.e., vision of the ball's trajectory was occluded at foot-ball contact) did observers appear to rely on the model's movement form to guide reproduction (Horn et al., in press). Similarly, Hodges and Franks (2000, 2001) found that outcome feedback relating to the relative positions of the arms in a complex bi-manual movement more effectively constrained movement than a demonstration. It is difficult to draw clear conclusions regarding the impact of outcome information on the use of information from demonstrations since no single study has directly manipulated this information.

The following experiments were designed to examine how the information content of a demonstration impacts on the reproduction accuracy of a relatively unfamiliar, whole body bowling action. The task context was manipulated to examine how variables pertaining to outcome goals mediate the effectiveness of demonstrations. In Experiment 1a, children and adult participants were required to reproduce a bowling action. Both groups watched a video demonstration and were asked to replicate the action either with or without a ball. In Experiments 1b and 1c, the effectiveness of point-light displays in conveying the critical information required in a non-outcome constrained bowling action was examined. In Experiment 1b, children and adults were compared under point-light and video demonstration conditions. In Experiment 1c, the effectiveness of providing a period of point-light training prior to viewing a demonstration was examined.

Experiment 1a

In view of expected differences in reproduction accuracy as a consequence of additional task goals (e.g., Horn et al., 2002), particularly for young children (e.g., Bekkering et al., 2000), the task complexity was manipulated in Experiment 1. Participants were required to imitate a model's bowling action either with a ball, and hence an outcome goal, or without a ball. It was predicted that children and adults would fail to accurately approximate a model's bowling action, irrespective of the instructions to adopt the movements of a model, when a ball and outcome goal were provided as additional task constraints, in comparison to a no ball situation. Due to the young children's limited information processing capacity and evidence that task goals are prioritised differently as a result of processing limits (Bekkering et al., 2000), children were expected to show a greater departure from the modelled action when challenged with the multiple goals of movement imitation and successful outcome attainment compared with adults.

Methods

Participants

Sixteen boys (6.7 ± 0.5 yr) and sixteen adult males (21.1 ± 2.8 yr) participated. All provided informed consent (children via parent or legal guardian) before taking part and the testing was conducted according to the ethical guidelines of Liverpool John Moores University. The children and adults were randomly assigned to a video (VID) or a video plus ball (VIDBALL) group, resulting in 4 groups of 8 participants per group.

Apparatus

Movement form data were collected using a VHS video camera (Panasonic M-40, Tokyo, Japan) (Kinematic data was also recorded during Experiment 1. However, due to considerable within and between group movement variability for the children it was analysed. It was very difficult to standardise the start and end-points of the movement for comparisons across trials and with the model. A quantitative form analysis scale was subsequently constructed to assess movement reproduction based on video recordings. A complete description of kinematic recording procedures is detailed in Experiment 2).

Demonstrations were front-projected onto a screen (107.5-cm x 107.5-cm) using a projector (Sharp XG-NV2E, Tokyo, Japan) and video recorder (Panasonic NV-HS 820, Tokyo, Japan). A child's small plastic football (Regent, SOFFS: model 98200; circumference = 43 cm) was used in the VIDBALL condition.

Task and Test Film Construction

The task was an under-arm movement similar to a crown green bowling action. This movement was selected because it was considered to be a complex multi-limb technique and relatively novel, particularly for young children. The primary aim for all groups was to imitate the model's movement pattern exactly. The VIDBALL groups had an additional outcome element that required participants to roll a ball to stop on a target line a distance of 6 m away

Table 2.1. A breakdown of the scoring system for the individual elements of the movements of the arm

Form Score	Back swing	Follow through	End arm swing
0	No movement Ambiguous movement	No movement executed Ambiguous movement	No back swing Unintentional movement
1 POOR	Minimal back swing Begins by hyper-flexing Displays a form of arm swing	Minimal (bodyline) Hyperflexed (>115°) Elbow bent (>30°)	Not continuous (>2 s) Merely returned Not swung (lateral movement)
2 AVERAGE	Shoulder extended (90°)- Inline with trunk Excessive back swing (hyper extends >45-50°) Arm is bent	Flexed to approx 40° Just past the trunk Elbow bent > 30° Not smooth (jerky)	Hyper extends past the trunk and returns to the side. Slight time delay between follow through and end arm swing
3 GOOD	Perfect form (extend approx 45-55°) Trunk slightly flexed Arm straight (elbow < 30°) Executed smoothly	Perfect form Arm flexes to approx. 90° (75-115°) Arm straight (elbow < 30°) Executed smoothly	Returned to end by 90° Arm must reside by the side Smooth and continuous Must be intentional Arm straight (elbow < 30°)

Table 2.2. A breakdown of the scoring system for the individual elements of the movements of the legs

Form Score	Lunge	End lunge
0	No Lunge (ambiguous movement) No Bend Walked	No end position executed Unintentional step or walked away Final position held
1 POOR	Both legs step forward Minimal knee bend No step – Bends both knees only	Intentional end position (fail to execute a return lunge) Max. score of 1 if no step is executed Movement ended in the forward position
2 AVERAGE	Lunge sort of exhibited Lunge executed – partial knee bend (slight step) Trunk flexed (partial bow) Both elements but step needed (evidence of step)	Returns to the correct position after a delay of 2 s Correct movement executed smoothly (wrong leg)
3 GOOD	Lunge clearly exhibited Approx. the correct form Lunge executed with either left or right leg (70°) Both lunge and trunk flexed	Perfect form Leg returns to the end position Must be the left leg Movement executed smoothly
4 VERY GOOD	Lunge pronounced knee bend (approx. 90°) Approx. 100° degrees in trailing leg (Significant trunk flexion) Must be left leg -movement executed smoothly	

The VID and VIDBALL groups were presented with a model specifying the movement pattern. Each group viewed a different model executing the same technique (child model = 6 yr old boy, adult model = 24 yr old male). The models practiced rolling a ball to the target line using a crown green bowling technique. Once a consistent level of success was achieved, they were instructed to reproduce the same bowling action without a ball as if they were bowling to the target. This procedure was carried out to ensure that the movement was executed with similar dynamics to that of an accurate bowl with a ball. Both models were filmed in the sagittal plane. The same scoring criteria used to rate the participant's likeness to the model was used to ensure that the presence of a ball did not change the manner with which the models executed the bowling action. The scoring systems for the arm and leg components are presented in Table 2.1. and 2.2. respectively. The model's actions did not differ in terms of movement form with and without the ball and there was no significant difference between the adult and child model (in all conditions the model's received a maximum form score of 16).

Procedure and Design

The participants in the VID group received standardised instructions to watch the display very closely and try to copy exactly what they saw. The participants in the VIDBALL group were given the same instructions and additionally told that their primary aim was to copy the model when bowling the ball to the target because this would lead to an accurate outcome. Participants were instructed to stand on the start line with their feet slightly apart and the right arm supinated and flexed at the shoulder to 90° (VIDBALL group participants were provided with a ball at this time).

Demonstrations were front-projected onto a screen placed 3 m from the observer. Participants viewed the demonstration at an angle of 45° to the screen such that they were orientated in a similar plane of movement to that of the model. Two repetitions of the model's action were presented prior to the first reproduction trial. The model was then shown once prior to subsequent reproductions. The participants underwent 10 reproduction trials in total. The children conducted a retention test 24 hours later that consisted of three retention trials where no movement demonstrations were provided (We were primarily interested in the type of movements imitated in the presence and absence of a ball to gain an understanding of what information is used to inform reproduction, rather than long term retention of a specific movement pattern. Previous observational learning experiments comparing point-light and video demonstrations investigations (see Horn & Williams, 2004 for a review) have not shown differential findings in performance (i.e., practice phase) and learning (i.e., retention phase). Based on these concerns only the child participants conducted a 24-hour retention test. In keeping with previous research, any differences between the groups were maintained in retention).

Dependent Measures

The bowling action was divided into two main components pertaining to arm swing and leg lunge. Each component was broken down into elements that characterised the full movement in progressive stages. The arm swing comprised the back swing, follow through and end arm swing (see Table 2.1.). The leg lunge comprised the actual forward step (i.e., the lunge) and the end lunge (see Table 2.2.). Each element was assigned an individual marking scale that classified whether a particular element was executed correctly. Trials 1 to 3 (start of practice) and 8 to 10 (end of practice) were examined and a score for each individual element allocated to all participants. The elements for both components were scored on a scale ranging from 0, indicating no similarity to the model to 3 (see Table 2.1.) or 4 (see Table 2.2.) denoting a close similarity to the model (good or very good). An overall measure of movement form was calculated based on the sum of scores awarded to the arm and leg elements of the movement. A maximum score of 16 denotes that the participant spatially reproduced all the elements accurately and in the correct temporal order.

To ensure consistency in measurement, independent observers rated the videotaped performances of four participants one from each experimental group. An inter-observer agreement of 88% was obtained (see Thomas & Nelson, 2001) and Spearman correlation values, performed on the different components in the movement, ranged from $r_s = 0.8$ to 1, indicating that the scoring system employed was reliable. On the basis of this analysis one rater evaluated all further trials.

Statistical Analysis

Practice.

Form data were collapsed (i.e., all individual elements were summed to make one global form score per trial) and analysed in a Condition (VID, VIDBALL) x Age (children, adults) x Block (start of practice, end of practice) mixed ANOVA with repeated measures on the last factor.

To determine whether there was a relationship between outcome error and change in movement form a Pearson Product Moment coefficient of correlation was conducted on these two measures. If a significant difference between the VID and VIDBALL groups was observed a correlation between these two measures of performance would lead to the suggestion that outcome error (i.e., feedback) was primarily responsible for change in movement form. An absence of a correlation would indicate that the mere presence of an outcome-goal affected movement imitation.

Retention.

The children's movement form data were analysed in a separate 2 Condition (VID, VIDBALL) x 2 Block (end of practice, retention) mixed ANOVA with repeated measures on the last factor.

In all three experiments reported in this paper Cohen's f effect size estimates have been reported for all ANOVAs and effect size values are treated as, small f = .1, medium f = .3 and large f = .5.

Results

Practice

As illustrated in Figure 2.1. both adult groups and the child video group improved their reproduction accuracy as a function of repeated observations and practice as evidenced by a main effect for block, $F(1, 28) = 23.61, p < .01, f = .21$. A significant main effect was observed for age, $F(1, 28) = 42.88, p < .01, f = .74$, and condition, $F(1, 28) = 35.33, p < .01, f = .65$.

The adults were more accurate than the children. Moreover, both age groups were more accurate when the task only required the reproduction of movement form without the additional outcome component. The predicted Age x Condition interaction was not significant ($F < 1$). The presence of an additional outcome goal affected both the adult's and children's reproduction accuracy.

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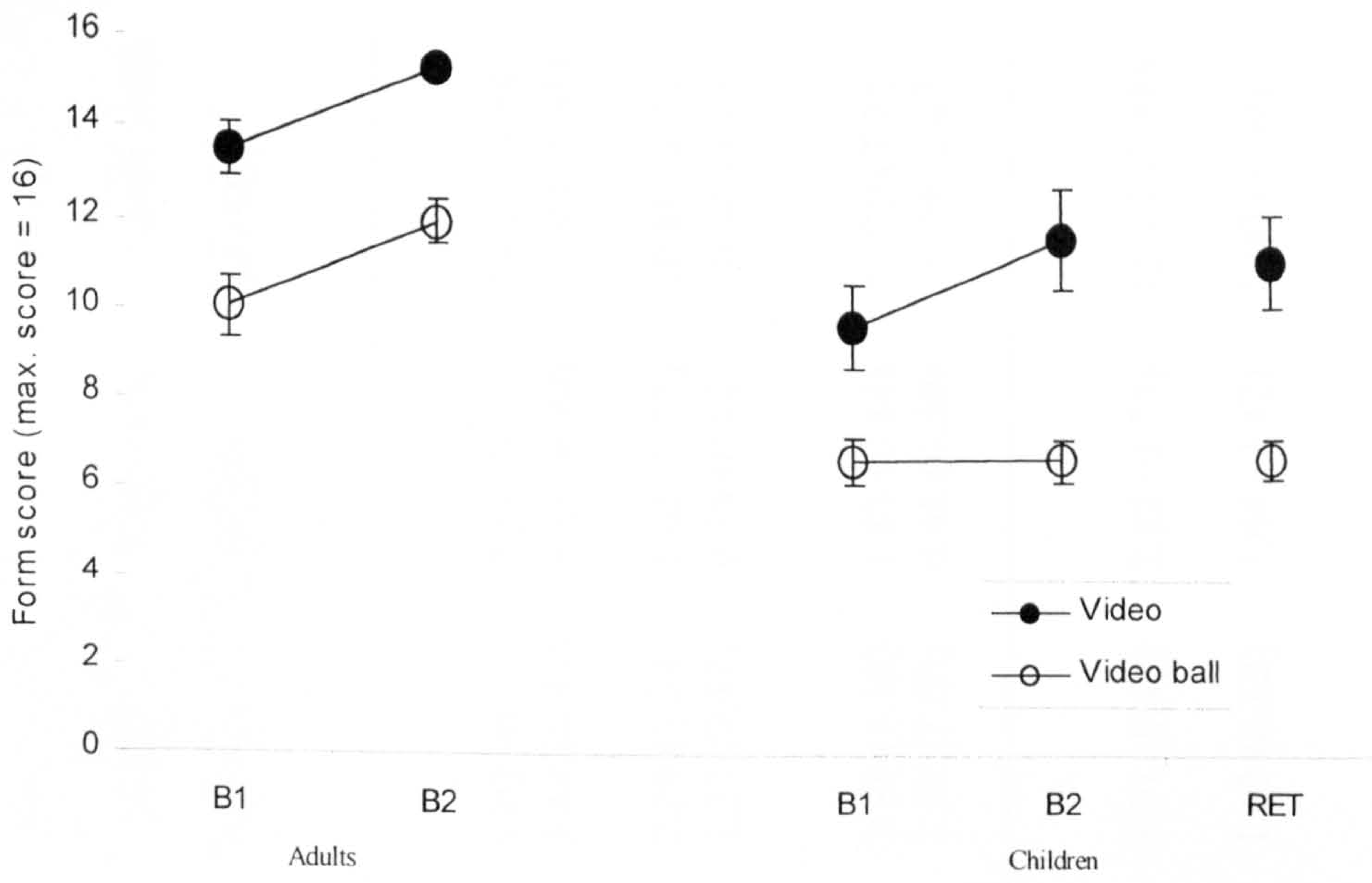


Figure 2.1. Mean form scores (and standard error bars) across practice blocks and retention for the children and across practice blocks for the adults as a function of condition (video and videoball) in Experiment 1.

Inspection of the individual elements of the bowling action indicated that the children were generally poorer than the adults in imitating the follow through, end arm swing, and lunge components of the action during practice attempts (see Table 2.3.). Participants who were asked to imitate the model's action while rolling the ball to a target poorly replicated the final position of the end arm swing and the leg lunge components, which was particularly noticeable for the children.

For the VIDBALL groups there was no relationship for either the adult ($r = -.19$) or the child ($r = -.08$) participants (all *ps* $> .05$) change in movement form and outcome score.

Table 2.3. Form and individual component mean (± SD) form scores for the adults and children in Experiment 1, 2 and 3.

Experiment / Block	Age	Condition	Arm: Back swing M (SD)	Arm: Follow through M (SD)	Arm: End arm swing M (SD)	Leg: Lunge M (SD)	Leg: End lunge M (SD)	Overall: Overall form M (SD)
EXP.1								
Practice								
	Adult	Video	2.71 (0.34)	2.65 (0.33)	2.25 (0.50)	3:92 (0.23)	2.88 (0.15)	14.40 (0.94)
		Vidball	2.46 (0.45)	2.27 (0.33)	0.98 (0.51)	3.44 (0.53)	1.83 (0.70)	10.98 (1.58)
	Child	Video	2.25 (0.39)	2.63 (0.34)	1.79 (0.62)	2.29 (1.24)	1.65 (0.73)	10.60 (2.71)
		Vidball	2.50 (0.43)	2.13 (0.49)	0.29 (0.40)	1.33 (0.47)	0.35 (0.42)	6.65 (1.25)
Retention								
	Child	Video	2.46 (0.59)	2.75 (0.46)	2.29 (0.74)	2.38 (1.30)	1.83 (0.84)	11.70 (3.21)
		Vidball	2.29 (0.33)	2.27 (0.84)	0.33 (0.50)	1.54 (1.00)	0.46 (0.50)	6.79 (1.63)
EXP.2								
Practice								
	Adult	Point-light	2.67 (0.56)	2.00 (0.88)	1.73 (0.82)	3.31 (0.40)	2.42 (0.73)	12.17 (2.88)
	Child	Point-light	0.85 (0.67)	0.81 (0.50)	0.67 (0.57)	1.63 (0.52)	1.04 (0.42)	5.00 (1.66)
Retention								
	Child	Point-light	1.00 (0.78)	1.00 (0.85)	0.58 (0.70)	2.04 (0.70)	1.33 (0.44)	5.94 (2.39)

EXP.3								
Practice								
	Child	Pre-training	1.88 (0.44)	2.25 (0.55)	0.71 (0.55)	1.75 (0.48)	1.75 (0.48)	7.65 (1.55)
Retention								
	Child	Pre-training	1.88 (0.59)	2.00 (0.78)	0.92 (1.11)	2.08 (0.96)	1.38 (0.78)	8.25 (2.82)

Retention

A significant main effect was observed for condition, $F(1, 14) = 15.79, p < .01, f = 1.03$. From inspection of the right side of Figure 2.1. it can be seen that the VID group remained more accurate at imitating the model's movement pattern than the VIDBALL group. The Condition x Block interaction approached an accepted level of significance, $F(1, 14) = 4.08, p = .063, f = .07$. Only the VID group showed any decrement in performance across the retention period.

Discussion

The aim of Experiment 1a was to determine how the presence of an outcome goal affected movement reproduction accuracy in adults and children who were asked to imitate a video demonstration. It was predicted that when the task had an additional outcome component, movement reproduction would be less accurate than when the task was only to imitate the model's movement pattern. It was predicted that children would be more affected by this manipulation compared to adults due to their tendency to prioritise the end goal to reduce processing demands on the task (Bekkering et al., 2000). However, it has been shown that adult learners elevate the importance of outcome feedback in comparison to pre-practice demonstrations when faced with a dual task goal of imitation and goal attainment (Horn et al., 2002).

In accord with our predictions, the form scores showed that the presence of an outcome goal, in addition to the requirement to imitate the model's movement, negatively affected the accuracy of the reproduced movement. The additional requirement to achieve a particular outcome appeared to constrain the movement response at the expense of the pre-practice demonstration. While there is plenty of evidence to show that knowledge of results has a significant impact on subsequent movement attempts (see Hodges & Franks, 2004), in this experiment, there was no relationship between change in movement form and outcome error. This finding suggests that the mere requirement to achieve a particular outcome results in this goal being prioritised at the expense of accurate imitation (see Wohlschläger et al., 2003). The individual components comprising the action revealed that both VIDBALL groups showed poor imitation of the end arm swing and end lunge components. The adults, and children in particular, failed to imitate the model's movement after the ball was released. It was likely that ball trajectory information became their primary focus of attention at the expense of movement form. In some cases children lay on the floor watching the ball's trajectory. These proposals are further supported by the retention findings whereby the children in the video group were more affected ($p = .063$) by the removal of the visual demonstration than children in the VIDBALL group. The lack of retention deficits for this group supports the suggestion that the primary guiding source of information for the VIDBALL group was related to outcome attainment and not the model.

In summary, these findings suggest that outcome attainment is the primary constraining source of information during learning and that it overrides the informational content of a demonstration (c.f. Bekkering et al., 2000; Gleissner, Meltzoff, & Bekkering, 2000; Horn et al., 2002; Swinnen, 1996). Bekkering and colleagues who instructed children to imitate a contralateral arm gesture (right hand to touch the left ear), found that they executed an ipsilateral movement (left hand to left ear) to achieve the task goal. This finding is consistent with the idea that in goal directed actions the selected outcome goal drives the movement response both in adults and children. Therefore, reducing goal complexity will aid reconstruction of an observed act, namely accurate imitation.

As predicted, the children were less accurate in their movements compared to the adults irrespective of task constraints. It has been proposed that unless young children are specifically guided to critical information sources and provided with cognitive rehearsal strategies, or the task is familiar or very simple (i.e., single degree-of-freedom movement), movement reproduction is relatively poor when compared to older children and adults (see McCullagh & Weiss, 2001; Yando et al., 1978). The accuracy form scores, pertaining to the individual elements of the bowling action, provide a potential insight into the reasons for this poor imitation. Generally, the children showed poorer reproduction of action components relating to the lunge. This finding would support a task-goal hierarchy interpretation, as proposed by Wohlschläger et al., (2003) in that attention is directed to features of the movement most directly related to goal attainment (i.e., the arm). Even the children in the video group showed a greater tendency to focus on the upper body in comparison to the adults, perhaps reflecting a preference for children to focus attention on specific components of the action, rather than the whole action to reduce information processing demands (see Chi, 1976; Yando et al., 1978). The purpose of Experiment 1b was to explore whether observation of the model's movement pattern and the subsequent reproduction of the action could be facilitated through the removal of distracting (i.e., non essential) information. This has been achieved in previous studies through the use of point-light displays. This type of display is believed to increase the salience of relative motion information, which has been proposed by Scully and Newell (1985) to be the primary constraining source of information during observational learning.

Experiment 1b

Researchers who have examined the relative effectiveness of point-light and video demonstrations have failed to yield consistent evidence for one display over another in facilitating motor skill acquisition (see Horn et al., 2002; Romack & Briggs, 1998; Scully & Carnegie, 1998). The nature of the to-be-learned task and performer characteristics seem to underpin the beneficial (Scully & Carnegie, 1998) or detrimental effects (Romack & Briggs, 1998) of watching a point-light as opposed to a video demonstration. Scully and Carnegie (1998) reported that observers were more accurate at reproducing a gymnastic technique from point-light compared to video demonstration, where the goal of the performer was to imitate and coordinate a large number of degrees of freedom, which was not additionally challenged by an outcome goal. In contrast, Romack and Briggs (1998) and Williams (1989) failed to find any benefits for point-light compared to video demonstrations using tasks that required children to imitate a model's movement pattern and achieve an outcome goal. Based on these findings it is anticipated that superior perception and reproduction of the critical invariant information sources from point-light displays will occur only when a whole-body movement is required that is sufficiently complex and has no additional outcome constraints associated with production of the movement. By removing all non-essential information from the display the processing demands associated with imitating a complex motor action should be reduced.

In Experiment 1b, the ability of children and adults to reproduce a whole-body bowling action after viewing a point-light demonstration was examined. These point-light groups were compared to the adult and child groups who viewed a video model in Experiment 1. It was predicted that the salience of relative motion in point-light displays would lead children to imitate the model's movement pattern more effectively than the children who viewed a video model. Children who viewed a point-light demonstration were also expected to reproduce the model's movement pattern as effectively as the adult participants who viewed a video demonstration. The adult participants who viewed a video demonstration (no ball) in Experiment 1a exhibited a ceiling effect in their form scores, moreover there did not appear to be any change in movement reproduction as a function of repeated exposure to the model and practice. Due to the global nature of the form scores that were primarily constructed to capture performance differences in the children, more subtle variations in spatio-temporal parameters as a function of repeated observations might not be detected. In Experiment 1b additional measures were gathered using three-dimensional movement analyses. If point-light displays are more effective at displaying spatial-temporal relationships (i.e., relative motion between joints) this should be evidenced in coordination differences between the adult point-light and video groups.

Method

Participants

Eight boys (6.7 ± 0.5 yr) and eight adult males (21.1 ± 2.8 yr) took part in Experiment 1b. These participants had not participated in Experiment 1a and comprised the child and adult point-light (PL) groups. For comparison purposes, the two PL groups were compared to the two-video groups from Experiment 1a. Informed consent was obtained as in Experiment 1a.

Apparatus

The apparatus was the same as in Experiment 1a. Additionally, movement kinematics were collected in the sagittal plane from reflective markers placed on major the major joints using three infra-red cameras (Pro-Reflex; Qualisys, Gothenburg, Sweden) sampling at 240 Hz.

Task and Test Film Construction

The task and primary aim were the same as in Experiment 1a. Four motion analysis cameras recorded the spatio-temporal positions of 15 reflective markers placed on the model's major joint centres. These markers formed a point-light display when viewed through a software viewing program (Q-Trac Motion Viewer, Beta 2.54; Qualisys, Gothenburg, Sweden). This image was then transformed in the program to match the video presentation and converted to VHS format to produce the point-light display model.

Procedure and Design

Before practice, reflective markers were placed on the right side of each participant's distal head of the 5th metatarsal (toe), the lateral malleolus (ankle), the lateral condyle of the femur (knee), the greater trochanter (hip), the acromion process (shoulder), the lateral epicondyle (elbow), the styloid process of radius (wrist) and on the left side, the distal head of the 1st metatarsal (toe). All other procedures were the same as detailed for Experiment 1a except no ball rolling was required.

Dependent Measures

Form analysis.

The form analysis was the same as in Experiment 1a.

Kinematic analysis.

Kinematic analysis was performed on the model's data and the coordination between the shoulder and elbow of the bowling action served as the criterion in which the adult group's data (i.e., video and PL) were compared. Due to high variability in the actions of the children only kinematic data from the adult participants were examined. The effects of viewing the point-light and video models were assessed via changes in intra-limb coordination at the start (trials 1-3) and end of practice (trials 8-10). The start and end points of the arm swing were determined based on the initiation of shoulder extension, in preparation for the start of the arm swing phase of the action, and of peak shoulder flexion in the follow-through element of the swing. The data were smoothed with a recursive 4th order Butterworth filter with a cut-off frequency of 7 Hz. A linear interpolation was performed to normalize this period to 100 data points enabling comparisons across trials and with the model.

The similarity in intra-limb coordination between the participants' and model's shoulder-elbow coordination profile was quantified using a modified version of Sidaway, Heise, and Schoenfelder-Zhodi's (1995) normalized root mean squared error (NoRMS). However, the root mean squared error was calculated based on disparity of each trial from the model's trace rather than the participant's trace. The score was normalized for number of trials and range of motion (see Horn et al., in press; Mullineux, Bartlett, & Bennett, 2001). The resulting measure was termed normalised root mean squared difference (NoRM-D, see Horn et al., in press).

Statistical Analysis

Practice.

An overall form score was calculated and the point-light display group's performance was compared to the adult and child video groups from Experiment 1a. Data were analysed in a 2 Condition (VID, PL) x 2 Age (children, adults) x 2 Block (start of practice, end of practice) mixed ANOVA with repeated measures on the last two factors. The NoRM-D scores for the shoulder-elbow coordination for the adult participants were analysed in a 2 Condition (VID, PL) x 2 Block (start of practice, end of practice) mixed ANOVA with repeated measures on the last factor.

Retention.

The children's overall movement form data were analysed in a 2 Condition (VID, PL) x 2 Block (end of practice, retention) mixed ANOVA with repeated measures on the last factor.

Results

Form Analysis

Practice.

The data for the VID and PL groups (dark symbols) are presented in Figure 2.2. A significant main effect for block, $F(1, 28) = 12.97, p < .01, f = .18$, showed that participants improved across practice. A significant main effect for age was also observed, $F(1, 28) = 49.76, p < .01, f = .84$, showing that adults were more accurate at imitating the movement pattern than the children. A condition main effect, $F(1, 28) = 25.43, p < .01, f = .51$, indicated that movements were reproduced more accurately after watching a video compared with point-light demonstration. The predicted Age x Condition interaction was observed, $F (1, 28) = 4.72$, $p < .05$, $f = .20$, although it was not in the expected direction. The children in the PL group did worse than the children in the video group, whereas there was no significant difference in reproduction accuracy for the adults who viewed a point-light or video demonstration.

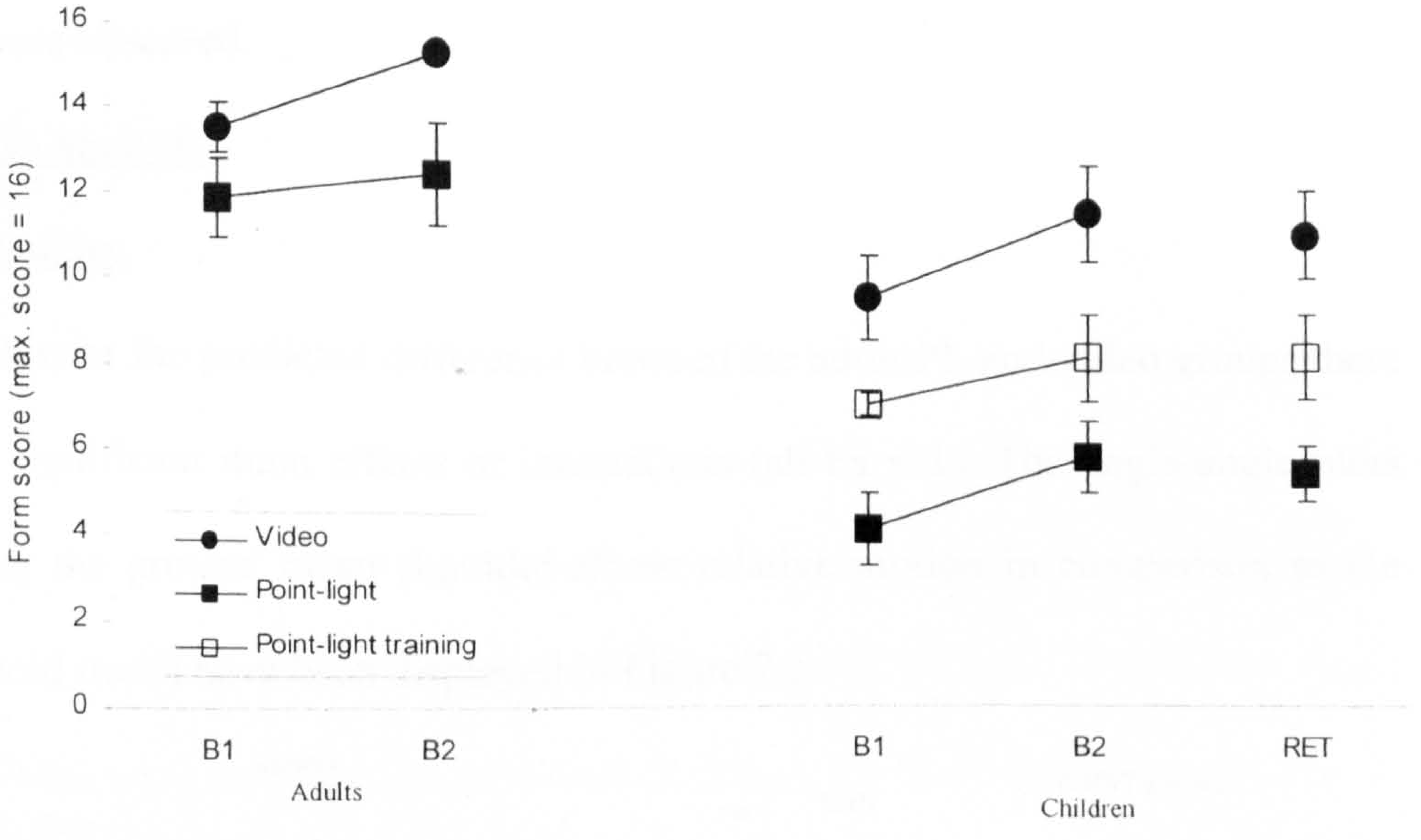


Figure 2.2. Mean form scores (and standard error bars) across practice blocks and retention for the children (video, point-light and point light training) and across practice blocks for the adults as a function of condition (video and point-light) in Experiment 1b.

The child PL group was poor at all elements of the bowling action (see Table 2.3.), displaying a very general form of arm swing, minimal knee flexion in the lunge or a completely different movement to the criterion model (e.g., walking, laying down). This was in contrast to the adult groups and the child video group who imitated the arm swing elements accurately, although children in the video group failed to accurately end the lunge.

Retention.

A significant effect for block was observed in retention, $F(1, 14) = 6.32, p < .05, f = .13$. Both child groups were significantly less accurate at reproducing the bowling action when the model was removed following a 24-hour retention period. However, the main effect for condition remained, $F(1, 14) = 21.67, p < .01, f = .41$, with the video group performing more accurately than the PL group. No interaction effects were observed.

Kinematic Analysis

Practice.

Despite the predicted difference between the adult PL and video groups there were no significant main effects or interactions (all Fs < 1). The angle-angle plots displaying the groups' mean shoulder-elbow relative motion in comparison to the model (bold trace) have been displayed in Figure 2.3.

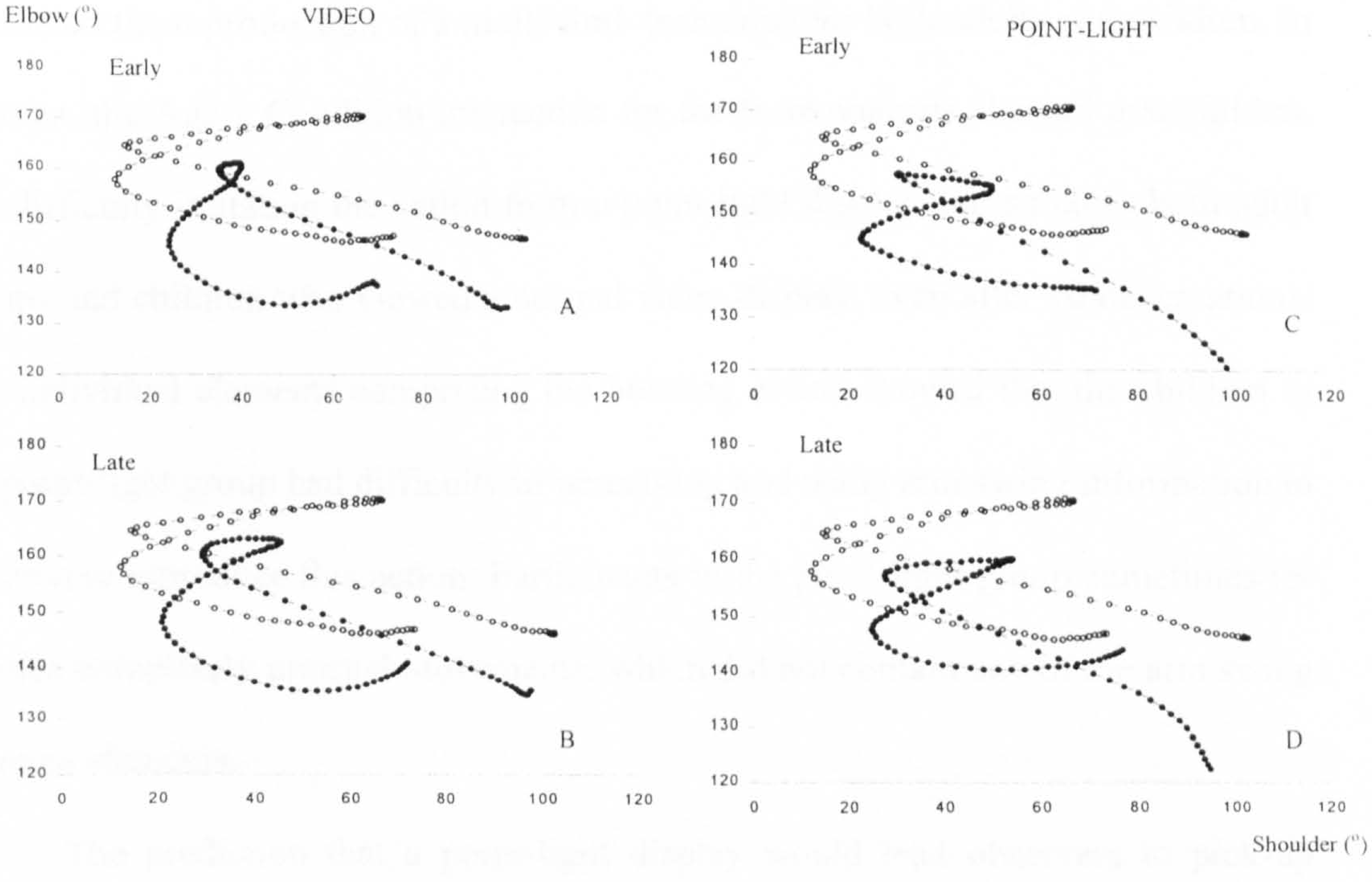


Figure 2.3. Angle-angle plots for the mean shoulder-elbow coordination profile in early (a and b) and late (c and d) practice for the adult video (a and c) and point-light (b and d) groups (open circles denote the model's trace)

Even after 10 exposures to the model and 10 reproduction attempts both groups did not show a strong approximation to the model's shoulder-elbow coordination profile. Both groups exhibited more elbow flexion and shoulder extension in the arm swing element compared to the criterion model. The mean NoRM-D scores for both groups were high, a score of zero would indicate a perfect likeness to the model's shoulder elbow profile (PL, $M = 92.03$ $SD = 32.07$; VID, $M = 86.05$ $SD = 20.02$).

Discussion

The aim in Experiment 1b was to examine whether the salience of relative motion in point-light displays would help constrain movements and encourage child observers to imitate the model's movement more accurately than observers who viewed a video model. There was, however, no evidence that point-light demonstrations facilitated the reproduction of a multi-limb technique for both adults and children. In contrast, the Age x Condition interaction for the form analysis showed that children had difficulty imitating the action from a point-light display compared to both adult groups and children who viewed a normal video display, even after 10 observations. The individual elements comprising the bowling action showed that the children in the point-light group had difficulty in perceiving and using arm swing information to effectively reproduce this action. Participants in the point-light group sometimes re-enacted completely unusual movements, which did not contain any of the arm swing or lunge elements.

The prediction that a point-light display would lead observers to pick-up more subtle coordination features of the model's relative motion properties and thus a more accurate reproduction profile was not supported. Kinematic analysis failed to yield any significant differences between the adult point-light and video groups' shoulder-elbow coordination; both groups showed relatively poor reproduction profiles in comparison to the model's shoulder-elbow coordination. Although both adult groups imitated the spatial and temporal characteristics of the movement more accurately than the children, the adult point-light group typically executed the lunge action with the wrong leg in comparison to the video group, indicating that critical depth information was disrupted as a result of this type of display.

The work of Johansson (1973, 1975) is often cited as evidence that humans are sensitive to certain invariant features of biological motion as presented in point-light displays. This sensitivity is thought to occur early in development (Bertenthal et al., 1984; Fox & Daniel, 1982; Pavlova, et al., 2001). However, like Romack and Briggs (1998), we found deficits in motor reproduction for young children after viewing a point-light compared to video demonstration. This finding leads to the suggestion that difficulties in perception are mediated by the level of development and /or experience with the task. Since the visual display and action used in this experiment were novel, children might have had problems translating the externally perceived model to their own body (i.e., conceptual mediation) in order to execute the movement (see Goldenberg, 1995).

In early learning, practitioners typically provide demonstrations to encourage the observer to get an 'idea of the movement' (Gentile, 1972) or to locate the invariant relative motion properties of the action (Scully & Newell, 1985). Before the observer attempts to execute the movement the information needs to be encoded and retained via a verbal or visual representation (Bandura, 1977; Goldenberg & Hagmann, 1997). The children may have lacked the appropriate 'cognitive set' and explicit knowledge to provide language for understanding the novel point-light action, and consequently, failed to use an effective strategy such as verbal labelling (see Cadopi et al., 1995; Viviani & Stucchi, 1992). The advantage of such a strategy is that it decreases the memory demands of the observer such that they are not required to remember and visually represent the whole action, rather they can recall a large component of the action through a verbal cue for example. The demonstration serves to parameterise an existing 'idea' of what a bowling action should look like, thus significantly decreasing the processing demands and in most cases facilitating reproduction (as long as the 'idea' of the correct action is similar to the demonstrated action).

If the children had problems labelling the novel bowling action, we might have expected similar imitation deficits for children in both the PL and video groups. However, the child PL group always performed worse than the child video group. Perhaps the contextual information cues present within a video display enabled the children to transfer and label the action with existing knowledge from long term memory. Decety et al., (1997) found that an area of the cortex (area BA 45 located in the left inferior frontal gyrus) associated with verbal encoding and functional knowledge was only activated when a to-be-imitated task was familiar.

All adults in the PL group correctly identified the bowling action in post practice interviews, whereas the young children in the same group reported a "boy moving" or a series of "moons". Since this group could not recognise or provide a definitive label to understand the action, it is likely that the visual information was processed in a different manner to the adult point-light group who found the action familiar. Petrides and Pandya (1984) have proposed that areas 40 and 6 in the dorsal stream are responsible for encoding novel movements. Differences in processing activities may therefore account for the poor reproduction scores and sometimes completely different movements shown by the child PL group in comparison to the adult group who received the same stimuli.

In summary, in Experiment 1b we showed that children who viewed a point-light display had problems imitating an action which may be underpinned by the lack of domain specific knowledge required to successfully recognise and imitate movements (e.g., Pinto & Shiffrar, 1999; Sparrow et al., 2001). Therefore, in Experiment 1c, we used a period of perceptual point-light training. This manipulation was designed to determine whether difficulties in providing pre-practice information via point-light displays is a conceptual problem or a problem due to the children's inability to perceive biological motion in unfamiliar movements at a young age of development.

Experiment 1c

In order to imitate successfully, an observer must translate the actions of an externally perceived model relative to their own body (i.e., conceptual mediation), and then execute the movement (Bandura, 1977; Goldenberg & Hagmann, 1997; Wohlschläger et al., 2003). Although adults (Horn et al., 2002; Al-Abood, et al., 2001) and older children (Williams, 1989) can process and reproduce kinematic and absolute features from point-light displays, younger children show reproduction deficits (see Experiment 1b and Romack & Briggs, 1998). These deficits may be due to an underdeveloped perceptual system (i.e., a problem perceiving and extracting relative motion information) or the result of difficulties in translation associated with unfamiliar displays and novel actions.

The main purpose of Experiment 1c was to provide a period of perceptual point-light training to develop the conceptual knowledge required to identify the movement kinematics from point-light stimuli. It was predicted that such perceptual training would lead children to imitate the model's movement pattern more effectively than children who viewed a point-light model without training in Experiment 1b. If there are benefits associated with a point-light display following training (see predictions from Experiment 1b) then the point-light group would be expected to out-perform the child video group.

Method

Participants

Eight boys (6.7 ± 0.5 yr) were recruited. These participants, who had not taken part in the earlier experiments, formed a child point-light display plus perceptual training (PLT) group. The child groups (PL and VID) from Experiment 1b served as comparisons. Informed consent was obtained as in Experiment 1a.

Apparatus

The apparatus were the same as in Experiment 1a.

Task and Test Film Construction

The task and test film were the same as in Experiment 1a.

Procedure and Design

The procedures were the same as detailed for Experiment 1b. However, prior to observing the model the PLT group observed a perceptual training video, called the 'dot man game', of various biological motions which included running, throwing, jumping, walking and kicking. The training video displayed an activity in video format first (i.e., a boy running) and then the corresponding activity in point-light format at two display speeds, normal and half speed. The video displayed five activities, totalling 15 demonstrations (5 video, 5 point-light and 5 half-speed point-light). After the perceptual training, participants observed a randomised test video of the five activities in point-light format. Children were asked to verbally identify each point-light activity to ensure that they understood the nature of the information represented in point-light stimuli. All participants answered with 100% accuracy.

Dependent Measures

Movement form reproduction was analysed using the same procedures as in Experiment 1a.

Statistical Analysis

Practice.

The PLT group's performance was compared to the child PL and video groups in Experiment 1b. The form scores were analysed in a 3 Condition (PLT, PL, VID) x 2 Block (start of practice, end of practice) mixed design ANOVA with repeated measures on the last factor.

Retention.

The children's data were analysed in a 3 Condition (PLT, PL, VID) x 2 Block (end of practice, retention) mixed ANOVA with repeated measures on the last factor. Any significant effects involving condition were analysed using the Tukey HSD post hoc test *($p < .05$)*.

Results

Form Analysis

Practice.

As shown on the right side of Figure 2.2. a significant main effect was observed for block, F (1, 21) = 7.25, $p = .05$, $f = .24$. All groups improved their reproduction performance across ten exposures of the model and reproduction attempts. A significant effect was also observed for condition, $F(1, 21) = 15.03, p < .01, f = .92$. Tukey post hoc analysis indicated that the PLT and video groups were more accurate at imitating the model's movement pattern than the PL group ($p < .05$). However, the video group was also more accurate at imitating the bowling action than the PLT group ($p < .05$). There was no interaction effect ($F > 1$).

The mean individual form scores are presented in Table 2.3. The PLT group (i.e., pre-training) was more accurate at imitating the initial elements of the arm swing, reaching a similar level to the adult and child video groups from Experiment 1a than the end arm swing or end lunge elements.

Retention.

No significant block effect or Block x Condition interaction was observed (both F's > 1). However, the condition main effect was still observed, $F(1, 21) = 9.23, p < .01, f = .88$. The video group remained more accurate at imitating the bowling action than the PL group ($p < .05$), but none of the other comparisons were significant.

Discussion

The aim of Experiment 1c was to determine whether perceptual training would help children develop the conceptual knowledge required to perceive and use a point-light model to facilitate movement reproduction in comparison to point-light model only and video groups. It was predicted that children who received perceptual training prior to viewing a point-light display would reproduce a novel motor action more accurately than a point-light group who did not receive this training. If this minimising of information to critical constraining features facilitated imitation then this group would out perform a video group.

In accord with our first prediction, perceptual point-light training facilitated children's perception and reconstruction of a novel motor action in practice, compared to the point-light group that did not receive this training period. The individual mean form scores involved in the action revealed that the training group was more accurate at reproducing the arm swing and follow through elements of the arm. However, this difference was not maintained in retention. Against our prediction, this training did not encourage children to locate task specific information from the point-light display and improve their ability to imitate the model's movement pattern compared to the video group. The removal of contextual information via a point-light display did not reduce the processing demands necessary to perceive the critical movement invariance within a demonstration.

In contrast to Williams (1989), the training provided to the point-light group in this experiment was relatively general, informing participants about point-light displays rather than providing a context and label to understand the bowling action. Without this domain specific knowledge the display might have remained relatively abstract to the pre-training group preventing the children in the point-light training group from using an effective verbal label to aid memory during reproduction (Cadopi et al., 1995).

General Discussion

In Experiment 1a, it was predicted that movement reproduction would be challenged if the task had multiple goals (i.e., movement imitation and goal attainment). This finding was expected to be more pronounced for children rather than adults. In Experiment 1b, contextual information was manipulated in an attempt to make the critical movement features of a display salient to children to aid in effective movement reproduction. In Experiment 1c, as a result of the failure of point-light demonstrations to facilitate movement reproduction in children, a period of perceptual training was provided to help the children understand and interpret the point-light information, arguably facilitating the transition from visual perception to motor execution.

The results from Experiment 1a showed that when multiple goals are required within a single task (i.e., outcome attainment and movement reproduction), the outcome goal is more likely to be preserved, leading to specific and consistent errors in imitative behaviour (Prinz, 1997; Wohlschläger et al., 2003). In light of the effect that outcome goals or the processing of feedback impose on skill acquisition, when a specific movement form is required the removal of outcome feedback (see Horn et al., in press) might be advantageous in these situations.

Reducing the demonstration to present only the information that pertains to the relations between body parts (i.e., point-light display) did not facilitate the reproduction of the bowling action for either the children or adults in comparison to the video demonstration. These data corroborate related research findings (Al-Abood et al., 2001; Horn et al., 2002, in press; Williams, 1989) and suggest that point-light stimuli offer no advantage for movement reproduction by making relative motion more salient. In fact, there appears to be some difficulty associated with the removal of contextual information, particularly for children. It appears that functional knowledge is important for perceiving key parameters from biological motion (see Sparrow et al., 2001; Ward, Williams, & Bennett, 2002). Because the motor action and display were novel to the children in the point-light group a lack of task relevant knowledge seemed to have prevented the information from being translated into an accurate motor representation ready for motor execution.

In Experiment 1c, a period of non task-specific perceptual training for the children facilitated the transition from visual perception to motor execution associated with the perception of point-light displays. However, the children still had problems using biological motion from point-light displays even after this training, in comparison to children in the video group. In contrast to Scully and Newell's (1985) proposal that relative motion is automatically processed and then acts as an informational constraint to guide the emergence of coordination (see Al-Abood et al., 2001), our data leads to the suggestion that to imitate a novel action accurately from point-light stimuli the observer must translate the image to topographic knowledge about the human body. Without some form of explicit knowledge of the task to help mediate this process, observers and especially children will have difficulties in perceiving and imitating the skill.

On the basis of these Experiments a number of suggestions can be made with respect to what and how information is picked up when learners view a demonstration. There is evidence that observers order outcome attainment at a higher priority than movement information such that this knowledge is used primarily to inform movement production. Difficulties following training and the use of point-light displays lead us to question whether relative motion is the critical constraining source underlying movement reproduction, particularly for children, and if it is, different methods for making this information salient need to be explored.

The child point-light group was not able to use the point-light stimuli present within the demonstration to accurately inform movement, even when some conceptual knowledge was provided (see Goldenberg & Hagmann, 1997). It appears that for novel skills the perception and subsequent benefits of using a demonstration to convey movement information is limited by domain knowledge, particularly so for impoverished stimuli such as point-light displays which require 'elaboration' on the part of the child for full understanding (see Bransford et al., 1982).

These experiments show how important it is to understand the task context where instructions and demonstrations are to be provided before administering this information. The fact that both adults and children prioritise outcome attainment at the expense of the movement process has important implications for the instruction process. For example, instructional methods that are designed to encourage a particular movement technique should be provided in a context where outcome goals are removed or explicitly downplayed and/or the demonstration is enhanced to make the critical information salient. There is little evidence to suggest that presenting models in the form of a point-light display facilitates this elaboration process, and difficulties have been observed in interpretation of this information. Perhaps superimposing points of light on top of a video demonstration may facilitate the saliency of relative motion information. However, it might be effective to focus the observer's attention towards only a few central markers associated with effective reproduction. For example, attention could be directed to the foot in a kicking task, with the supposition that task and body relevant knowledge will also be imparted to facilitate the perception and understanding of the display, aiding elaboration of less important features of the movement. Moreover, a progression from less information (i.e., the primary effector) to more whole-body information would help convey information from the rest of the body when the technique is particularly novel, or the coordination across joints is important.

It should be clear from this discussion that the question of what information is perceived and used for movement reproduction requires a complex answer dependent on both the observer characteristics and the constraints of the task. However, it is evident from these Experiments that imitation is not deemed to be as important as outcome attainment in tasks where the distinction between these two sources of information can be made and that perception and reproduction of motor skills are dependent on both the task and body-relevant knowledge of the observer.

Chapter 3

An evaluation of the minimal constraining information during observation for movement reproduction

Abstract

An important question in the field of imitation is what information is used for movement reproduction. While it is argued that relative motion information is perceived and minimised, direct evidence is lacking. In this experiment relative motion was manipulated to convey a novel kicking action. Twenty-four adults were assigned to one of three impoverished relative motion display groups showing only the TOE, FOOT or LEG. After practice with partial information, participants watched a full-body display and in a final condition performed the action with an additional context constraint (i.e., a ball). Movement kinematics were collected and difference scores between participants and the model analysed. The groups did not differ in terms of knee-ankle coordination. For hip-knee, the TOE group performed more like the model than the FOOT and LEG group. When transferred to the full-body display, there were no significant improvements. End-point trajectory information can provide sufficient information to reproduce key characteristics of movement form.

The process of imitation and learning from demonstrations is believed to underlie much of early development and the acquisition of motor skills throughout life. It is vital that scientists, as well as practitioners, understand how this observational process works such that key sources of visual information can be identified and provided to aid motor skill acquisition and performance. Several terms are used to describe the process underlying observation of movement with the aim of subsequent reproduction. Although these terms share similarities, their varied use reflect different beliefs concerning *what* information is perceived and *how* it is employed to inform movement reproduction. Generally, imitation is inferred 'when actors match their own movements to those of others' (Wohlschläger, Gattis, & Bekkering, 2003, p.1), implying a specific causal relationship between observation and execution. The observation process is judged based on the quality of the observed movement. If characteristics of the observed action are imitated, it is assumed that these characteristics were perceived and used to produce the movement. The terms 'modelling' and 'observational learning' have sometimes been used synonymously with imitation, although the quality of the movement is typically assessed over a longer period of time and often in the absence of a visual demonstration (McCullagh & Weiss, 2001). Since researchers have provided greater emphasis on *how* rather than *what* information is used to facilitate observational learning (e.g., Bandura, 1986; Carroll & Bandura, 1985), the quality of the observed movement is assumed to reflect the type of cognitive processes mediating perception and action.

An exception to the traditional cognitive approach was provided by Scully and Newell (1985). Following on from the work of Johansson (1973, 1975), who showed that the recognition of biological motion is guided by relative motion information (i.e., the way one part of the body moves in relation to other parts), Scully and Newell (1985) proposed that a model's relative motion pattern is directly perceived and used to constrain the coordination of novel or unfamiliar actions. Moreover, based on research by Cutting and Proffitt (1981), Scully and Newell proposed that the relative motion information within visual demonstrations is essential for the assembly of a novel movement, whereby observers attempt to replicate relative motion patterns to facilitate the acquisition of coordination (see also Scully & Carnegie, 1998). In situations where replication is the only goal, the model's coordination pattern is the optimal (or only) solution to the coordination problem. In some situations, however, a demonstration is only one of a number of possible task constraints which influence movement reproduction (Newell, 1986). Additional equipment or individual constraints (e.g., strength) can also interact to influence the movement. In these situations it has been argued that the model's coordination pattern guides the search for the task-optimal solution to the coordination problem (see Al-Abood, Davids & Bennett, 2001; Newell & McDonald, 1992).

Some researchers have argued that 'emulation' is a more appropriate term to define observation and the replication process in tasks which require interception of an object. Under these conditions it has been proposed that the observer intends to replicate an object's movement rather than the model's movements per se (e.g., Heyes, 2001; Tomasello, Kruger, & Ratner, 1993). In this case it is not the information within a demonstration that is perceived, but rather the intention of the actor. Chaminade, Meltzoff, and Decety (2002) presented neurophysiological data consistent with the above hypotheses, namely that imitation of a gesture activates an area of the brain (i.e., left pre-motor cortex) which is associated with the intention or goal of the observer, rather than the process or means of performing the action (see also Koski et al., 2002).

In the following experiment, the nature of information used to guide movement reproduction both in the absence (i.e., when the model's coordination pattern is the primary constraint on movement) and presence of task constraints in addition to a model. Thus far, there has only been indirect support for the proposal that relative motion information is the minimal, essential information necessary for movement reproduction and thus is both perceived and used to guide movement reproduction. The observation of a relative motion pattern similar to a model should not necessarily lead to the conclusion that this was due to such information being picked-up and used to guide action. This finding could equally be due to the extraction and selection of a particular feature or task goal inherent in the act (see Wohlschläger et al., 2003). The availability of relative motion information has not been manipulated experimentally to allow a more direct test of this hypothesis, and there have been no attempts to isolate the conditions under which this information might be used to constrain movement.

In a number of studies, relative motion information has been indirectly manipulated through the direct removal of structural/contextual information. It has been reasoned that if relative motion information is the minimal constraining information for movement reproduction, the removal of contextual information should not have a detrimental effect on performance. Moreover, it has been proposed that if relative motion is made salient through this removal process, observational learning will be facilitated. Scully and Carnegie (1998) transformed a movement display into points of light representing the major joints of the body during a gymnastic dance action. Point-light displays (PLDs) were more effective in leading to the production of the model's coordination profile than video. However, this result has not been replicated by other researchers (e.g., Al-Abood, Davids, Bennett, Ashford, & Martinez-Marin, 2001; Chapter 1; Romack & Briggs, 1998). Horn, Williams, and Scott (2002) failed to observe differences between demonstration groups (i.e., video and point-light) and a control group when learning a kicking action in terms of joint range of motion and hip-knee coordination. However, it was proposed that additional task constraints (i.e., the requirement to kick a ball and achieve target goals) may have had a more significant influence than the model on the observer's coordination pattern (despite instructions to copy the model). In other words, the availability of feedback relating to task performance may have reduced the importance of relative motion in constraining the observer's coordination pattern.

In a subsequent experiment, Horn, Williams, Scott, and Hodges (2004) removed outcome-based feedback at foot-ball contact in an attempt to increase the importance of the demonstration. The demonstration groups (point light and video) performed more like the model than the control group. It was argued that the primary constraining source of information guiding movement reproduction was the model's movement pattern and, more specifically, the relative motion information present within the display. However, the changes in intra-limb coordination were relatively immediate, suggesting that rather than the complexities of the model's movement being used to constrain movement reproduction over practice, the participants were allocating their attention onto more simple aspects of the display (e.g., knee or hip angle, range of motion of the knee or knee velocity). Since there was no direct manipulation of relative motion information and there were no significant differences between the video and PLD groups, the question remains whether relative motion was actually extracted and used to constrain action. Without a direct manipulation of relative motion information (i.e., its removal or distortion), it is not possible to conclude that relative motion is the essential information for the acquisition of coordination.

A further problem in assuming that relative motion information is both perceived and used to aid movement reproduction is that relative motion information is rarely available during reproduction attempts, such that the performer needs to both perceive and remember (or encode) this spatial-temporal information. There is evidence that this process is particularly difficult for novel and/or unfamiliar coordination patterns (see Collier & Wright, 1995; Hodges, Chua, & Franks, 2003). Whilst relative motion information could help the learner to recognise an action (e.g., a somersault or a bowling action in cricket or softball), it is debatable as to whether relative motion information per se is extracted and used as a subsequent guide for reproduction.

One way that observation for later reproduction might be simplified is for the observer to focus only on those sources of information or cues that are most pertinent to the task, such as the end-point of the action. Mataric and Pomplun (1998) showed that during observation of arm movements prior to reproduction, observers show a tendency to focus upon the hand and fingers, rather than the action of the whole arm. The observers were capable of filling-in details about the posture and control of a whole arm movement from a small window of information at the end-point. It is possible that whilst relative motion information might help an observer determine a specific class of action, such that this information is evaluated against a background of prior experiences (Cutting & Proffitt, 1982), information pertaining to the end-point of the action is extracted and used to guide later reproduction.

In the following experiment access to relative motion information is manipulated through the reduction and removal of such information from a model displaying an unusual, left-footed, kicking or 'scoop like' action. The model's movements will be shown only in the form of point-light displays. In the first phase of the experiment no additional contextual cues or task constraints, beyond demonstrations, will be provided, in order to evaluate the minimal essential information necessary for movement reproduction and determine whether relative motion information is essential for this process.

A repeated measures design is employed such that following replication attempts in the first phase of the experiment, the impoverished relative motion groups will then see a full-body demonstration. If relative motion information is the primary constraining source of information for movement reproduction, there will be a change in the kinematics of the three impoverished relative motion groups after viewing the full-body demonstration, such that the coordination profiles will more closely approximate the model. Finally, to understand how the task context influences movement observation and reproduction, participants will be asked to use the same movement as observed in the demonstration to kick a soccer ball over a height barrier to land on the same target achieved by the skilled model. If a change in the coordination profile of the participants is observed to more closely approximate the model, evidence that coordination is a consequence of other task constraints, rather than relative motion information, will be provided.

Methods

Participants

Twenty-four participants (18 men and 6 women) were randomly assigned to one of three experimental groups (TOE, FOOT or LEG), with the constraint that there were eight in each group and an equal ratio of males to females in each group (*M* age = 23.6 yr; *SD* = 2.50 yr; range 20 – 30 yr). Participants were right footed and had normal or corrected-to-normal vision. The experiment was conducted in accordance with the ethical guidelines of Liverpool John Moores University. Participants provided informed consent and were free to withdraw at anytime.

Apparatus

Movement kinematics were collected using a VHS video camera (Panasonic M-40, Tokyo, Japan) and four infrared motion analysis cameras (Pro-Reflex; Qualisys, Gothenburg, Sweden) sampling at 50 and 240 Hz respectively. The visual images were front projected onto a 3.0 m x 3.5 m screen (Cinefold, IN, U.S.A.) using a projector (Sharp XG-NV2E, Tokyo, Japan) and video recorder (Panasonic NV-HS 820, Tokyo, Japan). A regulation size 5 soccer ball was introduced in the final phase of testing. Moreover, two barriers consisting of small wooden poles attached to two chairs at a height of 75 cm, positioned 175 cm from the participant on either side of a carpeted grid were added. A target cross was also placed on the floor, at a distance of 250 cm from the participants.

Task and test films

A recreational, right-footed soccer player practiced a left footed soccer 'scoop' or chipping action over a period of nine days and more than 400 trials (see

Hodges, Hayes, Horn, & Williams, in press). On the final day of practice a successful kick was chosen (i.e., one where the ball cleared a height restriction and landed on the target) to represent the typical kinematic profile adopted by the model to achieve task success. Movement kinematics were recorded from eight reflective markers which were placed on the model's left side on the major joint centres. The markers were placed at T5 on the upper spine, acromion process (shoulder), epicondyle (elbow), ulnar styloid (wrist), the greater trochanter (hip), the lateral condyle of the femur (knee), the lateral malleolus (ankle), and the distal head of the 5th metatarsal (toe). A point light display (PLD) was produced using QTM-manager software (Pro-Reflex; Qualisys). The PLD acted as the source of information from which participants were required to extract visual information regarding the model's action in order to imitate the whole-body action associated with the demonstration. The PLD was edited to produce four different demonstration tapes. A full-body demonstration tape was developed for use in Phase II of testing, where participants saw all eight markers. Three PLD demonstration tapes were constructed for use in Phase I. In these tapes, either the markers corresponding to the knee, ankle, and toe (LEG), the ankle and toe (FOOT) or the toe only (TOE) were presented, reflecting various degrees of relative motion information. The information presented within the three conditions was extracted from the same lower-leg kicking action that was performed by the model.

Procedure

Before the experiment, reflective markers were placed on the left side of each participant's distal head of the 5th metatarsal (toe), the lateral malleolus (ankle), the lateral condyle of the femur (knee), the greater trochanter (hip), the acromion process (shoulder), and the distal head of the 1st metatarsal on the right foot (toe). Participants in the three groups then viewed a PLD perceptual training video to ensure that they were familiar with and fully understood the conceptual nature of PLD stimuli (see Hayes et al., submitted). The training video comprised a number of everyday and sporting actions including walking, jumping, running and throwing which were shown both in regular video and in point light format. Participants were tested individually, in the laboratory, with each test session lasting approximately 45 minutes. All trials were filmed using four infrared cameras (Pro-reflex; Qualisys) at a capture rate of 240 Hz. Prior to each trial, participants were required to stand behind a line depicted on the floor of the laboratory which was positioned to enable easy viewing of the demonstrations and capture the participants' movement kinematics. Three phases of testing were undertaken.

Phase I: Manipulation of relative motion information.

Standardised instructions were given to the participants outlining the aim of the task. These instructions specified that the task was to watch an edited demonstration and reproduce the whole-body action that produced the movement. Participants received 12 practice attempts in total. The demonstration was shown twice before the first trial and once prior to each of the remaining 11 trials. No specific verbal information about the type of action was provided. All groups were told that the point(s) of light depicted motions of the left side of a model's body. They were told which joints on the body these points of light represented (e.g., the FOOT group was informed that the lights showed the motions of the left toe and ankle). The participants from the TOE, FOOT, and LEG groups viewed a reduced PLD demonstration throughout the 12 trials corresponding to the toe, toe and ankle or toe, ankle and knee, respectively.

Phase II: Transfer to full-body display.

Following the 12 practice attempts, participants in all three impoverished relative motion groups watched a second display corresponding to a full-body PLD demonstration (i.e., all 8 markers) and attempted to replicate the model's movement over four subsequent demonstration-reproduction trials. The demonstration was viewed once prior to each practice attempt.

Phase III: Introduction of task constraints and contextual cues.

In the final four trials, participants were asked to imitate the same full-body PLD action in addition to kicking (or scooping) a ball to clear a height restriction (conveyed by two barriers) and land the ball on the specified target. Participants were told that the model's actions had produced a successful outcome.

Data analysis

The start and end points of the action were determined based on the initiation of knee flexion of the left leg prior to observation of a kicking action in the leg and ended at peak hip flexion following the kick. The data were smoothed with a recursive 4th order Butterworth filter with a cut-off frequency of 7 Hz. A linear interpolation was performed to normalize this period to 100 data points enabling comparisons across trials and with the model.

Similarity in intra-limb coordination between the participant and the model for both the ankle and knee and the knee and hip were quantified using a modified version of Sidaway, Heise, and Schoenfelder-Zhodi's (1995) normalized root mean squared error (NoRMS). In this approach, disparity from the model's trace, rather than the participant's mean trace, provides the measure of error. This measure is referred to as normalized root mean squared difference (NoRM-D; see Horn et al., in press).

To provide an indication of how the movement was controlled, as distinguished from coordination (see Newell, 1985), an analysis of peak hip angle and peak velocity of the knee joint was obtained during the kick. A difference score was calculated based on the model's data and these values were analysed using the same statistical methods as reported for intra-limb coordination. Partial-eta squared values are reported for all effects.

Phase I: Manipulation of relative motion information.

Kinematics collected from the first four trials and last four trials of this phase were analysed and compared to the model to yield a measure of intra-limb coordination in terms of movement disparity from the model (i.e., NoRM-D). These values were analysed in a 3 Group x 2 Block (first and last) mixed design analysis of variance (ANOVA) with repeated measures on the last factor. All effects involving the between-group factor were analysed using pre-planned orthogonal contrasts such that the two relative motion groups (LEG, FOOT) were compared to the no-relative motion group (TOE) and the two relative motion groups to each other. A similar analysis was conducted on the variables more related to the control of the movement (i.e., peak hip angle and knee velocity).

Phase II: Transfer to full-body display.

A second analysis was conducted following introduction of the full-body demonstration for the three impoverished relative motion groups. The last block of four trials prior to the introduction of this information in practice was compared to the four trials immediately following its presentation. The data were analysed in a 3 Group x 2 Display Type mixed design ANOVA with repeated measures on the last factor. Group effects were explored using pre-planned orthogonal contrasts.

Phase III: Introduction of task constraints and contextual cues.

The performance of each participant immediately following the full-body demonstration was compared to performance after the addition of task constraints (i.e., ball and target) using a 3 Group x 2 Context, mixed design ANOVA.

Results

Intra-limb Coordination

Knee-Ankle

Phase I: Manipulation of relative motion information.

The NoRMS-D scores calculated for the knee-ankle relative motion profiles for the three groups in comparison to the model are displayed on the left side of Figure 3.1. The groups were not significantly different from each other, $F < 1$. There was no improvement over practice blocks, $F < 1$, and no significant Group x Block interaction, $F\ (2, 21) = 1.44, p = .26, \eta_p^2 = .12$.

Phase II: Transfer to full-body display.

Despite the addition of relative motion information, there was no significant improvement in performance across the three groups after viewing the full-body display, $F < 1$. No significant group effect was observed, $F\ (2, 21) = 1.96, p = .16, \eta_p^2 = .16$. Figure 3.1. indicates that the TOE group showed some improvement after presentation of this information, whereas the FOOT group became less like the model in terms of ankle-knee coordination. The Group x Display interaction was not significant, $F\ (2, 21) = 3.12, p = .07, \eta_p^2 = .23$.

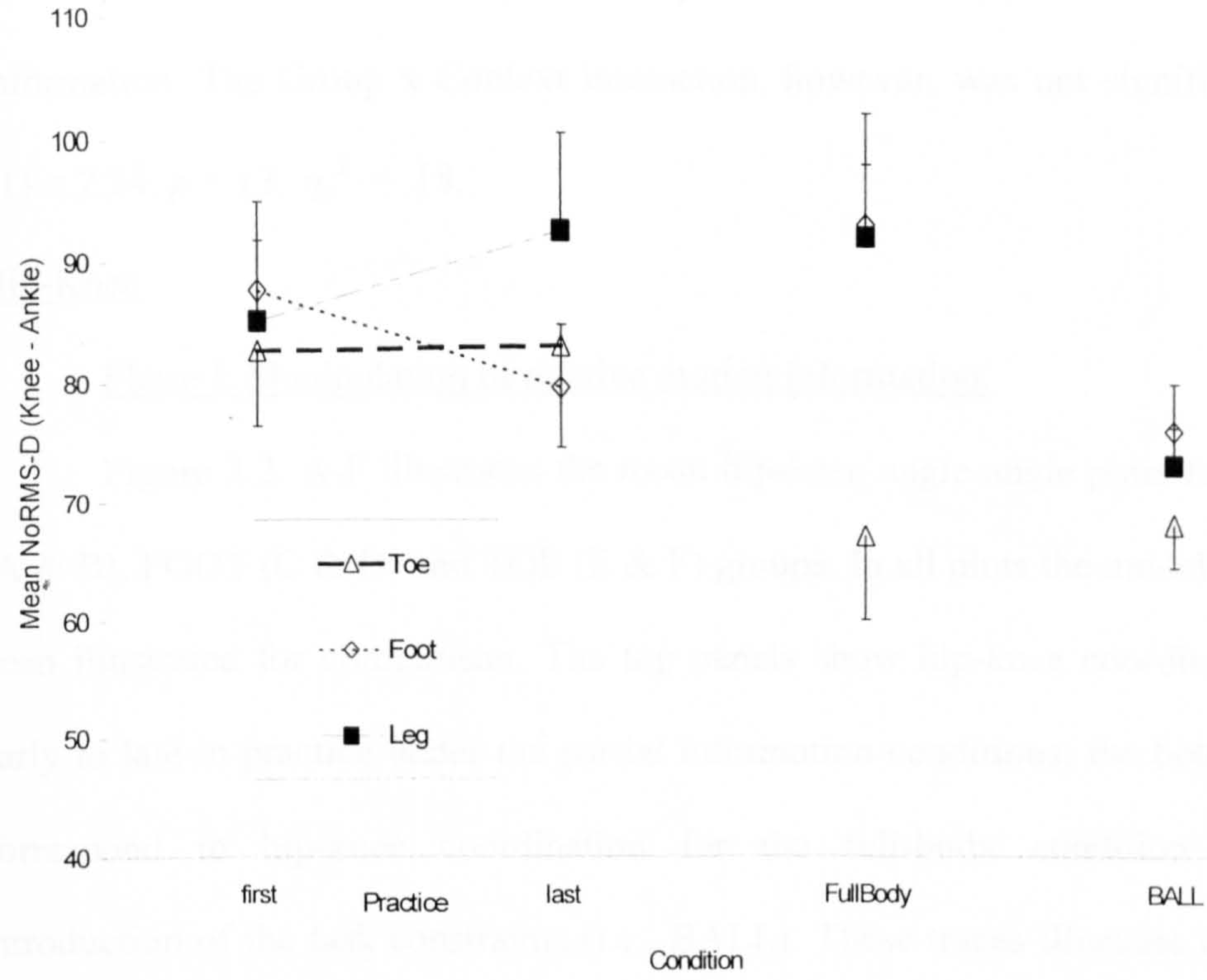


Figure 3.1. Mean NoRMS-D score for Knee-Ankle intra-limb coordination as a function of first and last practice block (Phase I) and following introduction of the full-body display (Phase II) and contextual information (Phase III, BALL).

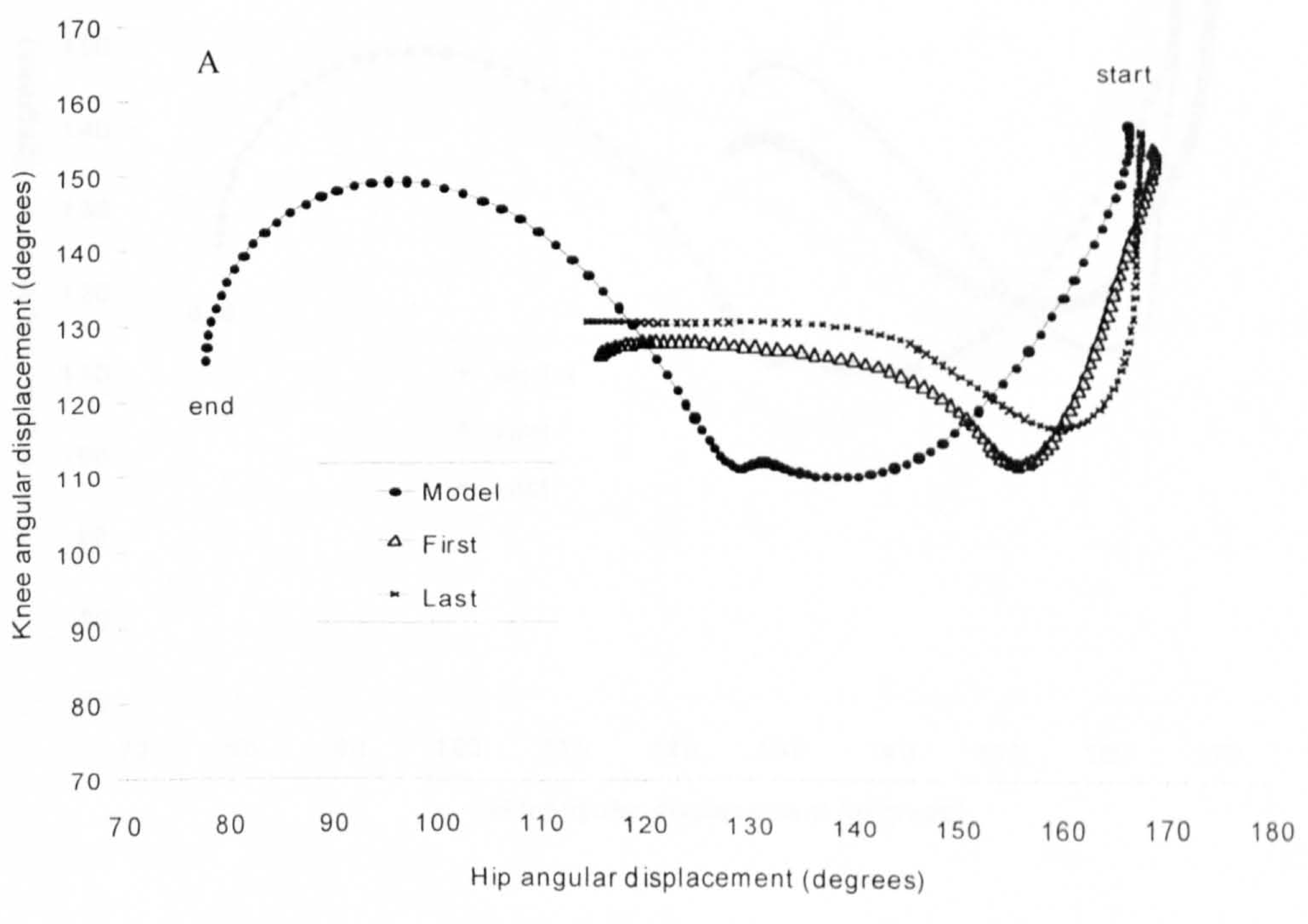
Phase III: Introduction of task constraints and contextual cues.

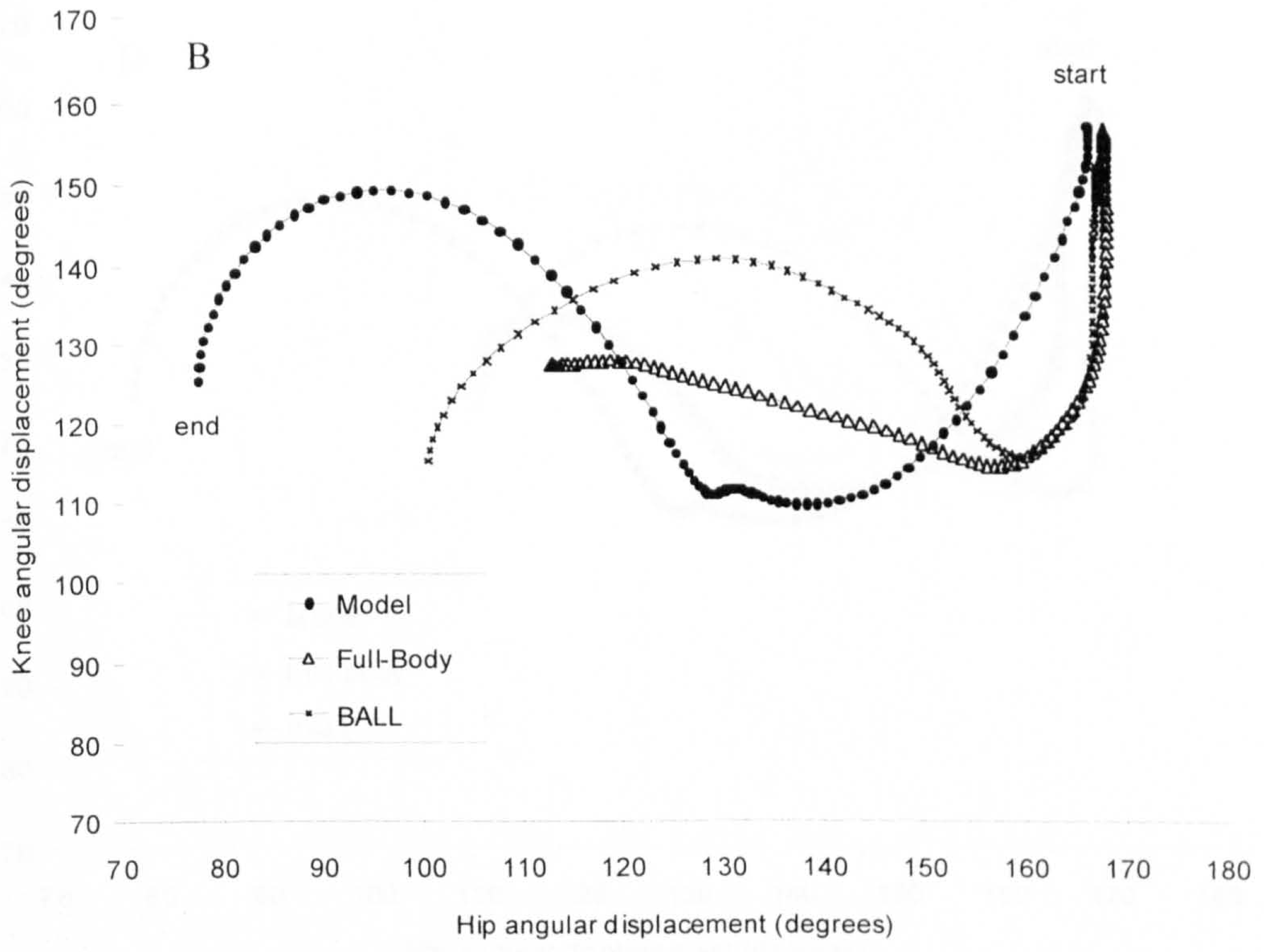
When participants were asked to perform the kicking action after the introduction of the ball and task constraints, a significant change in the relative motion profiles was observed as evidenced by a main effect for context, $F(1, 21) = 7.75$, $p < .01$, $\eta_p^2 = .27$. There was an overall reduction in the disparity of the participants' movements in comparison to the model. A significant effect was also observed for group, $F(2, 21) = 3.87$, $p = .04$, $\eta_p^2 = .27$. Although the FOOT and LEG groups were not significantly different from each other, the TOE group performed more like the model than both these groups, $p < .05$. Figure 3.1 shows an improvement in the relative motion profiles for the FOOT and LEG groups after the task context was introduced, in comparison to the provision of full-body information. The Group x Context interaction, however, was not significant, F (2, 21) = 2.24, p =.13, η_p^2 = .18.

Hip-Knee

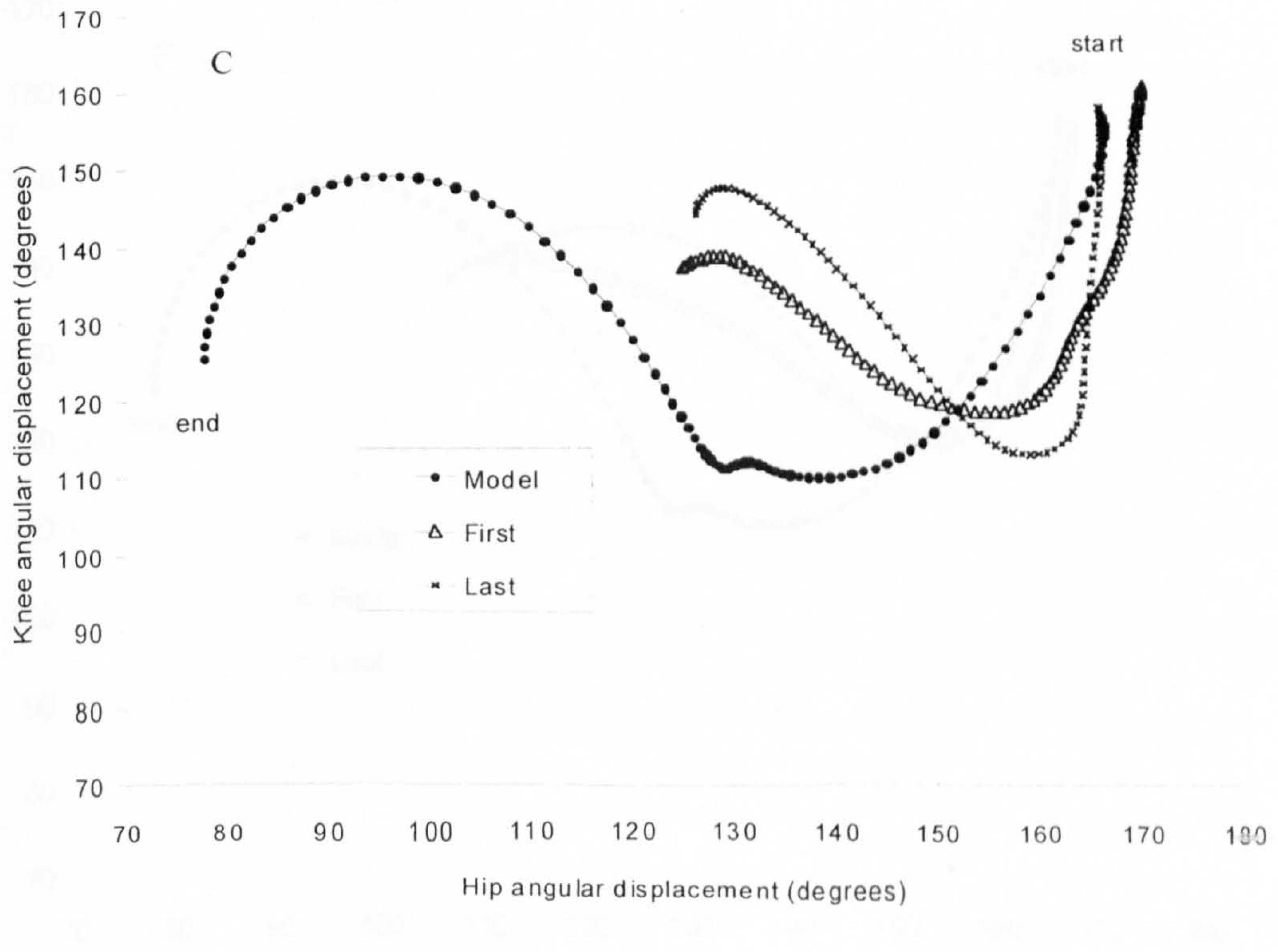
Phase I: Manipulation of relative motion information.

Figure 3.2. A-F illustrates the mean hip-knee angle-angle plots for the LEG (A & B), FOOT (C & D) and TOE (E & F) groups. In all plots the model's trace has been illustrated for comparison. The top panels show hip-knee coordination from early to late in practice under the partial information conditions, the bottom panels correspond to hip-knee coordination for the full-body condition and after introduction of the task constraints (i.e., BALL). These traces illustrate disparity in the spatial-temporal movement profiles of participants across the three groups in comparison to the model. During Phase I (i.e., Figures A, C and E), there was little change in the relative motion profiles across the first and last practice blocks.

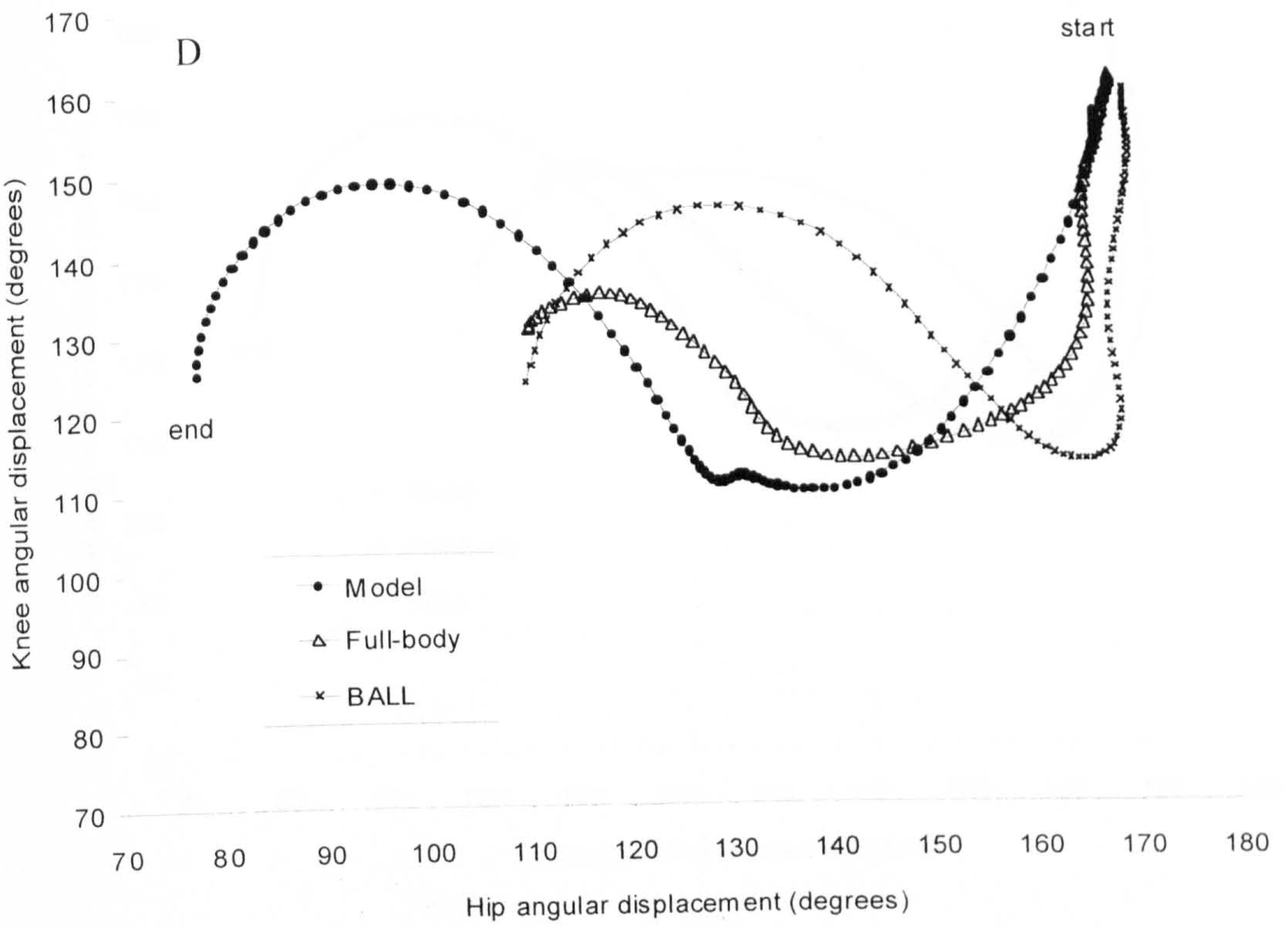




B
start
end
Model
Full-Body
BALL
Knee angular displacement (degrees)
Hip angular displacement (degrees)



C
start
end
Model
First
Last
Knee angular displacement (degrees)
Hip angular displacement (degrees)


D
start
end
Knee angular displacement (degrees)
Hip angular displacement (degrees)
Model
Full-body
BALL
170
160
150
140
130
120
110
100
90
80
70
70
80
90
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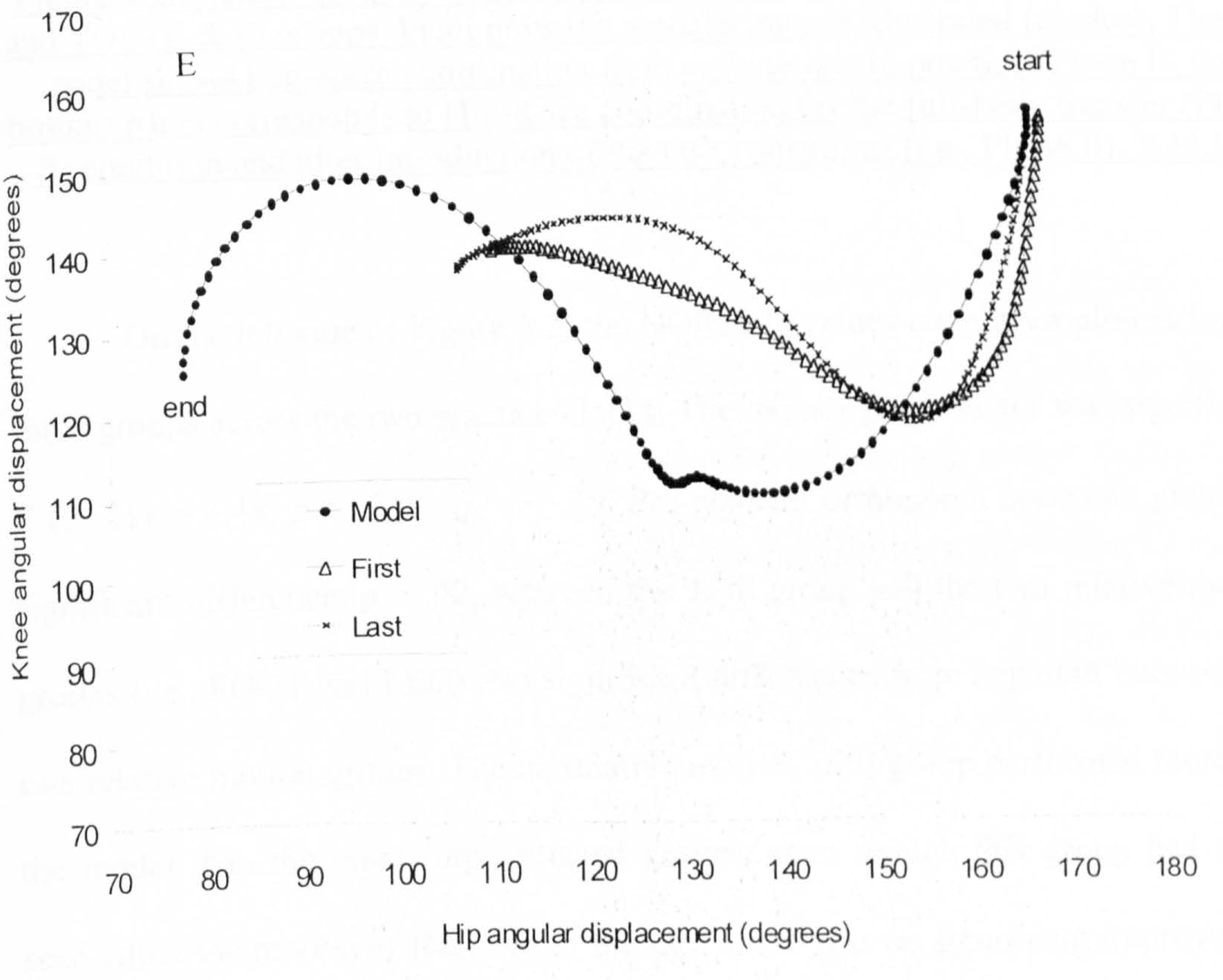
110
120
130
140
150
160
170
180


E
start
end
Knee angular displacement (degrees)
Hip angular displacement (degrees)
Model
First
Last
170
160
150
140
130
120
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90
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170
180

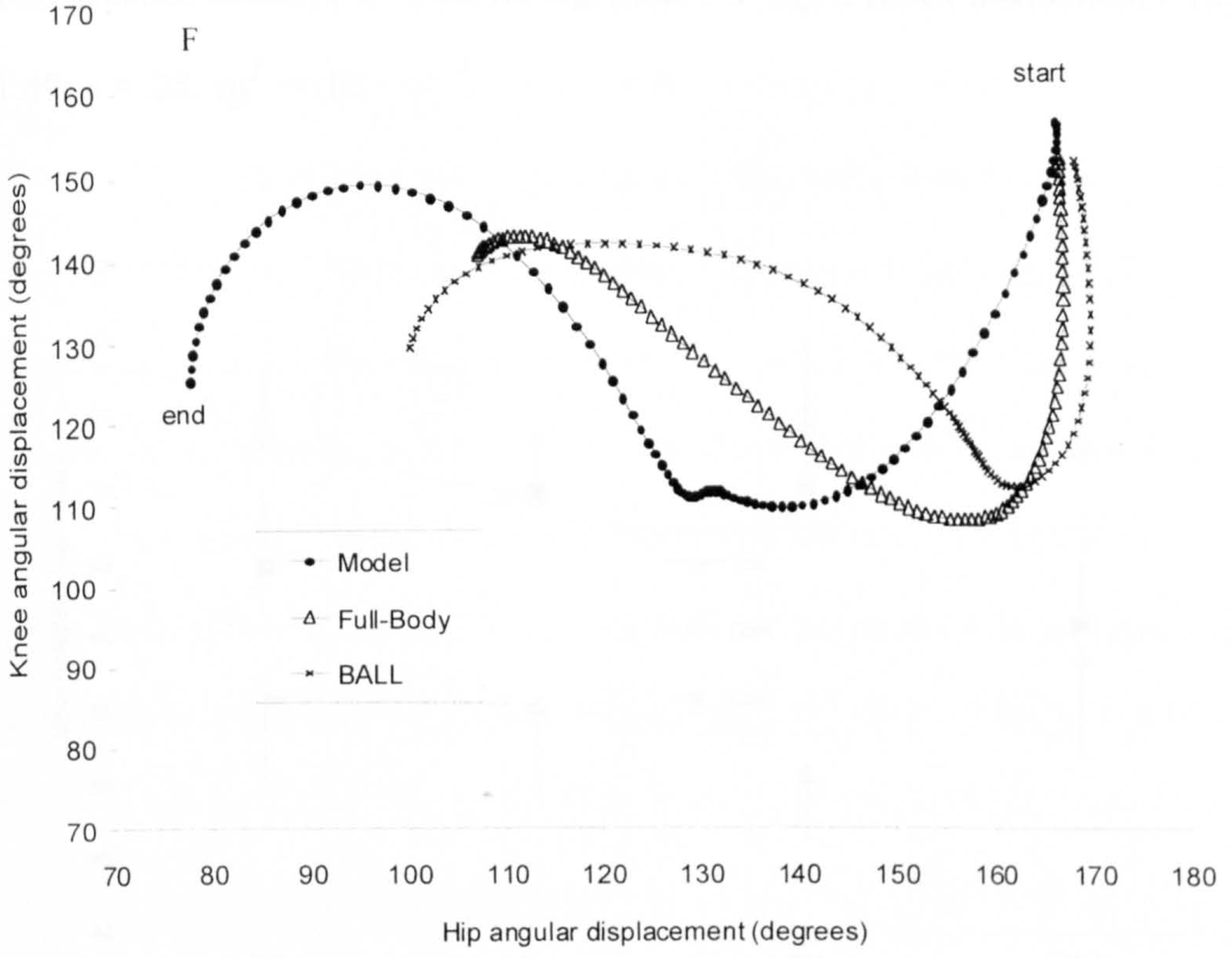


Figure 3.2. Mean Hip-Knee angle-angle plots for the LEG (A & B), FOOT (C & D) and TOE (E & F) groups. In all plots the model's trace is illustrated (circles). The top panel shows Hip-Knee coordination from early to late in practice (Phase I), the bottom panel corresponds to Hip-Knee coordination for the full-body transfer (Phase II) condition and after introduction of the task constraints (i.e., Phase III, BALL).

On the left side of Figure 3.3. the NORM-D values have been plotted for the three groups across the two practice blocks. The overall group factor was significant, F (2, 21) = 3.48, p = .049, η_p^2 = .25. Pre-planned orthogonal contrasts yielded a significant difference, p = .02, between the TOE group and the two relative motion groups (i.e., FOOT and LEG). No significant differences were apparent between the two relative motion groups. The no relative motion TOE group performed more like the model than the other impoverished groups, even though this group had never seen either the motion of the knee or the hip. There was no significant improvement across practice blocks, F < 1 and no significant Group x Block interaction, $F(2, 21) = 1.49, p = .25, \eta_p^2 = .12$.

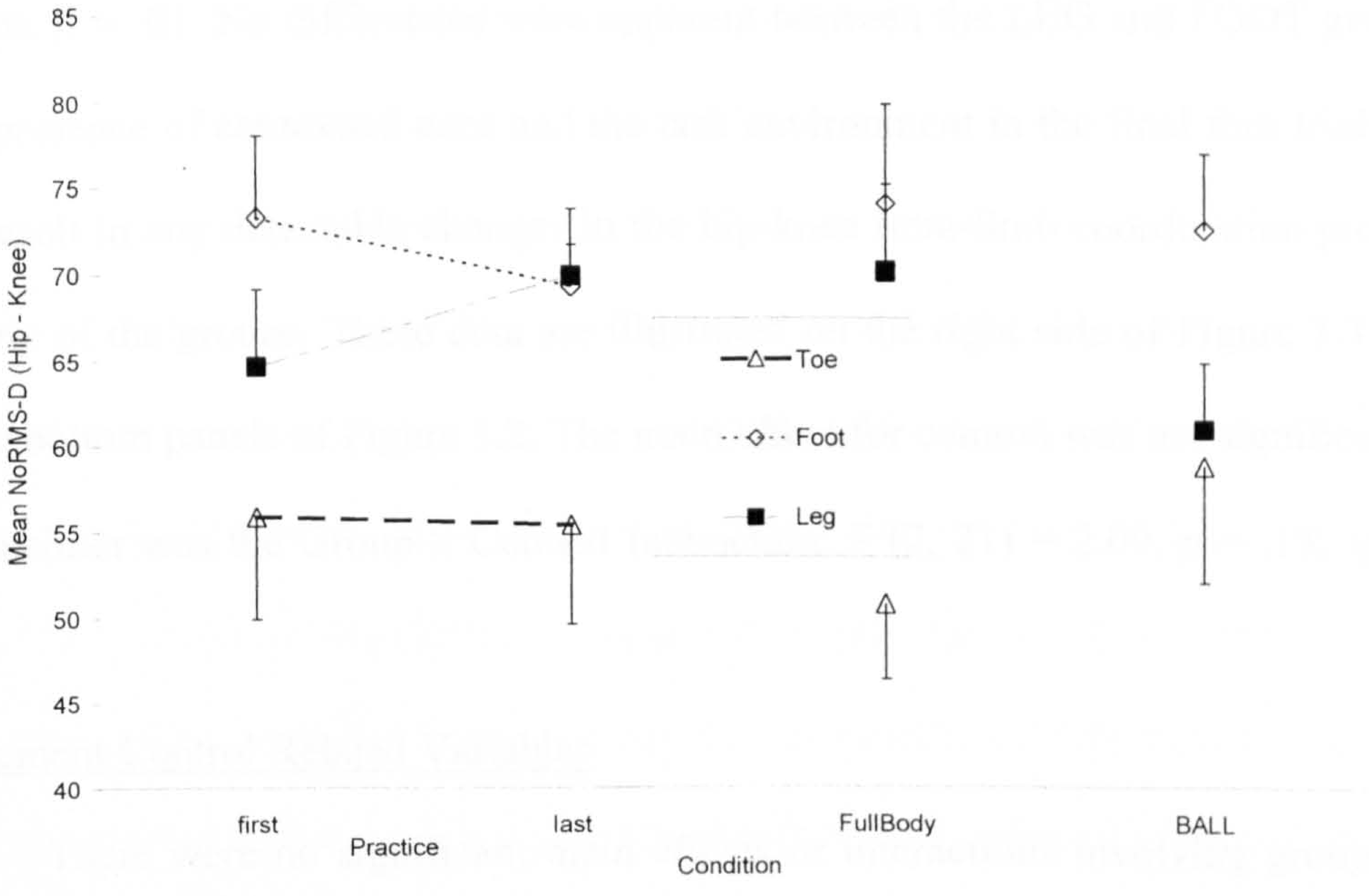


Figure 3.3. Mean NoRM-D score for Hip-Knee intra-limb coordination as a function of first and last practice block (Phase I) and following introduction of the full-body display (Phase II) and contextual information (Phase III, BALL).

Phase II: Transfer to full-body display.

No significant differences in the movements were observed after participants viewed the full-body display. These data are illustrated in Figure 3.3. and the bottom panels of Figure 3.2. (B, D & F). There were no significant effects for display or the Display x Group interaction, Fs < 1. Significant group differences remained between the TOE group and the FOOT and LEG groups, $p < .01$. The TOE group continued to produce movements which more closely approximated the model's than the other two groups.

Phase III: Introduction of task constraints and contextual cues.

The differences across the three groups remained, F (2, 21) = 4.87, p = .02, η_p^2 = .32. The TOE group performed more like the model than the LEG and FOOT groups, p = .01. No differences were apparent between the LEG and FOOT groups. The presence of contextual cues and the task environment in the final four trials did not result in any detectable changes in the hip-knee intra-limb coordination profiles for any of the groups. These data are illustrated on the right side of Figure 3.3. and in the bottom panels of Figure 3.2. The main effect for context was not significant, F < 1, neither was the Group x Context interaction, F (2, 21) = 2.09, p = .15, η_p^2 = .17.

Movement Control Related Variables

There were no significant main effects or interactions involving groups for any of the movement control related variables (i.e., peak hip angle and peak knee velocity).

Discussion

This experiment was designed to evaluate the minimal essential information needed to reproduce a novel and complex motor skill. In particular, the importance relative motion information was determined for the observation-reproduction process. To evaluate this proposal, three groups of participants were first compared under conditions where access to relative motion information was manipulated. In terms of closeness to the model's intra-limb coordination profile, significant differences were observed between the three groups for hip-knee coordination. Although participants in the TOE only group were not presented with relative motion information and were unable to view the knee or hip, the group exhibited hip-knee coordination profiles more like the model than the LEG and FOOT groups. There were no differences between the three groups for ankle-knee coordination and no differences were observed on measures deemed to be more reflective of motor control than coordination.

A second evaluation of the importance of relative motion information in informing action was conducted after the initial 12 practice attempts through a comparison of the three groups before and after receiving information pertaining to motion of the full-body. No significant differences across the two conditions were observed for either hip-knee or knee-ankle relative motions. Although the interaction effect was not significant for the knee-ankle coordination profile (p = .07), some improvements were apparent for the TOE group after receiving this information, whereas the FOOT group actually showed further disparity in their coordination profile from the model's.

Finally, the relative motion profiles of the three groups of participants were evaluated in Phase III, when contextual cues were introduced and participants were required to kick a ball over a height barrier onto a target. If these contextual cues facilitate movement reproduction over and above that conveyed in a full-body relative motion display, an improvement in the relative motion profiles of all groups should be apparent. However, it has been shown in recent studies (e.g., Chapter 1; Horn et al., in press) that the presentation of outcome goals and associated feedback may result in demonstration becoming a less important constraint on the acquisition of coordination. The introduction of task constraints following a period of practice without such constraints has not been examined previously.

Although the introduction of these contextual cues did not affect the hip-knee relative motion profiles, a significant change in intra-limb coordination of the knee and ankle was observed. This effect was primarily a result of an improvement in performance (i.e., coordination profiles more similar to the model) in the FOOT and LEG groups. The task constraints more directly influenced the patterns of movement than the full-body relative motion display. This result shows that a relative motion profile which approximates that of a skilled model is not, by default, a consequence of the extraction of this information from a model. More generally, whilst relative motion information specifying intra-limb coordination of a novel action can be used to help improve performance over practice attempts, this information is not necessary when information pertaining to the end-point of the action is available and/or the task constraints are suitably defined.

The fact that the FOOT and LEG group performed more poorly than the TOE group requires explanation if any conclusions are to be made about the nature of information perceived and used to inform actions. The differences between the partial relative motion and no relative motion groups might be related to the salience of the end-point. While attention to this point guides subsequent reproductions, attention to additional information (in the absence of the whole action), could distract attention away from this primary constraining source of information, leading perhaps to an attempt to replicate the motion of the knee or ankle, rather than the toe. Since participants in the FOOT and LEG groups received more information (i.e., in terms of the number of points of light), irrespective of the degree of relative motion information available, this could have led to a dispersion of visual attention. Research is needed to examine this proposal, where the relative motion is distinguished from the number of objects.

Hoenkamp (1978) provided some evidence that the timing of the lower-leg was the critical invariant in a display enabling participants to distinguish between various actions such as walking, running, and skating. In the current experiment, the leg and the foot might have provided such information to help with recognition of the action, but could have somewhat misleadingly led to the labelling of the action as a 'kick', when in fact it was a rather specialised soccer scoop-like action. The additional relative motion information from the leg might have led to the retrieval of a 'kicking' action associated with the observation, rather than the special, modified kick that was required in this instance.

It is important to note that all participants, irrespective of the type of information provided, received sufficient information to enable them to adequately scale the movement to their own body. The point light displays were presented on a full-body size screen, in the same plane of motion as the movement and participants were informed as to the location of the point of light on the body and asked to re-enact a whole-body action from these impoverished displays. Kourtzi and Shiffrar (1999) showed that novel views of human movement were more easily perceived when the motions fell within the biomechanical constraints that limit human movement behaviour. These authors proposed that any visual representation of movement is actually based on the inherent constraints of the human body and 'the dynamic interaction of motion and object-recognition processes' (p. 49). In this experiment the participants were all adults (in addition to the model) and therefore the relative lengths of body parts are considered to be relatively consistent across individuals (e.g., Dempster, 1955). However, for developing children, learning by observing the effects of an action could also be viewed as a more efficient strategy due to greater variation in relative lengths and weights of body parts, in comparison to adults.

Since evidence has been provided to suggest that relative motion is not essential for the acquisition of coordination and that participants likely focus on absolute features of the movement to aid in reproduction, a potential implication is that when watching to imitate, observers may be selective in terms of the type and amount of information to which they attend. This suggestion is consistent with the visual perception literature and the minimal principle of Hochberg (1957) who claimed that the perceptual response to an event is specified based on the least amount of information. In perceptual discrimination studies using PLDs researchers have attempted to isolate the minimal characteristics necessary for the perception of biological motion perception. Although according to the visual perception approach (e.g., Cutting & Proffitt, 1981) motions are perceived only in relative terms (such that the shoulder and hip act as a frame of reference for the knee and elbow) and analysis of the stimuli is hierarchical, proceeding from the proximal (i.e., trunk) to distal segments of the body (i.e., ankle and wrist), there has not been widespread support for this theory. Mather, Radford, and West (1992) presented evidence (through occlusion techniques) showing that the extremities were more critical for correct discrimination of motion than more proximal features. The extremities move furthest and show the most complex trajectory (in comparison to the other joints), therefore making them more distinct indicators of human motion. Mather et al. (1992) suggest that the visual system relies on these characteristic features to recognise human movement (see also Mataric & Pomplun, 1998).

The motor skill used in this experiment primarily required reproduction of the motions of one leg and hence intra-limb rather than inter-limb coordination was important. While it remains possible that as the novelty and complexity of the action increases relative motion information becomes more important, what these data show is that the approximation of relative motion need not be indicative of the fact that this information is used to constrain and produce the movement. Reproduction was also only examined over a limited time span such that conclusions about observational learning per se are not possible, particularly because no retention test was employed. It would be interesting to examine whether demonstrations that convey relative motion information facilitate movement reproduction after an initial phase of practice where only absolute motion pertaining to the end-point of the action was presented. Scully and Newell (1985) and Newell (1985) proposed that demonstrations are most effective during the early stages of skill acquisition and not for subsequent scaling or refinement. Alternatively, it may be that relative motion information does play a role later in practice, informing as to the more complex and subtle features of the movement. Blandin, Lhuisset, and Proteau (1999) showed that the absolute timing (i.e., the timing of one segment) in a barrier knock down task was learnt before the relative timing (i.e., the proportion of time between segments). Across Chapters 3 and 4 the generalisability of these findings will be examined to investigate when each type of information is most important for accurate movement reproduction and learning.

In conclusion, it has been have shown that intra-limb relative motion is not necessary for effective movement reproduction when absolute motion information is available pertaining to the end-point of the effector. On the basis of these data an element of caution is suggested as these data alone do not allow the conclusion to be made that that relative motion information is not important during the imitation process, nor that absolute properties of an action are more important than relative motion properties. Researchers should be cautious however when drawing conclusions as to the role of relative motion information in the modelling process. If an individual displays a relative motion pattern that more closely approximates a model following observation, this does not necessarily imply that relative motion information within the display was responsible for bringing about the change in coordination. As a function of experience with movements generally, learners develop an understanding of their own body (Kourtzi & Shiffrar, 1999), the movement context, and the inherent constraints within the body (i.e., the sometimes constrained relations of one joint in comparison to another). Observers are able to reproduce actions based on limited amounts of information, which in this experiment was the complete absence of relative motion information.

Chapter 4

An examination of end-point information as a facilitatory variable for observational learning

Abstract

The aim in this experiment was to investigate the role of end-point information for the acquisition of a multi-limb bowling action. In initial acquisition, two groups observed an end-point model (i.e., motions of the wrist and feet only) whereas a further two groups viewed a full-body model. These groups were further subdivided into a bowling or non-bowling group. Following retention, all participants observed the full-body model in a re-acquisition phase. Movement kinematics were collected throughout the experiment to determine similarity to the model. Outcome accuracy and consistency were evaluated through absolute constant error, and variable error, respectively for the bowling groups. In acquisition, the groups did not differ in terms of shoulder-elbow coordination. For hip-knee coordination, an interaction indicated that participants who observed a full-body model were more accurate, in terms of proximity to model, across the first block of practice, than the end-point groups. No difference between any of the groups was observed in retention. For outcome performance, there was no difference between the groups for error or consistency in acquisition. In retention, an interaction indicated that those who observed an end-point model were more consistent at attaining the distance-related goal. As predicted, there were additional benefits in outcome performance from observing the full body model in re-acquisition following only end-point information. Finally, relative motion information is not essential for constraining intra-limb coordination when task constraints are suitably defined and/or information pertaining to the action's end-point is available.

In early skill acquisition the learner is challenged with reducing the body's degrees of freedom into a controllable configuration that satisfies a desired movement pattern and/or an external goal (see Bernstein, 1967). The provision of prior-to-movement information specifying the to-be-learned movement dynamics and outcome is a common technique for facilitating skill acquisition. Demonstrations have been shown to play a role in conveying this information through a process known as observational learning. Theories of observational learning have differed with respect to the emphasis on cognitive meditation in the learning process. For example, Bandura (1986) proposed the social cognitive theory whereby perceptual blueprints or cognitive representations of an action are formed through observation and these are then used to guide and correct action. This representation is suggested to form a reference-of-correctness that contains the spatial and temporal dimensions of the observed act. Although Bandura (1986) indicated that in order for an individual to learn anything they must pay attention to the key features of the modelled behaviour, he did not specify the nature of the spatial and temporal information that is located and used during this attentional process. Based on this shortcoming a number of researchers have started to address the nature of information conveyed through demonstrations (see Newell, 1985; Scully & Newell, 1985; Whiting, Bijlard & Brinker, 1987). This question is the fundamental underpinning to the 'visual perception perspective' (VPP) to observational learning proposed by Scully and Newell (1985).

The VPP is based on both perceptual psychology (e.g., Cutting & Profitt, 1982; Johansson, 1971, 1973), whereby relative motion information (i.e., the motion of individual elements of a configuration relative to each other) is identified as the critical invariant underlying the perception/recognition of an action and Newell's

(1985) framework of coordination, control, and skill (see also Kugler, Kelso, & Turvey, 1980, 1982). For the acquisition of a new pattern of movement (i.e., coordination), Newell (1985) suggested that the learner must coordinate the free variables of the motor system into a functional behavioural unit (see also Bernstein, 1967). Importantly, the relative motions associated with a to-be-learned action are thought to play a significant role in constraining the degrees of freedom into the desired behavioural pattern (Newell, 1985; Scully & Newell, 1985).

The aim in this paper is to determine the importance of relative motion information in guiding motor skill acquisition. Scully and Newell (1985) proposed that a model's relative motion pattern is the critical essential information that is observed and reproduced by a learner during the acquisition of coordination. Through the systematic manipulation of relative motion information and careful examination of the reproduction process it is possible to examine its importance and role in observational learning. In the past, researchers have examined relative motion by indirectly manipulating this information through the removal of structural information in the form of point-light models. It has been predicted that movement reproduction would be facilitated by making relative motion salient through the presentation of point-light models (see Runeson, 1984) and subsequently these types of models have been compared to normal video displays (e.g., Al-Abood, Davids & Bennett, 2001; Horn, Williams & Scott, 2002; Horn, Williams, Scott & Hodges, in press; Scully & Carnegie, 1998).

The findings from these studies have failed to provide a consistent and clear picture as to the important role of relative motion information in the observational learning process. Horn and colleagues (Horn, et al., 2002; Horn, et al., in press) have isolated conditions where observers are more likely to attend to and reproduce relative motion information. For example, in a soccer kicking experiment, Horn et al. (2002) failed to observe differences in joint range of motion and hip-knee coordination between demonstration groups (video and point-light) and a control group. They proposed that the requirement to propel a ball over a height barrier onto an external target had a greater impact on the observer's coordination pattern than the model's relative motions (thus leading to a lack of difference between the model and control groups). The presence of feedback and/or task constraints relating to kicking the ball reduced the impact of the demonstration in general, even though the learners were instructed to imitate the model's movement.

This tendency to prioritise attainment of a distance-related goal at the expense of movement form has since been shown in both adults and children (see chapter 2). Therefore, the prediction that relative motion is important information for the acquisition of a new coordination pattern is questioned in goal-directed tasks (see also Bekkering, Wohlschläger, & Gattis, 2000; Gleissner, Meltzoff, & Bekkering, 2000; Wohlschläger, Gattis, & Bekkering, 2003). When there are additional outcome constraints, the movement pattern appears to be a consequence or emergent feature of the task, rather than a product of observational learning. Under these conditions, the model might serve to provide general strategy type information (e.g., Burwitz, 1975). Indeed, Horn et al (2002) found that the model groups replicated features such as the number of steps to approach the ball. Overall, however, there is little evidence that the relative motions of the model are picked up and used to constrain movement reproduction. In contrast, there is evidence that the model's kinematics plays a more constraining role in situations where imitation of movement form is the only or primary constraint on action. For example, Horn et al (in press) prevented visual feedback of the ball's trajectory and hence information about outcome success and found that the model groups more accurately imitated the coordination features of the model.

The role of relative motion in this process has been inferred from comparisons of the movement kinematics of the observer to that of the model. If observation of a point-light or video model resulted in within and between limb relative motion profiles that were more similar to a criterion model than those of control participants then imitation of relative motion was assumed (for example, Al-Abood, et al., 2001; Horn, et al., in press; Scully & Carnegie, 1998). However, because the model's relative motion pattern was not systematically manipulated within these experiments (i.e., the reduction or removal of relative motion through occlusion methods) it cannot be concluded that relative motion was the primary constraining source of information in observational learning.

There is evidence that observers' hone their attention to end-point features of an action when watching with the goal of later replication. Mataric and Pomplun (1998) showed that observers fixated on the fingers of the hand during the observation phase of a whole arm imitation task. Despite this localisation strategy, there were no costs in later reproduction, in that accurate whole arm configurations were observed. This is an important finding as most of the skills used to examine relative motion information have involved the coordination of a primary effector in order to achieve a particular end-point (i.e., foot-ball contact in soccer kicking; or spatial end-point during a dart throw). Since both relative and absolute motion are available in dynamic action displays it is possible that observers may have located and used the end-point of the action to constrain their action as opposed to relative motion. Whilst relative motion features might be important for general recognition and perhaps labelling of an act, more specific and localised, end-point related, absolute features of the movement (such as the dynamics of the foot in kicking), might act as the primary constraint on action reproduction (see Chapter 3; Hodges, Hayes, Breslin & Williams, press).

In order to directly examine the importance of relative motion in the movement observation-reproduction process, Hodges, Hayes, Breslin, and Williams (in press) examined the reproduction of a specialised soccer kicking action from impoverished point-light models. The reproduction process was examined across two phases in the absence of any task constraints or contextual cues (i.e., the model's movement is the primary constraint on movement), and in a third phase where the presence of contextual cues was added (i.e., participants were given a ball and a target barrier to kick the ball over). Across three groups, participants saw either the motions of the lower leg, the foot or just the toe (displayed on a full body-size screen) presented as a point-light model. Despite the lack of relative motion information for the toe group, the relative motion pattern of the kicking leg for this group more closely resembled the model than the foot and leg groups (i.e., intra-limb coordination). The subsequent viewing of a full body model did not significantly change the coordination profiles of participants across the three groups indicating that absolute end-point information was sufficient for constraining and bringing about a soccer kicking action (even in the absence of any contextual cues). When participants were asked to perform the kicking action after the introduction of the ball and task constraints, a significant change in the relative motion profiles was observed for the knee-ankle intra-limb coordination. These data contrast previous research experiments (see chapter 2; Horn et al., 2002) that have shown the opposite effect within an increase in the disparity of the participants' movements in comparison to the model.

Whilst these findings question the importance of relative motion for motor reproduction, more research is required to validate this finding in other motor skills and across learning. The motor skill required in chapter 3 was a relatively simple kicking action, where the single end-point trajectory of the kicking foot may have been sufficiently constraining to enable accurate replication of the kinematics of the whole leg. To extend our understanding of the nature of information used for observational learning, the importance of relative motion and potential benefits associated with the highlighting of end-point information needs further examination. It is important to evaluate the acquisition of motor skills which involve replication within and across a number of joints and across practice and retention so that the guiding nature of this information can be determined both in practice and after a period of retention when it is no longer available.

The aim in this experiment is to investigate the importance of relative motion information in the acquisition of a whole-body multi-limb bowling action. Through the removal of within limb relative motion and providing an end-point model it will be possible to examine whether relative motion information plays an important role in constraining skill acquisition both in practice (when the information is provided before every trial) and in retention (when it is removed). Further, we are also able to examine any benefits in highlighting end-point features of a movement, both in constraining attention in acquisition and perhaps in decreasing the reliance on the demonstration when the action is assessed in a no-model retention test.

In view of discrepancies in the literature when participants are required to reproduce an action in the absence or presence of additional task goals, the two types of models will be examined under both contexts. In condition 1, participants will be asked to watch and imitate the actions of a model and no additional task constraints (either outcome goal or contextual information) will be provided. In the second condition, two different groups of participants will be required to watch and imitate the model while additionally being required to bowl a ball to a target location. In this condition we expect the type of display to have less of an effect on the movement response, due to the constraining role of the task on movement kinematics. However, this is an important condition to examine for both practical and theoretical reasons. From a practical viewpoint, there are a vast number of motor skills which require both attainment of movement form in addition to outcome goal success. From a theoretical stance, an appreciation of the hierarchical nature of task and informational constraints will aid with the understanding of the observational learning process in general. Although a task constrained condition was included following practice in the initial soccer kick study reported in chapter 3, there was no comparison of the various display conditions during practice under task and non-task constrained environments.

Finally, to provide additional information about the importance of relative motion in the observational learning process, a re-acquisition condition was included following retention testing on day 2. In this condition, all participants will watch a full-body model (i.e., relative motion information will be shown to the end-point groups) to determine whether relative motion information is used to change or refine the action later in practice. If relative motion has an important role to play in constraining the action then it is expected that the end-point group will show increased similarity to the model in terms of intra-limb relative motion. Additionally, if relative motion continues to be an important constraining source of information later in practice for refinement, then the full-body group is also expected to show further improvements in terms of producing movements that more closely match the model.

Method

Participants

Thirty-two participants (*M* age = 22.1 yr; *SD* = 2.50 yr; range 18 – 30 yr) were randomly assigned to one (n = 8) of four experimental groups. Two groups watched a full-body point-light model displaying a side-on-view of a crown-green bowling action (FULL) or a reduced body point-light model displaying only the wrist marker on the right bowling arm and the left and right toe markers (ENDPT). In addition, these two groups were further subdivided such that they either did (BALL) or did not (NO BALL) bowl a ball to a target throughout testing. All participants were right handed and had normal or corrected-to-normal vision. The experiment was conducted in accordance with the ethical guidelines of Liverpool John Moores University. All participants provided informed consent and were free to withdraw from the experiment at anytime.

Apparatus

Movement kinematics were collected using a VHS video camera (Panasonic M-40, Tokyo, Japan) and six infrared motion analysis cameras (Pro-Reflex; Qualisys, Gothenburg, Sweden) sampling at 50 and 240 Hz respectively. The demonstrations were front projected onto a 3.0 m x 3.5 m screen (Cinefold, U.S.A.) using a projector (Sharp XG-NV2E, Tokyo, Japan) and video recorder (Panasonic NV-HS 820, Tokyo, Japan). For the BALL groups the participants were required to bowl a small plastic ball (Regent, SOFFS: model 98200; circumference = 43 cm) to the 6 m target.

Task, design and test-film construction.

All participants were required to observe and imitate a crown-green bowling action. This movement was selected as a complex multi-limb technique that was relatively novel to all participants. The two ball groups were additionally required to bowl a ball to a target line located 6 m from the start line.

A 26 year old male acted as the model and practised (approx. 100 trials) rolling a ball using a crown-green bowling action to a 6 m target. The model was filmed from the sagittal plane using a digital video recorder and movement kinematics were captured using six pro-reflex motion analysis cameras. Once a consistent level of performance was achieved, a successful bowl (i.e., one where the ball stopped on the target line) was chosen which represented the kinematic profile adopted by the model to achieve task success. The spatio-temporal positions of 15 reflective markers placed on the model's major joint centres formed a point-light display when viewed through a software-viewing program (QTM-Manager, Qualisys, Gothenburg, Sweden). These data points were used to compare the participants' movements against the criterion model (see dependent measures and data analysis section for an explanation of the kinematic analysis). A point light display of the model's bowling action was produced using the QTM software package. The point-light model was edited to create the two demonstration tapes whereby either all fifteen markers were presented (FULL) or three markers relating to the right wrist and right and left toe (ENDPT). The observers viewed both models from the sagittal plane, therefore at particular stages during the model's movement (i.e., the start) some of the markers were not were visible (left shoulder marker). The information presented within the two demonstration tapes was extracted from the same bowling action that was performed by the model.

Procedure

Before each experimental phase (practice, retention and re-acquistion), reflective markers were placed on the right and left side of the participant's distal head of the 5th metatarsal (toe), the lateral malleolus (ankle), the lateral condyle of the femur (knee), the greater trochanter (hip), the acromion process (shoulder), the lateral epicondyle (elbow), the styloid process of radius (wrist). Participants in all four groups then viewed a point-light perceptual training video to ensure that they were familiar and fully understood the conceptual nature of point-light stimuli (see chapter 2; Hayes et al., submitted). All the testing was conducted individually with each test session lasting approximately 50 minutes. All trials were filmed using six infrared cameras (Pro-reflex; Qualisys) at a capture rate of 240 Hz and a digital video camera positioned in the sagittal plane. Before each trial the participants stood behind a start line depicted on the laboratory floor that was positioned to enable easy viewing of the demonstrations and capture of the participants' movement kinematics. Three phases of testing were undertaken; acquisition, retention and re-acquisition.

Standardised instructions were given to the participants outlining the aim of the task. These instructions specified that the task was to watch a point-light demonstration and reproduce the whole-body action associated with the model's movement. The ENDPT groups were informed that the three markers on the model corresponded to the left and right toe and the right wrist viewed in the sagittal plane. The participants in the two BALL groups were additionally instructed to imitate the observed action in order to bowl a ball to stop on or as close to a 6 m target line as possible. Participants received 20 practice attempts in total and a demonstration was shown twice on the first trial and once prior to each of the remaining trials. No specific information about the type of action (i.e., a crown-green bowling action) was provided to any group. Participants completed a 5 trial retention test 24 hours later (no demonstrations were provided). Following the 5 retention trials, all participants underwent a further period of practice (i.e., re-acquisition). Participants in all 4 groups viewed the full-body point-light model and underwent a further 10 practice trials. The demonstration was viewed twice on the first trial and once before each of the remaining trials. The BALL groups continued to roll the ball to the 6 m line.

Data analysis

Kinematics.

The start and end points of the arm swing and right leg movement of the bowling action were determined and used for the kinematic analysis. The start and end points for the shoulder were based on the initiation of shoulder extension, in preparation for the start of the arm swing phase of the action, and ended at peak shoulder flexion in the follow-through element of the swing. For the right leg movement the analysis started at the initiation of knee flexion and ended at peak knee flexion. This normalisation process allowed for comparisons across participants, trials and with the model. These data were smoothed with a recursive 4th order Butterworth filter with a cut-off frequency of 7 Hz. A linear interpolation was performed to normalise this period to 100 data points.

The similarity between the participants' and model's hip-knee and shoulder-elbow coordination was quantified using a version of Sidaway, Heise, and Schoenfelder-Zhodi's (1995) normalised root mean squared error (NoRMS). In the modified version (see Horn et al., in press, who refer to this measure as normalised root mean squared difference, NoRM-D) the disparity (i.e., approximation) of the participant's mean trace (across three trials) from the model's trace is calculated.

In the initial acquisition phase all kinematics were analysed on the first three (FIRST, 1-3), middle three (MIDDLE, 9-12) and last three (LAST, 18-20) trials of practice and compared to the model to yield a measure of intra-limb coordination in terms of proximity to the model's movement (i.e., NoRM-D). These values were analysed in a 2 Model (FULL; ENDPT) x 2 Ball (BALL; NO BALL) x 3 Block (FIRST; MIDDLE; LAST) mixed design ANOVA with repeated measures on the last factor. In Retention, the three trials were analysed in a 2 Model (FULL; ENDPT) x 2 Ball (BALL; NO BALL) factorial ANOVA. Finally, the re-acquisition data was analysed in a 2 Model (FULL; ENDPT) x 2 Ball (BALL; NO BALL) x 3 Block (RET; RE-ACQ FIRST; RE-ACQ LAST), whereby the last three trials of retention were compared to the first and last 3 trials of re-acquisition.

Outcome-related measures.

To determine whether the amount of information provided within the two demonstrations was differentially beneficial for attaining a distance related goal an evaluation of the outcome scores was conducted for the BALL groups. In practice outcome success was measured in terms of distance from the target. From this data absolute constant error, |CE| and variable error, VE were calculated. These data were analysed in 2 Model (FULL, ENDPT) x 2 Block (FIRST, MIDDLE, LAST) mixed design ANOVA with repeated measures on the last factor. In Retention, the three trials were analysed in a 2 Model (FULL; ENDPT) x 2 Ball (BALL; NO BALL) factorial ANOVA Performance in re-acquisition trials was assessed in a 2 Model (FULL, ENDPT) x 3 Block (RET, RE-ACQ FIRST, RE-ACQ LAST) mixed design ANOVA. A Greenhouse-Geisser correction was applied when violations to sphericity were observed. Partial-eta squared (η_p^2) values are reported for all significant effects. Comparisons of interest involving more than two means were examined using Tukey HSD procedures (Significance was set at $p < .05$).

Results

Intra-limb coordination.

Shoulder-elbow intra-limb coordination

Figure 4.1 shows the shoulder-elbow NoRM-D scores as a function of acquisition (first, middle and last block), retention and re-acquisition (first and last block) for the No-Ball (a) and Ball (b) groups. As illustrated in Figures 4.1a and b, shoulder–elbow coordination for the two model groups during acquisition were not significantly different from each other, despite a trend for the ENDPT groups to perform more like the model than the Full Body groups, $F(1, 28) = 2.65$, $p = .12$, $\eta_p^2 = .09$. There was no main effect of acquisition block, $F < 1$, nor interactions involving this or any other variable (all F's <1).

In retention, there were no significant main effects for model, $F(1, 28) = 1.30$, $p > .05$, $\eta_p^2 = .05$, ball, $F(1, 28) = 1.44$, $p > .05$, $\eta_p^2 = .05$, or Model x Ball interaction, $F < 1$. Despite the initial predictions, there were no significant group effects following additional exposure to the full body model (all Fs < 1).

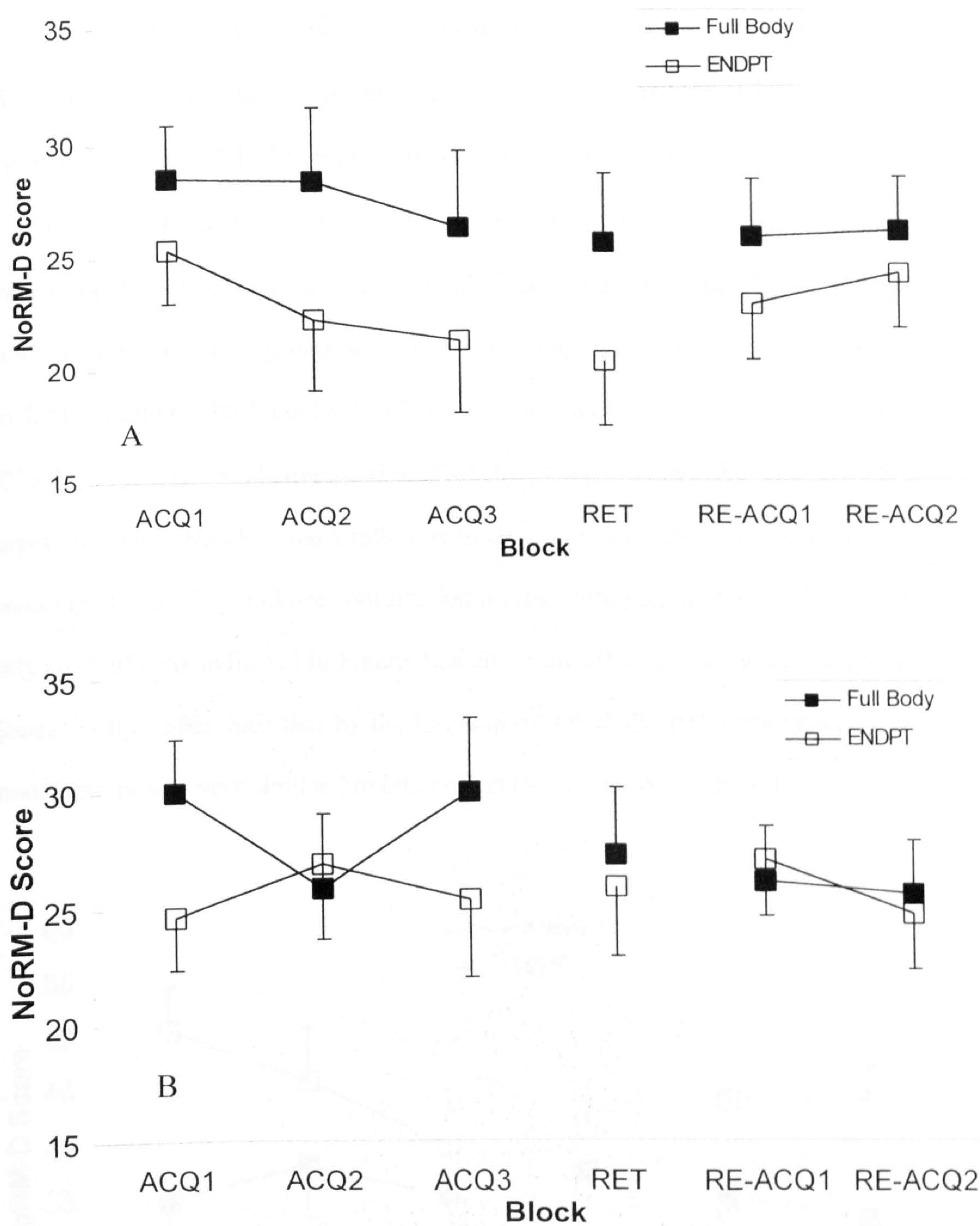
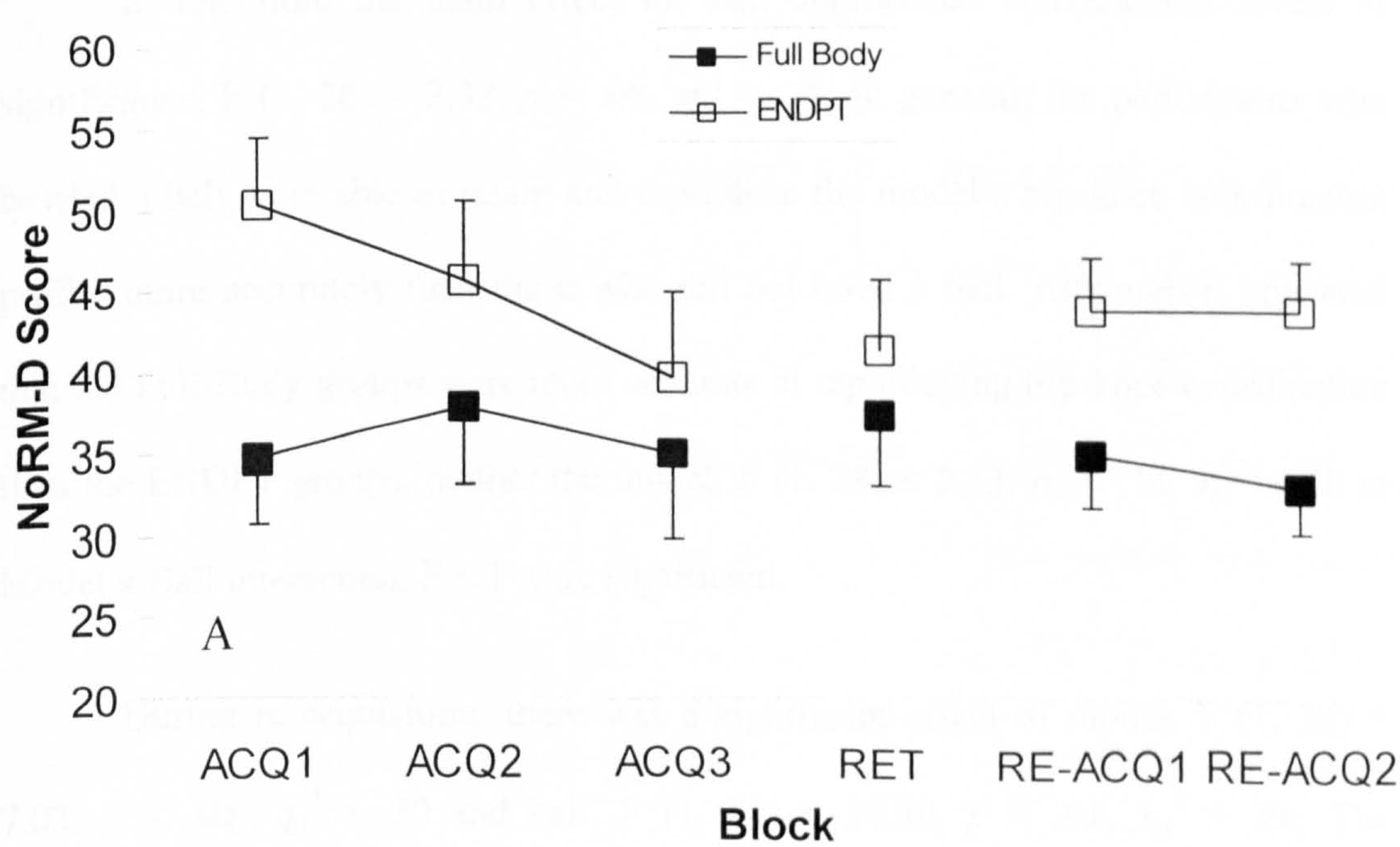


Figure 4.1. Mean NoRM-D (standard error bars) scores for the participants' shoulder-elbow coordination in terms of proximity to the model across all test blocks (A) No-BALL groups and (B) BALL groups

Hip-knee intra-limb coordination

Figure 4.2 shows the hip-knee NoRM-D scores as a function of acquisition (first, middle and last block), retention and re-acquisition (first and last block) for the No-Ball (a) and Ball (b) groups. The main effects for model, F (1, 28) = 3.65, $p = .06$, $\eta_p^2 = .11$ and ball, F (1, 28) = 3.80, $p = .06$, $\eta_p^2 = .12$ approached conventional levels of significance. The Full Body groups performed more like the model than the ENDPT groups and the BALL groups were more accurate than the no BALL groups. The Model x Block interaction was also significant, F (2, 56) = 207.67, $p < .05$, $\eta_p^2 = .11$. Irrespective of whether the participants bowled a ball to a target line, those that observed a full-body model were significantly more accurate at imitating the model's hip-knee coordination profile during the first acquisition block only ($p < .05$). As indicated in Figure 4.2a and b the difference between the groups decreased thereafter such that by the last acquisition block the performance of the model groups was very similar. No other effects were significant, Fs < 1.



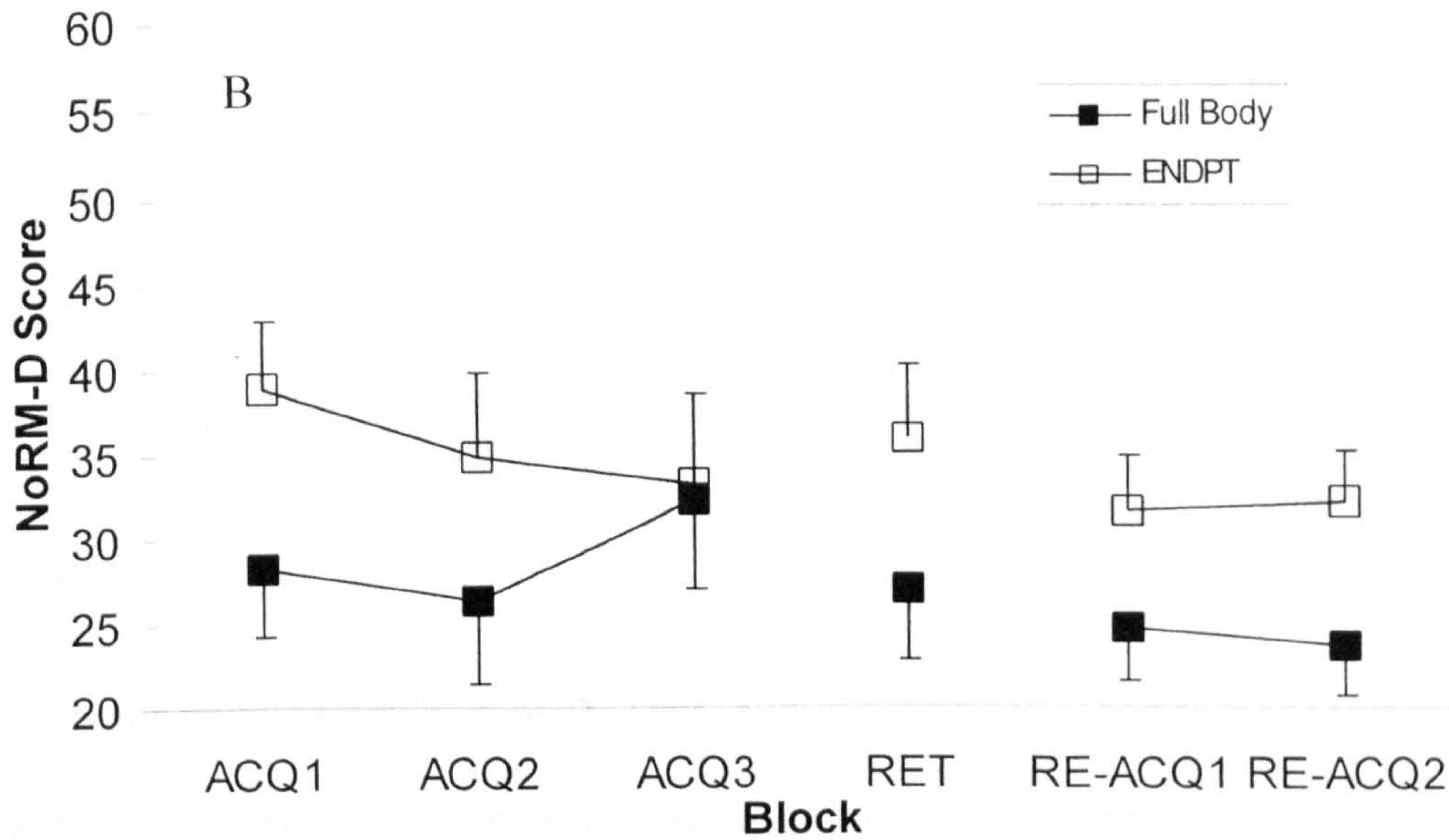


Figure 4.2. Mean NoRM-D (standard error bars) scores for the participants' hip-knee coordination in terms of proximity to the model across all test blocks (A) No-BALL groups and (B) BALL groups

In retention, the main effect for ball approached conventional levels of significance, F (1, 28) = 3.32, p = .08, η_p^2 = .11. In general, the participants who bowled a ball were able to retain and reproduce the model's hip-knee coordination profile more accurately than those who did not bowl a ball. Although it appeared that the Full-Body groups were more accurate at reproducing hip-knee coordination than the ENDPT groups, neither the model, F (1, 28) = 2.23, p = .14, η_p^2 = .08 or Model x Ball interaction, F < 1 were significant.

During re-acquisition, there was a significant effect of model, F (1, 28) = 7.03, p < .05, η_p^2 = .20 and ball, F (1, 28) = 10.80, p < .01, η_p^2 = .28. The participants who observed a full-body model during acquisition and in the re-acquisition phase maintained their accuracy in approximating the model's hip-knee coordination profile, in comparison to the ENDPT groups whose accuracy appeared to decrease (see Figure 4.2a and b). As with earlier, participants who bowled a ball to the target line were more accurate at reproducing the model's hip-knee intra-limb coordination profile than the observation only groups.

Outcome error.

The results for |CE| and VE have been illustrated in Table 4.1. No significant effects involving either group or acquisition block were observed for |CE| or VE, all Fs < 1.

In retention, the two model groups did not differ in terms of target accuracy (i.e., |CE|), F < 1. However, for VE, a significant main effect involving model was observed, $F\ (1,\ 14) = 12.25, p < .01,\ \eta_p^2 = .47$. After a 24-hour retention period the ENDPT model group was significantly more consistent (less variable) in their bowling than the full-body group.

In re-acquisition, a significant main effect for group was observed for |CE|, $(1,\ 14) = 4.80, p < .05,\ \eta_p^2 = .25$. The ENDPT group who watched a full-body model after the retention period showed reduced error in comparison to the group who received a full body model throughout testing. For VE, a significant main effect for block was observed, $F\ (1,\ 28) = 4.05, p < .05,\ \eta_p^2 = .22$, showing that both groups became more consistent across the re-acquisition trials. The Model x Block interaction was not significant, $F\ (1,\ 28) = 1.87, p > .05,\ \eta_p^2 = .12$..

Table 4.1. Mean (± SE) mean absolute constant error (|CE|) and variable error (VE) across acquisition, retention and re-acquisition

	ACQ1	ACQ2	ACQ3	RET	RE-ACQ1	RE-ACQ2
Model Variable	M (± SD)	M (± SD)	M (± SD)	M (± SD)	M (± SD)	M (± SD)
Full Body						
|CE|	48.8 (20.2)	27.9 (10.0)	43.2 (10.0)	55.0 (9.9)	59.0 (11.8)	69.4 (10.2)
VE	67.3 (14.9)	41.5 (15.4)	37.6 (11.0)	90.8 (7.2)	57.3 (19.4)	35.8 (8.6)
End Point						
|CE|	67.7 (20.2)	60.5 (10.0)	44.6 (10.0)	48.5 (9.9)	44.0 (11.8)	31.0 (10.2)
VE	66.0 (14.9)	56.2 (15.4)	67.4 (11.0)	54.8 (7.2)	64.6 (19.4)	40.2 (8.6)

Discussion

The aim in this experiment was to investigate the role of relative motion information in the observational learning of a multi-limb bowling action. Relative motion was manipulated through the removal of particular joints from a point-light model. It was predicted that if relative motion information is the primary constraining source of information for reproducing a complex motor skill, participants who watch a full-body model following reproduction attempts would show a closer approximation of the model's coordination profile than those who observed an end-point model (where no intra-limb relative motion was provided). To further understand how task constraints affect the type of information used during observational learning, two groups were additionally required to bowl a ball to a target line. All groups completed a re-acquisition phase following retention where full-body relative motion information was provided. This condition enabled a further test of the role of relative motion in learning, whereby improvements in coordination among the ENDPT groups are expected if this information serves to constrain coordination.

In terms of approximating the model's shoulder-elbow, intra-limb coordination profile, no significant difference was observed between the FULL-BODY and ENDPT groups, in fact there was a trend for the ENDPT participants to perform more like the model than the FULL-BODY participants. If relative motion information is important for constraining the acquisition of whole-body coordination skills then this result would not be expected (cf. Scully & Newell, 1985). The FULL-BODY and ENDPT groups approximated the model's shoulder-elbow coordination pattern relatively accurately, as evidenced through low NoRM-D values. There was, however, no improvement across acquisition blocks such that the information constraining shoulder-elbow coordination was used in the first three trials of practice. Because the aim was to investigate the perception and replication of end-point information no pre-test or verbal instructions associated with the motor skill were provided before testing and therefore no baseline measure of performance was available for comparison. Immediate changes in coordination during acquisition of relatively novel motor skills have also been observed in similar actions (see Horn et al., in press; Scully & Carnegie, 1998).

For hip-knee, intra-limb coordination there was evidence that relative motion information from the lower body was used in accurately performing the lunge component of the action. The Model-x Block interaction revealed that participants who observed the FULL-BODY display more closely approximated the model's hip-knee coordination pattern than those who observed the ENDPT model during the first block of practice. By the last block of acquisition the coordination profiles for the participants in the ENDPT groups had improved to become more like the model and similar to those that observed the full-body relative motion model. The presence of task constraints (i.e., bowling a ball) influenced the learners' pattern of hip-knee coordination ($p = .06$), to more closely approximate the model. As detailed in Chapter 3, the additional constraint to propel an object to a target (i.e., kick a ball) resulted in coordination profiles that more closely matched a skilled model. These differences as a function of condition (i.e., bowling a ball) were maintained in retention.

A further manipulation of relative motion information was conducted in the re-acquisition phase. The two groups who had initially observed an end-point model were shown the full-body model. Despite the additional information available to the ENDPT groups there was no improvement in shoulder-elbow coordination across the re-acquisition periods. Irrespective of task conditions, participants who had originally observed a full-body model retained their coordination profile and were significantly more accurate at reproducing the model's hip-knee coordination profile than participants who had originally viewed an ENDPT model (see Figures 4.2a and b). Providing additional relative motion information to observers who had originally viewed an end-point model did not change their coordination profile to more closely approximate the model. In fact, there was some evidence that this change in information (i.e., a different model) led to increased disparity from the model. Finally, the additional constraint to bowl a ball to the target resulted in coordination profiles that more closely matched the model's hip-knee coordination. These data corroborate the findings from Chapter 3 which indicated that the additional requirement of kicking a ball over a height barrier constrained lower limb coordination in such a way that the movement profiles more closely approximated the model (cf. Chapter 2; Horn et al., 2002).

A second evaluation of the importance of relative motion information in observational learning was garnered through outcome success. The absolute constant error and variable error data did not yield significant differences between the two model groups in acquisition. In retention, both groups achieved similar outcome success in terms of mean absolute constant error. For variable error, the participants who observed a full-body model showed high variability in retention (90.8 cm) in comparison to the ENDPT group (54.8 cm). The FULL-BODY group showed an increase in variability of 53 cm from the last block of acquisition to retention in comparison to a reduction of 13 cm for the ENDPT group. The difference between these two model groups may indicate that the participants in the FULL-BODY group were more dependent on the model to achieve task outcome success, in comparison to ENDPT participants, who with less information were arguably less affected by the removal of the demonstration in retention. After the retention period both groups of observers received the full-body model to further test the role of relative motion in learning. A significant main effect for group indicated that the ENDPT group who viewed additional full-body relative motion was significantly more accurate at stopping the ball near to the target location than participants who continued to observe a full-body model.

Scully and Newell (1985) and Newell (1985) proposed that demonstrations are most effective during the early stages of skill acquisition and not for subsequent scaling or refinement. These data, however, indicate that relative motion information does play a role later in practice if observers viewed a model displaying only the end-point features. Because the shoulder-elbow relative motion properties did not change across re-acquisition, but outcome performance did, it is likely that the observers picked-up subtle features of the movement that pertained to absolute movement control.

In summary, there was little evidence to show an important role for intra-limb relative motion information in facilitating outcome success and developing a desired movement pattern across acquisition and retention (cf., Scully & Newell, 1985). Similar to the findings reported in Chapter 3, the participants who observed an end-point model accurately reproduced the shoulder-elbow component of the bowling action without access to intra-limb information, even when no additional task constraints (i.e., bowling a ball) were present. An explanation for these data is that participants naturally focus attention onto the end-point of the action during the observation phase of the imitation process (Mataric & Pomplun, 1998; Mather, Radford, & West, 1992). Mataric and Pomplun (1998) postulated that observers may use this strategy to track the trajectory of the end-point dynamics to form an end-point trajectory plan that controls the movement (see also Morasso, 1981). In skills where the primary effector is coordinated to achieve a specific spatial end-point location (e.g., kicking or throwing) absolute end-point information may be sufficient or even beneficial for constraining intra-limb coordination. These findings question the conclusions reached in earlier experiments where it was assumed that relative motion information was located and reproduced during observational learning. For example, Al-Abood et al. (2001) employed a dart throwing skill that required a primary effector to be coordinated to achieve a spatial end-point location. Therefore, their modelling group who executed a more accurate upper limb relative motion pattern, compared to a control group, might have used information pertaining to the model's hand as opposed to the proposed intra-limb configuration when reproducing the throwing action.

It has been suggested that because the extremities of a movement exhibit the most complex trajectory and move the furthest, that this information is critical for discriminating motion perception as opposed to more proximal features (Mather, et al., 1992). This processing is defined as 'local processing' where information (local relations) from a small temporal window (i.e., "small spatial neighbourhoods", Pinto & Shiffrar, 1999) is integrated and constructed into a whole through higher processing units (see Tse, 1999; Van Essen & DeYoe, 1995). This type of 'local' processing (see Mather et al., 1992) may account for the perception and reproduction of end-point models that exhibit movements primarily requiring the motion of one effector (i.e, the bowling arm in the present study; and a kicking action, as detailed in Chapter 3). It might be the case that as the complexity of the movement increases a more sophisticated processing system operates which is more reliant on relative motion information (Pinto & Shiffrar, 1999).

Following testing, participants were asked about the cognitions involved in imitating the action. Fourteen of the end-point observers reported that they worked out the lunge component through examination of the wrist trajectory (i.e., because the wrist was close to the ground a significant knee bend was inferred). Moreover, ten of the participants who viewed the full-body model indicated that they worked out the degree of knee flexion based on how far the knee was from ground and not the intra-limb knee angle. Although these data are post hoc and based on introspection it may be that it is the relative relationship between an absolute point (i.e., knee) and an environmental cue (i.e., ground) that determines the angle to which knee is flexed as opposed to intra-limb relative motion (i.e, knee angle). Regardless of the interpretation, there is evidence that the human visual system is flexible and exploits the information present to achieve the demands of the task (see Bertenthal & Pinto, 1993).

In conclusion, intra-limb relative motion is not necessary for effective movement reproduction when end-point information describes an action that is coordinated to attain a spatial end-point location. Therefore, when learning these type of actions, end-point information models might be more effective as they contain the most useful information (see Mataric & Pomplun, 1998; Mather et al., 1992; Latash, 1996). When the to-be-imitated action is not governed by a spatial end-point location, such as when a central joint is extended or flexed and the end-point remains stationary, relative motion may be helpful initially but not imperative for constraining a movement pattern. Providing intra-limb relative motion in the later stages of skill acquisition actually facilitated outcome performance only if observers had learnt the skill through end-point information. More research is required to examine the nature of kinematic information that is located from the model (i.e., shoulder or wrist velocity, see Horn & Williams, 2004; Shim & Carlton, 1997) and used to scale a motor skill in order to attain a distance-related goal.

These current data indicate that the presence of task constraints directly influenced the patterns of movement across acquisition and re-acquisition compared to only imitating a relative motion and/or end-point model (see Newell, 1986). Although these data contrast recent findings (Chapter 2; Horn et al., 2002) it is apparent that a closer approximation of a model's relative motion may also emerge through a confluence of task constraints (see also Chapter 3). This result shows that a relative motion profile that approximates the criterion model is not, by default, a consequence of the extraction of this information from a model. Whilst a model specifying relative motion intra-limb coordination helped observers imitate limb coordination that is not governed by a spatial end-point location, relative motion is not necessary when task constraints are suitably defined and/or information pertaining to the action's end-point is available.

Chapter 5

Scaling a motor skill through observation and practice

Abstract

It has been proposed that the process of scaling a motor skill is achieved through physical practice, rather than via observation of a model. The aim in this experiment was to examine this proposal through the manipulation of motor skill ability and provision of a model. Thirty-two participants, across four groups, did or did not receive initial practice at reproducing a bowling action to a target located 8 m away as demonstrated by a model. In a subsequent assessment phase, they either did or did not observe the same model bowling to a target at a distance of 4 m. Participants who viewed a model in assessment, irrespective of previous practice, were significantly more accurate and consistent in terms of spatial deviation from the target. These participants also showed shoulder and wrist velocity profiles more similar to the 4 m model than the no model groups. The results indicate that demonstrations facilitate the acquisition of control-related features of a movement. In tasks that require an object to be propelled to a target, observers locate and replicate kinematic information associated with the shoulder and wrist velocity of the primary effector.

Recent work in the area of observational learning has been driven by the desire to understand the nature of information picked-up and used during skill acquisition (e.g., Al-Abood et al., 2001; Hodges, Hayes, Breslin, & Williams, in press; Horn, Williams, & Scott, 2002). This question was earlier formalised by Scully and Newell (1985) who proposed the 'visual perception perspective' (VPP) on observational learning. The VPP was developed from perceptual and ecological psychology (e.g., Cutting & Profitt, 1982; Gibson 1979; Johansson, 1971, 1973) whereby relative motion information (i.e., the motion of individual elements of the configuration relative to each other) is identified as the critical invariant underlying the perception of a given activity (e.g., walking and running).

Scully and Newell (1985) integrated the VPP with Newell's (1985) framework of motor learning that distinguishes the processes of coordination, control, and skill. Based on earlier distinctions made by Kugler and colleagues (Kugler, Kelso, & Turvey, 1980, 1982), coordination was described as the function that constrains the free variables of the motor system into a behavioural unit (see also Bernstein, 1967). The relative motions associated with a to-be-learned action are thought to play a significant role in constraining the degrees of freedom into a behavioural unit (Newell, 1985). Control is the process where the learner is required to scale the coordination function to meet the demands of the task, with optimal scaling of the coordination function reflecting skilled behaviour. Scully and Newell (1985) proposed that modelling (imitation) is an important mechanism for the acquisition of coordination through the pick up of, and attunement to, relative motion information, but not in the scaling and refinement of coordination.

This latter viewpoint has been shared by others (e.g., Schmidt, 1975; Gentile, 1972, 1998) who have suggested that only through physical practice, rather than subsequent observations of a model, will optimal scaling of coordination be achieved. Physical practice is believed to be necessary for optimal scaling due to individual anatomical and morphological differences (Scully & Newell, 1985). For example, when a performer is required to throw a ball a certain distance the absolute parameters of an individual's action need to be scaled to their intrinsic constraints (e.g., height, weight, strength). Despite the emphasis on practice to actually scale coordination, there has been a significant accumulation of research showing that observers can pick up information specifying scaling related factors. For example, it has been shown that individuals can be quite accurate in making perceptual estimates of a lifted weight (Bingham, 1987; Shim & Carlton, 1997; Shim, Carlton & Kim, 2004) and in judging the relative-mass of colliding objects (Jacobs, Michaels, & Runeson, 2001).

The kinematic specification of dynamics (KSD) principle was proposed to explain these results (Runeson & Frykholm, 1981, 1983). Runeson and Frykholm (1983) argued that individuals are able to perceive causal factors of an action by picking up kinematic information within either the object(s) or the person. Participants who observed a point-light display of an actor throwing a sandbag could accurately judge the distance thrown even though they only saw the actor's shoulder, elbow, and wrist and not the kinematics of the hand or the object. Shim and Carlton (1997) raised concerns with this experimental paradigm, in particular its inability to provide specific information on the kinematics which are most informative for perceptual judgements. Subsequently, Shim and Carlton (1997) systematically manipulated various kinematic variables such as hip angle, dwell time and lift velocity during observations of a person lifting a box. Variations in lift velocity had the greatest effect on perception of a lifted weight (see also Bingham, 1987). However, it was not clear which velocity variable (i.e., the box, centre of gravity of the lifter or angular velocities of various joint motions during the lift) contributed to, or was most useful for, determining the weight of the box. Shim, Carlton, and Kim (2004) manipulated the size and strength of the lifter and showed that observers are more sensitive to the lifter's effort than to the weight of the box and that they use the velocity profile of the lifter to make such estimates. These results show that motion perception involves the detection of features relating to scaling or control, rather than, or in addition to, features related to coordination. It is not clear from these data however, whether these findings generalize from perceptual judgements to action reproduction (see also Runeson, Juslin, & Olsson, 2000).

The nature of information pick up during motor skill acquisition was later evaluated by Scully and Carnegie (1998). Performers were required to watch and imitate a gymnastic skill. Based on successful landing accuracy (a distance target) they concluded that observers' perceived and used absolute motion properties (i.e., control features) in addition to relative motion properties (i.e., coordination features) to perform the action. However, the evidence in support of these conclusions was not strong. Their findings may simply be a consequence of the observers' attempts at achieving the target landing distance and not a function of accessing and using control related information observed from the model. Moreover, the authors did not observe differences in absolute timing properties between those participants who perceived a still image model and those who observed a video model. The observers' movement control profiles may therefore reflect trial and error (discovery) attempts to learn the task rather than the perception and replication of dynamics per se (Vereijken, van Emmerick, Whiting, & Newell, 1992).

The current experiment was designed to address controversies in the modelling literature concerning what information is used for motor skill acquisition and the lack of evidence that individuals perceive and use scaling (control) related information for action reproduction. The aim was to examine whether information from a model is used to rescale an already acquired action. To answer this question, half of the participants first received pre-practice at a similar yet differently scaled bowling action. Following this practice phase, model information was manipulated to examine the benefits of this new information in scaling a previously performed movement.

In this experiment, participants were required to watch and perform a crown green bowling action. Whilst this task is relatively novel and complex, requiring inter and intralimb coordination, the general movement pattern can be replicated in a relatively short practice period (see Horn, Williams, Scott & Hodges in press). We predicted that participants would improve their coordination profiles in the practice phase such that they perform more like a model. More importantly, if demonstrations facilitate the scaling of an existing movement, it was predicted that those who acquire the action in the practice phase, and then observe a newly scaled model in assessment, will perform more accurately (i.e., target attainment) and more like the model than those who have not observed the model or received previous practice.

Methods

Participants

Thirty-two male participants (range 18–40 yrs) were randomly assigned to one of four groups (n = 8 per group). In these groups, participants either did or did not receive practice (PRAC) at reproducing a crown green bowling action to a target 8 m away as demonstrated by a model (preceding the assessment phase). In assessment, they either did or did not observe a demonstration (DEMO) of the same model bowling to a target 4 m away. The four groups were defined as: PRAC+DEMO; No-PRAC+DEMO; PRAC+No-DEMO; and No-PRAC+No-DEMO. All participants were right handed and were an opportune sample of university students. The experiment was conducted in accordance with the ethical guidelines of Liverpool John Moores University. All participants provided informed consent and were free to withdraw from the experiment at anytime.

Apparatus

Movement kinematics were collected using a VHS video camera (Panasonic M-40, Tokyo, Japan) and six infrared motion analysis cameras (Pro-Reflex; Qualisys, Gothenburg, Sweden) sampling at 50 and 240 Hz respectively. The demonstrations were front projected onto a 3 m x 3.5 m screen (Cinefold, U.S.A.) using a projector (Sharp XG-NV2E, Tokyo, Japan) and video recorder (Panasonic NV-HS 820, Tokyo, Japan). In the assessment phase, participants were required to bowl a small plastic ball (Regent, SOFFS: model 98200; circumference = 43 cm) to a target located 4 m away.

Task, Design, and Test-Film Construction

In the assessment phase, participants were required to perform an under-arm bowling action to bowl a ball to a target line located 4 m away. This movement was selected as a complex multi-limb technique that was relatively novel to participants. However, two of the groups had received practice at performing the bowling action to roll a ball to a target located a distance of 8 m away prior to the assessment phase (PRAC+DEMO and PRAC+No-DEMO.

A 26 year old male acted as the model and practiced (~ 200 trials per target) rolling a ball using a crown green bowling technique to targets located at distances of 8 m and 4 m respectively. The model was filmed from the sagittal plane using a digital video recorder and movement kinematics were captured using six motion analysis cameras. Following practice a consistent level of performance was achieved, a successful bowl (i.e., one where the ball stopped on the target line) for each target was chosen. The video data for these trials were transformed into video demonstration models to be used in the practice phase (8 m model) and assessment phase (4 m model). Only the model's action was shown, not the ball's trajectory. The spatio-temporal positions of 15 reflective markers placed on the model's joint centres formed a point-light display when viewed through a software-viewing program (Q-Trac Motion Viewer, Beta 2.54; Qualisys, Gothenburg, Sweden). These data points were used to compare participants' movements against the criterion model.

Procedure

Reflective markers were placed on the right and left side of each participant's distal head of the 5th metatarsal (toe), the lateral malleolus (ankle), the lateral condyle of the femur (knee), the greater trochanter (hip), and the acromion process (shoulder) and on the right hand side of the lateral epicondyle (elbow) and the styloid process of radius (wrist). All testing was conducted in the laboratory and each test session lasted approximately 40 minutes. All trials were recorded using six infrared cameras (Pro-reflex; Qualisys) at a sampling frequency of 240 Hz and a digital video camera positioned in the sagittal plane. Before each trial, participants were required to stand behind a line depicted on the floor that was positioned to enable easy viewing of the video demonstrations and the capture of movement kinematics. There were three testing conditions; pre-test, practice, and assessment. The experimental design is presented in Figure 1.

Group		Pre-test	Practice-phase	Assessment-phase
Practice group	Demo	-3 Trials -No model -No ball -No target	-12 Trials -Observe & imitate the 8 m model -No ball	-12 Trials -Observe & imitate the 4 m model -Bowl a ball to a 4m target
	No-Demo	3 Trials -No model -No ball -No target	-12 Trials -Observe & imitate the 8 m model -No ball	-12 Trials -No demonstration -Bowl a ball to a 4m target
No-practice group	Demo	3 Trials -No model -No ball -No target	-No practice	-12 Trials -Observe & imitate the 4 m model -Bowl a ball to a 4m target
	No-Demo	3 Trials -No model -No ball -No target	-No practice	-12 Trials -No demonstration -Bowl a ball to a 4m target

Figure 5.1. A summary of the experimental design.

Pre-test.

Participants received standardized instructions to execute a whole-body crown-green bowling action. Participants were not required to bowl a ball and hence no target constraints were placed on the action. The action was repeated three times and all trials were recorded.

Practice phase (8 m model).

Standardised instructions were provided to participants in the two practice groups (i.e., PRAC+DEMO and PRAC+No DEMO). Participants observed the model and imitated this movement pattern as accurately as possible across 12 attempts. Imitation was performed without a ball. To encourage participants to play close attention to the dynamics of the model, on the first trial and every fourth trial thereafter they were asked to estimate where the model had bowled the ball by placing a marker on the ground corresponding to the expected ball end location. A demonstration was shown twice on the first trial and once before each of the remaining eleven trials. During the practice phase, the two no-practice groups performed a non-task related computer activity that was matched for time (~ 20 min).

Assessment phase (4 m model).

The aim for all four groups in the assessment phase was to bowl a ball as close as possible to a target line located 4 m away using a crown-green bowling action. There were 12 trials in total. The two demonstration groups (PRAC+DEMO; No-PRAC+DEMO) were instructed to observe a model's movement technique before each performance attempt and to use the model to help achieve a successful target outcome. The model was presented twice before the first trial and only once on subsequent trials.

Dependent Measures and Data Analysis

Kinematics.

The start and end points of the arm swing and right leg movement of the bowling action were determined and used for subsequent kinematic analysis. The start and end points for the shoulder were based on the initiation of shoulder extension, in preparation for the start of the arm swing phase of the action, and ended at peak shoulder flexion in the follow-through element of the swing. For the right leg, the start of the movement was the initiation of knee flexion and ended at peak knee flexion. This normalization process allowed for comparisons across participants, trials, and with the model. The data were smoothed with a recursive 4th order Butterworth filter with a cut-off frequency of 7 Hz. A linear interpolation was performed to normalize this period to 100 data points.

Similarity between the participants' and model's hip-knee and shoulder-elbow coordination was quantified using a version of Sidaway, Heise, and Schoenfelder-Zhodi's (1995) normalized root mean squared error (NoRMS). In the modified version (see Horn et al., in press who refer to this measure as normalized root mean squared difference, NoRM-D), the disparity of the participant's mean trace (across three trials) from the model's trace is calculated. In addition to spatial relative motion features that are indicative of intra-limb coordination, two elements of movement control (see Newell, 1985) were measured; absolute time to peak velocity and peak velocity in both the wrist and shoulder before ball release. As with the NoRM-D analysis, difference scores were calculated in reference to the model.

In the pre-test, all kinematic variables were analysed in a four group between participants ANOVA. To determine change in kinematics across practice, the two practice groups' (PRAC+DEMO, PRAC+No-DEMO) pre-test scores were compared to the first (trials 1-3) and last (trials 10-12) blocks of practice in a two group x three block (Pre-test; First; Last) mixed design ANOVA. In the assessment phase, all four groups were compared in a two practice group (PRAC; No-PRAC) x two demonstration group (DEMO; No-DEMO) x two block (first, t1-3; last, t10-12) mixed design ANOVA. To provide a measure of effect size, partial-eta squared (η_p^2) values are reported for all effects in this and other analyses. Comparisons of interest involving more than two means were examined using Tukey HSD procedures. Statistical significance was set at $p < .05$.

Outcome-related measures.

Participants in the practice phase also estimated the model's bowling distance on select trials. These estimates were examined in a two group x four trial (1, 4, 8, 12) mixed design ANOVA with repeated measures on the last factor. In the assessment phase, outcome success was measured in terms of distance from the target. Absolute constant error, |CE| and variable error, VE were calculated. These data were analysed using a two practice group x two demonstration group x two block (first; last) mixed design ANOVA, with repeated measures on the last factor.

Results

Pre-Test

Intra-limb coordination.

The NoRM-D scores for the hip-knee and shoulder-elbow relative motion profiles in comparison to the model are displayed on the left-side of Figure 5.2.a (hip-knee) and Figure 5.2.b (shoulder-elbow).

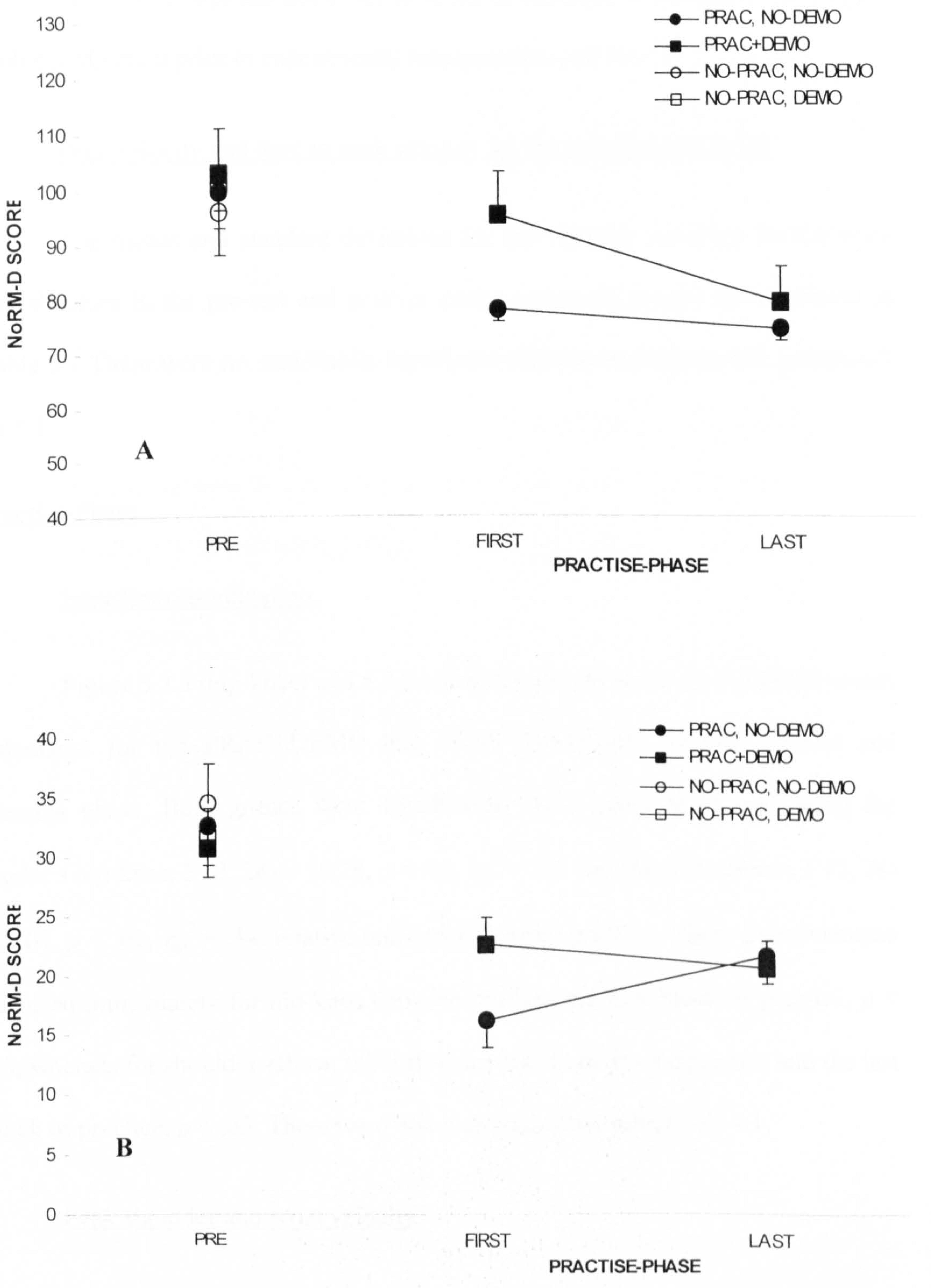


Figure 5.2. (A) Mean NoRM-D (standard error bars) scores for the participants' hip-knee and (B) shoulder-elbow coordination in terms of proximity to the model across the pre-test and practice-phase.

The four groups did not differ in terms of hip-knee or shoulder-elbow intra-limb coordination prior to experimental manipulations, all Fs < 1.

Peak velocity and time to peak velocity for the shoulder and wrist.

The means and standard deviations for the velocity variables for the wrist and shoulder in the pre-test and practice phase across all groups are displayed in Table 5.1.There were no statistically significant differences between the groups, all Fs < 1.

Practice-Phase

Intra-limb coordination.

Figure 5.2.a (hip-knee) and 5.2.b (shoulder-elbow) show the NoRM-D scores calculated for the PRAC+DEMO and PRAC+No-DEMO for the pre-test and practice phase. Both groups were significantly more accurate at replicating the model's hip-knee, $F (2, 28) = 19.28, p < .01, \eta_p^2 = .58$, and shoulder-elbow, $F (2, 28) = 7.07, p < .01, \eta_p^2 = .34$, relative motions following practice. These improvements occurred immediately for hip-knee between pre-test and first-block of practice, $p < .05$, whereas for shoulder-elbow, the difference was between the pre-test and the last block of practice, $p < .05$. There were no other significant effects, Fs < 1.

Peak shoulder and wrist velocity.

As with measures of coordination, significant differences following practice were observed for peak shoulder velocity, $F (2, 28) = 9.97, p < .01, \eta_p^2 = .41$, and peak wrist velocity, $F (2, 28) = 6.58, p < .01, \eta_p^2 = .32$. Post hoc comparisons showed that the participants' peak wrist velocity became more like the model from pre-test to the last practice block and from the first to the last block of practice, both ps < .05. For shoulder velocity, participants immediately changed their velocity to become more like the model from pre-test to the first practice block, $p < .01$. There were no other significant effects, all Fs < 1.

Time to peak shoulder and wrist velocity.

A significant main effect for block was observed for time to peak wrist velocity, F (2, 28) = 23.19, $p < .01$, $\eta_p^2 = .62$ (see Table 5.1.). The difference between the participant and the model actually increased across the first and last practice block, $p < .01$. No other effects were significant, Fs < 1.

Estimated distance.

With repeated observations of the model, both groups significantly improved their accuracy at estimating the model's bowled distance of 8 m, F (3, 42) = 8.11, $p < .01$, $\eta_p^2 = .37$. Trial 8 ($M = 6.96$, $SD = .81$) and trial 12 ($M = 7.10$, $SD = .72$) were significantly more accurate than trial 1 ($M = 6.19$, $SD = 1.00$). No other significant differences were observed, all Fs < 1.

Assessment-Phase

Intra-limb coordination.

NoRM-D scores calculated for shoulder-elbow coordination are illustrated in Figure 3. There were no significant main effects for demo group, F (1, 28) = 1.66, $p = .21$, $\eta_p^2 = .05$, or practice group, F (1, 28) = 3.21, $p = .08$, $\eta_p^2 = .10$. However, in addition to a main effect for practice block, F (1, 28) = 3.00, $p < .05$, $\eta_p^2 = .09$, the Prac x Demo group interaction was significant, F (1, 28) = 4.99, $p < .05$, $\eta_p^2 = .15$.

The No-Prac+No-Demo group was significantly different from the others groups in terms of error in shoulder-elbow coordination profile in comparison to the model, $p < .05$. No other effects were significant, Fs < 1.

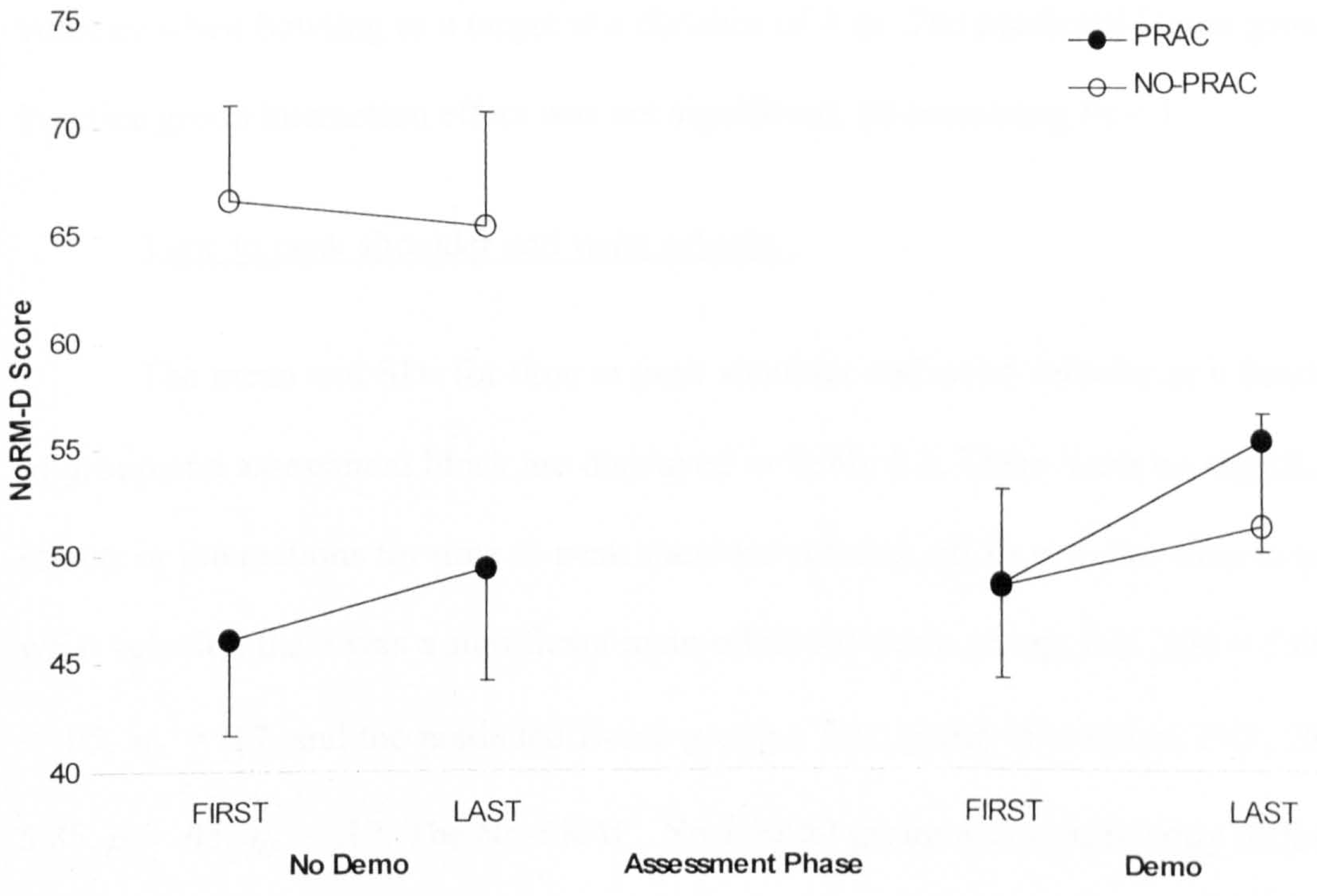


Figure 5.3. Mean NoRM-D (standard error bars) scores for the participants' shoulder-elbow coordination in terms of proximity to the model across the assessment phase.

Peak shoulder and wrist velocity.

Significant main effects for demo group were observed for peak shoulder velocity, $F(1, 28) = 8.24$, $p < .01$, $\eta_p^2 = .23$, and peak wrist velocity, $F(1, 28) = 7.22$, $p < .01$, $\eta_p^2 = .21$. Participants who watched the 4 m demonstration showed velocity kinematics more similar to the model than those who did not view the model. A significant effect for practice group was also observed for peak wrist velocity, $F(1, 28) = 13.17$, $p < .01$, $\eta_p^2 = .32$. Participants who previously practised the actions of the 8 m model were more accurate at reproducing the model's wrist velocity when bowling to a target at a distance of 4 m. The predicted Demo group x Practice group interaction effect was not significant, all remaining Fs < 1.

Time to peak shoulder and wrist velocity.

The mean and SDs for time to peak shoulder and wrist velocity as a function of group and assessment block are displayed in Table 5.2. There were no significant effects or interactions for time to peak shoulder velocity, all Fs < 1. For time to peak wrist velocity, there was a significant main effect for demo group, $F(1, 28) = 5.60$, $p < .05$, $\eta_p^2 = .17$, and the predicted Demo group x Prac group interaction, $F(1, 28) = 5.85$, $p < .05$, $\eta_p^2 = .17$. The No-PRAC, No-DEMO group was significantly different from the three other groups in terms of time to peak wrist velocity, $p < .05$, showing greater departure from the model than the other 3 groups.

Table 5.1. The participants' mean (± SD) peak shoulder and wrist velocity (mm/s) and absolute time to peak shoulder and wrist velocity (ms)

		Pre-test	Practice-phase - First	Practice-phase - Last
Kinematic variable				
Group		Mean (SD)	Mean (SD)	Mean (SD)
Peak shoulder velocity				
Prac	No Demo	1704.6 (321)	1379.2 (218)	1429.7 (195)
	Demo	1614.6 (400)	1337.7 (164)	1301.9 (158)
No Prac	No Demo	1639.6 (242)		
	Demo	1653.5 (258)		
Model			**1131.2**	
Peak wrist velocity				
Prac	No Demo	4599.4 (1172)	3522.1 (665)	3517.1 (421)
	Demo	4470.7 (888)	3612.8 (766)	3521.4 (352)
No Prac	No Demo	5144.9 (1283)		
	Demo	4189.2 (550)		
Model			**3467.7**	
Time to peak shoulder velocity				
Prac	No Demo	997.8 (295)	1088.9 (253)	1076.9 (219)
	Demo	927.4 (131)	1018.5 (260)	999.2 (246)
No Prac	No Demo	916.7 (74)		
	Demo	1030.1 (182)		
Model			**1098.5**	

Time to peak wrist velocity				
Prac	No Demo	1293.0 (312)	1394.8 (152)	1413.5 (150)
	Demo	1267.4 (160)	1394.3 (285)	1422.9 (217)
No Prac	No Demo	1231.4 (349)		
	Demo	1403.4 (134)		
Model			**1295.6**	

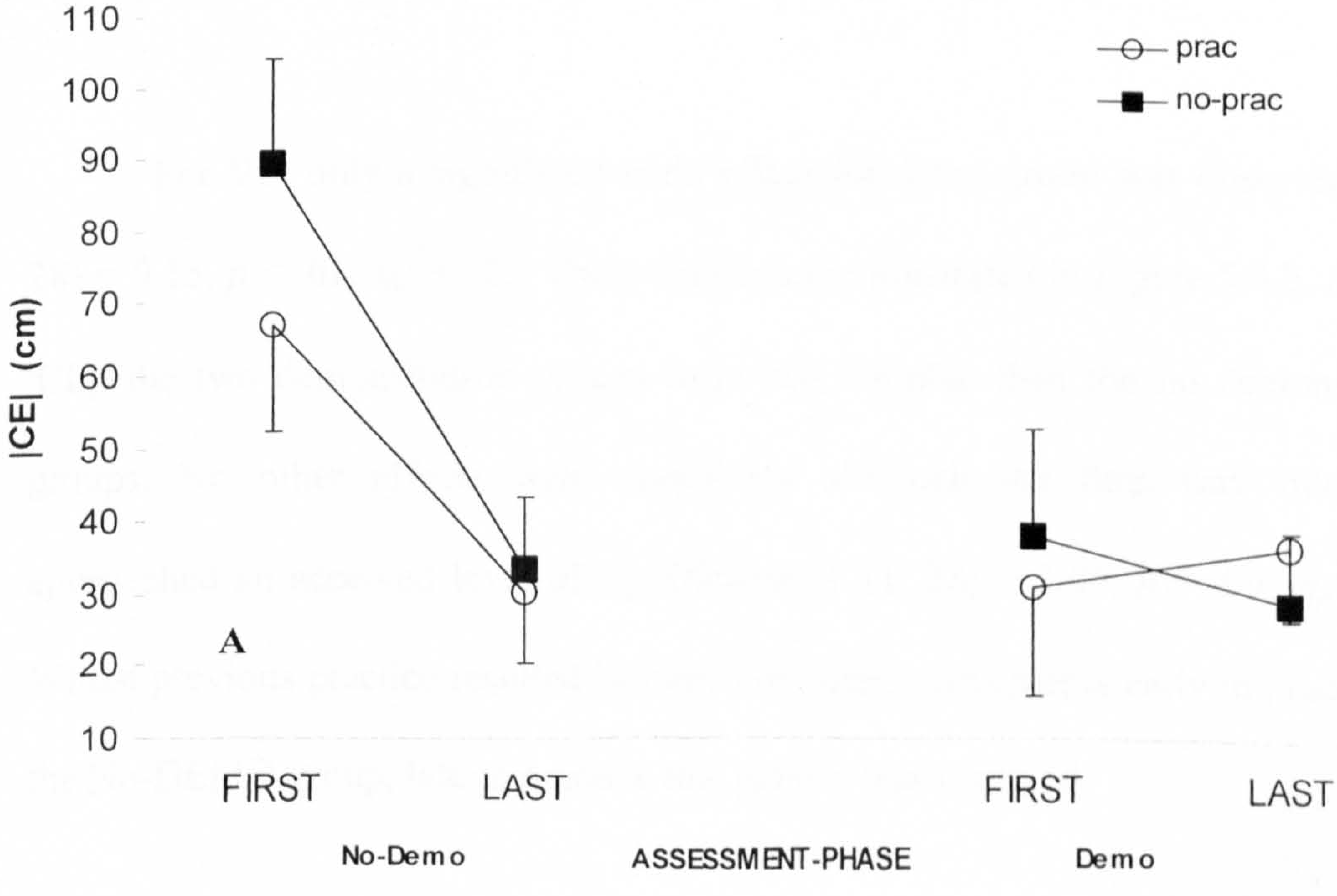
Table 5 2. The participants' mean (± SD) peak shoulder and wrist velocity (mm/s) and absolute time to peak shoulder and wrist velocity (ms)

Kinematic variable		Assessment-phase - First	Assessment -phase - Last
Group		Mean (SD)	Mean (SD)
Peak shoulder velocity			
Prac	No Demo	1268.9 (198)	1185.9 (218)
	Demo	1127.6 (131)	1160.7 (124)
No Prac	No Demo	1456.6 (222)	1430.8 (383)
	Demo	1080.8 (131)	1116.9 (170)
Model		**762.1**	
Peak wrist velocity			
Prac	No Demo	2370.4 (432)	2276.2 (434)
	Demo	1978.8 (318)	2127.5 (270)
No Prac	No Demo	2755.5 (571)	2674.9 (832)
	Demo	2421.6 (242)	2599.2 (258)
Model		**1881.7**	
Time to peak shoulder velocity			
Prac	No Demo	1122.9 (422)	1008.4 (261)
	Demo	957.2 (255)	1083.1 (289)
No Prac	No Demo	914.1 (180)	973.9 (141)
	Demo	1042.9 (94)	1047.5 (204)
Model		**1036.5**	

Time to peak wrist velocity			
Prac	No Demo	1378.1 (186)	1394.5 (221)
	Demo	1433.9 (224)	1498.0 (285)
No Prac	No Demo	1165.8 (181)	1237.0 (190)
	Demo	1394.7 (69)	1512.7 (176)
Model		**1512.9**	

Outcome error.

Analysis of |CE| as shown in Figure 5.4.a revealed a significant main effect for demo group, $F(1, 28) = 4.65$, $p < .05$, $\eta_p^2 = .14$, but not for practice group, $F < 1$. Participants were more accurate following observation of the 4 m model in the assessment phase. A significant block effect, $F(1, 28) = 9.64$, $p < .01$, $\eta_p^2 = .26$, showed that all participants improved following practice at bowling to the 4 m target. The only significant interaction was between Demo x Block, $F(1, 28) = 8.32$, $p < .01$, $\eta_p^2 = .23$. The demonstration groups were more accurate, in terms of spatial deviation from the target, than the no-demonstration groups in the early trials only, $p < .05$.



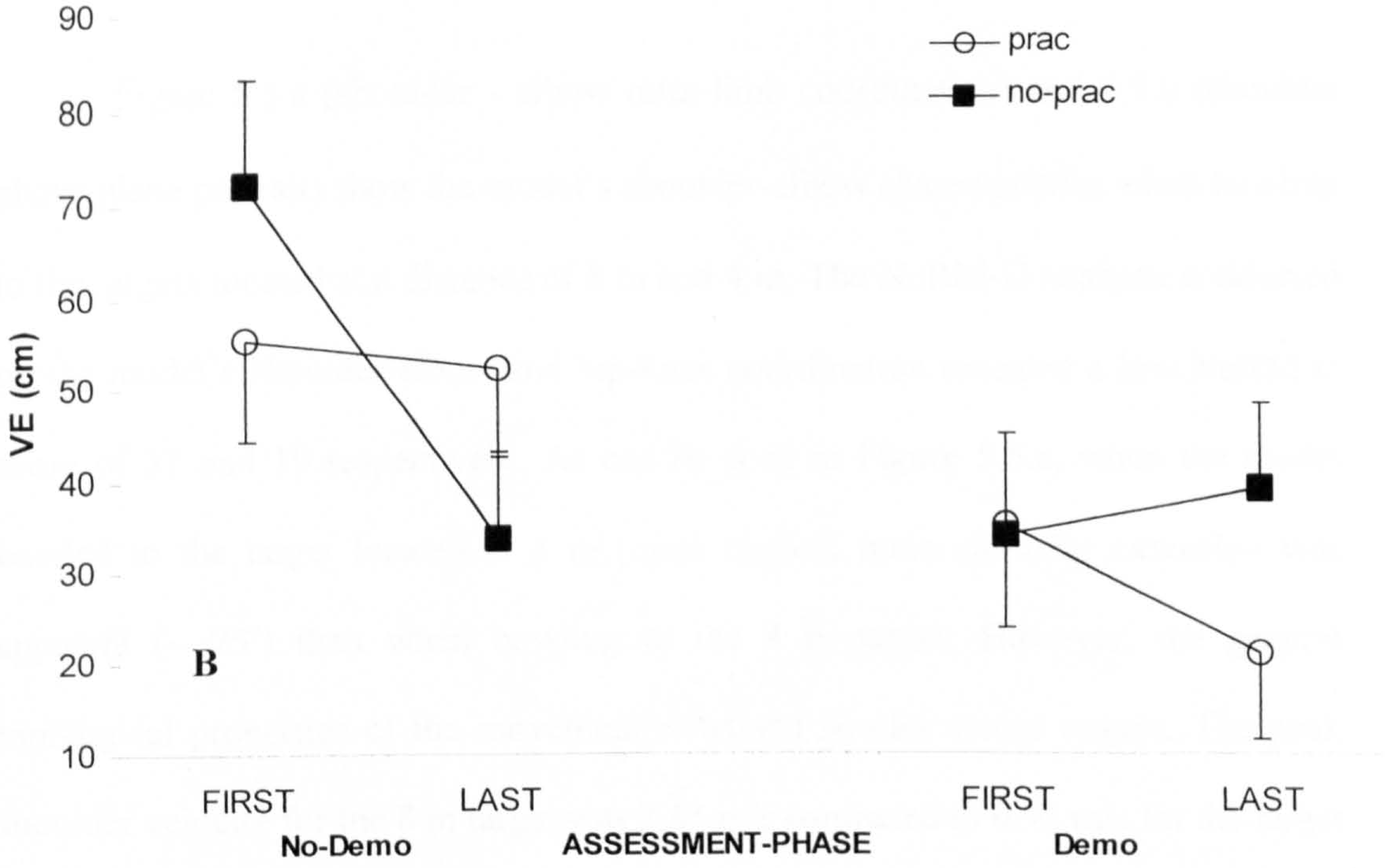
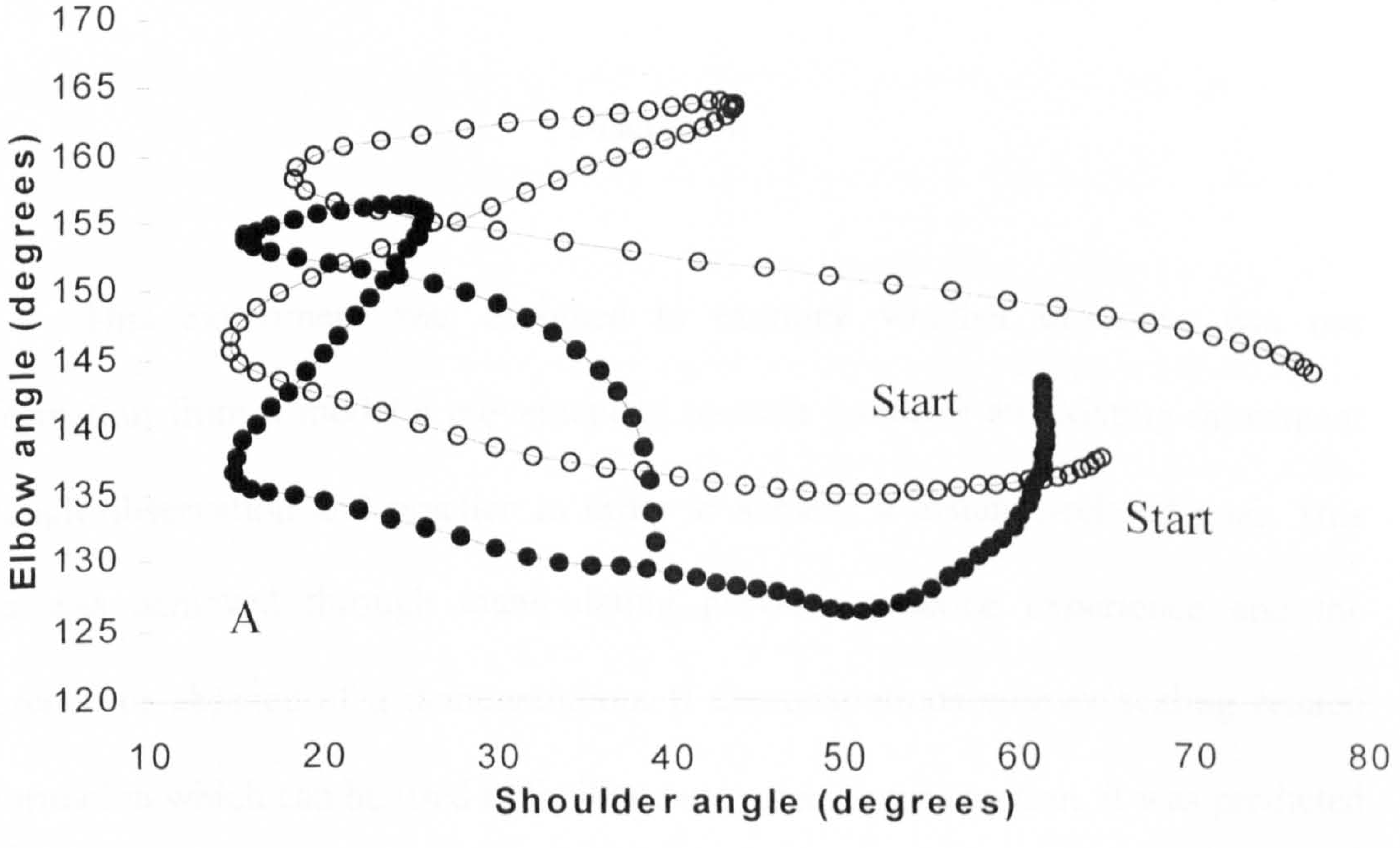


Figure 5.4. (A) Mean spatial deviation (|CE|) from the target across the assessment-phase for all groups (standard error bars) (B) standard deviation (VE) around the target (standard error bars).

For VE, only a significant main effect for demo group was observed, F (1, 28) = 9.15, $p < .01$, $\eta_p^2 = .25$. These findings are illustrated in Figure 5.4.b. As with |CE|, the two demonstration groups were less variable than the no demonstration groups. No other effects were significant although the three-way interaction approached an accepted level of significance, F (1, 28) = 3.06, $p = .09$, $\eta_p^2 = .10$. Whilst previous practice resulted in more consistent movements early in practice for the No-DEMO group, late in practice this pattern was reversed.

Model's kinematics across the 4 m and 8 m targets.

Figure 5.5.a (shoulder - elbow intra-limb coordination) and 5.5.b (shoulder phase-plane portrait) show the model's shoulder-elbow characteristics when bowling to the targets located at a distance of 8 m and 4 m. The NoRM-D analysis conducted on the model's shoulder-elbow and hip-knee coordination revealed a low NoRM-D score of 37 and 19 respectively. As can be seen in Figure 5.5.a, when the model bowled to the target located at 8 m (open circles) more shoulder extension was apparent (~ 25°) than when bowling to the 4 m target. However, the general topological properties of the movement remained similar across targets. The peak shoulder velocity for the 8 m target was 2.43 m/s compared to 0.92 m/s for the target located a distance of 4 m away. Proportion of time to peak shoulder velocity for both targets occurred approximately at the same time (i.e., within 5 %, see Figure 5.5.b).



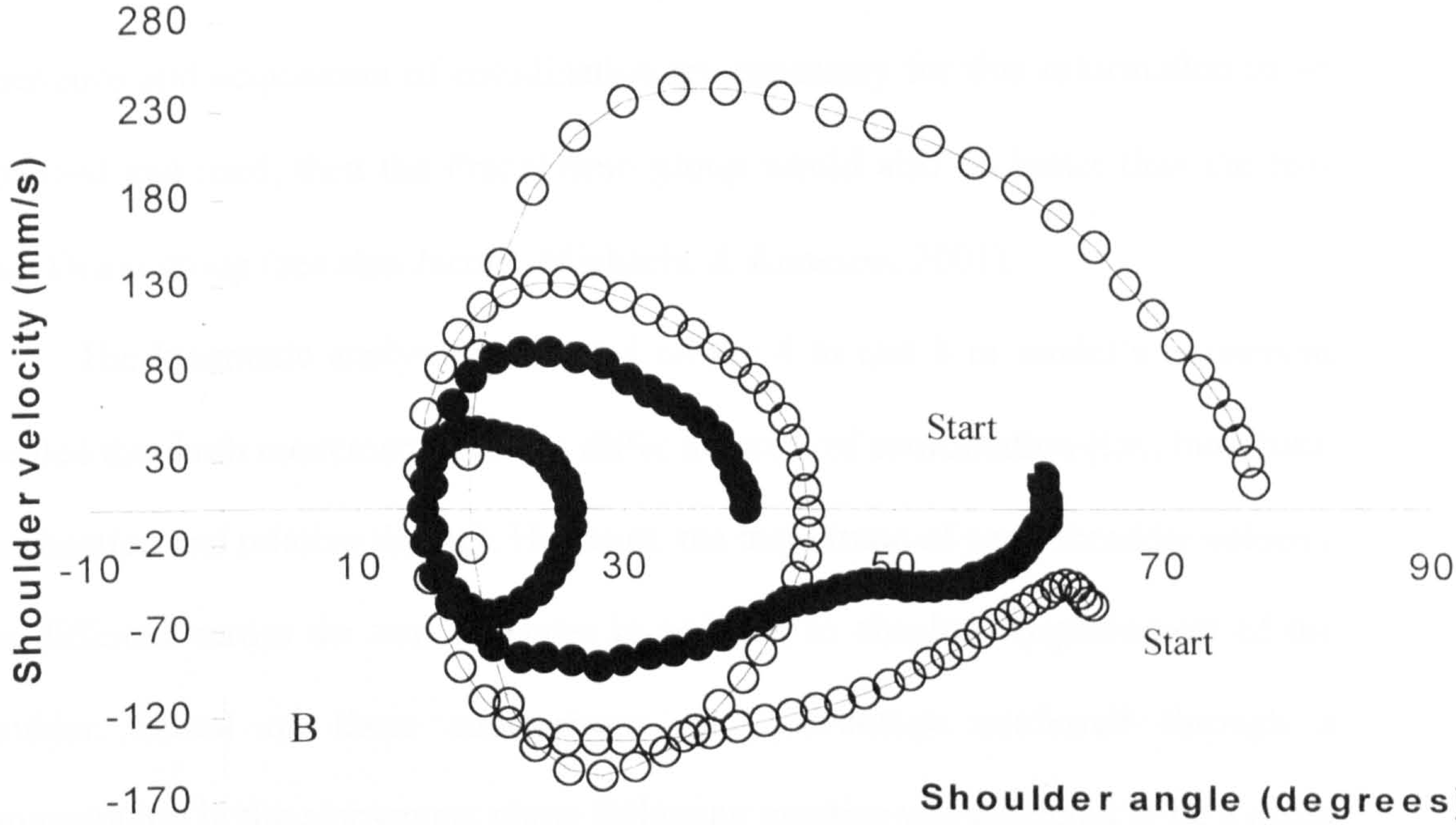


Figure 5.5. (A) The 8 m (open circles) and 4 m (filled circles) model's shoulder-elbow intra-limb coordination profile (B) The 8 m (open circles) and 4 m (filled circles) model's shoulder angle plotted against shoulder velocity represented as a phase-plane.

Discussion

This experiment was designed to examine whether observers can use information from a model's movement to re-scale (control) an existing movement through observation and practice in order to achieve a distance-related goal. This aim was achieved through manipulating previous practice experience and the presence or absence of a demonstration. If demonstrations convey scaling related information which can be used to facilitate movement reproduction, it was predicted that the Prac+Demo group would demonstrate movement kinematics more similar to the model, in terms of velocity of the wrist and shoulder, than the Prac+No-Demo group. Moreover, this ability to perceive control related information from a model would be reflected in more accurate target attainment. If the previous practice experience and acquisition of coordination are necessary for this information to be perceived and used, then the Prac+Demo group would also do better than the No-Prac+Demo group (see also Jacobs, Michaels, & Runeson. 2001).

The kinematic analysis conducted on the 4 m and 8 m model's movement revealed that both movements did not differ in terms of coordination (i.e., intra-limb coordination and relative timing). However, the magnitude of peak shoulder velocity was different across the two distances in addition to absolute displacement of the shoulder. Based on these comparisons, any advantage conferred through a demonstration in the assessment phase following practice was expected to be a result of differences in absolute, control related variables (time to reach peak velocity of the shoulder and wrist, and the magnitude of the velocity value at this time point) rather than the general pattern of coordination.

In the pre-test, there was no significant difference between groups for shoulder-elbow and hip-knee intra-limb coordination. As predicted, both groups of participants significantly improved their approximation of the model's shoulder-elbow and hip-knee intra-limb coordination with repeated observations of the model and attempts at imitation. As with intra-limb coordination, observers improved their approximation of the model's kinematic control related properties in the practice phase. Post-hoc analysis indicated that the model's peak shoulder velocity profile was immediately replicated (i.e., from pre-test to the first block of practice), whereas subsequent observations and replication attempts were needed to approximate the model's wrist velocity (last block of practice). Whether these changes in kinematics resulted from the pick up of relative motion information or scaling related information is difficult to determine without direct manipulation of these variables in subsequent experimentation. However, because of the practice manipulations it was possible to examine whether features related to movement control were used to later refine a newly scaled movement.

In addition, the perceptual estimation data showed that across practice, both groups became more accurate at estimating how far the model bowled the ball. Because no contextual or augmented information (i.e., the ball's weight or feedback about their estimation(s)) was available to facilitate their perceptual judgements, kinematic properties from the model's movement were located and used to predict the bowled distance. These findings corroborate data showing that observers used kinematic specifying information to make accurate estimates of a lifted weight (Shim & Carlton, 1997; Shim, Carlton & Kim, 2004) and the distance an object was thrown (Runeson & Frykholm, 1983).

The aim in the assessment phase was for all participants to bowl a ball to a target line located 4 m away from the participant. Two of the groups watched a demonstration before attempting the action. Participants who viewed a model were significantly more accurate and consistent (i.e., less variable) in terms of spatial deviation from the target than participants who did not view a model. There was no interaction with prior practice experience. Demonstrations, irrespective of previous practice at a similar yet differently scaled action, facilitated performance. The Demo x Practice interaction indicated that demonstrations conferred an advantage early in practice only.

In terms of kinematic variables, both previous practice experiences and demonstrations of the newly scaled model resulted in performance advantages in coordination. For example, the shoulder-elbow NoRM-D data showed that participants in the No-PRAC+No-DEMO groups were significantly less like the model in terms of their coordination profile than the PRAC+No-DEMO. Because the PRAC+No-DEMO group executed a similar movement pattern as the two groups who observed a 4 m model, evidence is provided to indicate that participants in these three groups had acquired the general movement pattern (from either the 4 m or 8 m demonstration). Time to peak velocity showed a similar pattern of results. However, there was also evidence that the participants who had seen the 4 m model in assessment had also picked up control related features of the movement which incurred advantages in target accuracy (i.e., CE and VE) during early practice trials. Since there were no differences in the shoulder–elbow coordination between the PRAC+DEMO, No-PRAC+DEMO and PRAC+No-DEMO groups, it seems that the general intra-limb coordination profile was not the primary contributor to outcome success otherwise all groups would have attained a similar outcome performance (see also Horn & Williams, 2004). Kinematic examination of the control properties associated with the armswing revealed that the two demonstration groups controlled the magnitude of shoulder and wrist velocity differently than the other groups. The demonstration groups showed velocity profiles that were similar to those of the model.

The fact that the two demonstration groups were significantly more accurate at attaining the target distance than those who did not view a model, and that they also showed velocity profiles more similar to the model, provides evidence that observers scaled and controlled their movement through observation. Scully and Newell (1985) argued that optimal scaling is achieved through physical practice not through further observations of a model. Based on our data, (i.e., differences between the demonstration groups and the lack of difference between the two demonstration groups as a function of previous practice), we argue that control/scaling related information is important early and late in practice to reproduce a motor skill. Following a demonstration, participants were better able to attain a target distance irrespective of previous practice. It is likely that early improvements in coordination variables are mediated through kinematics related to coordination (i.e., the general movement pattern and relative spatial and temporal information) and control features (i.e., the absolute speed of the primary effector).

It can be inferred from the kinematic analysis that wrist and shoulder velocity information were used to scale and facilitate the attainment of the distance-related goal. Shim, Carlton, and Kim (2004) stated that multiple kinematic parameters are likely to be perceived and used from a whole body action during the perceptual process of identifying information for action. Using an occlusion paradigm to try and isolate the primary kinematic information that underpins the perception of a lifted weight, they found that variables such as lift velocity, dwell time, and/or knee angle underpinned successful perceptual judgements. However, in a task such as bowling or throwing, the final destination of the ball is governed by release angle and release velocity of the primary effector (Feynman, Leighton, & Sands, 1965). Because both demonstration groups were more successful at rolling the ball to the target line, and their armswing kinematic profiles were similar to the model, it is likely that shoulder and wrist velocity information was used to scale the bowling arm. Further experimentation is necessary involving direct manipulation of this information before firm conclusions can be made.

The results of the present experiment have important implications for the implementation of demonstrations. It has been assumed that demonstrations serve the purpose of providing information for the acquisition of a new coordination pattern in early skill acquisition (Adams, 1987; Bandura, 1977; Gentile, 1998; Scully & Newell, 1985). The present results indicate that demonstrations also facilitate control-related features of a movement and the scaling of an existing coordination function in order to attain a successful distance related goal (see also Blandin, Lhuisset, &, Proteau, 1999 who showed that absolute features of a movement were acquired before relative features during observational learning of a barrier knock-down task). In tasks that require an object to be propelled to a target, observers locate and replicate kinematic information associated with shoulder and wrist velocity of the primary effector.

Chapter 6

Epilogue

The Nature of Information used during Observational Learning

The primary aim in this thesis was to examine the constraining role of relative motion information during observational learning. In the first three experiments (see Chapters, 2, 3, 4) the kinematic content of a demonstration and task context was examined to investigate their impacts on reproduction accuracy. The task environment was examined to investigate how target-outcome related variables mediate the effectiveness of demonstrations. In Experiments 2 and 3 relative motion information was directly examined using various occlusion techniques. Finally, to understand how demonstrations generally and relative motion more specifically affects both the acquisition of coordination and the scaling of this action, in Experiment 4, comparisons were made across different 'stages' of motor learning to examine the processes of coordination and control (see Newell, 1985). The four experiments and key findings are summarised in Figure 6.1.

Task constraints

The data reported in Experiments 1, 2, and 3 confirm the importance of objects (and their treatments) and task constraints in observational learning, using adults and children (see also, Bekkering et al., 2000; Hayes, Horn, Hodges, Scott, & Williams, in press; Horn et al., 2002, in press). The findings from Experiment 1 (Chapter 2) show that adults and children imitated the model's bowling action less accurately when attempting to attain an external outcome goal than just imitating the model's action. It seems, therefore, that it is primarily the treatment of an object that shapes the imitated movement form, as opposed to the model's movement pattern.

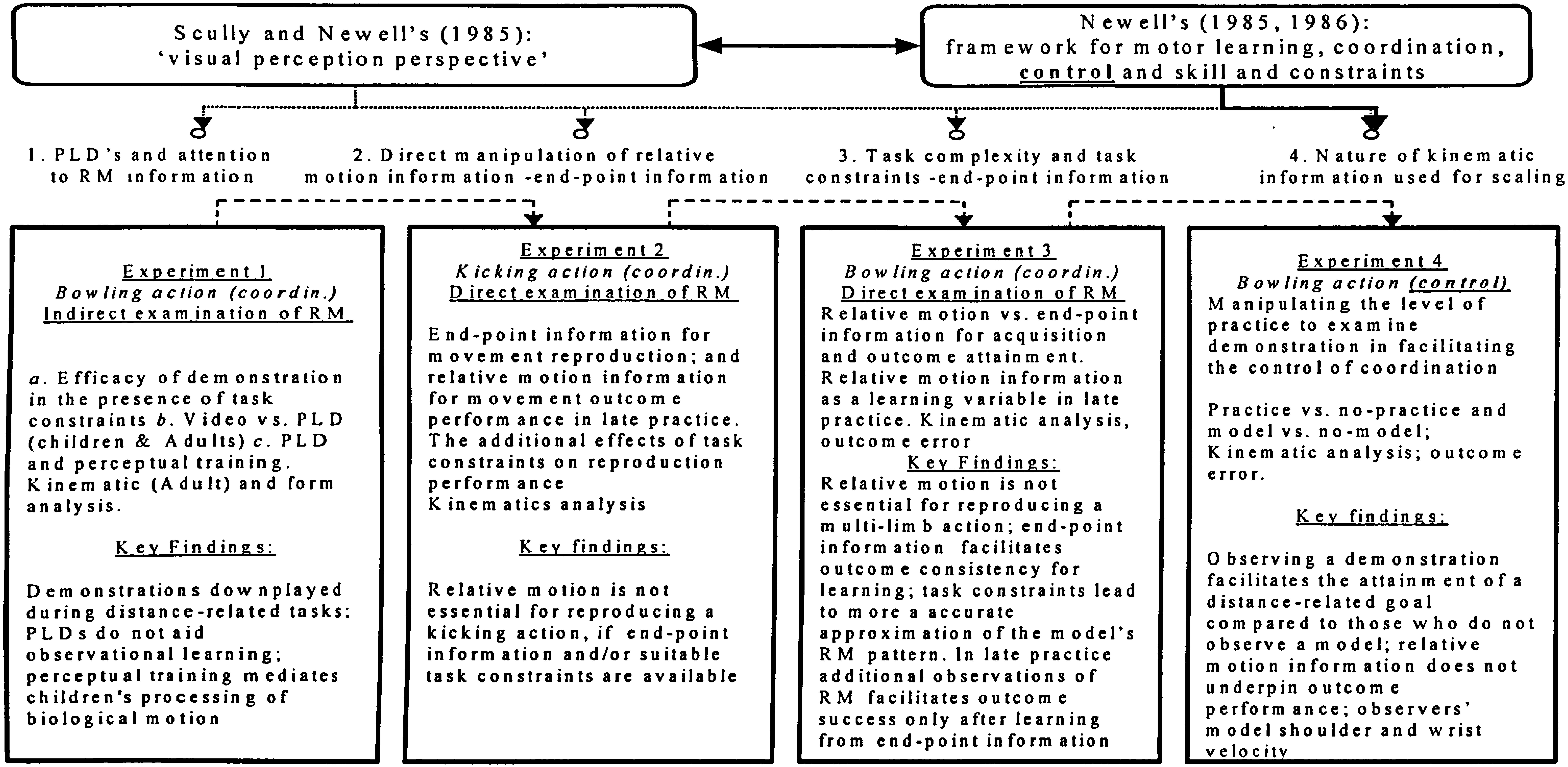


Figure 6.1. Diagram to illustrate the structure, purpose, flow, and key Findings of the four experiments.

These data contrast Scully and Newell's (1985) proposals that relative motion is the essential information to be imitated during observational learning. To interpret current findings the mechanisms of imitation (Bekkering et al., 2000; Wohlschlager et al., 2003) and the influence that task constraints have on a performers emerging coodination pattern (Newell, 1985, 1986) will be addressed.

In terms of the mechanisms underpinning imitation, these findings are in line with the predictions presented by Wohlschlager and colleagues within their theory of goal-directed imitation. They postulated that during imitation the reproduced movement is guided by cognitively specified goals as opposed to being directly constrained by the invariant topological properties (believed to be relative motion) of the model's movement pattern (see Scully & Newell, 1985). According to Wohlschlager et al., the observer during goal-directed imitation does not imitate the model's movement as a whole (as proposed by Scully & Newell, 1985), but decomposes the observed act into separate constituent components. These components are hierarchically ordered based on experience and task complexity with the primary component being the observer's goal (see also Bekkering et al., 2000). For example, the most dominant goal for adults and children in the bowling task seemed to be the requirement to roll the ball to the target line (even though they were explicitly instructed to copy the model's movement). This priority to attain a successful target goal manifested in the adults and children's movements being less accurate compared to when they were tasked only with imitating the model's movement. In the latter, the actual goal is to imitate the model's movement form and therefore the reproduced movement pattern is similar to the model's movement (see Chapters 2, 3 and 4; Horn et al., in press).

The kinematic data collected from Experiment 2 and 3 show a similar pattern of coordination differences when observers are challenged with attaining an external goal. However, these data differ from Experiment 1 in that the knee-ankle (Experiment 2) and hip-knee (Experiment 3) intra-limb coordination, across two different motor actions, were more like the criterion model after bowling or kicking a ball. One explanation for why the adults' bowling movements appeared to be more accurate in Experiment 3 compared to Experiment 1 (see mean form data in Table 2.3.) was the different methods of quantifying movement kinematics. As stated in Experiment 1, due to high inter- and intra-participant movement variability among the children the primary measure of movement form was based on the analysis of video and coding of actions into different movement components. The form component analysis showed that the adults tended not to replicate the end of the bowling arm swing and that there was no difference between the BALL and No-BALL groups for the lunge component. In Experiment 3, intra-limb coordination was quantified through NoRM-D procedures and showed that those who bowled a ball were in fact more accurate at approximating the model's hip-knee, intra-limb coordination compared to those who did not bowl a ball. The lack of form score differences for lunge component between the adults who bowled and those who did not in Experiment 1(see mean lunge component form scores Table 2.3.) in comparison to Experiment 3 likely reflects the additional sensitivity of measurement of the NoRM-D procedure.

In the context of explaining imitation on a hierarchy of goals it is important to note that the goals themselves are somewhat determined by the constraints of the task (Newell, 1985, 1986). The research reported here indicates that in goal-directed tasks the resulting movement pattern is primarily influenced by the outcome constraints and these have a positive or negative influence on movement form approximation. Whilst these data support a constraints-based perspective of motor learning (see Newell, 1985, 1986, 1989), they do not support Scully and Newell's (1985) proposal that relative motion information is the essential information required for constraining a new coordination pattern. Scully and Newell (1985) predicted that because actions are described by their topological relative motions (Johansson, 1971; Newell, 1985), these properties provide the solution to a learner's problem of acquiring a new motor skill. For example, if a performer is challenged with learning a somersault, it is predicted the relative motions that describe that somersault are the essential information to be observed and imitated during observational learning (Scully & Newell, 1985). What Scully and Newell (1985) failed to make explicit was that motor actions are also influenced by several different constraints. Specifically, three categories of constraint interact ('Task', rules of the game; 'Organism', cognitive development; 'Environment', gravity) from which a certain behaviour pattern emerges (Newell, 1986). During observational learning, therefore, relative motion is only one constraining variable in goal-directed actions and that it may not be the primary constraining variable unless the to-be-learnt action is the goal.

Combining the present research with Newell's (1985, 1986) model of constraints, a degree of caution is needed in making conclusions about the "pick up" and "use" of relative motion information based on the performers' action. It has been shown that task constraints play a significant role in constraining the performers' movement pattern. Schoenfelder-Zhodi (1992) found that when learning a ski-slalom technique a no-demonstration-discovery group showed a similar pattern of coordination to participants who observed a skilled model (see also Vereijken, et al., 1992; Whiting, et al., 1987). She concluded that the primary constraining variable that influenced the performers' movement patterns was the mechanical constraints of the ski-simulator apparatus and not the model. What is interesting about the current findings is that the bowling and soccer kicking actions are more on the "open" skill (e.g., return in tennis) end of the "open-closed" (closed skill e.g., bench press) continuum (see Gentile, 1972). Despite the comparative freedom of the soccer and bowling tasks the external target goals still served to significantly constrain the emergent pattern of coordination. In fact, the patterns of intra-limb coordination for the performers who bowled or kicked a ball were more similar to the model than those who only imitated the action. It is important to note that a relative motion that is similar to a model's pattern is may not necessarily result from the learner copying the model's action. In terms of relative motion, there is little doubt that relative motion is used to recognise a movement but in goal-directed actions the reproduced movement pattern is also a consequence of attaining a task outcome rather than the performer extracting and using relative motion information.

To effectively test Scully and Newell's (1985) prediction that observers pick-up and become constrained by the model's relative motion it is important to consider the nature of the to-be-imitated action and task environment. Therefore, motor skills that have no outcome goals or closed motor actions, where the rules of an event specify that a particular coordination pattern must be produced (e.g., Yamashita vault in gymnastics), are more likely to be conducive to the benefits of imitating a model's relative motion pattern. Without further examination of more novel or complex closed skills it is not possible to make firm conclusions about the importance of task constraints and/or their interaction with augmented instructional constraints such as demonstration.

Manipulation of relative motion

Point-light displays.

The role of relative motion has typically been examined using point-light display models (Al-Abood, et al., 2001; Horn et al., 2002; Scully & Carnegie, 1998). It was predicted in Experiment 1 that observers would acquire a model's relative motion pattern more effectively through point-light rather than video models because all non-essential information is removed, thus focusing attention to the critical information (which was believed to be relative motion). Since young children process information less effectively than adults (Chi, 1976, 1977), and have difficulty attending to multiple information sources (Yando et al., 1978), young children (Experiment 1) were expected to benefit from point-light models because removing non-essential information would reduce the processing demands of imitating a complex motor skill. In contrast, the children who viewed a point-light model were actually less accurate at imitating the bowling action than those who observed a video model. It seemed that because there were no additional task constraints to influence the perception and action of the bowling action and the novelty of the task, the six-year children from Experiment 1 had problems understanding/processing the information within the point-light displays (see McCullagh & Weiss, 2001). However, the adults (Horn et al., 2002, in press) and older children (Williams, 1989) have been shown to imitate as accurately from a point-light or video model. A plausible reason why the children and adults, in their respective studies, accurately perceived and imitated the point-light models was not due to a more developed visual system but merely down to task experience stimuli (see Sparrow et al., 2001). In fact, by providing the children in Experiment 1 with a small period of perceptual point-light training there were then able to imitate the action relatively accurately. These data go against some suggestions that the invariant relative motion properties of a model's movement directly constrain the observer's action without recourse to additional processing mechanisms (Al-Abood et al., 2001; Scully & Newell, 1985; Scully & Carnegie, 1998). Because in Experiment 1 the observers required a sufficient level conceptual knowledge in order to identify and imitate specific kinematic characteristics from the point-light model (see Goldenberg, 1995; Sparrow et al., 2001).

The prediction that presenting a point-light model would direct adults' attention to the critical details of relative motion information and thus facilitate the acquisition of a complex multi-limb action was not supported (cf. Scully & Carnegie, 1998). The NoRM-D data indicated that there was no difference in intra-limb coordination between the adults who observed a point-light or video model (see also Al-Abood et al., 2001; Horn et al., 2002, in press; Williams, 1989). Based on these data it seems that the constraining source of information within a display is perceived and used from either point-light or video stimuli. The question as to what this important information is, however, cannot be determined from these types of manipulations alone. Just because the observers in Experiment 1 (and other experiments Al-Abood et al., 2001; Horn et al., in press) reproduced a relative motion pattern that was similar to the model, this does not confirm that relative motion was extracted and used to constrain the imitated action. There is evidence that observers fixate on the end-point of an action, not the relative motion properties when asked to watch and imitate (e.g., Mataric & Pomplun, 1998). No clear conclusions can therefore be made whether relative motion was used by an observer to constrain an imitated action until relative motion is directly manipulated.

Removal of relative motion information.

In Experiments 2 and 3 relative motion information was manipulated to examine its importance in constraining two different motor skills that varied in their degree of complexity. Data from Experiment 2 showed that participants who observed a demonstration that only contained end-point information (i.e., the 'toe' marker where no intra-limb information was present) reproduced a lower-limb kicking action more accurately than those who viewed models containing relative motion information pertaining to the whole leg. Moreover, when participants transferred from the partial information conditions to a full-body display condition (see Phase II Chapter 3), the hip-knee and knee-ankle intra-limb coordination profiles did not change to become more like the model following observation of this information (i.e., relative motion). Because end-point information was sufficient (and indeed for some measures beneficial) for constraining a full-body action, this finding questions the fundamental notion that relative motion is essential for the acquisition of intra-limb coordination (cf. Scully & Newell, 1985).

To corroborate and extend upon these findings an evaluation of end-point information as a facilitatory variable in the process of observational learning was examined in Experiment 3. Rather than a relatively constrained soccer kicking action, the acquisition of a whole body complex bowling action was examined in Chapter 3. For shoulder-elbow intra-limb coordination there was no difference between the end-point and the full-body groups, replicating the findings from Experiment 3. For hip-knee coordination, an interaction indicated that in early practice the full-body group was more accurate at replicating hip-knee coordination than the end-point group. With more exposures to the end-point model the observers' hip-knee coordination became more accurate and no different to the full-body model group by the end of practice. These data further question the proposition that relative motion is the essential information within a demonstration for acquiring the topological characteristics of a whole body motor skill (cf. Scully & Newell, 1985; Scully & Carnegie, 1998).

From the two actions examined in Experiment 2 and 3 (soccer kicking action and a crown-green bowling action, respectively) these data offer a number of important insights into the nature of information used, and why it is used, during observational learning. First, if the action is constrained by a spatial end-point location, such as a the <u>hand</u> in a throwing action or the <u>foot</u> in kicking action, the present data indicates that end-point information seems to be sufficient or even beneficial for acquiring the associated intra-limb coordination. A reason why end-point information is sufficient to constrain an action is because the end-point carries the most important information about the task such that observers' derive the specifications of the to-be-imitated movement by tracking the trajectory of its end-point (Latash, 1996; Mataric & Pomplun, 1998). Mataric and Pomplun (1998) postulated that observers use end-point information in order to form an end-point trajectory plan that controls the movement (see also Morasso, 1981). Second, the current data provide a rationale for questioning those who have concluded that relative motion information was extracted and used during observation learning (e.g., Al-Abood et al., 2001; Williams, 1989). Al-Abood et al. (2001) concluded that because a modelling group was significantly different to a control group and showed a similar relative motion pattern to the model, that the modelling group used relative motion to imitate the throwing action. In contrast, the observers relative motion pattern might have been influenced by the constraints of throwing task and /or they extracted and used end-point information as opposed to the relative motion information as evidenced in the present experiments (see also Williams, 1989, dart-throwing action; Horn et al., in press, kicking).

The data from Experiment 3, serve to extend these conclusions beyond spatially constrained tasks. In Experiment 3, participants were required to perform a whole-body bowling action. Although the arm component is coordinated to a final end-point location the right lower-limb remains stationary (i.e., the end-point remains stationary and a central joint is extended or flexed). Even though the right foot remains stationary and therefore no end-point trajectory information is provided, which is deemed to be to be most important information for identifying an action, the impoverished end-point model still served to constrain an otherwise invisible whole body action. Observers did, however, require additional observations of the end-point model to acquire a similar hip-knee coordination pattern as those who observed a full-body model. A possible mechanism that underpins successful reproduction from impoverished stimuli is that a human observer is sophisticated enough to use a combination of information sources available to perceive a full-body action (Pinto & Shiffrar, 1999). For example, end-point observers reported that they extracted inter-limb (left and right toe) motion to establish that the model stepped forward and specifically they located how far the wrist marker swung relative to the ground as a reference for imitating right knee flexion that was otherwise not available. These data support the suggestion that in some actions relative motion information might be more efficient, but not necessary, in constraining intra-limb coordination. Although these data from Experiments 2 and 3 indicate that end-point information constrains movements to attain a spatial end-point location, it is likely that as the complexity of the movement increases observers may need more relative motion information to facilitate perception and action through imitation processes.

The nature of information used to attain a successful outcome

Within Experiments 3 and 4 relative motion was manipulated to examine its role in facilitating coordination and control during motor skill acquisition. In addition to encouraging coordination, it was important to examine how demonstrations impact on task goal attainment. There was no difference between the end-point and full-body groups target accuracy performance across practice. In retention, participants who observed a full-body relative motion model showed increased variability in outcome attainment in comparison to the end-point groups. A plausible explanation for this finding is that the partial information conditions in practice may have reduced any potentially negative guidance effects which manifest when augmented information is high in practice but reduced or removed in retention (Salmoni, Schmidt, & Walter, 1984; Schmidt, 1991). Although the end-point participants were more consistent in retention there was no difference between the two groups in terms of outcome accuracy. The end-point performers became significantly more accurate at attaining the distance related goal in the re-acquisition phase after receiving a full-body relative motion model compared to the full-body observers who continued to observe a full-body model.

Despite improvements in outcome success following introduction of relative motion information, neither of the groups that bowled a ball actually refined their shoulder-elbow coordination topology (i.e., the movement topology did not become more accurate) after receiving more exposures to the model (see also Experiment 2). It is therefore possible that outcome accuracy was achieved through more refined scaling of the action, following observation, rather than the acquisition of coordination (see Newell, 1985). It seemed that by observing an end-point model in early practice, followed by viewing a full-body model later in practice, actually facilitated the observers' attunement to a scaling or control related kinematic information. These data contrast Scully and Newell (1985) and Newell's (1985) proposals that demonstrations are most effective during the early stages of skill acquisition and not for subsequent scaling or refinement. Moreover, as Blandin, Lhuisset, and Proteau (1999) showed, absolute timing (i.e., the timing of one segment) in a barrier knock down task was learnt before the relative timing (i.e., the proportion of time between segments). Based on the current data, perhaps absolute features of the movement are acquired early in practice such that relative motion information then plays a significant role later in practice, informing the learner as to the more complex and subtle features of the movement.

Using demonstrations to scale a motor skill

The aim in Experiment 4 was to examine the nature of information extracted from a model to scale a motor skill. More specifically, the provision of demonstration was manipulated later in practice to examine whether information from a model could be used rescale (i.e., execute the same movement topology but to attain a different outcome distance) an already practised motor action. There was evidence that participants who viewed a model late in practice (irrespective of previous practice conditions) replicated control-related features of the movement that incurred advantages in target accuracy (i.e., CE & VE). Kinematic examination of the arm-swing control properties revealed that the two demonstration groups controlled the magnitude of shoulder and wrist velocity similar to the model's kinematic profile than the two control groups. There were no differences in shoulder–elbow coordination between the two groups who had observed a model and a control group who did not (much like the end-point and full-body groups from Experiment 3). The general relative motion pattern was not the primary contributor to outcome success (Horn & Williams, 2004). These data indicate that observers extract and use velocity information to scale motor actions, perhaps the learners from Experiment 3 extracted wrist and shoulder velocity features from the full-body model in the re-acquisition phase to control the bowling action.

Practical implications and Considerations for Future Research

Practical implications

From the present findings a number of possible recommendations can be made for practitioners and teachers who have generally been suggested to use demonstrations as a 'first port of call' during the skill acquisition process (i.e., "watch, listen and learn" see Hodges & Franks, 2004). What should be clear from the preceding experimental discussions is that the efficacy of a movement demonstration is affected by the nature of the task, environment and whether or not the observer understands the movement demonstration and task goal. When the task requires the learner to acquire a new movement shape by imitating a model and also attain an outcome goal the resulting movement pattern is a consequence of both the model's stimuli and surrounding task constraints (i.e., apparatus, external target or knowledge of results). It is therefore important for the learner and instructor to be clear on the task goal and that the instructor prioritises the task demands (e.g., movement technique versus outcome performance). For example, if the instructor is primarily interested in the learner acquiring an optimal movement form (e.g., soccer chipping action) but is also concerned about keeping ecological validity (e.g., kicking the ball) then removing vision of the ball flight and promoting attention to the model's movement form may be an optimal strategy in the early stages of motor learning (see Horn et al., in press). Once a relatively consistent pattern of coordination is acquired through this technique the instructor can then allow vision of ball trajectory and knowledge of the ball's landing position in order to facilitate the refinement of the movement and outcome accuracy based on feedback information.

In situations where the learner is primarily concerned with outcome attainment (i.e., soccer kicking task to an external target), but goal attainment is driven by a particular movement technique, perhaps providing novel pre-practice instructional strategies might be more effective for facilitating skill acquisition. In self-paced motor skills such as golf chipping, basketball free throw shots or a soccer lofted pass a learner is tasked with propelling a ball to an external target by creating an optimal ball trajectory. Instead of providing a typical form of demonstration (i.e., a model) it could be more beneficial to show only the ball's trajectory and allow the learner to discover how their action influences the effects of the ball as opposed to how the external effects are associated with the model's actions (see Hodges & Franks, 2004; Wulf & Prinz, 2001). This type of strategy may be particularly important with young children as they seem to show a spontaneous tendency to adopt an external outcome based strategy (therefore downplaying the importance of the movement demonstration) at the expense of copying a model's movement (see Bekkering et al., 2000; Chapter 2).

For movement skills that require the observer (especially young children) to imitate a complex multi-limb action a demonstration may need to be accompanied with some form of additional instruction that relates to the task or stimulus being observed. When the movement is complex or novel it has been shown that young children have problems understanding the to-be-observed movement based on a less developed perceptual-motor repertoire and as such the processing of movement information can be debilitated (see Cadopi et al., 1995; Chapter 2). Therefore, it is important that an instructor understands the most effective way to convey movement information across population samples. For example, additional perceptual training could be provided to young children before they engage in learning new skills from novel demonstration techniques such as point-light demonstrations. In addition to providing verbal training or perceptual training, instructors could also facilitate the perception of key sources of kinematic information by providing cues that direct the observer to key information such as velocity scaling information centred around the primary effector (see Chapter 5).

Considerations for future research

The experiments conducted within this thesis provide some evidence as to the to the nature of the information picked-up from a demonstration to facilitate motor skill acquisition. As with the majority of research there are still questions to be answered. For example, it would be interesting to examine how end-point and relative motion models interact with closed-skills that are complex in nature (multiple-limb gymnastic technique), the surrounding task constraints and the stage of practice.

Data from Experiment 3 and 4 provide evidence that the nature of demonstration can facilitate the processes of coordination and control associated with skill acquisition. In Experiment 3, it was found that when end-point models are presented in early practice and then later in practice a full-body model is introduced, participants show improvement in replicating control related features of the model's action (see Figure 6.2. for a schematic outlining demonstration, practice and task constraints). This is in comparison to participants who remain viewing a full-body model late in practice. In tasks that are goal-directed, it seems that velocity information relating to the primary effector appears to be important for attaining a distance-related goal. It would be useful to examine how this information can be highlighted within demonstrations to facilitate attention to this control/scaling information. Perhaps through instruction learners could be educated to perceive specific cues or key sources of kinematic (e.g., velocity) information (see Jacobs, et al., 2001).

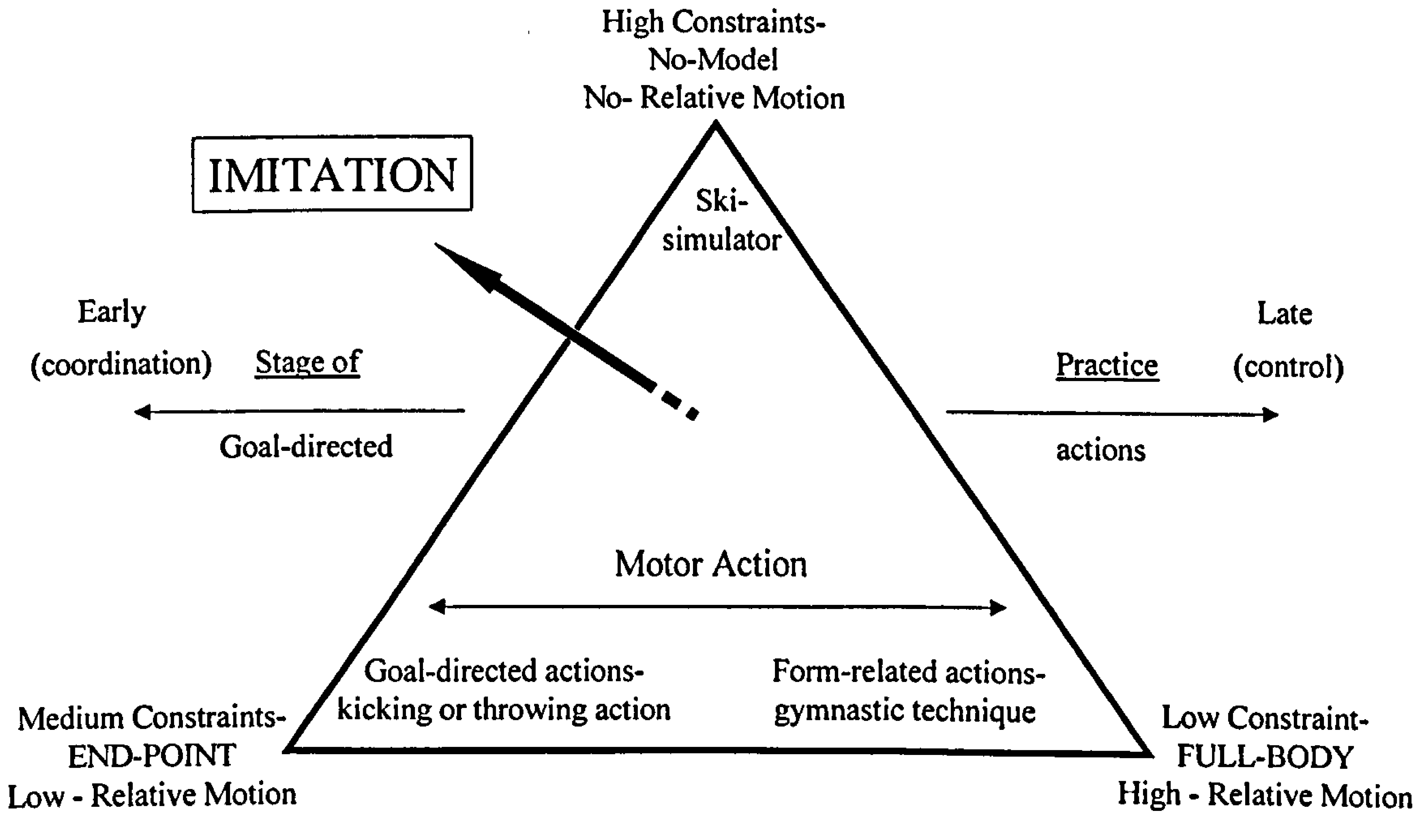
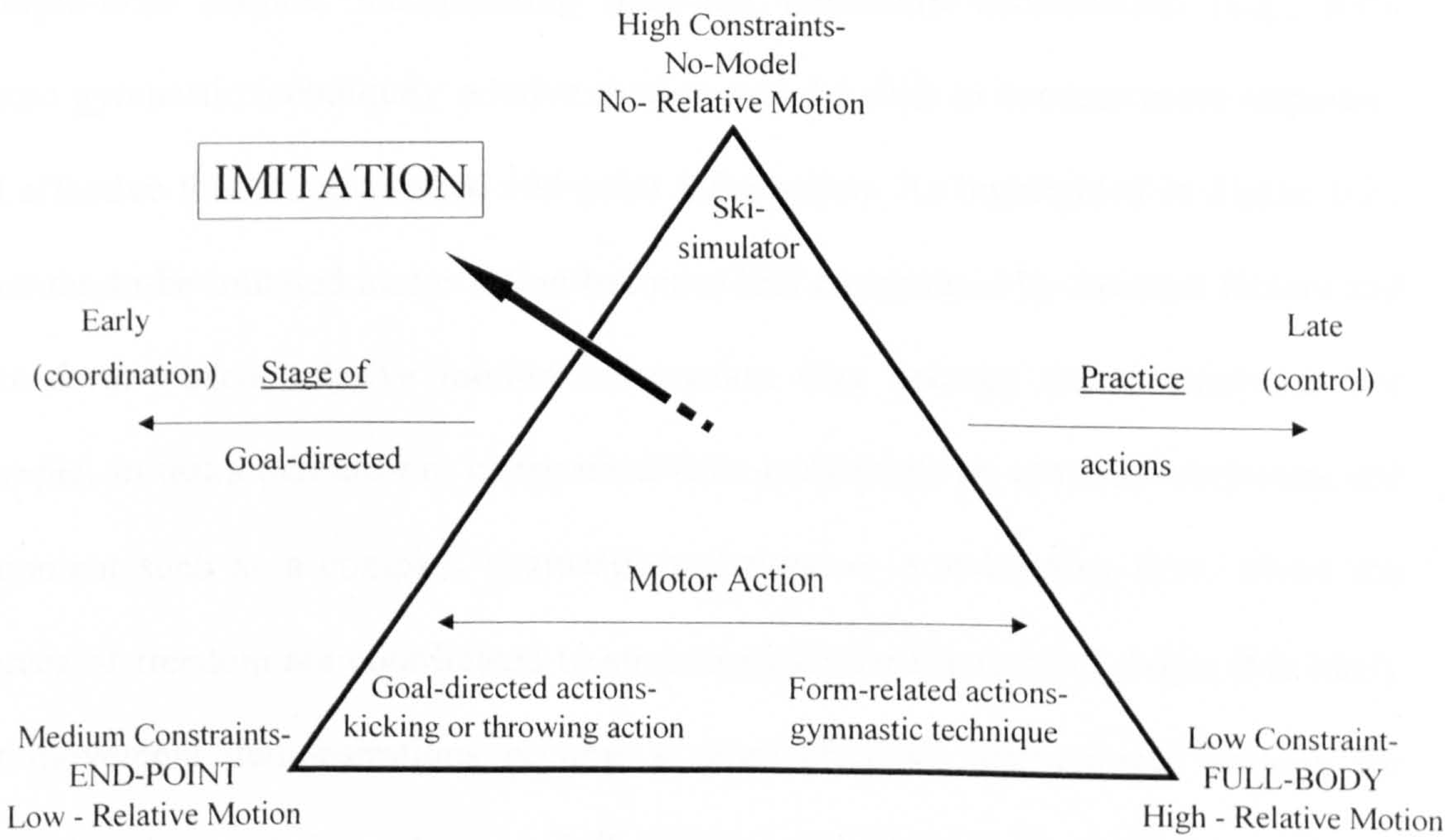


Figure 6.2. A schematic model displaying the proposed implementation of demonstration, based on task constraints and the stage of practice

The present findings provide evidence against the claim that relative motion is the essential constraining source of information during observational learning (cf. Scully & Newell, 1985). Further work across a range of motor actions is needed to examine what is the essential constraining information for skill acquisition. Arguably, relative motion information becomes progressively more important when the complexity of the task increases or the performers skill level is less developed. For example, it is has been shown that as people become more skilled they develop a better model late in practice. In tasks that are goal-directed, it seems that velocity information relating to the primary effector appears to be important for attaining a distance-related goal. It would be useful to examine how this information can be highlighted within demonstrations to facilitate attention to this control/scaling information. Perhaps through instruction learners could be educated to perceive specific cues or key sources of kinematic (e.g., velocity) information (see Jacobs, et al., 2001).



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The present findings provide evidence against the claim that relative motion is the essential constraining source of information during observational learning (cf. Scully & Newell, 1985). Further work across a range of motor actions is needed to examine what is the essential constraining information for skill acquisition. Arguably, relative motion information becomes progressively more important when the complexity of the task increases or the performers skill level is less developed. For example, it is has been shown that as people become more skilled they develop a better understanding of their own body (Kourtzi & Shiffrar, 1999), the movement context, and the inherent constraints within the body (i.e., the sometimes constrained relations of one joint in comparison to another). Skilled observers, therefore, are more likely to perceive and reproduce actions based on limited amounts (end-point information) of information (see also Pinto & Shiffrar, 1999). For less skilled people, that are challenged with learning skills that require them to harness information across multiple-limb actions, incorporating inter-and intra-limb coordination (e.g., form related gymnastic technique), relative motion may be shift to become more important and effective than impoverished end-point information. As highlighted in Figure 6.2., when the to-be-imitated motor action becomes less constrained by external factors and more form-related, relative motion information may become more important. For example, in tasks that are not constrained (low constraint) by external environmental equipment such as a complex gymnastic technique or a swimming dive, where the degrees-of-freedom are coordinated to attain a particular topological shape, it is likely that movement demonstrations become a more effective instructional strategy for facilitating the acquisition of motor skill. Whereas in highly constrained tasks such as a ski simulator movement (see the top point of the triangle, Figure 6.2) a demonstration may actually become somewhat redundant because the learner can solve the motor problem by the guiding affects of the external apparatus (i.e., there is only one direction that the apparatus can move in). In fact, it has been shown in a number of imitation studies that discovery learners (who do not observe a model) become as consistent and fluent, in terms movement amplitude and movement topology, as a group of observers who observed a skilled model (see Schoenfelder-Zohdi, 1992; Whiting & den Brinker, 1982). Therefore, it is important that instructors are aware of the different situations when demonstrations are most effective – for example, Figure

6.2 highlights that when the task requires a person to learn a new movement shape, that is not additionally constrained to attain an outcome goal (low constraint), demonstrations are postulated to be most important.

The present data indicate that end-point information is <u>important</u> and <u>sufficient</u> for constraining intra-limb coordination when actions require a limb to be coordinated to attain a spatial end-point location (e.g, hand in a throwing action compared to a limb that remains stationary like the standing foot in a plie). If the most important information is available at the end-point or distal musculature then systematic removal of a model's kinematic joint markers (information is removed in a distal-proximal direction) will help answer this question. It would be hypothesised that occlusion of the wrist marker from an action that is governed to attain a spatial end-point location would remove the critical trajectory information required to effectively imitate the observed action.

Although the present data indicates that end-point information is sufficient for constraining both less constrained motor actions and more complex full body movements more research is required to understand when across the motor skill continuum relative motion is more beneficial. It is quite possible that when learners are tasked with acquiring a novel complex action that requires inter-limb coordination (for example a cricket bowling action) relative motion information that describes the whole movement may be more informative than end-point information. Only through a systematic program of research that is designed to examine a multitude of motor skills will an extensive knowledge of what information is essential for acquiring a motor skill be attained.

To further examine the question of what information is used in the process of observational learning, experimental paradigms that incorporate event occlusion and the recording of eye movements should be used in conjunction with the systematic quantification of movement coordination. For example, an extension of the occlusion work carried out across Chapters 3 and 4 could be based on reversing the process of movement occlusion by removing end-point information in order to verify the informative nature of end-point information and to determine what amount of information is necessary for skill acquisition. Moreover, the use of eye tracking systems would provide an additional measure for quantifying the nature of information extracted from a demonstration to facilitate movement coordination and control as the locations of visual search pathways would monitor the areas of importance. This type of technique may also be very fruitful in cases where certain populations have perceptual impairments due to attentional problems such as children with A.D.H.D. (attentional deficit hyperactivity disorder). By examining various populations more effective and efficient instructional strategies can be designed to facilitate skill acquisition and potentially rehabilitate people who have lost movement coordination (such as stroke patients).

Chapter 7

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