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Visual Attention and Information in Observational Learning

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Thesis Abstract

Four experiments were conducted to examine the role of demonstration, and the nature of information used to facilitate changes in coordination and movement outcomes. The studies examined ecological theories of perception (Runeson & Frykolm, 1981), demonstration (Scully & Newell, 1985), and practice (Handford et al., 1997; Newell, 1985). To do this, kinematic analyses were performed and a new method was designed to quantify the data (NoRM-D; Horn et al., in press). Experiments 1 and 2 also assessed visual search during the observation of a demonstration of a soccer chip. The combined results indicated that visual search, coordination changes, and movement outcomes, were dependent on the availability of intrinsic visual knowledge of results (KR). With intrinsic KR present, participants learned to become more accurate, but changed coordination only at a global level of analysis. This was supported by a broad-to-narrow visual search strategy. However, when constrained to use the model in the absence of this information, rapid and enduring changes in intra-limb coordination were found at the expense of changes in movement outcomes. Experiment 3 examined the rate of change in intra-limb coordination in a novel throwing task. Participants observing the model immediately adapted their relative motion to resemble the model. This change was associated with improvements in the velocity of throws. Participants not observing the model made no changes in coordination or ball velocity during practice. The final study indicated that a model can also facilitate immediate changes in the parameterization of a movement pattern. Participants extracted velocity information at the moment of ball release to accurately perceive and replicate the unknown dynamics of a task. These studies extend our understanding of the mechanisms, rate, and extent of change that may be facilitated by demonstration.

Chapter 1

Observational Motor Learning: Is it Time we Took another Look?

With the exception of a small repertoire of phylogenetic behaviours, humans are born without motor skills. Instead they are acquired through practice, experience, and observation (Bandura, 1977). In essence, they are learned. Definitions of learning have evolved to reflect concomitant trends in behavioural psychology. To behaviourists, learning was the strengthening of stimulus-response bonds. For cognitive psychology, the definition changed to incorporate the comparison of overt action with an internal representation of the act, and the process of refinement in memory. Finally, more recent dynamic views see learning as changes in preferred, stable states of the movement system, known as *attractors*. Common to all theoretical perspectives is the view that learning is a relatively permanent change in behaviour. Learning also reflects the capacity to represent the cumulative effects of past experience on present behaviour, whilst providing an indication of likely future behaviour (Champion, 1969).

Although the process of learning is not yet fully understood, Blandin, Proteau, and Alain (1994) note that the information accessible to the learner before practice commences is vital. Thus, critical to facilitating the early stages of learning is the transfer of information from the instructor to the learner conveying how to act. The mode for delivering this information may take many different forms, but demonstration has intuitive appeal – it meets the twofold requirements of conveying an enduring impression of how to act with maximal efficiency.

Not surprisingly, demonstration is estimated to be the most commonly used mode of instruction in skill acquisition (Magill, 2001; Rink, 1998), a fact reflected in recent physical education texts. The most common teaching technique in physical education settings is *direct instruction* (Graham, Holt-Hale, & Parker, 2001) or *interactive teaching* (Rink, 1998) both of which consider that a demonstration is the first and arguably most significant stage of the skill acquisition process. However, the

influence of modelled behaviour is not restricted to physical education and sports skills. Instead, researchers report applications in far reaching domains such as nursing and surgery (e.g., Bahn, 2001), mechanical assembly (Sheffield, 1961), sign language for the deaf (Stewart, 1990), and ergonomically correct lifting techniques (Williams & Thompson, 1994).

Concepts of Imitation and Observational Learning

In theoretical terms, demonstration changes behaviour through processes such as observational learning, imitation, emulation, and echokinesis. In the psychology literature, imitation is the prevalent term for copying behaviours. According to Miller and Dollard (1941), there are two types of behaviour that fall under the process of imitation. The first is matched-dependent behaviour, in which the 'follower' is dependent on the 'leader' for action, as only the leader has access to relevant environmental information. The second is copying in which the copier must adapt his/her response to be more like the model. For motor skill acquisition, the second of these is more appropriate. Heyes (2001) defined imitation as the copying by an observer of a component feature of the body movement of a model. This definition implies a causal relationship between the observation of the component feature of the model's movement, and the execution of the feature by the observer.

In addition to copying the movements of the body, a learner can also reproduce the movement of an object. This has been labelled emulation (Tomasello et al., 1993; Heyes, 2001). Prinz (1987) presents a similar distinction between the imitation of perceived movements as spatio-temporal events, and actions, for which the intention is to attain the same goal states as the model, independent of the movement performed. For the copying of perceived movements, Prinz (1987) preferred the term echokinesis used

by Katz (1960) as a specific type of ideo-motor action in which movement is imitated. Because goals can be emulated independently of specific movement patterns, Byrne and Russon (1998) ascribe this the lowest level in their hierarchical account of imitation. For them, the next level of imitation is program level, in which an observer copies the structural organization (including sub-routines) of the action, but specific details are added on a trial-and-error basis. This process is assumed to account for the majority of imitation occurring on an everyday basis. In the highest, action level of imitation, a comprehensive, linear description of the act is acquired from the model.

What then is the difference, if any, between imitation and observational motor learning? Observational motor learning (also known as modelling) should arguably not be simply considered as imitation within the specific arena of motor behaviour. Williams, Davids, and Williams (1999) define observational learning as the process by which observers watch the behaviour of another, and adapt their own behaviour as a result of the interaction. Though imitation (or emulation) is clearly the core process, observational learning is more relevant for the study of skill acquisition because in measuring learning, it accounts for long-term changes in behaviour. Observational learning and imitation are also assessed in a different manner. Imitation is typically measured using frequency counts as a dichotomous measure of whether or not the desired behaviour is present (e.g., Bandura's Bobo Doll experiments: Bandura, Ross, & Ross, 1961). In contrast, observational learning is assessed using specific qualitative and quantitative measures of performance. Furthermore, in observational learning, changes in behaviour are directional. Learning occurs if performance has improved with reference to a pre-determined criterion goal.

Cognitive Accounts of Observational Learning

According to Bandura (1971), the earliest accounts of observational learning by Morgan (1896) and McDougall (1908) amongst others, described imitation as an innate propensity. As such, the empirical testing of observational learning was stifled. Following the denouncement of the instinct doctrine, imitation was described in connectionist terms. Miller and Dollard's (1941) Social Learning and Imitation theory applied behaviourism and reinforcement to the study of imitative behaviours. In their experiments, participants displayed matched-dependent behaviour. This describes the effect where the rewarding of a model's specific behaviour, coupled with the rewarding of the participant for repeating the behaviour, results in powerful imitation that can be generalised to other situations and models.

Behaviourist accounts were deemed inappropriate for observational learning due to their failure to recognise the influence of mediating factors that are internal to the organism. Moreover, behaviourism fails to explain how a new matching behaviour is acquired through observation in the first instance (Bandura, 1971). Finally, behaviourist accounts are not applicable to learning from observation where the observer does not overtly perform the model's actions in the environment in which they were demonstrated, where reinforcements are not administered, and when the acquired responses are not displayed until a later time when the model is not present (Bandura, 1971).

Sheffield (1961) first broke from traditional behaviourist accounts of stimulus-response reinforcement. His Systematic Representational Theory was developed to assess the effectiveness of filmed demonstrations in the learning of mechanical assembly tasks, and represents a vital step toward a testable theory of learning in complex human motor skills. It supposes that when observing a skill, the observer

formulates a cognitive-representation of the action through processes of association and contiguity. The cognitive representation subsequently acts as a blueprint to guide reproduction of the skill.

Bandura's (1986) Social Cognitive Theory

Although Sheffield's theory of cognitive symbolic representation preceded the work of Bandura, it is Bandura's Social Learning Theory (later revised to Social Cognitive Theory in 1986) that has been the foundation of the majority of research on observational learning. Bandura (1969, 1971, 1977, 1986a) incorporated Sheffield's idea of systematic representation, but expanded its scope to account for the acquisition and modification of behaviour and social skills (Williams, Davids, & Williams, 1999). Bandura concurred that behaviour is stored in representational form, with this representation being used to mediate the action response. However, unlike Sheffield, he considered that in many instances a learner observes a model without performing any concurrent response. The modelled response is acquired in representational, cognitive form before being acted out. Bandura (1965) designated this 'no-trial learning', and it echoes his rejection of behaviourist accounts of modelling through repeated reinforcement.

According to Bandura (1971), the sub-processes of attention, retention, (behaviour) production, and motivation govern the observational learning process. He also argued that a good theory of vicarious learning should explain why different observers show different levels of response acquisition when exposed to the identical stimuli. Figure 1.1 highlights the four sub-processes and internal mediators such as cognitive capabilities and past experience.

Bandura (1977) believed that attention represents the start of the modelling process, stating that we cannot learn unless we attend to and accurately perceive the

significant features in the display. Attention was considered a selective mechanism that determines which information will constitute the cognitive representation of the skill. The basis of this selection of information was considered to be both externally and internally determined, based on various features of the demonstration (e.g., speed, distinctiveness) and the observer (e.g., level of arousal). Also relevant is the extent to which the learner can associate the observed behaviour with previous experiences, and the functional value of the display. Bandura (1977) hypothesised that observers pay closer attention to models that possess symbols reflecting status, are older, and are highly skilled. This hypothesis has been the basis of the majority of observational learning research.

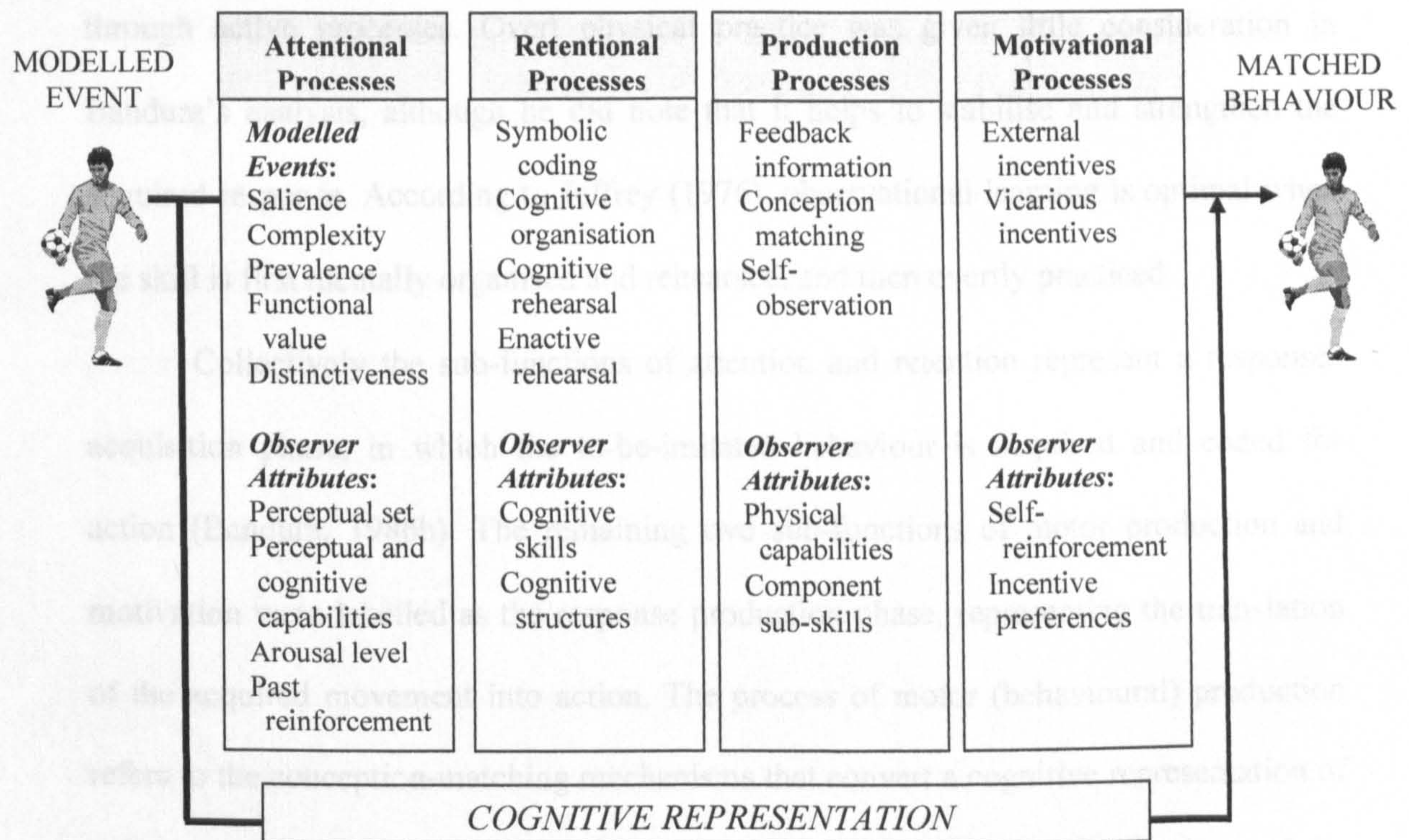


Figure 1.1. The sub-processes of observational learning according to Bandura's (1986) Social Cognitive Theory (adapted from Bandura, 1986).

The selective mechanisms of attention are redundant unless the observer can store the information in representational form. Bandura (1977) assumed two

representational systems achieve this within the sub-process of retention, namely, the imaginal and verbal systems. Similar to Sheffield's (1961) concept of a perceptual blueprint, sequences of corresponding sensory experiences become associated or integrated in the imaginal system (Bower & Hilgard, 1981), resulting in the formation of enduring and retrievable representations. The cognitive processes that regulate behaviour are assumed to be verbal and are thus the domain of the verbal system. The process of verbal coding allows chunking of information in a format that facilitates memory.

Rehearsal is an additional factor in retention processes. Bandura (1971) argued that covert, mental rehearsal facilitates learning not through simple repetition, but through active processes. Overt physical practice was given little consideration in Bandura's analysis, although he did note that it helps to stabilise and strengthen the acquired response. According to Jeffrey (1976), observational learning is optimal when the skill is first mentally organised and rehearsed, and then overtly practiced.

Collectively the sub-functions of attention and retention represent a response-acquisition phase, in which the to-be-imitated behaviour is acquired and coded for action (Bandura, 1986b). The remaining two sub-functions of motor production and motivation were labelled as the response production phase, representing the translation of the acquired movement into action. The process of motor (behavioural) production refers to the conception-matching mechanisms that convert a cognitive representation of behaviour into approximate overt performance, and guide later reproductions of the skill. A feedback mechanism is employed to determine discrepancies between the symbolic representation and physical enactment of the skill, which in turn provides cues for corrective action (Bandura, 1977). Bandura (1971) indicated that the physical capabilities of the learner are a limiting factor in this sub-process. An observer may

acquire a representation of the skill, but might not possess the physical attributes to replicate the task. Typically, researchers do not assess whether participants possess the necessary physical attributes, and assume that deficiencies in performance reflect problems in perception rather than action.

The final sub-process involved in observational learning is motivation. According to Bandura (1971), incentives act to regulate the overt expression of the matching behaviour, exert a selective control over the cues in the demonstration to which the observer attends, and aid selective retention by activating the deliberate coding and rehearsal of the response.

A review of research underpinned by social cognitive theory

The research work relating to Social Cognitive Theory includes manipulations of model type and tests of cognitive involvement in observational learning.

Model characteristics. The majority of observational learning research has manipulated the type of model presented to the participant. Particularly prevalent are tests of Bandura's (1977) prediction that observers pay closer attention to models that have a higher status, are more skilled and of the same gender as themselves.

Status. The impact of social status on imitative actions was illustrated in an early study by Lefkowitz, Blake, and Mouton (1955). A jaywalking model 'planted' on a busy street corner was followed by significantly more people when dressed in business attire than when dressed in soiled clothes. In a motor learning context, McCullagh (1986) found that participants performed significantly better on the Bachman Ladder task in response to a high compared with a low status model. The Bachman Ladder task involves a six-foot wooden ladder with three uprights. The number of rungs climbed by the learner before the ladder falls to the ground is taken as a measure of performance.

Skill level. In Bandura's analysis, the cognitive representation formed should correspond to a perfect performance of the skill. As such, a highly skilled model is recommended (this tenet currently underlies the direct instruction method of teaching; Kovar, Combs, Campbell, Napper-Owen & Worell, 2004; in press). In early tests of this prediction, Landers and Landers (1973) used the Bachman Ladder with 5th and 6th grade children. The model manipulations were skill level (skilled/unskilled) and status (teacher/peer). Participants who observed the skilled teacher climbed the most rungs on the ladder. However, a main effect for skill level was not observed. Participants who viewed the unskilled peer model recorded higher scores than the skilled peer model. Lirgg and Feltz (1991) replicated this study with 6th grade children, combining model skill level and status with videotaped rather than live models. Participants performed better after observing a skilled model. No model type by skill level interaction was reported. These findings lead to the suggestion that peer models are less effective than higher status models.

Several authors have questioned whether expert models are more effective than learning models (e.g., see McCullagh & Caird, 1990; Pollock & Lee, 1992). They note that information processing based theories such as Adams' (1971) closed loop theory and Schmidt's (1975) schema theory, view motor learning as a problem-solving process. In this process, feedback is received, and action is adjusted on a trial-and error basis. As such, the provision of an expert model may be at odds with the problem-solving process, as no error information is provided (Pollock & Lee, 1992).

Gender. Studies involving non-motor specific tasks suggest that elementary aged schoolboys learn more about the behaviour of a same sex model than an opposite sex model (e.g., Grusec & Brinker, 1972). Similar results have been found in the motor domain for ball-snatch tasks (Feltz & Landers, 1977; Gould, 1978). These results were

explained in terms of motivation to emulate the model (Gould & Roberts, 1982). Gould and Weiss (1981) used a leg extension endurance test to investigate the effects of model-observer similarity in athletic ability and gender. Women observing a non-athletic, female (similar) model performed better than those watching an athletic, male (dissimilar) model. In an attempt to separate these factors, George, Feltz, and Chase (1992) found that similarity in athletic ability, and not model gender was responsible for the effects. However, Griffin and Meaney (2000) found that gender did influence learning in a scarf-juggling task. While no differences occurred in retention or transfer of the skill, female participants learned significantly more strategies as a result of viewing same sex rather than opposite sex models. Also, the authors replicated the finding that participants learned more strategies from a learning rather than a skilled model.

Research evidence for cognitive involvement in observational learning

Repetition. There is evidence supporting the role of cognitive representations in observational learning, based upon the tenet that clearer or stronger cognitive representations will yield greater learning. In the last of a series of experiments using semaphore-like arm-paddle movements, Carroll and Bandura (1990) compared the effects of viewing two or eight demonstrations, with and without verbal coding of the pattern. Cognitive representation was assessed using a recognition test to detect correct photographs of the movement, and by pictorial arrangement tests to assess memory of the appropriate movement sequence. Eight presentations yielded a more accurate cognitive representation of the action than did two. Reproductions of the movement were also significantly more accurate with the higher number of demonstrations. Moreover, learning was facilitated by verbal coding only when the higher number of

demonstrations was provided, suggesting that a clear cognitive blueprint of the act is required before cognitive processes aiding retention can be effective.

Several researchers have indicated the benefit of multiple demonstrations with adult participants using the Bachman Ladder task, perceptual modeling with the Bassin anticipation timer and a wiffle-golf task (Feltz, 1982; Sidaway & Hand, 1993; Weeks, 1992; Weeks & Choi, 1992). Similar results have been reported with children using a sequential movement task and a softball pitch (Weiss & Klint, 1987; Weise-Bjornstal & Weiss, 1992). However, the relationship between performance and number of demonstrations is not monotonic. For example, Weeks and Choi (1992) found ten pre-practice demonstrations facilitated acquisition performance, while one or five demonstrations did not provide sufficient time or exposure for the formation of a usable cognitive representation.

Cognitive strategies. Researchers who have examined the effects on performance of cognitive strategies such as coding and imagery have also provided support for the cognitive nature of observational learning. Gerst (1971) found that imaginal coding, in which the learners imagine themselves performing the task, facilitated the acquisition of sign language. Similarly, Jeffrey (1976) found imaginal coding to aid learning of complex 3-D construction tasks. Assigning symbolic codes to movements (in the form of numbers or letters), and symbolic rehearsal have also resulted in significantly greater immediate and delayed retention of performance (e.g., Bandura & Jeffrey, 1973; Carroll & Bandura, 1990).

Concurrent monitoring. According to Social Cognitive Theory, concurrent monitoring of performance and augmented feedback are presumed to improve reproduction via conception-matching processes. In support of this proposal, Carroll and Bandura (1985) found that concurrent monitoring of a movement skill facilitated

learning, while delayed monitoring (shown after 100 seconds) did not. This implies that the delay led to deterioration in the conception-matching process. McCullagh (1993) proposed that split-screen techniques could be employed to display the model's template movements simultaneously with the participant's own imitative attempts. However, assessment of this proposal has produced inconclusive results (see Laguna, 1996).

Variability of demonstration and cognitive load. The cognitive processes underlying observational learning have also been addressed with reference to concepts of practice variability and contextual interference. According to Lee and Magill's (1985) action plan reconstruction hypothesis, high variability in practice leads to greater learning because the variability necessitates the reconstruction of action plans from one trial to the next. In observational learning, Lee and White (1990) suggested that observing a model performing under highly variable conditions mimics this process, leading to greater cognitive involvement in the learner. Researchers have provided support for this proposal using a barrier knockdown task (Blandin, Proteau, & Alain, 1994) and a computer key sequencing task (Wright, Li, & Coady, 1997; Wright, Black, & Brueckner, 2001). In the studies by Wright and colleagues the contextual interference effect was replicated. Participants observing models performing under high variability showed better retention than those watching models performing under blocked practice.

Social Cognitive Theory: Limitations in Theory and Research

Social Cognitive Theory has undoubtedly advanced our understanding of the mechanisms involved in observational learning. Yet, there are some significant limitations with the theory and its supporting research. A fundamental concern has been that it is based on social rather than motoric learning (e.g., McCullagh et al., 1989; Williams, 1993). Horn, Williams, and Scott (2002) have argued that the mechanisms of

motoric and social learning are likely to be disparate. Social learning tends to prescribe to the aforementioned description of imitation, in that measurement tends to be dichotomous (present or not present), somewhat coarse, and non-directional. In contrast, motor learning involves a precise directional change in behaviour and in the qualitative mechanisms underpinning these changes.

Central to Social Cognitive Theory is the concept of a cognitive representation. Williams et al. (1999) have argued that this concept has never been fully elaborated, such that the nature and location of these representations are somewhat nebulous. There are also concerns with the use of recognition tests as a valid measure of the existence of cognitive representations. In presenting images of the act from which participants must choose the one that they observed, this pre-supposes that the cognitive representation is some form of reference of correctness, similar to that suggested by Adams (1971). A recognition test performed after experimental trials naturally invokes memory of the task. Thus, it is a test of the sub-component of retention. Bandura's notion of coding would suggest that the imaginal system accounts for matching between an internal representation and an external image. Yet, Bandura suggests that most coding occurs in verbal form. The conceptual links between the two systems have not been established.

While sequential tasks such as arm paddle movements lend themselves to memorial coding strategies, without which they perhaps could not be performed, an important question regards whether such coding can guide the performance of complex multi-limb coordinative actions. If cognitive representations of these skills are found to be poorly developed, it suggests that the cognitive representations of the skills in Carroll and Bandura's studies may not be a kinematic representation of the act that covertly guides the skill, but a simple symbolic code.

Few studies have used kinematic measures of learning in conjunction with inference of cognitive representations by recognition tests. One notable exception by Weise-Bjornstal and Weiss (1992) measured kinematic variables and applied a recognition test at the end of each trial block during acquisition. The results suggest that for children at least, the addition of verbal cues to a pre-existing visual model resulted in the greatest increase in the recognition of correct form. No clear relationship between recognition and form scores was reported.

Research related to Social Cognitive Theory has typically measured learning by outcome rather than process measures of performance, and this may have contributed to some equivocal findings in observational learning. Clearly, the addition of process measures increases measurement sensitivity. Moreover, if performance is measured by outcomes without reference to the movement pattern employed, then the model can become a redundant source of information. The learner may engage in emulative processes, or engage an existing movement pattern to maximize outcome performance under the guidance of intrinsic or extrinsically derived knowledge of results.

Byrne and Russon (1998) describe novelty as a 'cardinal requirement of imitation'. However, in observational learning, several studies have ensured task novelty at the expense of ecological validity. Most of the tasks employed have been somewhat manufactured and simplistic. Such tasks include ball-rolling (Martens, Burwitz, & Zuckerman, 1976), ladder climbing (e.g., Landers & Landers, 1973), knocking down barriers (e.g., Blandin & Proteau, 2000), horizontal positioning (e.g., Bird & Rickli, 1983), coincident anticipation (e.g., Weeks, 1992), and computer based tracking (Pollock & Lee, 1992) and sequencing (Wright et al., 1997). It is also worth noting that when teaching sports skills to beginners, such skills are rarely 'novel' since

it is likely that learners will already have had some exposure to the skill, mainly through the vicarious learning opportunities provided by watching others participating.

The social cognitive approach to observational learning emerged while information processing theory prevailed in motor behaviour. However, theoretical shifts toward ecological theories of perception and action have occurred in recent years. To complement these developments, it has been argued that research should examine complex motor skills in settings mimicking their ecology. Outcome scores are discouraged in favour of the analysis of changes in coordination in an interdisciplinary manner (e.g., Christina, 1987; Williams et al., 1999).

Shaw and McIntyre (1974) stated that psychology presents three analytical concepts of *how*, *what* and *who*. With this in mind, Scully and Newell (1985) provided the most significant criticism of cognitive accounts of imitation. They argued that Bandura's theory merely focuses on *how* the process of observational learning occurs, and does not address the question of *what* information is perceived and used in the process. For example, even in Bandura's sub-process of attention, where the nature of information ought to be significant, concepts such as functional value, salience and distinctiveness simply relate to *how much* attention is allotted. Interest in the nature of information taken from the model was the driving force behind Scully and Newell's ecological view of modelling, known as the *visual perception perspective*.

An Ecological Alternative to Cognitive Accounts: the Visual Perception Perspective

Direct perception and 'what' information

Scully and Newell's belief that a theory should focus upon what information is used rather than how the process works is a concept attributable to James Gibson's theory of direct perception (1950, 1979). Gibson rejected Helmholtz's notion that since the retina

of the eye yields two-dimensional information of a three-dimensional world, information processing (epistemic mediation) is required to translate and make sense of incoming information. Gibson believed that the visual system has the ability to directly 'pick up' information in the visual field, via the structure of light in the 'optic array'. Features such as texture, relative position, and affordances (i.e., what the environment offers the perceiver in action-relevant terms; Williams et al., 1999) are directly and unambiguously specified without recourse to information processing. Moreover, Gibson's notion of mutual interdependency (meaning that information perceived is functionally specific for the action that follows) promotes the concept of perception-action coupling.

Scully and Newell also drew upon Gibson's view that motion is essential to seeing. When we observe movement, three perceivable types of motion are available. 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. Considerable evidence from studies involving biological and non-biological motion points towards our preference for relative motion information.

Biological motion perception

To study the perception of human motion, Johansson (1971) revived Marey's (1895/1972) point-light technique. This procedure removes structural information, presenting only moving dots (point-lights) or strips (patch-lights) of light. Using this technique, Johansson (1971, 73, 75) found that events that were not discernable when the points of light were static were immediately salient when motion was introduced. When viewing point-light displays humans can identify gender (e.g., Barclay, Cutting,

& Kozlowski, 1978; Mather & Murdoch, 1994; Stevenage, Nixon, & Vince, 1999), friends (Cutting & Kozlowski, 1977), different animal species (Mather & West, 1993), and American sign language (Poizner, Bellugi, & Lutesdriscoll, 1981). Intention and emotion may also be perceived from point-light displays. Bassili (1978) showed that patches of reflective tape placed on the face facilitated the recognition of expressions of emotion. Participants can also recognize emotion portrayed in dance (Brownlow, Dixon, Egbert, & Radcliffe, 1997; Dittrich, Troscianko, Lea, & Morgan, 1996), aesthetic quality from gymnastics (Scully, 1986), affordances for actions (estimated optimal and maximal seat heights; Stoffregen, Gorday, Sheng, & Flynn, 1999), and the perception of underlying dynamics (e.g., Runeson & Frykolm, 1981, 83).

In Scully and Newell's (1985) analysis, relative motion has a fundamental role in observational learning. When an observer watches a demonstration, they are assumed to perceive and minimize the relative motion of the event. In subsequent attempts to re-enact the observed movement pattern, the relative motion is believed to constrain the emergence of coordination via its informational and instructional properties (see Warren, 1990). Scully and Newell's (1985) perspective is best understood in conjunction with Newell's (1985) embedded hierarchy of coordination, control, and skill. Newell operationalized the concepts first presented by Kugler, Kelso, and Turvey (1980). Coordination represents the assembly of a novel movement topology. Control is the parameterization, or scaling of the movement pattern. Finally, skill represents the optimal, flexible scaling of the movement pattern. As an embedded hierarchy, learners do not progress serially through coordination and control stages. Instead, they operate synergistically such that coordination is the organization of control. However, in early learning of an observed movement pattern, the dominant function appears to be coordination. As such Scully and Newell (1985) estimate that the influence of a model's

relative motion pattern is greatest at this stage. When a learner approximates the model's relative motion pattern within 'certain bandwidths', this is considered to indicate that the action has been modelled (Scully & Newell, 1985). As learners progress, they are assumed to increasingly emphasize the scaling of the movement pattern. In this period of skill acquisition the exploration of the dynamics of the task is emphasized and demonstration is presumed to be less effective (Scully & Newell, 1985).

Research Pertaining to the Visual Perception Perspective

Research related to the visual perception perspective fits into four broad categories: comparison of learning by modelling and discovery methods, and via point-light and video models, evidence for coordinative rather than control-based functions in learning, and evidence for the role of motion. As a detailed overview of key research findings in the visual perception perspective are given in Chapters 2, 3, and 4, just a brief outline of research is given here.

Studies comparing kinematic measures of learning by modelling and discovery methods have typically indicated superior learning from a model (e.g., Whiting, Bijlard, and den Brinker, 1987). More specifically, in support of the visual perception perspective, Schoenfelder-Zhodi (1992) and Al-Abood, Davids, and Bennett (2001) found participants observing a model illustrated changes in relative motion to become more like the model than participants from discovery groups.

Studies comparing learning from video versus point-light models have examined the prediction that the absence of structural information in point-light facilitates the perception of motion because the removal of non-essential information leaves relative motion salient (Runeson, 1984). Pellechia and Garrett (1997) have presented some support for this notion in lumbar stabilization in physical therapy. In learning studies

though, a clear pattern of results has not emerged. Romack (1995) found a detrimental impact of a point-light model for children learning to dribble a basketball. A follow-up study also showed superior outcome scores from the video rather than PLD display (Romack & Briggs, 1998). Scully and Carnegie (1998) obtained more favourable results for learning of a ballet movement. Participants observing a point-light model demonstrated more accurate landing positions, and closer imitation of the model's angular displacement and relative timing than those observing a video model.

In accordance with the predictions of the visual perception perspective, Scully and Carnegie (1998) found evidence in support of the role of demonstration in conveying coordinative rather than control-based information. Participants observing a ballet sequence successfully approximated the model's landing position, angular displacement and relative timing. However, they were unable to replicate forces at take-off or landing. Further research is required to expand upon these findings.

Finally, there is evidence in support of the importance of motion in observational learning. Gray, Neisser, Shapiro, and Kouns (1991) reported significantly better reproduction of ballet sequences from point-light displays than from a series of still images. Furthermore, in instances when the original speed of demonstration is reduced, but relative timing is intact, the learning of complex multi-limb coordination has not typically been affected (e.g., Fehres & Olivier, 1986: gymnastic movements; Scully & Carnegie, 1998: ballet routine). In contrast, in tasks where the absolute speed of the movement is a critical feature, movement reproduction is impeded by changes in demonstration speed (e.g., Al-Abood, Davids, Bennett, Ashford, & Martinez, 2001; Williams, 1989b).

Toward a Program of Research: Aims of the Thesis

In the eighteen years since Scully and Newell presented an ecological account of observational learning, few researchers have tested its predictions. A credible reason for this is that it requires kinematic data for the direct comparison of model and learner movement patterns. While measures of movement can be quantified, the typical method has been to analyse movement qualitatively or, at best, using subjective measures of movement form such as rating scales (e.g., Cadopi, Chatillon & Baldy, 1995; Ille & Cadopi, 1995; Magill & Schoenfelder-Zhodi, 1996; McCullagh & Meyer, 1997). Although this type of analysis provides a gross estimation of changes in movement form, objective and quantitative assessment of movement kinematics is imperative to identify specific changes in timing and spatial orientation as a function of observation and practice.

Measuring coordination

In order to effectively compare kinematic data between groups, and between a model and observer, this program of research aims to quantify coordination. Several techniques are available to do this. *Cross-correlation*, for example, summarizes a coordination pattern in a single number and has been used to quantify coordination in observational learning (e.g., Al. Abood et al., 2001). However, this technique assumes a linear relationship between joints and was thus considered inappropriate for the kicking, throwing, and bowling movements used in this program. One solution to the linearity problem is to first apply the *chain-encoding methods* of Freeman (1961) and Whiting & Zernicke (1987). These techniques lay directionally structured grids over the movement patterns and convert ratio data to nominal data. However, in order to normalize unequal data lengths to the same number, different sized grid overlays would be required. This treats each trial differently, and varies the degree of error introduced. Also, regardless of techniques to transform the data, cross-correlation has been criticised for taking a

narrow view of coordination since it assumes that joints are co-ordered when they illustrate proportionality throughout their range of motion (Sidaway et al., 1995).

Many alternative techniques were also deemed inappropriate for the task and analyses used in this program. For example, *continuous relative phase* provides a tempo-spatial measure of coordination, but is not appropriate for discrete tasks. Conversely, *discrete relative phase* and *return maps* would be appropriate for the tasks, but measure coordination at only one point in a cycle.

The preferred solution was to use *normalized root mean squared error* (NoRMS; Sidaway et al., 1995). This was developed as a measure of consistency or variability in movement patterns over several cycles of a discrete task. Unlike cross-correlation, it does not require linear data. Data is first normalized to equal lengths. Then at each instant in the cycle, a resultant compares both joint angles to a mean trace. The resultants at each instant then contribute to a root mean squared error for each trial, which is then summed. The root mean squared error becomes normalised when divided by the *resultant excursion* (based on the range of motion at each joint) multiplied by the number of cycles in the analysis. By simple substitution of the mean trace with a criterion trace an index of proximity to a criterion (i.e., the model's movement pattern) is possible. The result is normalized root mean squared difference, and this technique is explained in more detail in Chapters 3 and 4.

Coordination changes

The role of relative motion. The primary aim of this thesis is to clarify the constraining role of the model's relative motion in observational learning. To do this the movement kinematics of both the model (video and point-light) and learner are measured and directly compared. Expanding upon previous research, coordination is examined at both a *local* intra-limb level, and a *global* participant-object level. To

further add to the extant literature, the role of the model is substantiated in Experiments 2 and 3 by the quantification of both movement variability and the proximity of coordination between the model and learner. To date only Al-Abood et al. (2001a, b) have done this. However, both of these studies are hindered by the lack of a pre-observation skill test. Without this, the immediate and long-term impact of the model may only be inferred. This thesis aims to redress this problem, outlining the immediate impact, longevity, and stability of relative motion changes in response to demonstration.

The role of relative motion is also assessed in the comparison of imitative performance from point-light and video models in Experiments 1, 2, and 4. If, as predicted by Runeson (1984), the removal of non-essential information leaves relative motion salient, we may anticipate superior imitation of coordination in response to point-light models.

Coordination changes with and without intrinsic visual KR. To further expound the effect of the model, this thesis aims to compare participant's coordination changes in learning environments when the model is the primary, constraining information source (Experiment 2) with those in environments in which participants also receive information from visual intrinsic knowledge of results (Experiments 1 & 3). Using these collective methods, this thesis aims to provide the most comprehensive assessment of coordination changes in observational learning to date.

Understanding 'what information'

The final aim of this thesis is to elucidate what information is picked up from demonstrations. Although this was the driving force behind the visual perception perspective, researchers have had only limited success. Two techniques appear to be especially appropriate to shed light on this question. These are event occlusion and analysis of visual search.

Visual search. Researchers have successfully used occlusion in studies of biological motion (e.g., Mather, Radford, & West, 1992) and observational learning (e.g., Scully & Carnegie, 1998). Despite this, it was decided that visual search analysis may offer greater ecological validity since it allows the whole visual display to remain intact. In addition, Experiments 1, and 2 compare learning from video and point-light models and it was considered difficult to maintain equivalent occlusion across these conditions.

The employment of eye movement analysis to determine what information is used in observational learning originates from the assumption that eye movements direct our attention to areas from which we extract information. Some credence for this argument comes from mounting evidence that eye movements are preceded by a shift in attention, and that this coupling between attention and eye movements is inevitable (see Hoffman, 1998 for a review). More specifically, the relationship between visual search and learning is inferred by a study of Williams (1989c). Participants who were asked to observe a demonstration with visual search patterns counter to their naturally occurring ones experienced more error in reproducing movements than matched controls.

At present the only known study to employ eye movement recording to determine areas of visual search interest in observational learning, examined finger and hand movements (Mataric & Pomplun, 1998). Such fine movements did not necessitate movement of the eyes to gather information. This thesis aims to examine the areas of information extraction for a gross, inter-limb task. In addition, it aims to examine whether visual search shows refinement from early pre-practice observation to later in acquisition.

Dynamic information for movement parameterization. Finally, to address ‘what’ information is picked up by the display, this program of research aims to examine

whether point-light and video models portray information for the control, or parameterization of movement. As well as testing predictions in the visual perception perspective, this directly examines Runeson and Frykholm's (1981) kinematic specification of dynamics (KSD) principle, which states that a movement's kinematics portray its underlying dynamics. Experiment 4 will extend previous research by examining whether participants can not only immediately *perceive* the dynamics of a modelled event, but if they can immediately replicate them. More specifically, by a systematic analysis, the thesis will examine whether the perception of relative motion contributes to the perception and replication of dynamics.

Chapter 2

**Learning from Demonstrations: The Role of Visual Search During
Observational Learning from Video and Point-light Models**

Abstract

This study examined the visual search strategies employed during observation of video and point-light display (PLD) models. Also, the relative effectiveness of video and PLD models in facilitating the learning of task outcomes and movement patterns was considered. Twenty-one female novice soccer players were divided equally into VIDEO, PLD and no-model (CONTROL) groups. Participants chipped a soccer ball onto a target area from which radial and variable error scores were taken. Kinematic data were also recorded using an opto-electrical system. Both a pre- and post-test were performed, interspersed with three periods of acquisition and observation of the model. A retention test was completed two days after the post-test. There was a significant main effect for test period for outcome accuracy and variability, but observation of a model did not facilitate outcome-based learning. Participants observing the models acquired a global movement pattern that was closer to that of the model than the controls, although they did not acquire the local relations in the movement pattern, evidenced by joint range of motion and angle-angle plots. There were no significant differences in learning between the PLD and VIDEO groups. The PLD group employed a more selective visual search pattern than the VIDEO group, while both groups became more selective with successive trials and observation periods. Results are discussed in the context of Newell's (1985) hierarchy of coordination and control and Scully and Newell's (1985) visual perception perspective.

A common assumption is that demonstrations are more favourable than verbalisation and trial-and-error methods for acquiring information during skill acquisition. Not surprisingly, therefore, there is widespread use of demonstrations during the instructional process in sport and other settings. Yet, a review of the research on observational learning shows equivocal support for the effectiveness of demonstrations. Furthermore, since the majority of previous research has manipulated model type (e.g., status, skill level), there is limited knowledge of the specific information perceived during the learning process. This paper aims to address this issue by assessing learners' visual search strategies during observation of a model.

Thus far, observational learning research has been underpinned by cognitive-mediational theories. Sheffield (1961) proposed that observation of a model allows the learner to form a (cognitive) blueprint of the action, against which later attempts to reproduce the movement are matched (for a review, see Williams et al., 1999). In extending Sheffield's initial ideas, it is Bandura's Social Learning Theory (1969, later revised to Social Cognitive Theory in 1986) that has exerted most influence on observational learning research. Bandura (1969) proposed that the four inter-related sub-processes of attention, retention, motor production and motivation combine to form a cognitive representation of the act. Like Sheffield's blueprint, the cognitive representation guides subsequent movement production. Research has predominantly investigated the sub-process of attention through somewhat obsessive manipulation of model type. Many of these studies have tested Bandura's (1977) prediction that observers pay closer attention to models that are older, more skilled, and possess symbols that reflect status. Research has inferred support for this prediction with regard to status (McCullagh, 1987), age (Brody and Stoneman, 1981), and skill level (see Landers and Landers, 1973; Lirgg and Feltz, 1991). However, several studies suggest

that since learning is problem-solving in nature, a model engaged in learning the task may be preferred to an already skilled model (McCullagh and Caird, 1990; Pollock and Lee, 1992; McCullagh and Meyer, 1997).

Although Social Learning Theory has been examined in a motor skills context (e.g., Carroll and Bandura, 1990), a fundamental criticism is that Bandura's theory was developed as an explanation of social rather than motoric learning (McCullagh et al., 1989; Williams et al., 1999). The mechanisms of social and motoric learning are likely to be very different. For example, social learning involves a gross form of imitation in which the measure is a dichotomous split between the behaviour being present or absent after exposure to the model. Motoric modelling is entirely more specific in nature, since both the precise outcome of the behaviour and the way in which the outcome is achieved are of interest.

Research stimulated by Social Learning Theory has also typically measured learning using outcome rather than process measures of performance. The loss of measurement sensitivity provided by the use of outcome measures may have contributed to the equivocal findings. If learning is measured by outcomes, independent of the movement pattern that the learner uses, then the model may become a redundant source of information. The learner is likely to ignore the model, engaging an existing movement pattern to maximise performance outcomes, guided by knowledge of results.

Several researchers have criticised observational learning research for using contrived, simplistic tasks (e.g., McCullagh et al., 1989; Williams, 1993) such as ball rolling (Martens et al, 1976), ladder climbing (Landers & Landers, 1973) and knocking down barriers (McCullagh & Caird, 1990). Though these studies have contributed to our knowledge of observational learning, the tasks appear akin to nonsense syllables in memory studies, in as much as they guarantee task novelty but offer limited ecological

validity. The tasks used in testing the effects of coding and cognitive strategies can also be questioned, in that they required discrete, serial movements, which could not be reproduced without storage in memory. The benefits of such strategies may be less apparent in complex, non-serial movements.

To better complement modern concepts of motor control and learning, several authors have called for research to examine complex motor skills in realistic settings. In this endeavour learning should not be assessed purely by outcomes, but by changes in coordination and form, in an integrated, interdisciplinary manner (Christina, 1987; Williams et al., 1999). Furthermore, in an applied motor learning context, emphasis should be upon the ability to actually reproduce movement patterns after a period of time, rather than the ability to recognise correct from incorrect form (cf. Carroll and Bandura, 1990).

Scully and Newell's (1985) ecologically based visual perception perspective was motivated by the aforementioned limitations in theory and research. This approach is concerned with what information or cues are picked up from the display, rather than how the process occurs. The notion that theory should focus on what is perceived rather than how it is perceived is attributed to Gibson's theory of Direct Perception (1950, 1979). Scully and Newell maintain that motion is an essential ingredient for perception. Static displays convey little information about a movement pattern to be learned, whereas the movement topology is revealed in motion. This issue is most clearly illustrated through the revival of Marey's (1895/1972) point-light display (PLD). These minimalist displays show only dots of light at the major joint centres and are useful in their omission of structural information. Johansson (1971) showed our ability to rapidly distinguish different forms of biological motion (e.g., walking, running, limping, cycling, dancing) in these displays. Other research has highlighted the capacity to

identify gender (Barclay et al., 1978, Mather and Murdoch, 1994), friends (Cutting and Kozlowski, 1977), different species of animals (Mather and West, 1993), American Sign Language (Poizner et al., 1981) and a single degree of freedom darts-style throw (Williams, 1989a). Moreover, participants have been shown to perceive somewhat less superficial characteristics such as aesthetic quality in gymnastics (Scully, 1986), the emotion portrayed in dance (Dittrich et al., 1996; Brownlow et al., 1997), dynamic properties such as the weight of lifted boxes (Runeson and Frykolm, 1981) and the distance of a thrown object (Runeson and Frykolm, 1983).

An explanation of our ability to perceive these events may be found in Johansson's non-biological motion studies. Johansson (1975) found that two lights following each other around a rectangular pathway were perceived as lights at the end of a rigid stick moving in 3-dimensions. Similarly, a square expanding and shrinking inside a fixed square was perceived as a constant sized square advancing and retreating in 3-dimensions. The perception formed is the simplest one which maintains a rigid connection between the stimuli. The general formula proposed by Johansson is one of spatial invariance plus motion. If a point of light is perceived as having an invariant, rigid connection to adjacent lights, then despite constant changes in their absolute motion, the display is recognised through their relative motion (the motion of individual elements in the configuration relative to each other). Although Gestalt psychologists explain perception in terms of brain organisation, it appears that the Gestalt principle of *pragnanz* in which perception moves toward simplicity and wholeness, applies to the perception of biological motion. Cutting and Profitt (1982) have proposed that a minimum principle operates simultaneously to minimise relative and common motion (motion common to all elements in a configuration), allowing us to perceive an apparently complex pattern. The visual perception perspective suggests that relative

motion is perceived and minimised, and later used to constrain reproduction of the action. Scully and Newell (1985) suggest that when the learner approximates the relative motion pattern within certain bandwidths, then the activity is considered to have been modelled.

If relative motion within a video or PLD is minimised and used to constrain action in observational learning, one would expect equivalent or superior learning from the minimalist PLD, in comparison to live or videotaped models. Newell and Walter (1981) and Runeson (1984) have argued that live and video models contain too much (structural) information, making them ineffective in isolating the important parameters of the movement. Few studies have tested this prediction. Williams (1989b) found a point light and a video model to be equally effective in learning a darts-style throw in terms of number of trials to achieve the correct sequence, angular displacement at the elbow and timing of elbow flexion. However, since all participants learned the task quickly, a single degree of freedom task may be too simple to differentiate between groups. Romack (1995) found preference for video rather than PLD modelling in the learning of a basketball dribble in 6-year old children. Results indicated that following acquisition periods over 6 consecutive days, participants observing the PLD performed fewer consecutive bounces of the ball per trial than those in the no-model and video-groups. Kinematic analysis was also performed on the model and on one participant per group over 7-8 cycles of ball bouncing. The results indicated that the model had a slight phasing difference between the ball and hand, whereby the hand slightly led the ball. All three participants showed the hand leading the ball by a much larger margin and those observing the PLD showed greater disparity with the model than the video and no-model groups.

In contrast, Scully and Carnegie (1998) found a PLD model of a ballet sequence induced superior landing accuracy over a video model (even though the PLD contained no reference point). Furthermore, observation of a PLD produced closer replication of angular displacement and relative timing than observation of a video model, even when the hip, knee, ankle or toes were occluded from the PLD. Further studies are required to investigate these discrepancies in findings. In addition, the visual perception perspective has inspired limited progress in both identifying what sources of information are used, and in establishing perception-action links in observational learning. Toward this end, studies may benefit from the measurement of visual search data during observation of the model, since as Gray et al. (1991) note, if qualitative aspects of a movement are to be imitated, it must be on the basis of optical information structures that specify the uniqueness of the movement.

Traditionally, in motor behaviour research, visual search has been used in the expert-novice paradigm. Significant differences have been found in search rate (e.g., Bard et al., 1980; Helsen and Pauwels, 1993), although Williams and Davids (1998) have recently found that search rate characteristics are task dependent. As a result of experience, experts also exhibit superior anticipatory performance, distinguishing redundant areas while sampling areas of pertinent future action (e.g., Helsen and Pauwels, 1993; Williams et al., 1994). In learning studies, where participants are novices, there is little experience on which participants can draw. As a result the selectivity shown by experts is unlikely to be present in early observations, with participants requiring a somewhat global interpretation of the movement. However, with repeated exposure and practice one would anticipate greater selectivity in search patterns as participants become attuned to the relative motion information and seek more specific information.

Only two known studies have assessed visual search during observational learning of gross motor skills. The first of these monitored and classified visual search strategies during the observation of a throwing action (Williams, 1989c). Participants classified as trackers and saccaders were asked to observe the model in the counter-preferred manner. In comparison to matched controls, these participants showed a significant increase in error. This appears to testify to the existence of powerful links between perception and subsequent action in observational learning. In the second study by de la Pena, Janelle, Hass and Ellis (2000), visual search was measured during observation of video, PLD and stick figure models of a basketball free-throw. Differences in search were found for the different conditions and the authors suggested that the PLD induced an optimal search pattern.

No single study has investigated the visual search induced by video and PLD models of a complex, motor skill in conjunction with the measurement of movement kinematics. The assessment of learning by kinematic analysis is vital if the predictions borne out of Scully and Newell's (1985) approach are to be examined. Several researchers have used subjective ratings of movement form (e.g., Cadopi et al., 1995; Ille and Cadopi, 1995; McCullagh and Meyer, 1997, Magill and Schoenfelder-Zhodi, 1999, Weeks and Anderson, 2000), yet objective assessment of the movement would provide a more valid understanding of the types of changes occurring as a function of observational learning. Although a few researchers have measured movement kinematics, the findings are limited by the absence of a retention test (Southard and Higgins, 1987; Weise-Bjornstal and Weiss, 1992), or by the omission of a comparison between the kinematics of the model and the participants (Southard and Higgins, 1987).

This aim of this study was to add to the literature by comparing the effectiveness of video and PLD models in producing correct patterns of coordination at several levels

of analysis. Coordination has been defined as relative movements between segments of the same limb (intra-limb coordination), of different limbs (inter-limb coordination) and between limb segments and an external object (Newell 1985; Turvey, 1990). The task chosen was a soccer chip, as it was considered to be less intrinsic in nature than the more typically analysed instep kick. This assumption was based on the longitudinal, developmental studies of Wickstrom (1975) and Bloomfield et al (1979), which describe the phases of development that occur in the natural emergence of mature kicking. These descriptions convey a pattern of movement which more closely approximates an instep kick, than a controlled chip (for a review of biomechanical analysis of the soccer kick, see Lees and Nolan, 1998; Davids et al., 2000). At a global level, coordination will be assessed in terms of the step approach to the ball. While at a local level, intra-limb coordination will be assessed using angle-angle plots, and relative phase timings of knee flexion and extension.

Based on Scully and Newell's (1985) position that relative motion is perceived, minimised and used to constrain reproduction of movements in observational learning, it was predicted that participants observing a PLD would perform better (in terms of movement outcomes and coordination) than those viewing a video model. Also, following the preceding comments of Newell and Walter (1981) and Runeson (1984), it was hypothesised that in the absence of structural information, participants observing the PLD would show more selective search strategies, characterised by fewer fixations to less disparate areas of the display. Finally, it was predicted that both model groups would show more stable and selective search patterns with repeated viewing and practice as they became more attuned to relative motion information.

Method

Participants

Twenty-one female students (M age = 22.2 years; SD = 4.7) volunteered to take part in the study. None of the participants had played soccer on a regular basis, or had received formal instruction. All had normal or corrected to normal vision and were right-side dominant for everyday activities. All participants gave their informed consent prior to taking part.

Task and production of test films

A female, national standard soccer player (age = 18.6 years) acted as the model. The task was to chip a soccer ball a distance of 5.0 m, over a barrier 0.35 m in height. The barrier was located 2.5 m from the target. A 2.4 m² target area was constructed and covered with a 5cm depth of wet sand to facilitate the collection of error scores. A cross hair marked the target centre. During the performance of a successful chip, the model was filmed in a sagittal plane using a video camera (Panasonic M-40). Simultaneously, 6 infrared cameras (Pro-Reflex, Qualisys) relayed the tempo-spatial positions of 18 retro-reflective markers, placed at the conventional anatomical landmarks of the model's major joint centres. The PLD was generated using the Q-Trac View Motion Viewer (Beta 2.54; Qualisys). This was then manipulated in the programme to match the video presentation and converted to VHS format. Films were edited using the Media 100 system (*i-Finish* software), such that in both conditions 3.24 s of action was presented. A 5 s warning was added before the first trial.

Procedure and design

In order to examine changes in visual search behaviour with ongoing practice, the design highlighted in Figure 2.1 was employed. Participants were matched on pre-test radial error scores and assigned to one of three equal ability groups: video model

(VIDEO); point light display model (PLD), or no demonstration (control). Following the pre-test, participants in the VIDEO and PLD groups engaged in three cycles of observing the model followed by practice. Participants then performed an immediate post-test, and a retention test to measure learning was administered two days later (see Figure 2.1). The CONTROL group followed the same design, without observation of the model.

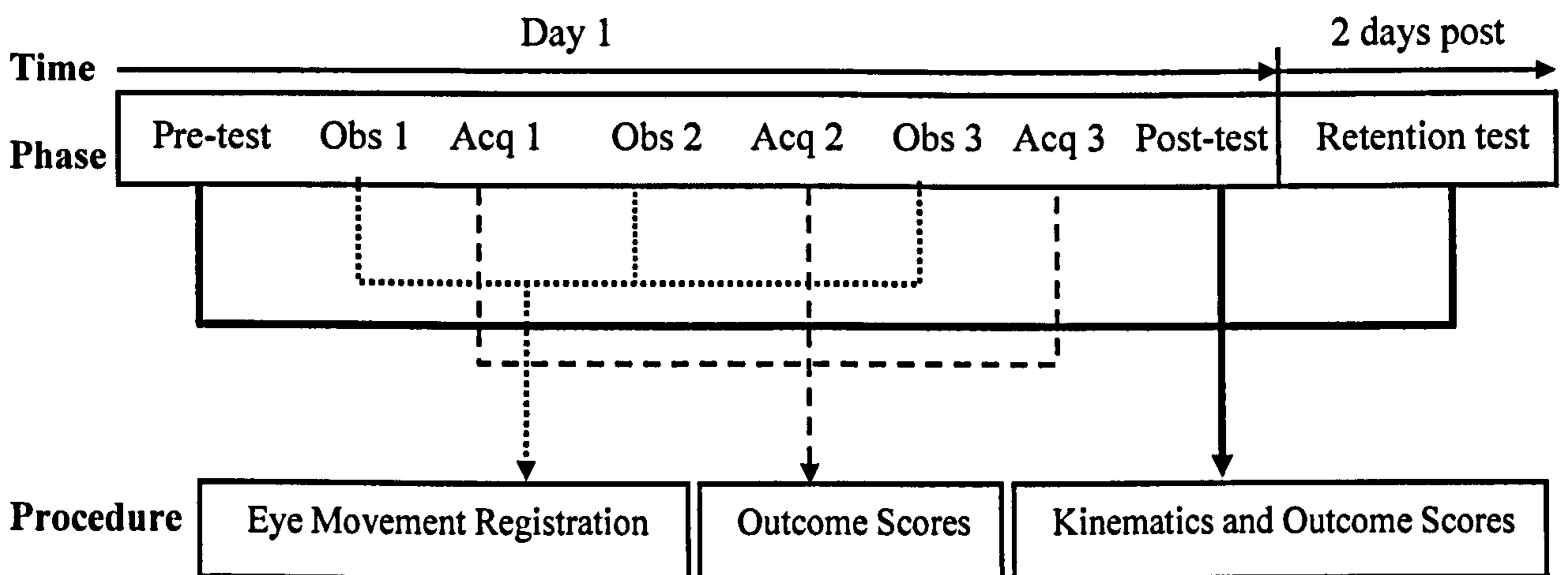


Figure 2.1. Summary of the experimental design and procedure
(obs = observation, Acq = acquisition).

Before the pre-test, participants were given standardised instructions, presented via a tape recorder (Sony M-425). The instructions informed participants to approach the ball in a straight line, kick with their right foot, and to keep their hands above the height of their hips. Retro-reflective markers were placed on the ball (size 5, 10psi) and on the participant's right side at the 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). Each acquisition and test period comprised 10 trials. On trials 1, 5 and 10 of the pre-, post- and retention tests, kinematic data were

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collected using 3 infrared cameras (Pro-Reflex; Qualisys) at 240 Hz. The system was calibrated using a Qualisys Wandkit (750.9 mm) wand prior to each test session.

The participants received further standardized instruction before the first observation period. The instructions explained that the demonstration they were about to observe resulted in a perfect kick (radial error = 0 cm). The instructions placed equal emphasis on the replication of performance outcomes and form/style. The video and

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placed 5 m from the participants, such that the model subtended a realistic visual angle of 18°. Each observation period presented 5 repetitions of the model's action. Visual search behaviours were recorded using an Applied Science Technologies (ASL) 4000SU eye-movement registration system and a magnetic head tracker (Ascension Technologies, Flock of Birds 6DFOB). This system uses a headband mounted eye camera (50 Hz, PAL) to measure line of gaze based on the positions of pupil and cornea relative to a 9-point calibration frame superimposed over the projection screen. The system was accurate to within $\pm 1^\circ$ of visual angle. Calibrations were performed before each observation period, and checked at the end of each presentation block.

Dependent measures and data analysis

Outcome scores. On each trial, the x and y coordinates of the ball's landing position were measured in centimetres from the centre of the mark left by the ball in the sand to the horizontal and vertical lines of the cross-hair respectively. The scores were recorded to produce radial (calculated as the hypotenuse of the triangle made from distances x and y) and variable error scores.

Visual search. Each frame of the test films was converted to a bitmap image and analysed using *Fixplot 1.1* (ASL; 1998). This program generates a time-scaled scan path that is integrated with the calibration frame used in the collection of eye data. When

superimposed over the bitmap images, the scan-path indicates duration and location of fixations. Fixations were parameterised within Fixplot as stable periods of no eye movement lasting 100 ms or more. This value equates with the definition of fixations in video-based eye movement analysis, that has typically classified fixations as periods in which the cursor is stationary for 3 or more frames with NTSC (99.99 ms; e.g., Vickers, 1996) or PAL (120 ms; e.g., Singer et al, 1998) systems.

The following three measures were assessed:

Search rate. This measure included the mean number of fixations and the mean fixation duration per trial.

Relative fixation time per location. This measure reflected the amount of time spent fixating the upper body (including head/neck, shoulder, chest, trunk, arms, wrist/hand), lower body (hip, thigh, knee, calf ankle/foot) and non-bodily areas (ahead of the body, lagging the body, the ball/ball's trajectory).

Number of areas of the model sampled. The mean number of areas fixated across trials was assessed. This variable was obtained by dividing the display into the following regions: head/face; shoulder; chest/trunk; arm (mid-segment); elbow; wrist/hand; hip; thigh; knee; calf/shin; right foot/ankle; left foot/ankle.

Kinematics. Three assessments of coordination were made. The first was a measure of limb coordination relative to the ball. In this analysis, the number of steps in the approach to the ball was documented for all participants on all test trials. A more detailed analysis of all trials was then conducted for a single participant for each group. Each participant selected was considered to be representative of their group. This was based on a qualitative analysis of angle-angle plots for a single trial in pre-, post- and retention tests for all participants. Intra-limb coordination was assessed using angle-angle plots for the knee-hip and knee-ankle. This assessment required the start and end

points of the analysis of the kick to be normalised due to large variation in approach to the ball. Analysis commenced at the initiation of right knee flexion in preparation for the back swing of the kick and ended at the moment of maximal right knee extension following contact with the ball. In addition to this analysis, joint range of motion was assessed over the same period of time. Finally, the relative temporal phases of knee flexion and extension were examined from the initiation of the back swing of the kick through to maximal post-contact knee extension. Data were smoothed with a 4th order Butterworth filter with a cut-off frequency of 7 Hz. The filter was applied twice (the second pass in the reverse direction) to negate phase lag (Winter, 1990).

Statistical analysis

Visual search data were analysed using separate factorial analyses of variance (ANOVA) in which viewing condition (VIDEO; PLD) was the between-groups factor and observation period and trials the within-groups factors. Outcome data were analysed using separate repeated measures ANOVA in which group (VIDEO; PLD; control) was a between-groups factor and test period a within-groups factor. Significant effects were followed up where appropriate using the Tukey HSD ($\alpha = <.05$). Where violations of the assumption of sphericity for repeated measures ANOVA were observed, data were adjusted with a Greenhouse-Geisser epsilon factor.

Results

Outcome scores

ANOVA revealed main effects for test session in radial error, $F(2, 36) = 21.74$, $p < .01$, and variable error across the x- , $F(2, 36) = 11.53$, $p < .01$, and y- axis $F(2, 36) = 7.76$, $p < .01$. *Post hoc* Newman-Keuls analysis indicated a significant increase in accuracy and reduction in variability from pre- to post-test. These differences were

maintained on the delayed retention test. A main effect for viewing condition was not observed. Radial and variable error scores are presented in Figure 2.2.

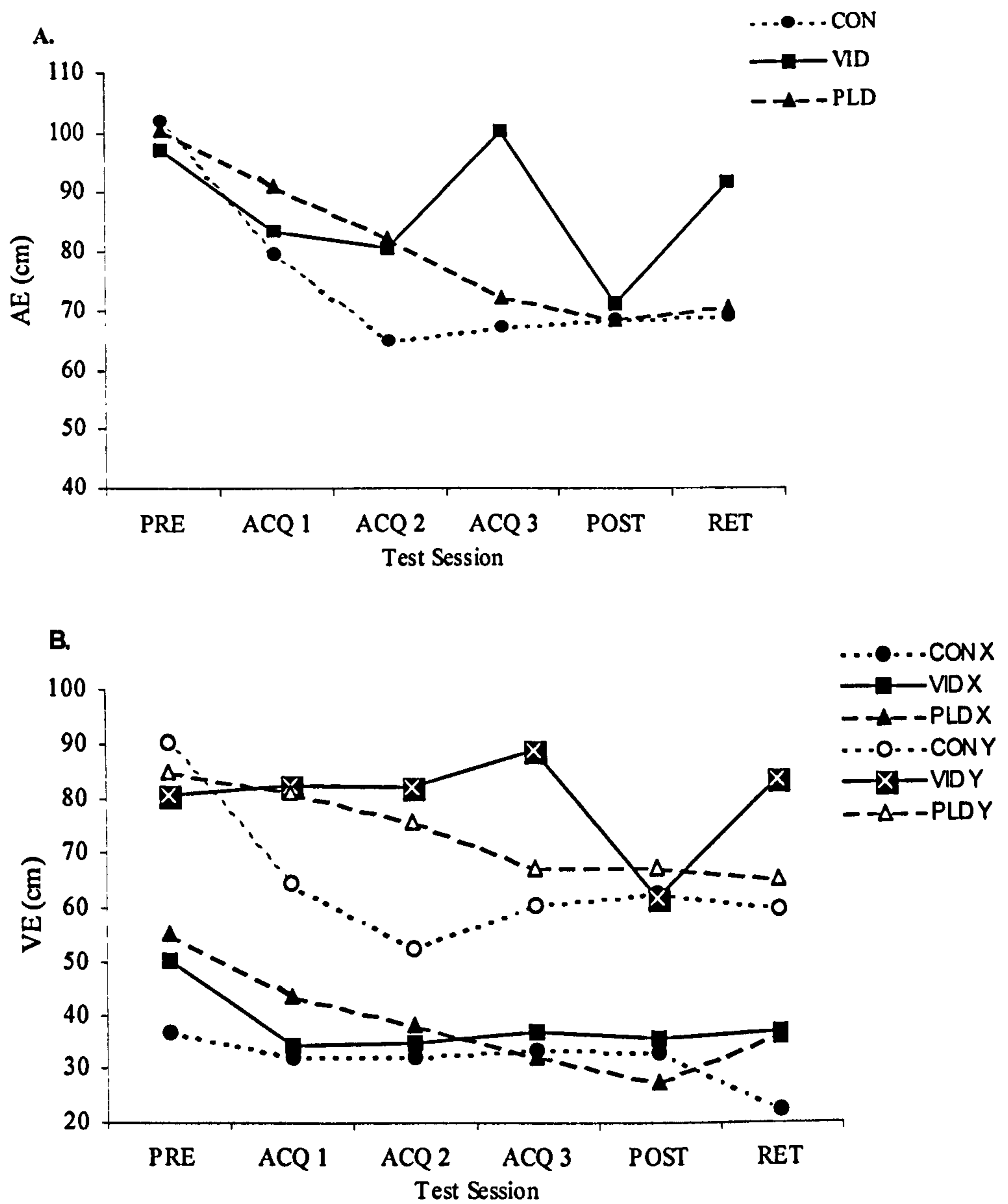


Figure 2.2. Mean Radial (A) and Variable Error (B) for all Groups Across Test and Acquisition Conditions

Visual search data

Search rate. No significant differences were noted between the video and point-light display groups for mean number of fixations per trial or mean fixation duration (p

> .05). Similarly, main effects for observation period and trials were not observed. The search rate data are shown in Table 2.1.

Relative fixation time per location. ANOVA indicated a significant main effect for fixation location, $F(2,24) = 63.01, p < .01$). The participants spent more time fixating on the lower body than the upper body. A Viewing Condition x Fixation Location interaction was also present, $F(2,24) = 6.63, p < .01$). Post hoc analysis showed that the PLD participants exhibited a more even distribution of fixations over the lower body ($M = 48.98\%$) and non-bodily areas ($M = 42.27\%$). Furthermore, they fixated for relatively less time on the upper body than the VIDEO group ($M = 8.75\%$ versus 17.8%). The VIDEO group spent more time fixating the lower body ($M = 53.96\%$) compared with the upper body (mean = 17.79%) and non-bodily areas ($M = 28.30\%$). Relative fixation time per location data are shown in Figure 2.3.

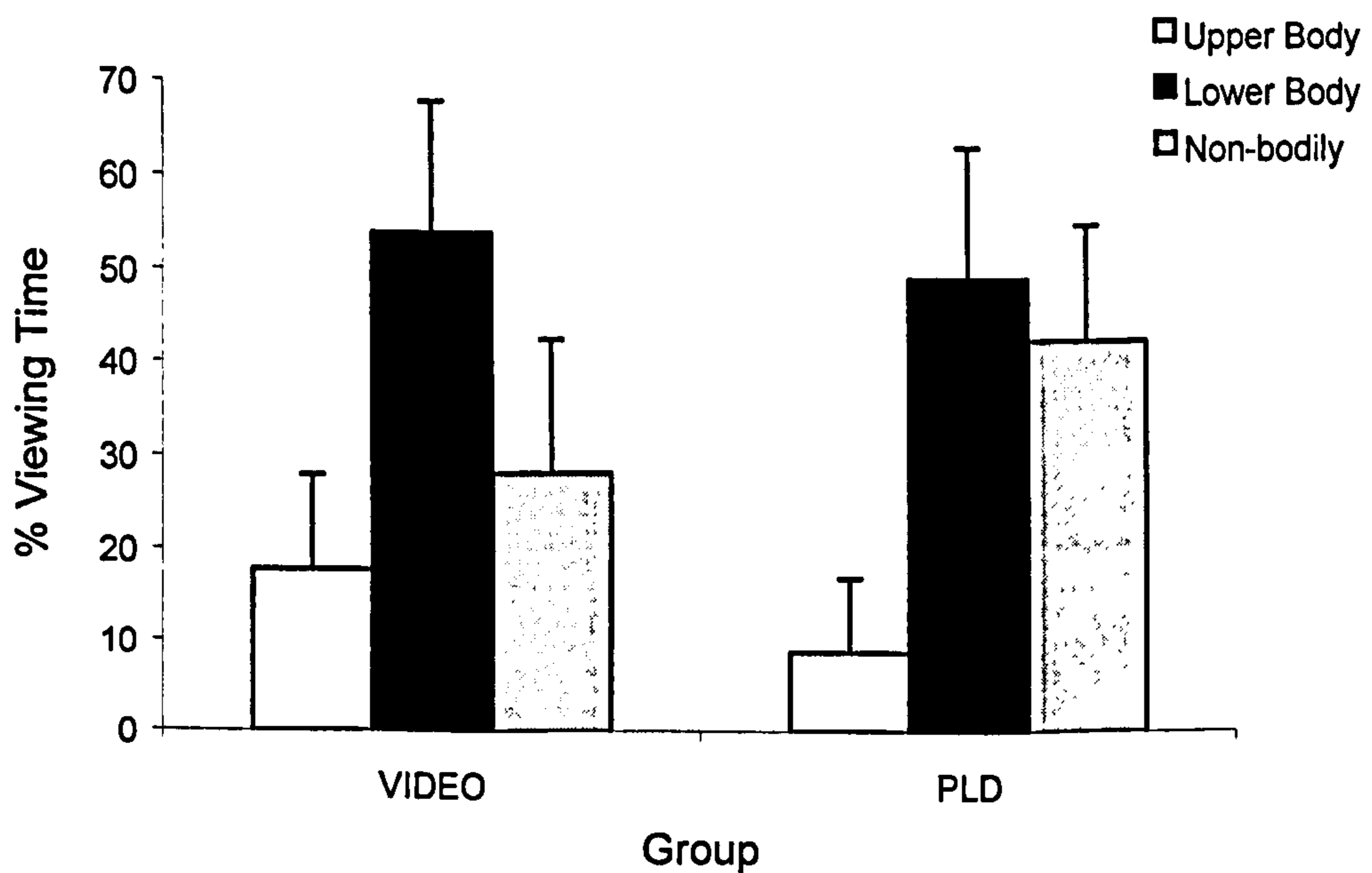


Figure 2.3. Percentage of viewing time allocated to the model's upper body, lower body and to non-bodily areas.

Table 2.1. Comparison of search rate between participants observing video and point-light display models (\pm SD)

		Observation 1		Observation 2		Observation 3	
	Fixations (<i>n</i>)	Fixation duration (<i>ms</i>)	Fixations	Fixation duration	Fixations	Fixation duration	Fixations
VIDEO	7.9 (1.2)	310 (60)	7.4 (.7)	340 (40)	8.1 (1.3)	330 (60)	
PLD	8.5 (1.2)	300 (90)	8.0 (1.1)	330 (70)	7.5 (1.2)	340 (60)	

Number of areas sampled. A main effect for observation period was observed, $F(2, 24) = 3.90, p < .05$. *Post hoc* analysis indicated that participants fixated on fewer areas of the body across each of the observation periods from 1 ($M = 3.57, SD = .99$) to 2 ($M = 3.06, SD = .64$) to 3 ($M = 2.97, SD = .72$). ANOVA also revealed a significant main effect for trial, $F(4, 48) = 4.21, p < .05$. *Post hoc* analysis indicated that participants fixated on fewer areas of the display in trial 5 ($M = 2.67, SD = 1.20$) than trial 1 ($M = 3.56, SD = 1.47$), trial 2 ($M = 3.38, SD = 1.23$) or trial 4 ($M = 3.17, SD = 1.45$). There was no main effect for viewing condition (VID $M = 3.50, SD = 1.45$; PLD $M = 2.90, SD = 1.13$; $F(1, 12) = 4.16, p < .06$). However, given the marginal significance level and small sample, an effect size statistic was calculated for the viewing condition main effect. The analysis revealed a moderate effect size of .45.

Kinematics

Approach to the ball. An assessment of the number of steps in approach to the ball indicated significant main effects for group, $F(2, 18) = 6.88, p < .01$. A significant main effect for test period was found, $F(1.27, 22.85) = 4.48, p < .05$. A Group x Test Period interaction was also present, $F(2.54, 22.85) = 6.81, p < .01$. As a whole, the participants increased the number of steps in their approach to the ball, becoming more like the model (the model employed a three step approach, where contact with the ball occurred at step three). Although all three groups were closely matched on pre-test scores, in retention the VIDEO and PLD groups increased their steps beyond that of the control group to become more like the model. The control participants decreased the number of steps used to become less like the model. These results are shown in Table 2.2.

Table 2.2. Mean (\pm SD) number of steps in approach to the ball for all groups across test conditions.

Group	Pre-test	Post-test	Retention test
VIDEO	2.2 (.8)	2.8 (.4)	2.9 (.4)
PLD	2.0 (.1)	2.5 (.5)	2.6 (.5)
CONTROL	2.2 (.5)	1.9 (.4)	1.7 (.5)

Phasing of knee flexion and extension. Figure 2.4 illustrates the relative phasing of knee flexion and extension in the soccer chipping motion. The CONTROL group participant increased her ratio over test conditions to become less like the model. In addition, her variability in retention (as indicated in standard deviations) remained similar to pre-test levels. Conversely, the VIDEO group participant decreased her ratio in post-test and retention-test conditions by shortening the period of knee flexion so as to be nearly identical to the model. Furthermore, the VIDEO participant greatly reduced the variability in her flexion-extension phasing in the post- and retention-tests. The PLD participant also became more like the model, but maintained a moderate degree of variability in retention.

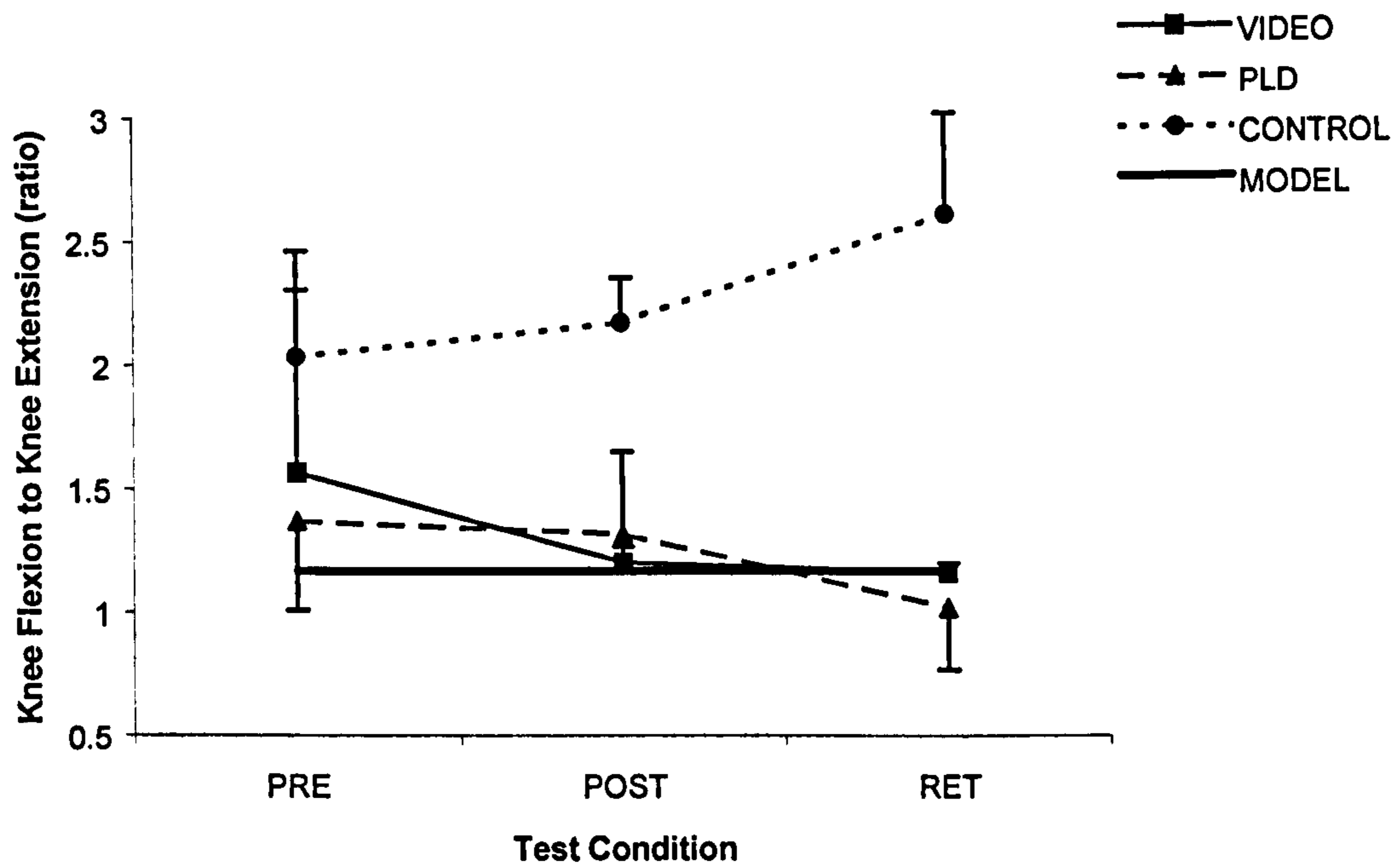


Figure 2.4. The ratio of time for knee flexion to time for knee extension during the soccer chip across test conditions.

Intra-limb coordination. The joint range of motion results are presented in Figure 2.5. The model chipped the ball using a large knee range of motion, while keeping hip range of motion low and the ankle almost locked (6° of motion). The VIDEO participant learned to decrease her ankle and hip range of motion, but could not increase knee range of motion to be more like the model. The PLD participant showed very little change in all range of motion pre- to retention tests. Finally, through practice, the CONTROL participant increased range of motion at the knee, and decreased range of motion at the hip to perform more similarly to the model, but also increased ankle range of motion.

The angle-angle plots presented in Figures 2.6 - 2.11 provide an appropriate indication of relative motion and intra-limb coordination, as they illustrate the movement independent of *control* variables such as velocity and acceleration. The problems encountered in acquiring the model's range of motion are reflected in the

knee-hip angle-angle plots (see Figures 2.6, 2.7 and 2.8) and knee-ankle angle-angle plots (see Figures 2.9, 2.10, and 2.11). The model's relative motion pattern of minimal hip and ankle motion (i.e., width across the x-axis on the plot) coupled with large range of motion at the knee (i.e., depth on the y-axis), are indicated by narrow, deep *wells*. These are not closely approximated due to the aforementioned errors in replicating range of motion.

The model's movement appears to proceed in three phases (see Figure 2.6). Moving clockwise, there is initially extensive knee flexion coupled with hip stability (back-swing). This is followed by hip flexion with moderate knee extension. Finally, there is considerable knee extension with the return of stability in the hip angle as a result of no follow-through. For the VIDEO participant the knee-hip coordination is not learned. The first phase of movement is attenuated by minimal knee flexion (see Figure 2.6), the second phase is exaggerated by over-extension of the hip in the follow through. As a result, phase three does not occur. The only qualitative improvement for the VIDEO participant appears to be in the symmetry of the movement in retention. Figures 2.7 and 2.8 show that the three phases of movement are more pronounced for the PLD and control participant respectively. The PLD participant shows greatest improvement from the pre-test to the retention test. However, in retention, her patterns are not closer to the model than those of the CONTROL participant, who also illustrates greater stability.

For knee-ankle coordination, the model again shows the two distinct periods of knee flexion and extension, with extension preceded by only slight ankle flexion. None of the participants were able to approximate this pattern as a result of excessive ankle motion. The CONTROL participant again shows greatest stability in her movement pattern (see Figure 2.11).

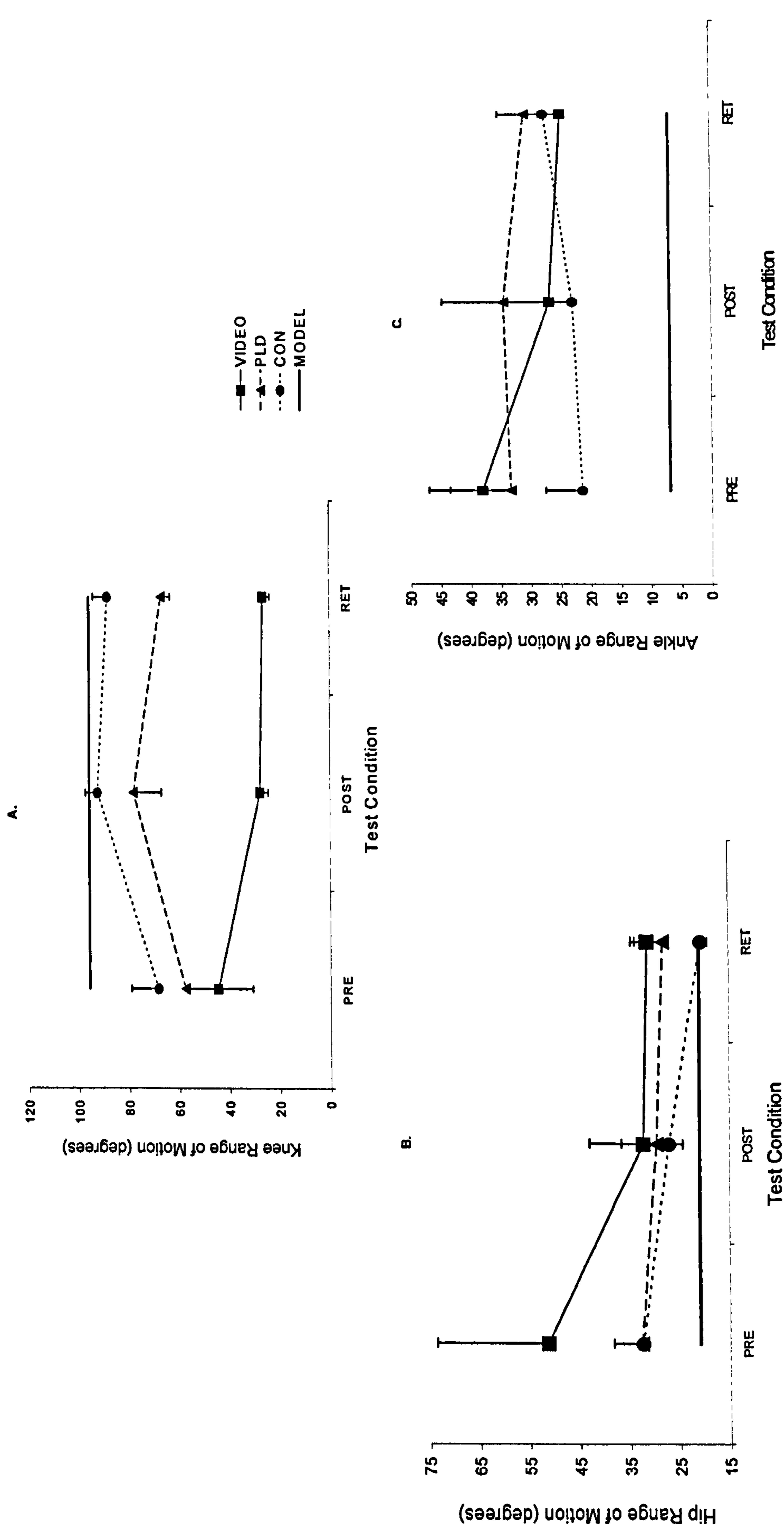


Figure 2.5. Mean joint range of motion at (A) the knee, (B) the hip, and (C) the ankle for representative participants across test conditions.

MODEL

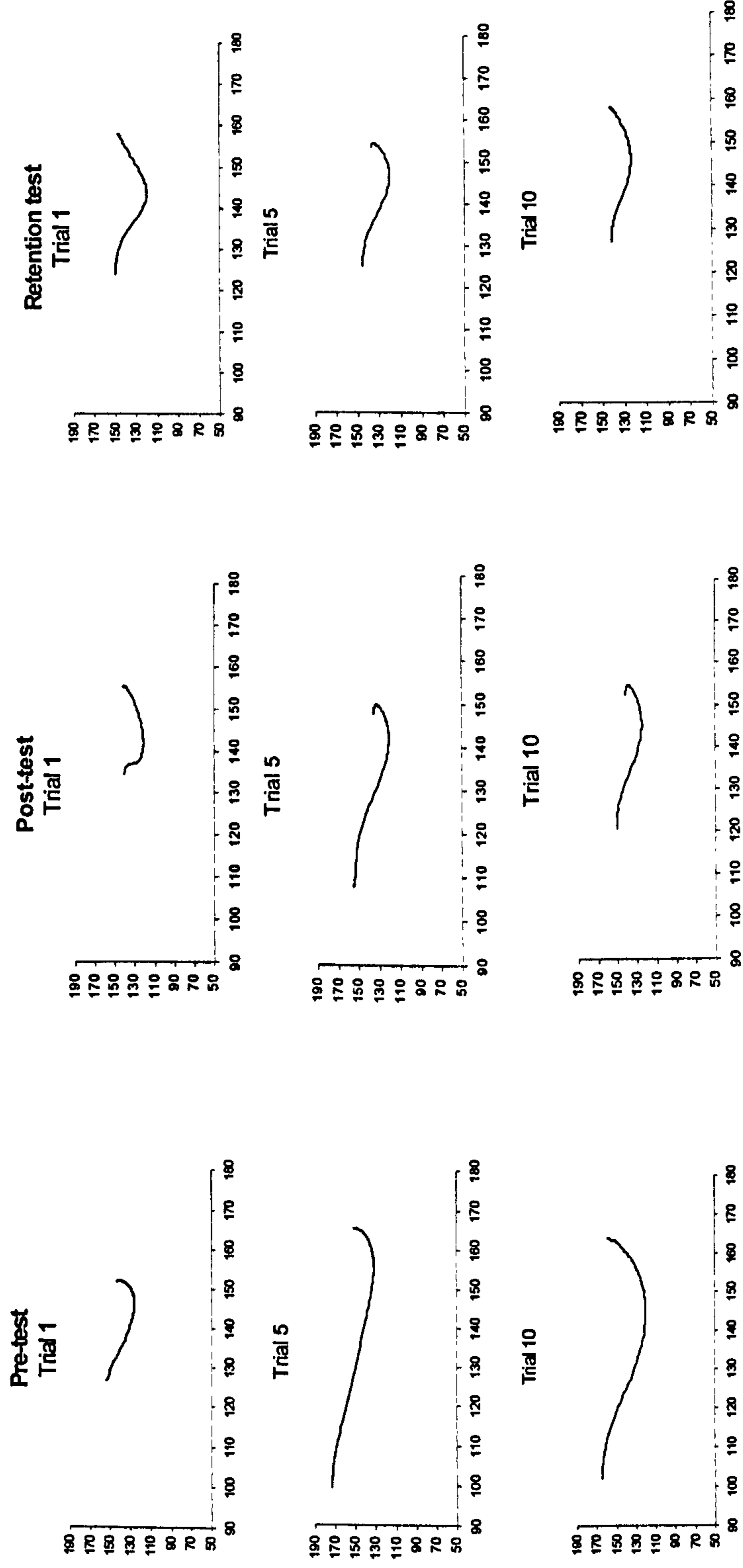
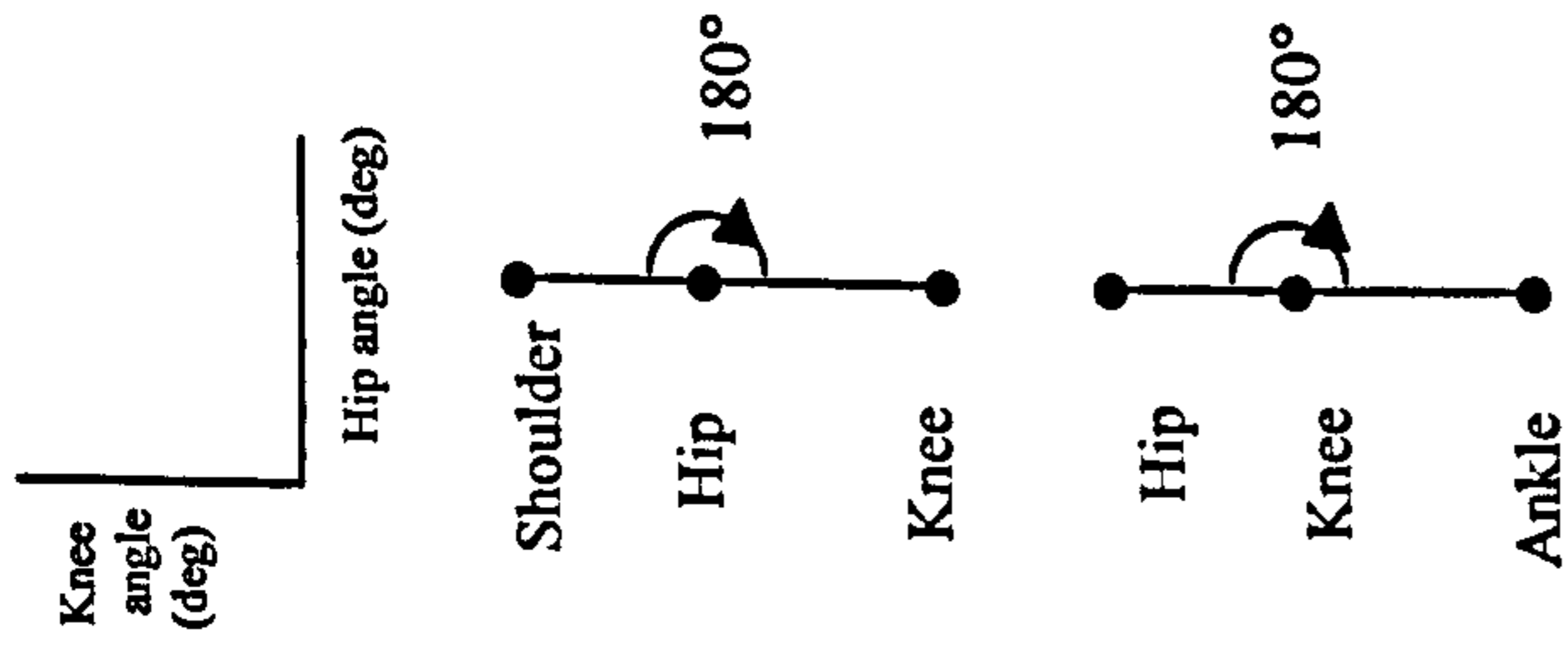
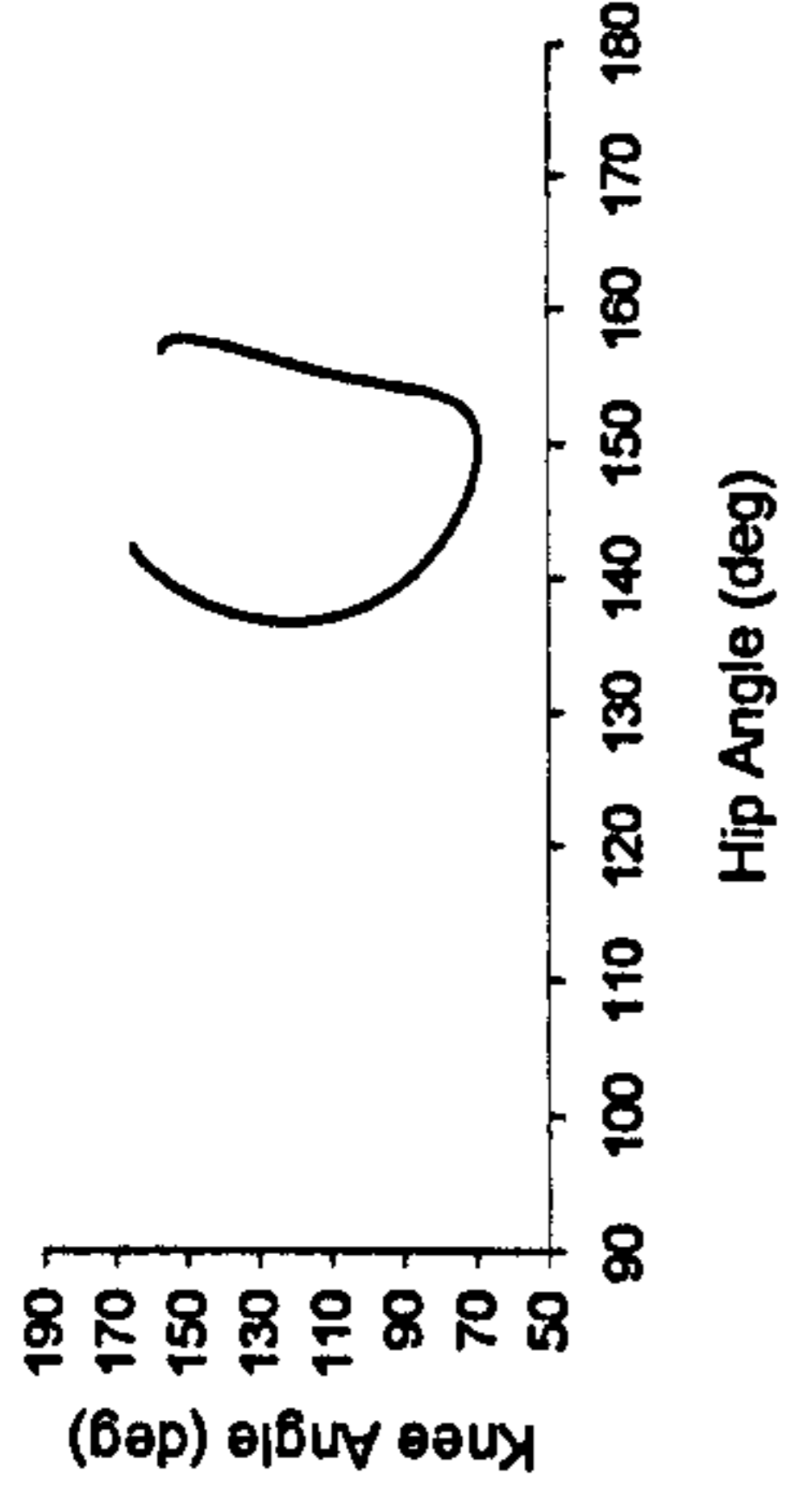
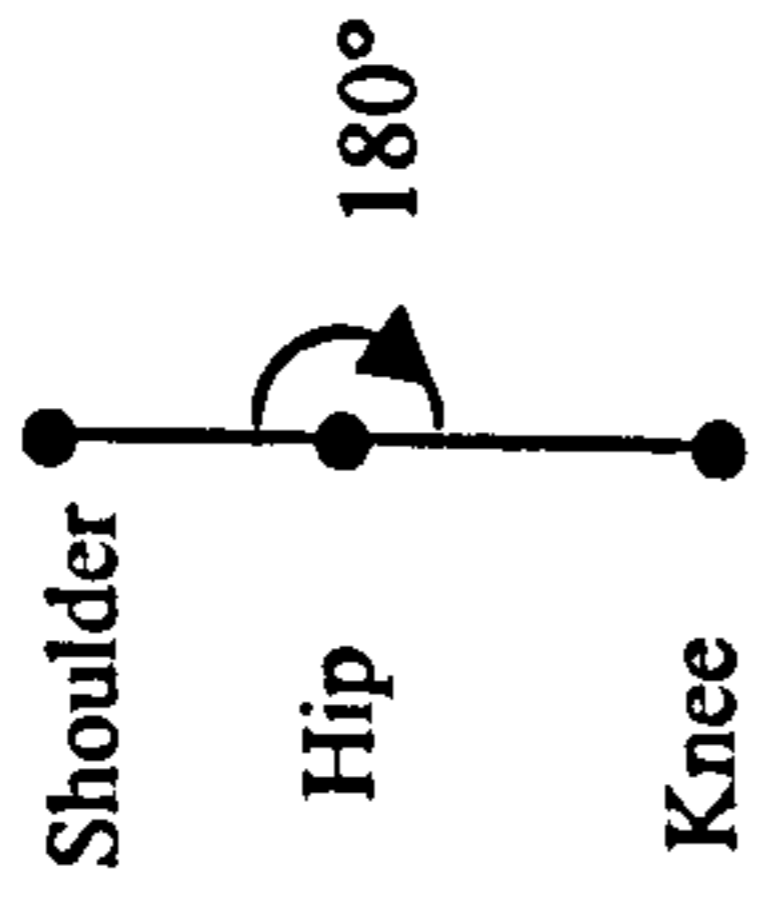
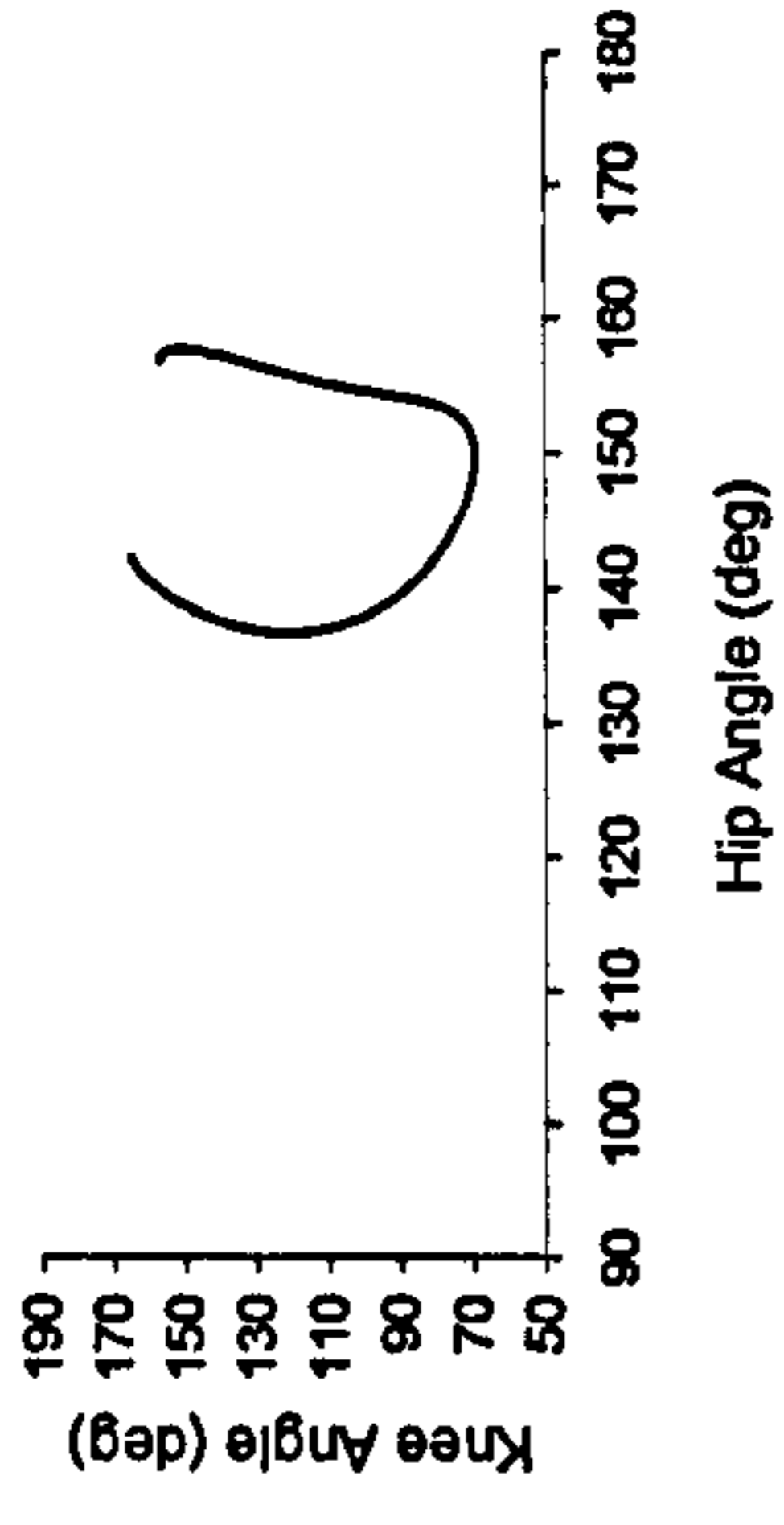
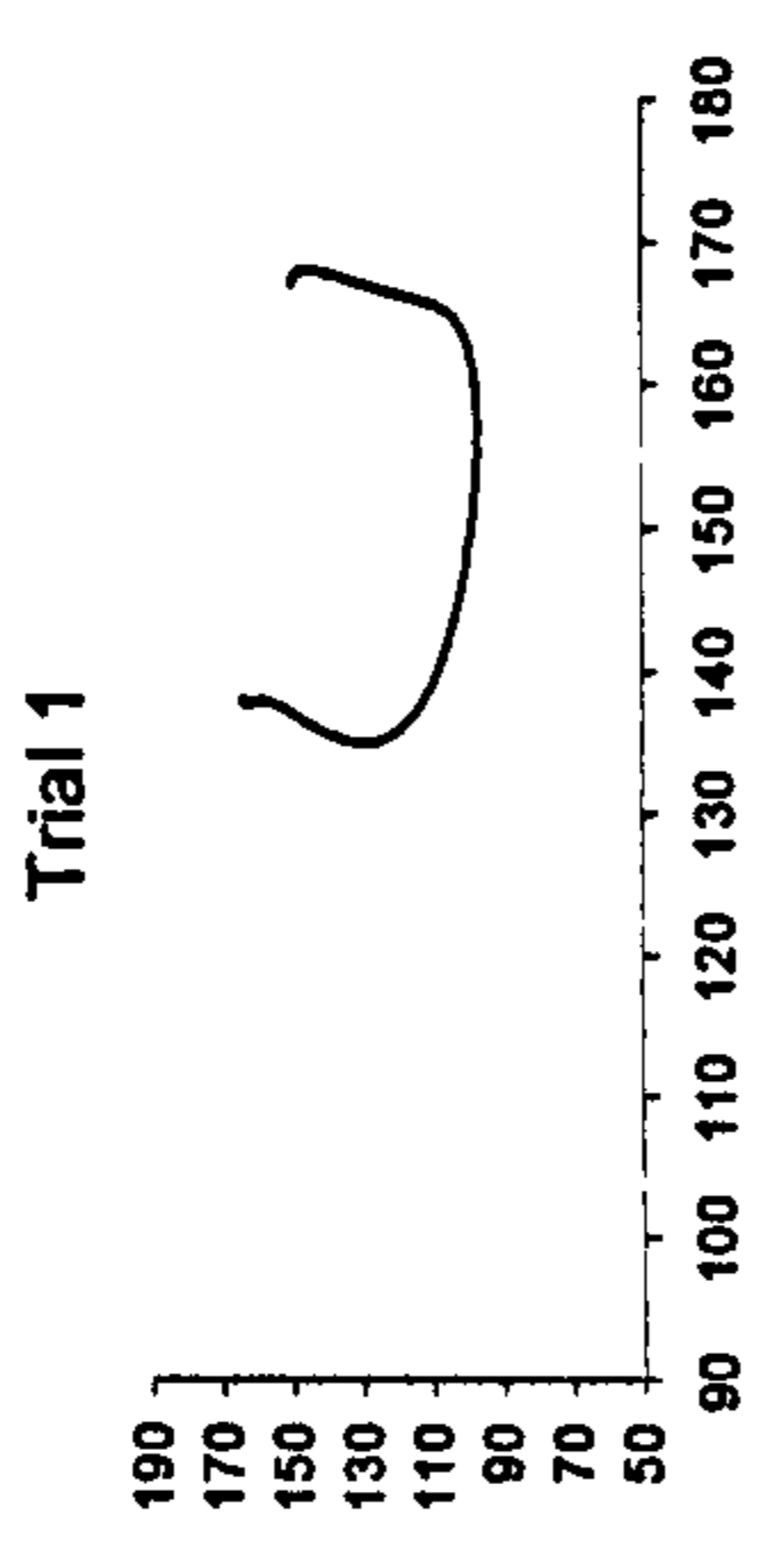


Figure 2.6 Knee-hip angle-angle plots for the VIDEO participant in pre-test, post -test and retention test.

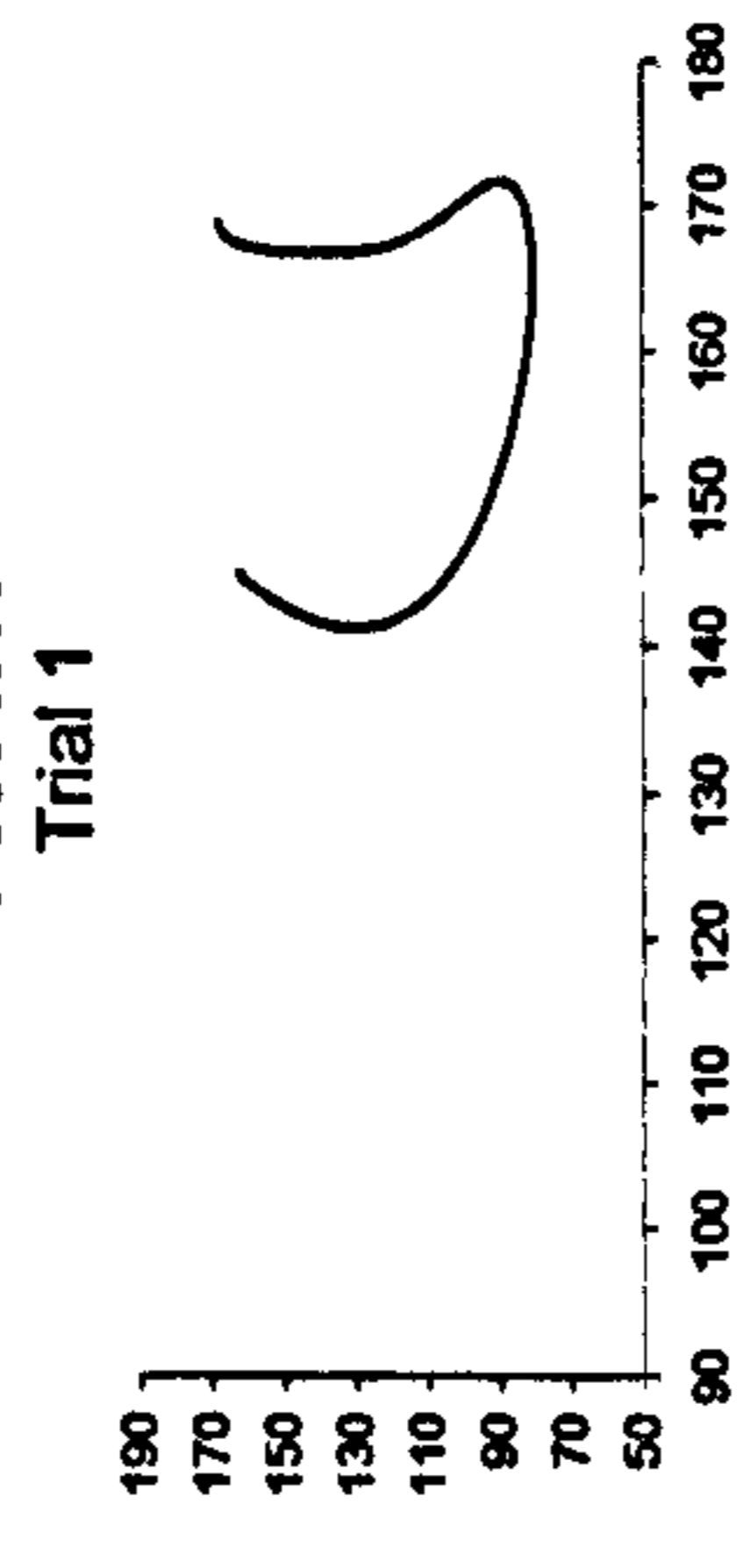
MODEL



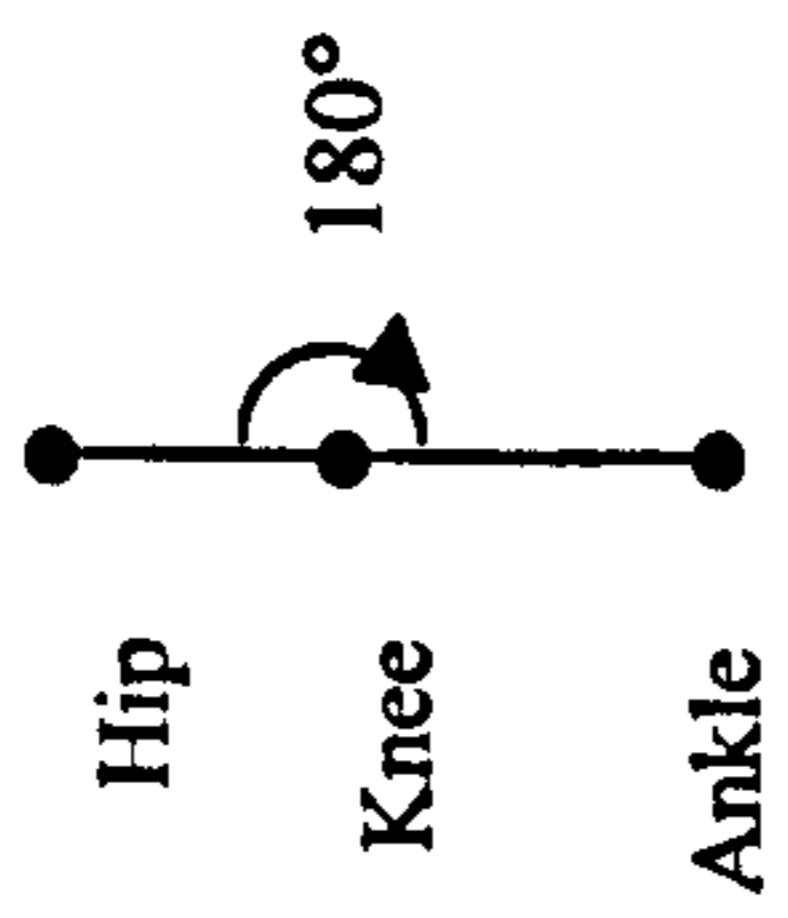
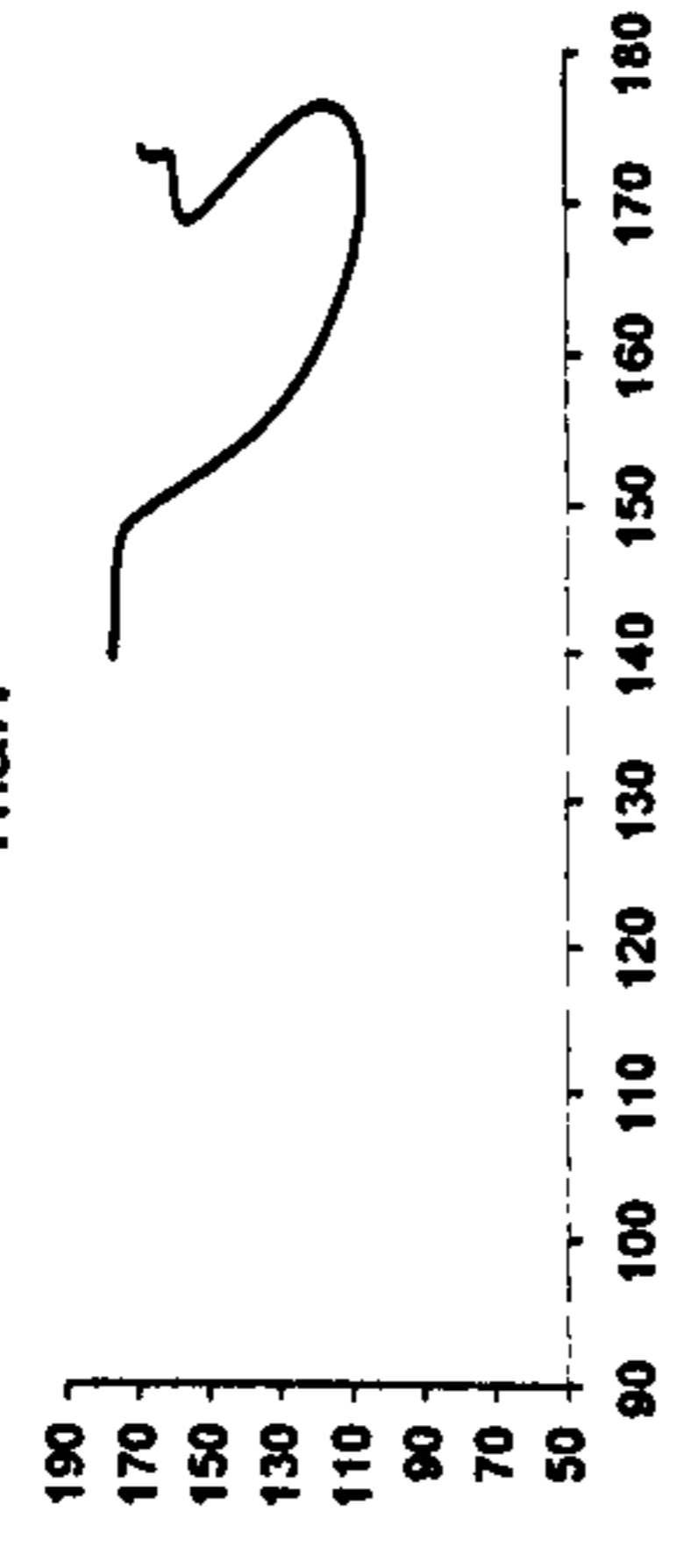
Retention test



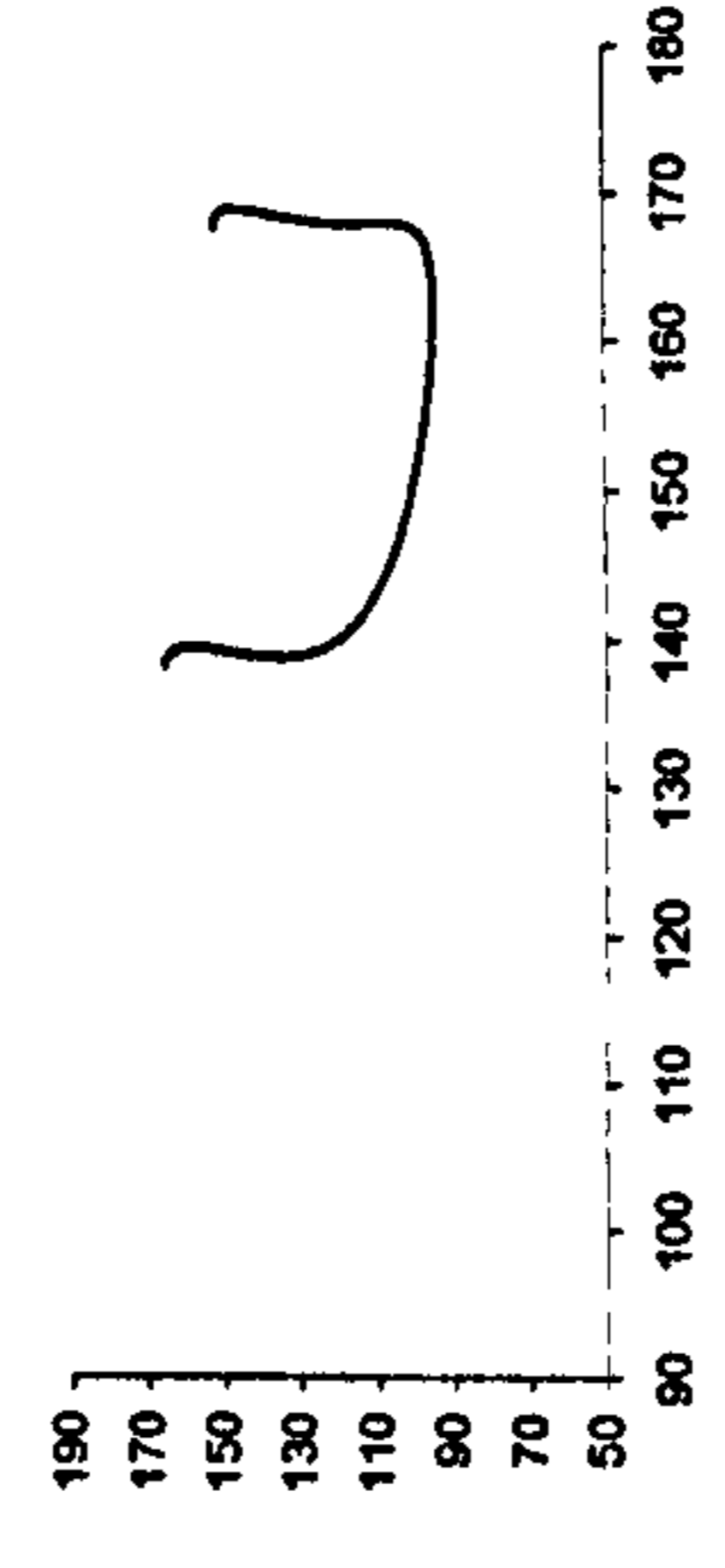
Post-test



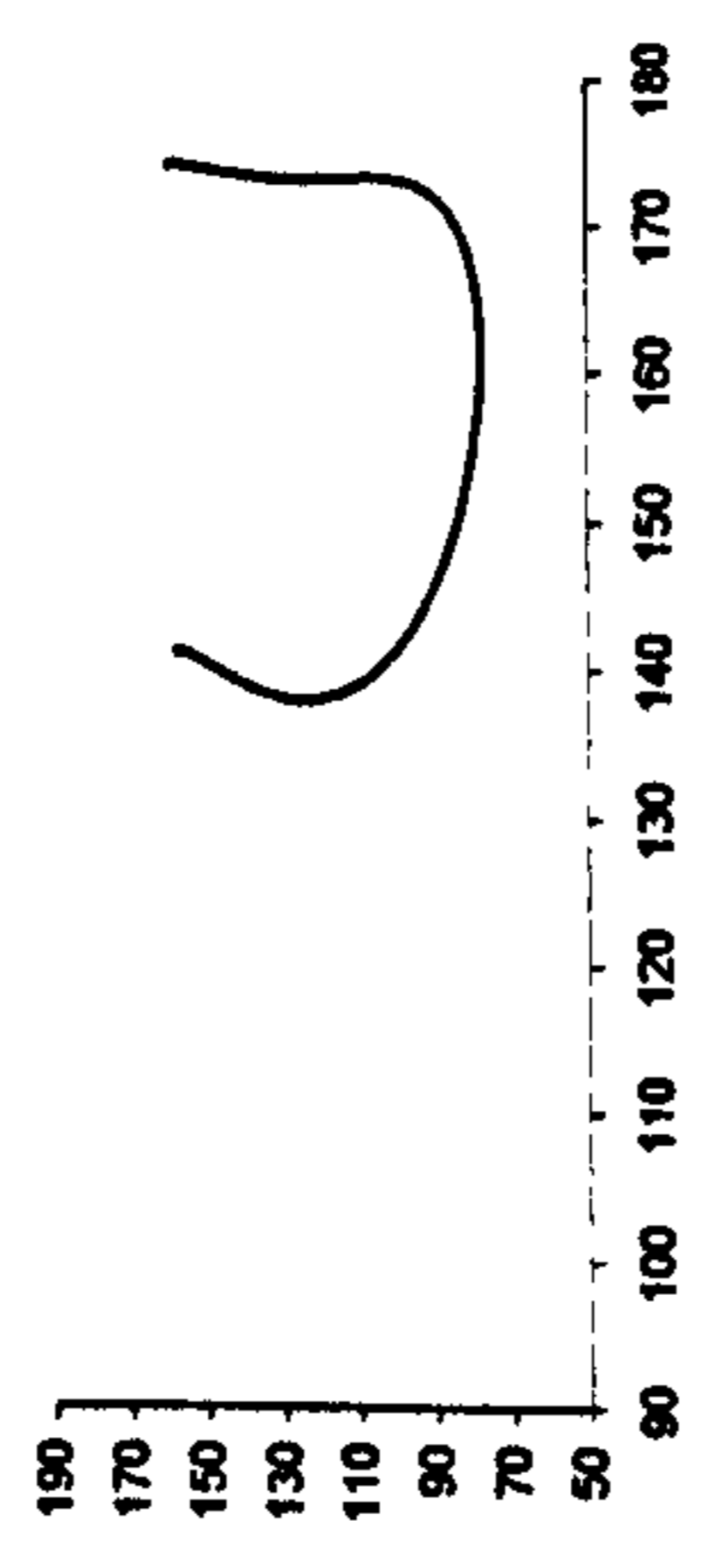
Pre-test



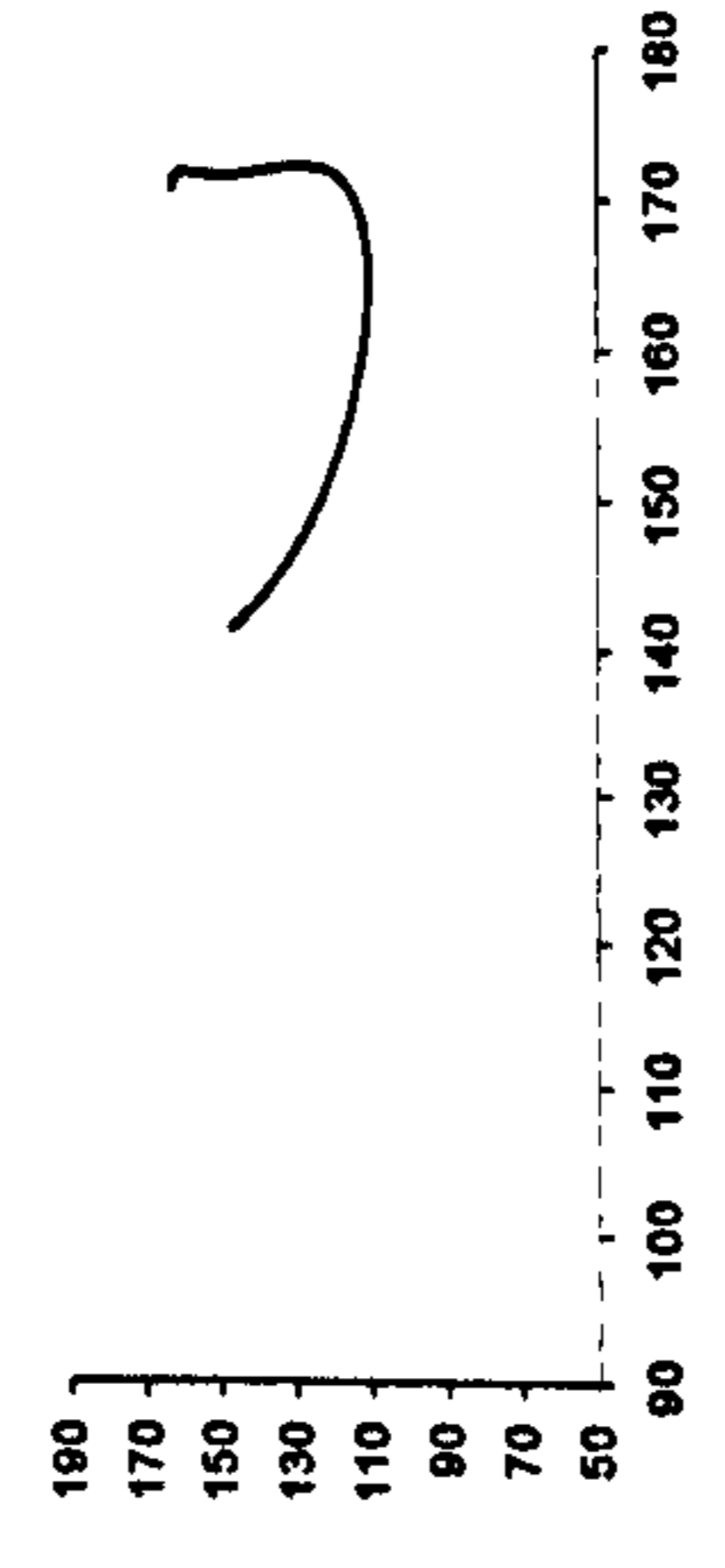
Trial 5



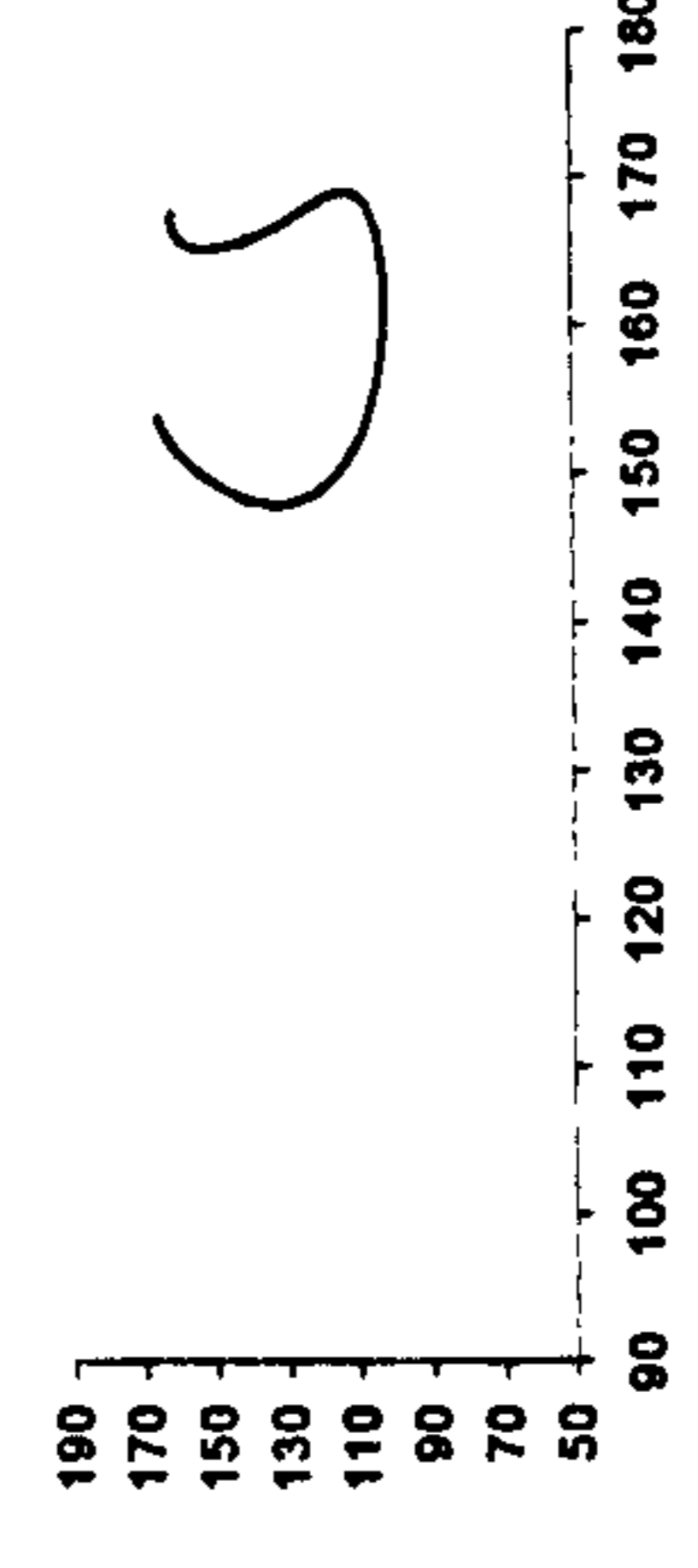
Trial 5



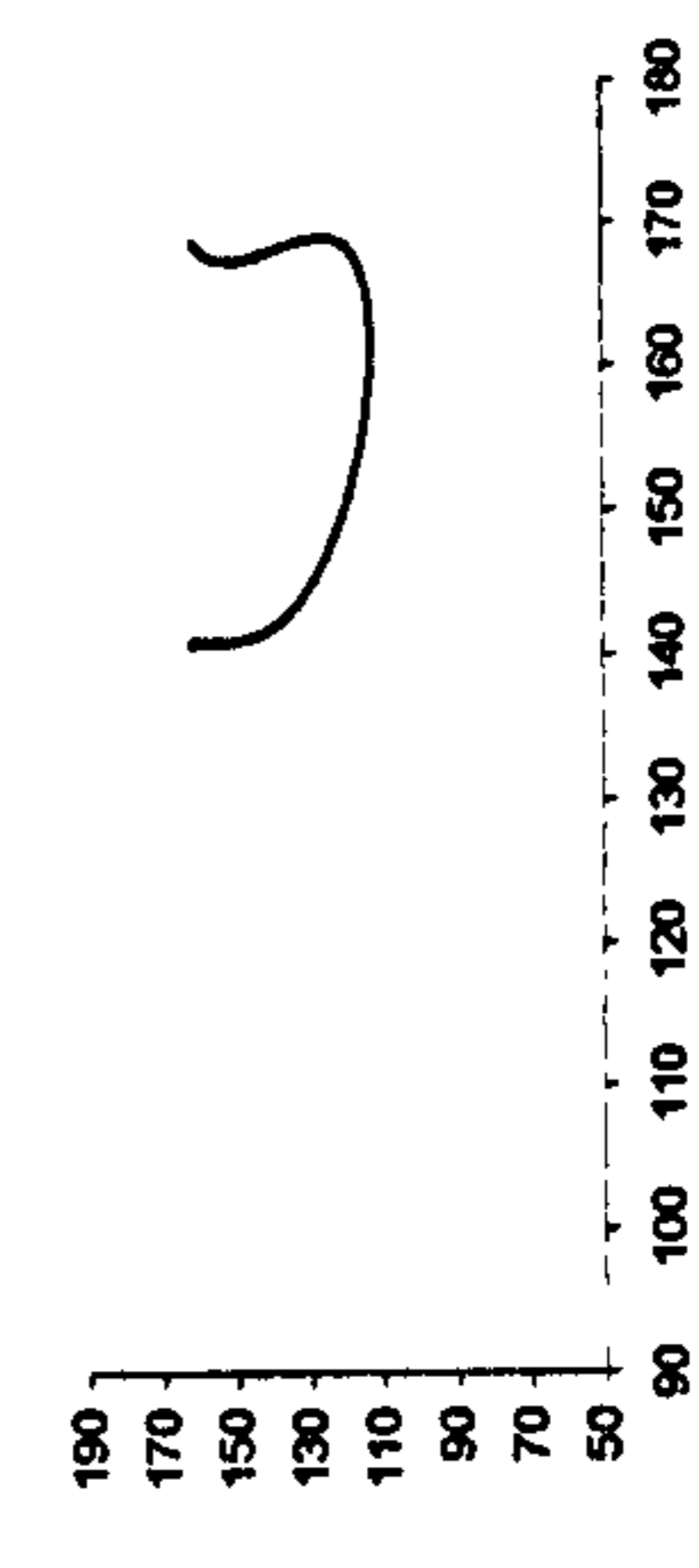
Trial 5



Trial 10



Trial 10



Trial 10

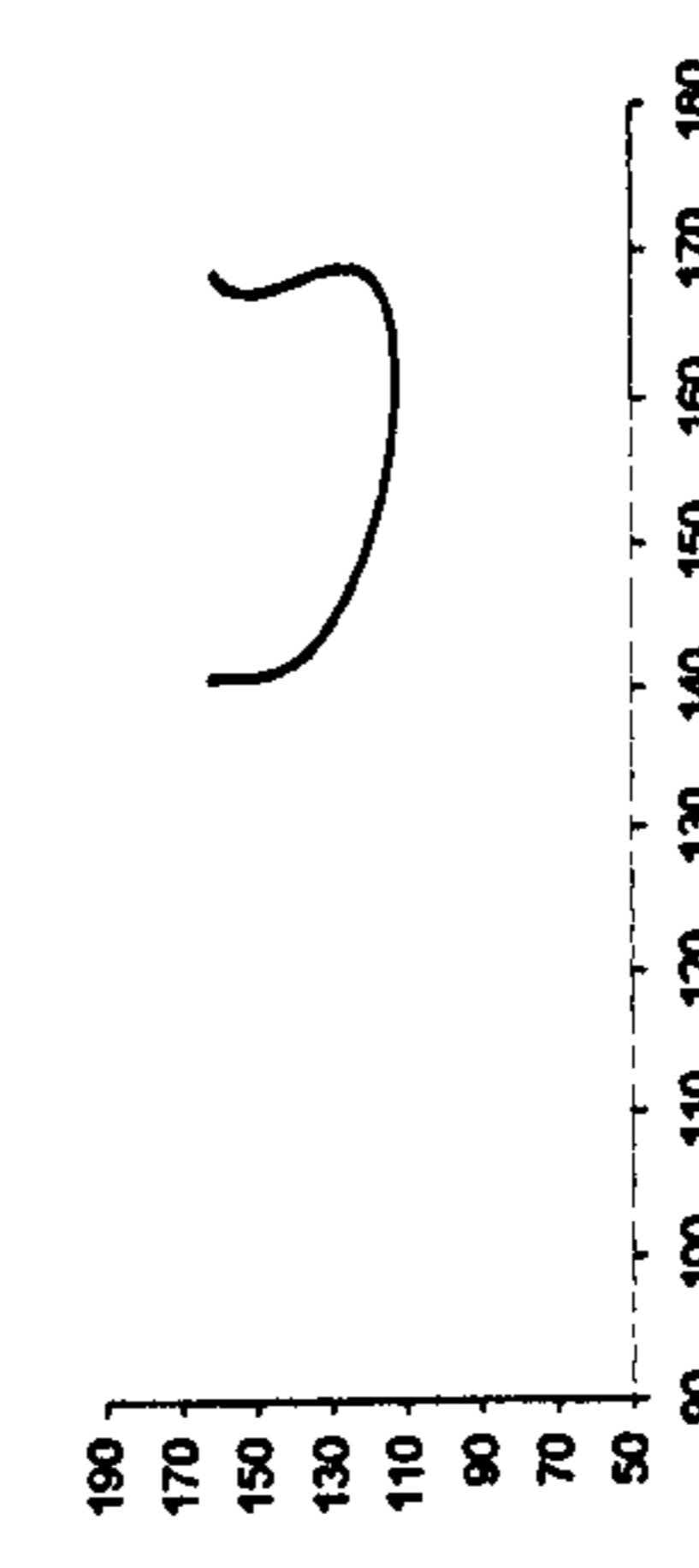


Figure 2.7. Knee-hip angle-angle plots for the PLD participant in pre-test, post-test, and retention test.

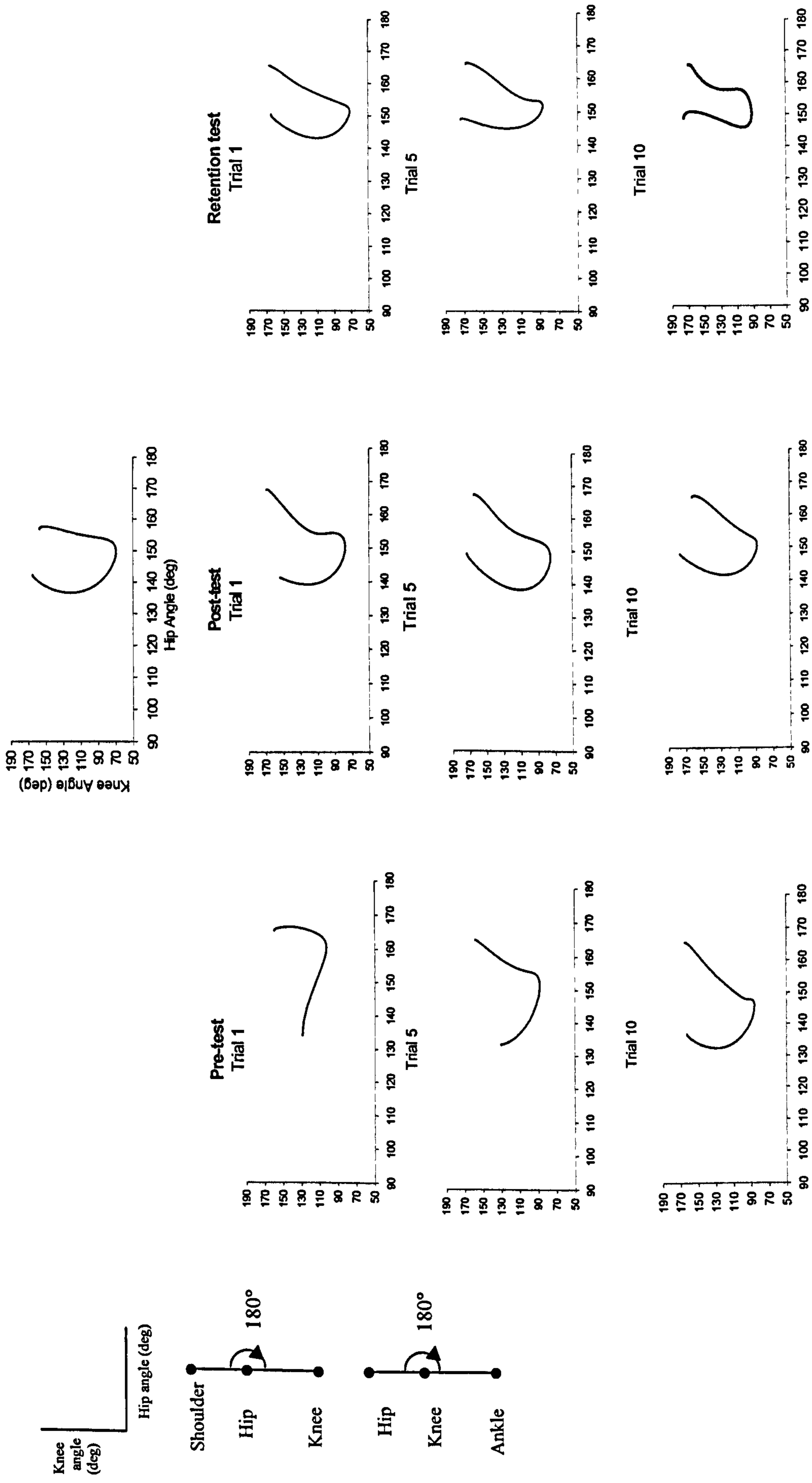
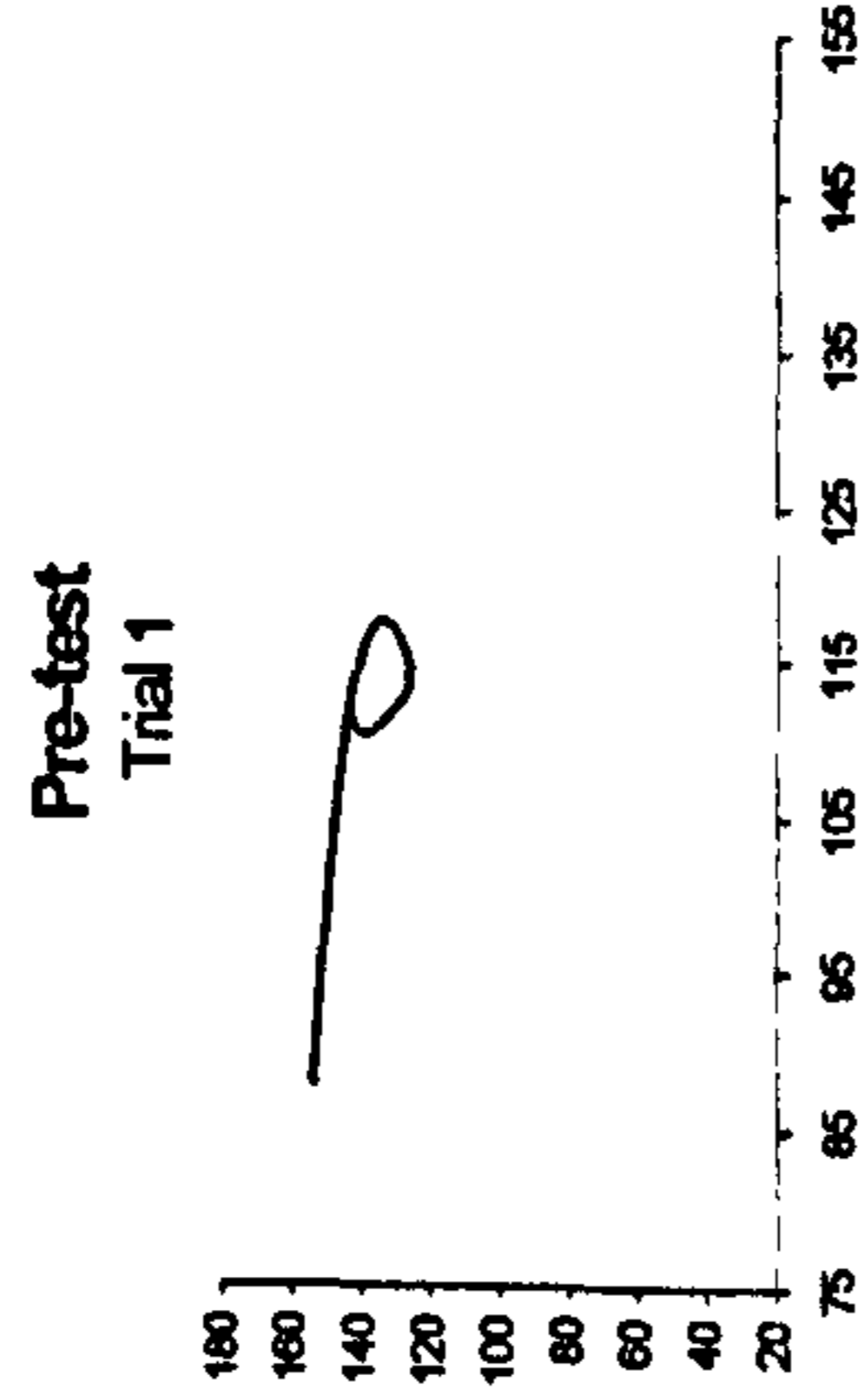
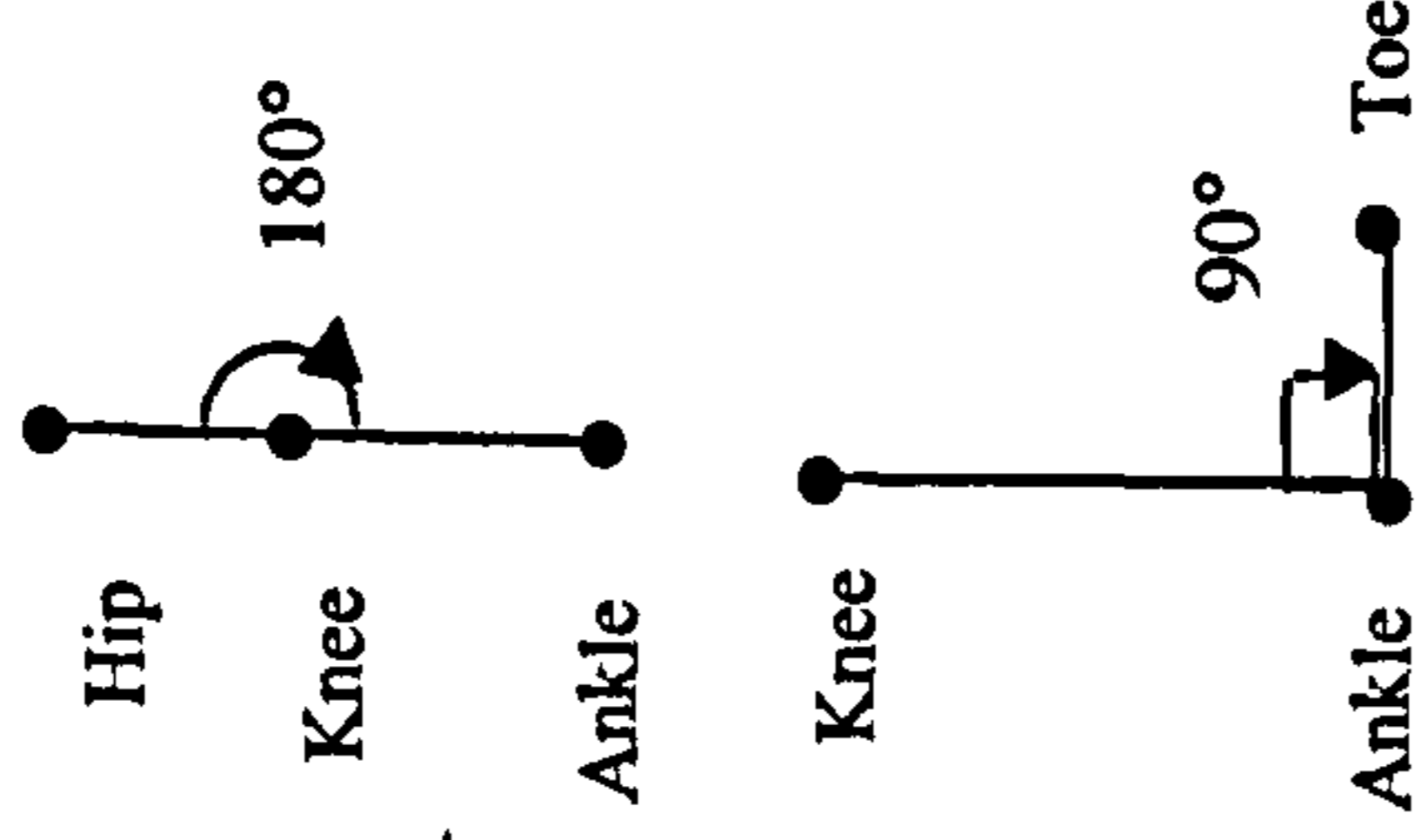
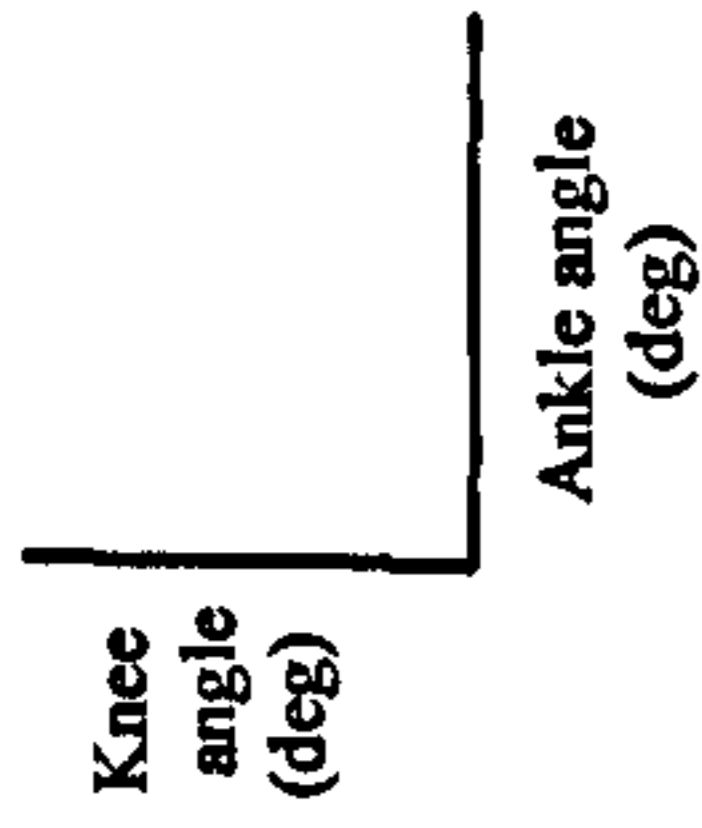
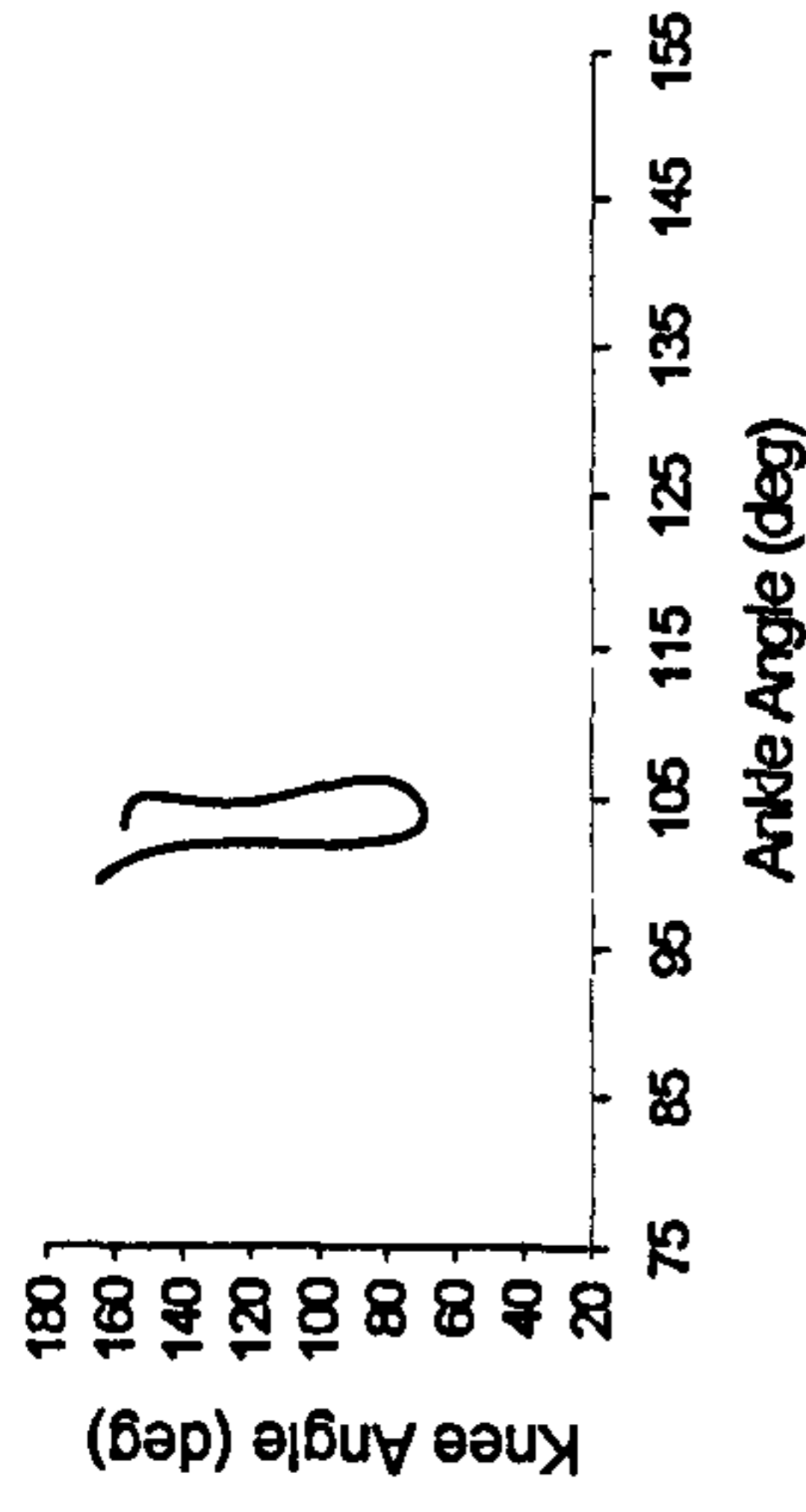
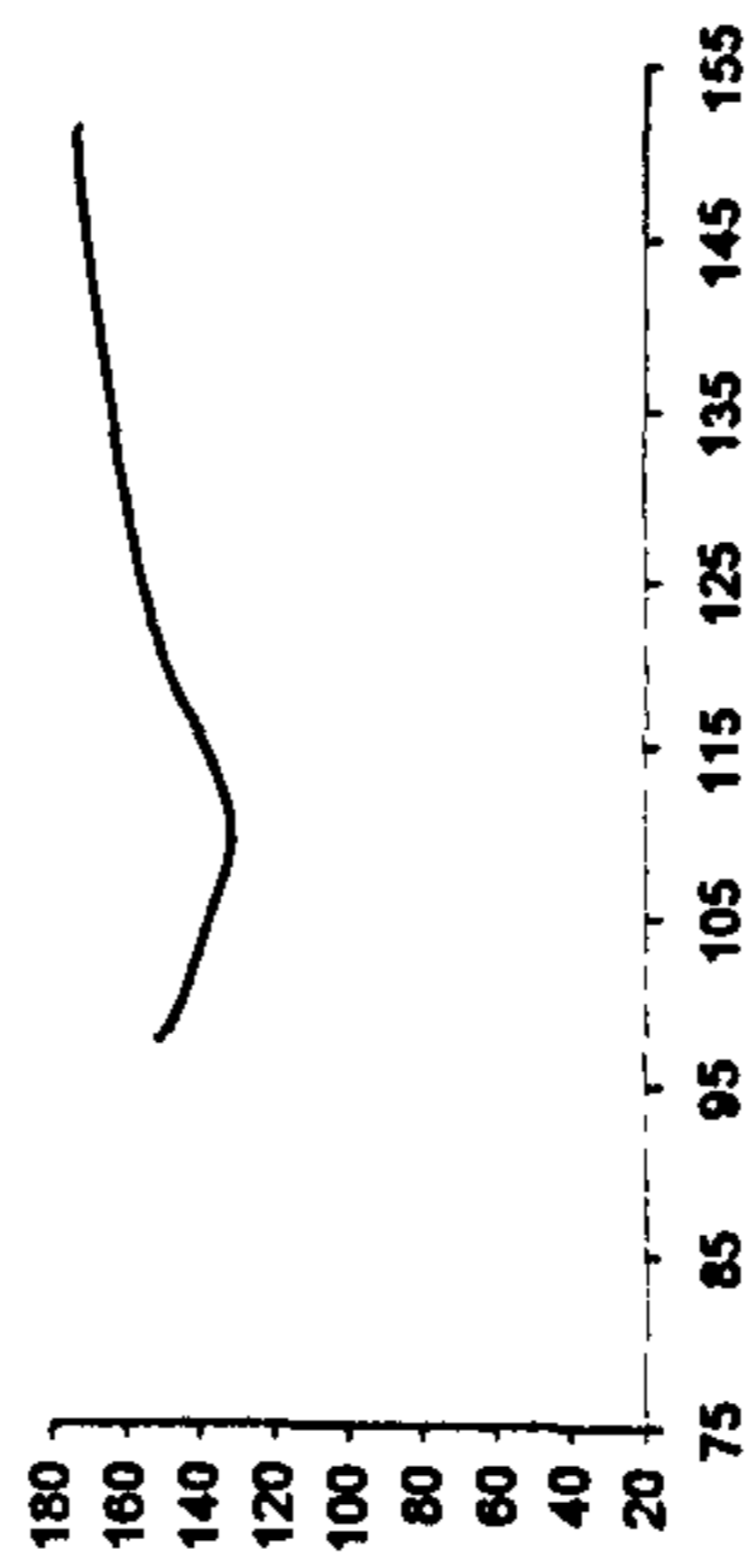


Figure 2.8. Knee-hip angle-angle plots for the control participant in the pre-test, post-test, and retention test.

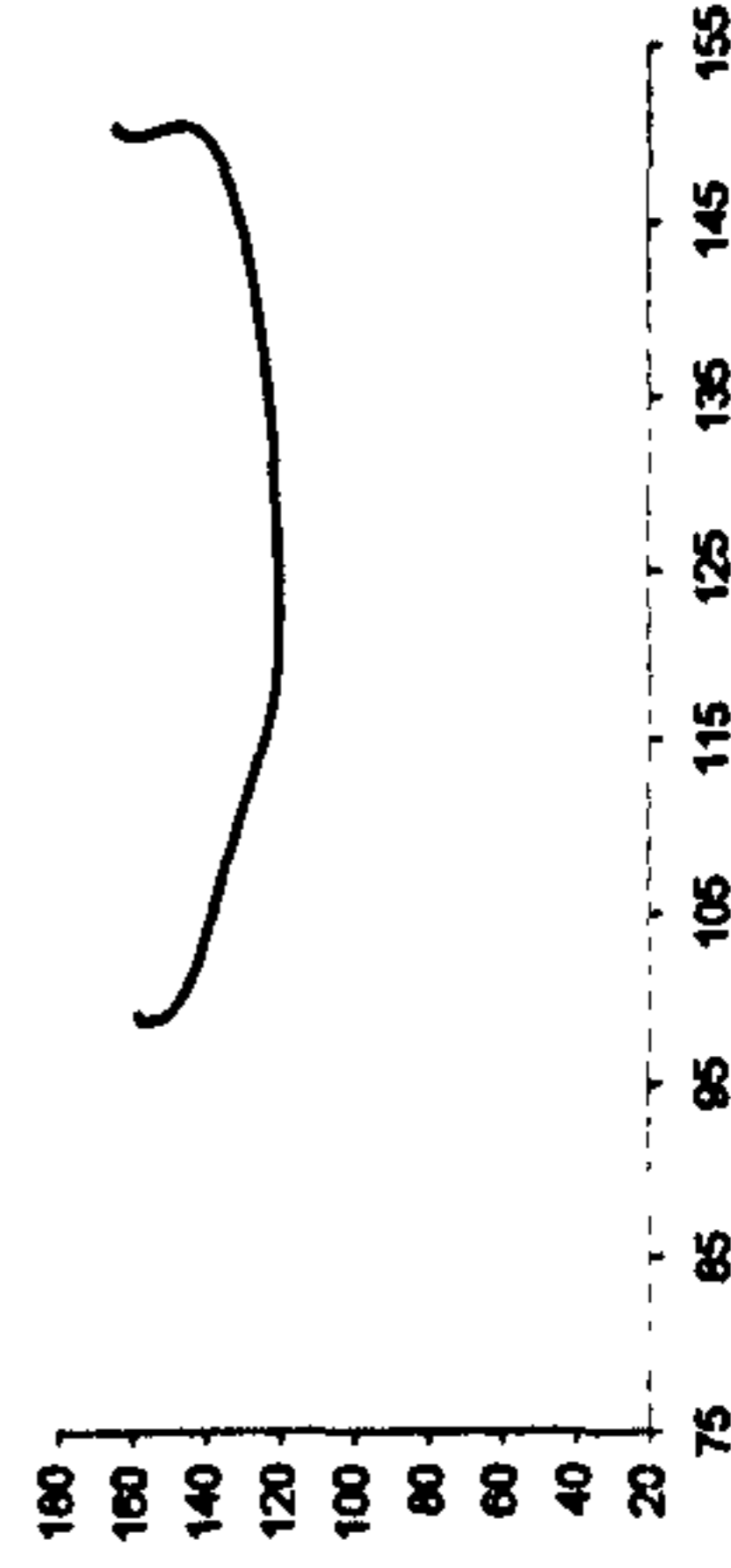
MODEL



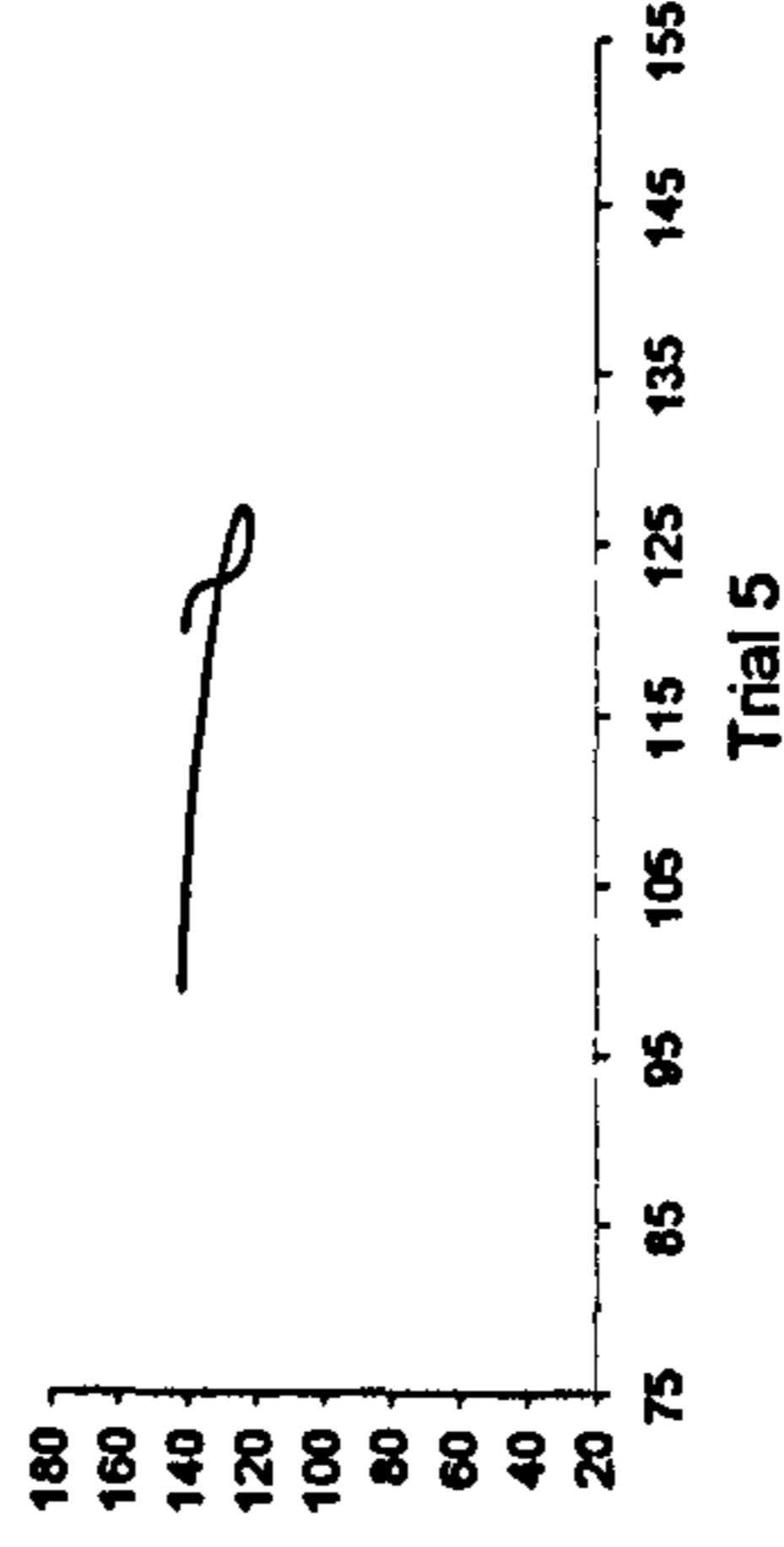
Trial 5



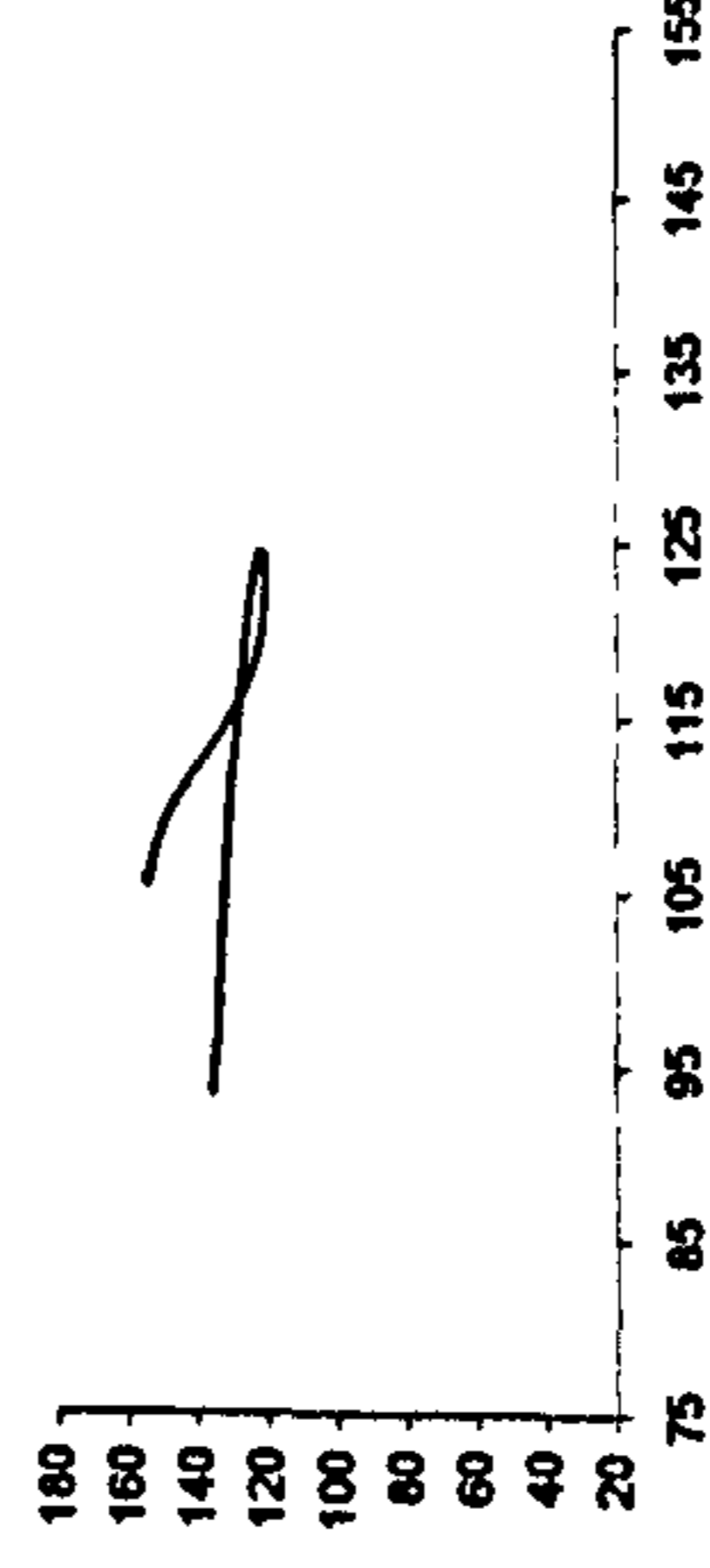
Trial 10



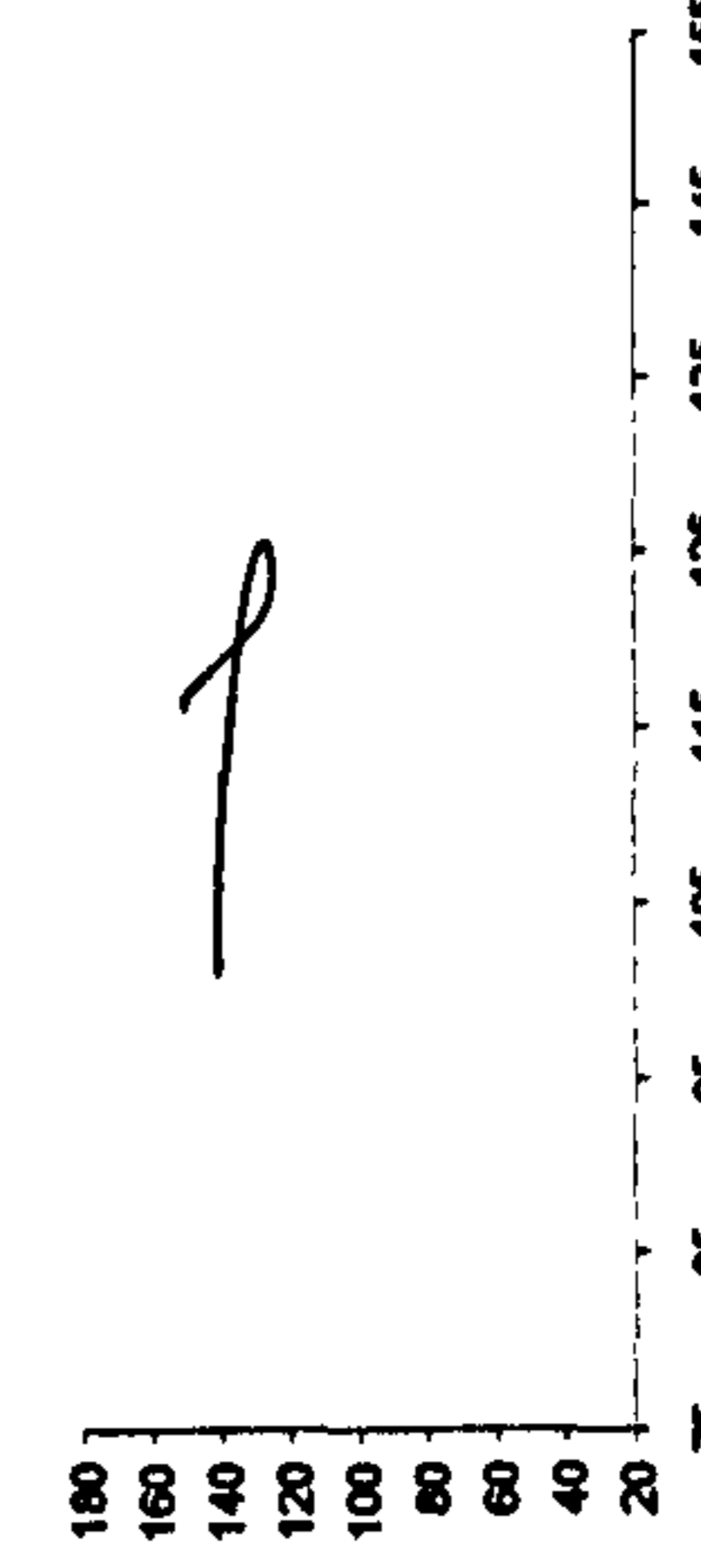
Post-test Trial 1



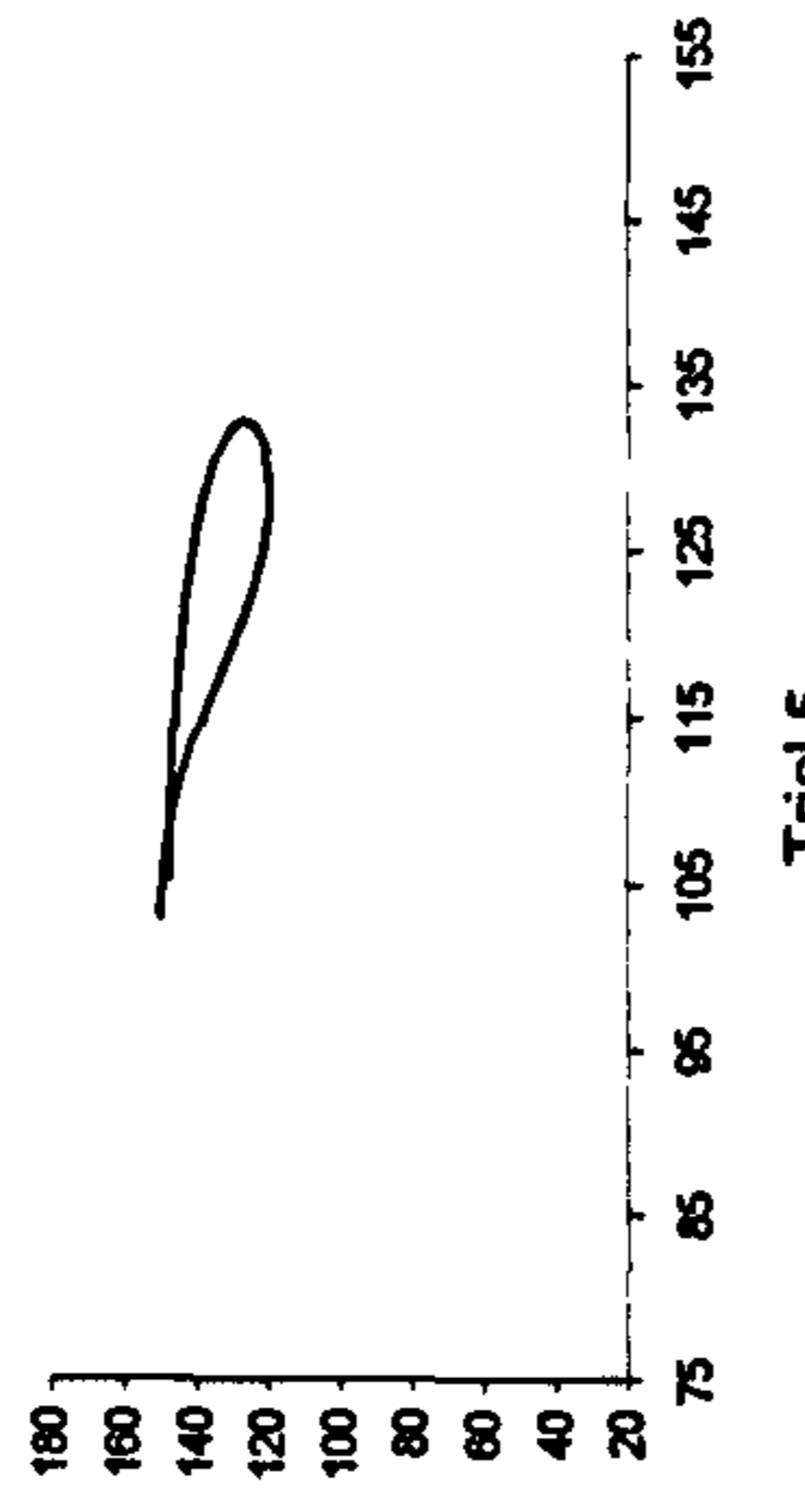
Trial 5



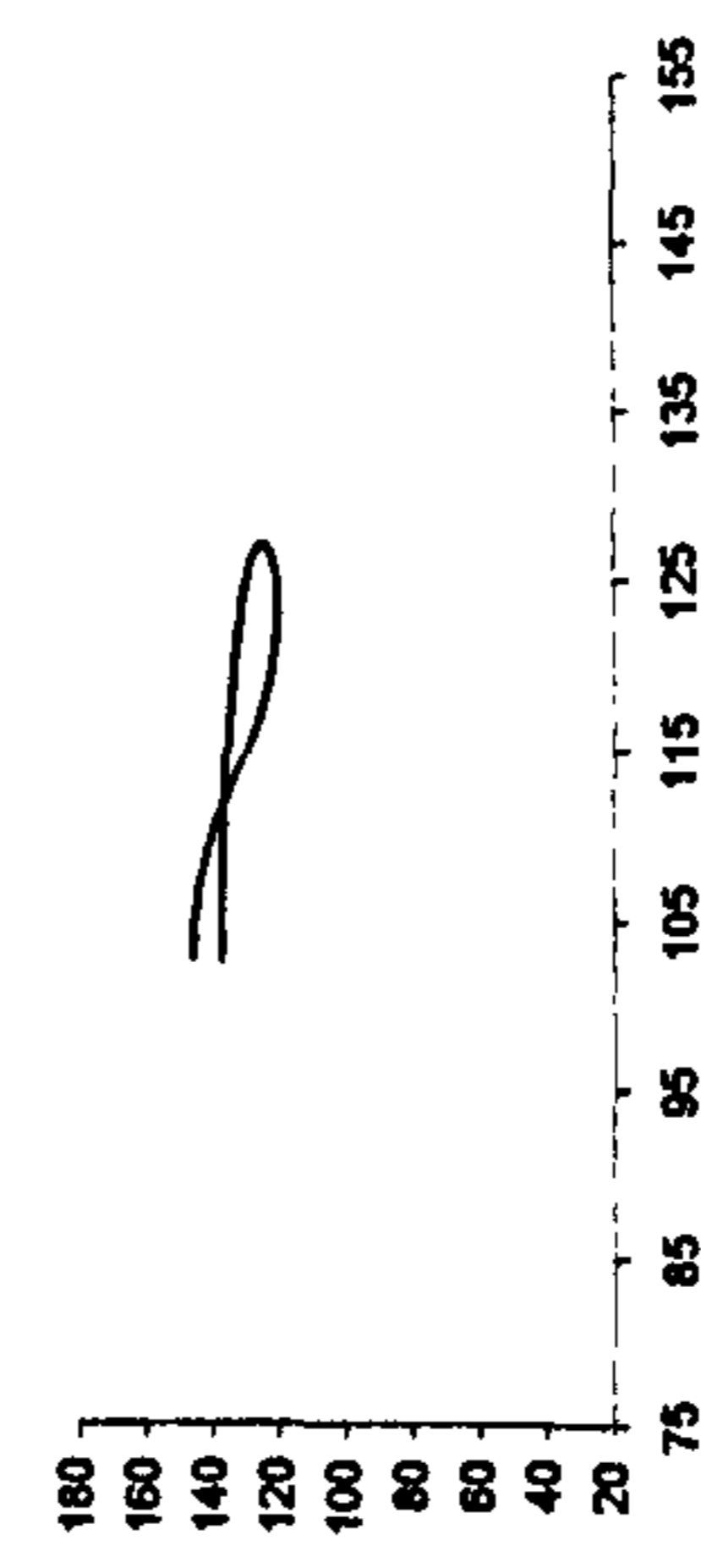
Trial 10



Retention test Trial 1



Trial 5



Trial 10

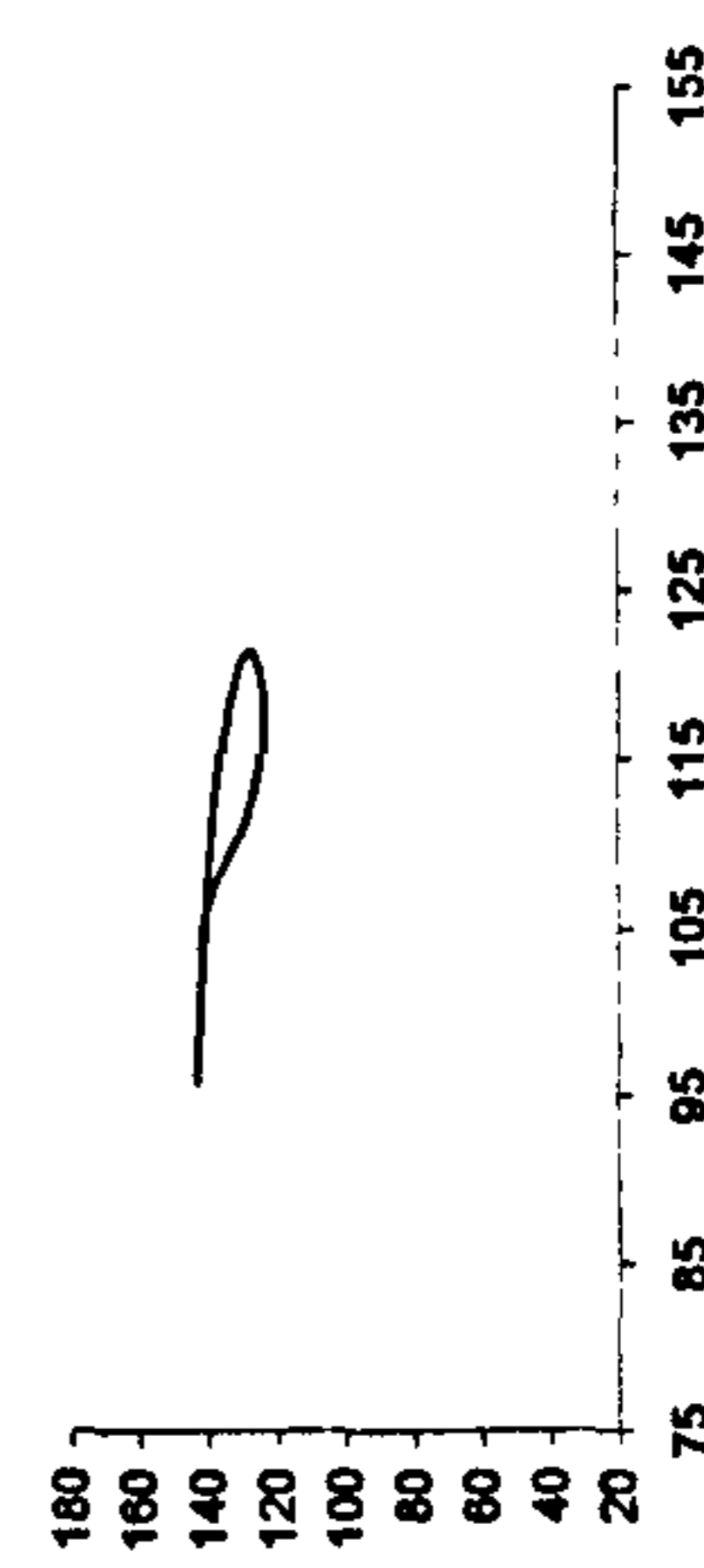


Figure 2.9. Knee-ankle angle-angle plots for the VIDEO participant in pre-test, post-test, and retention test.

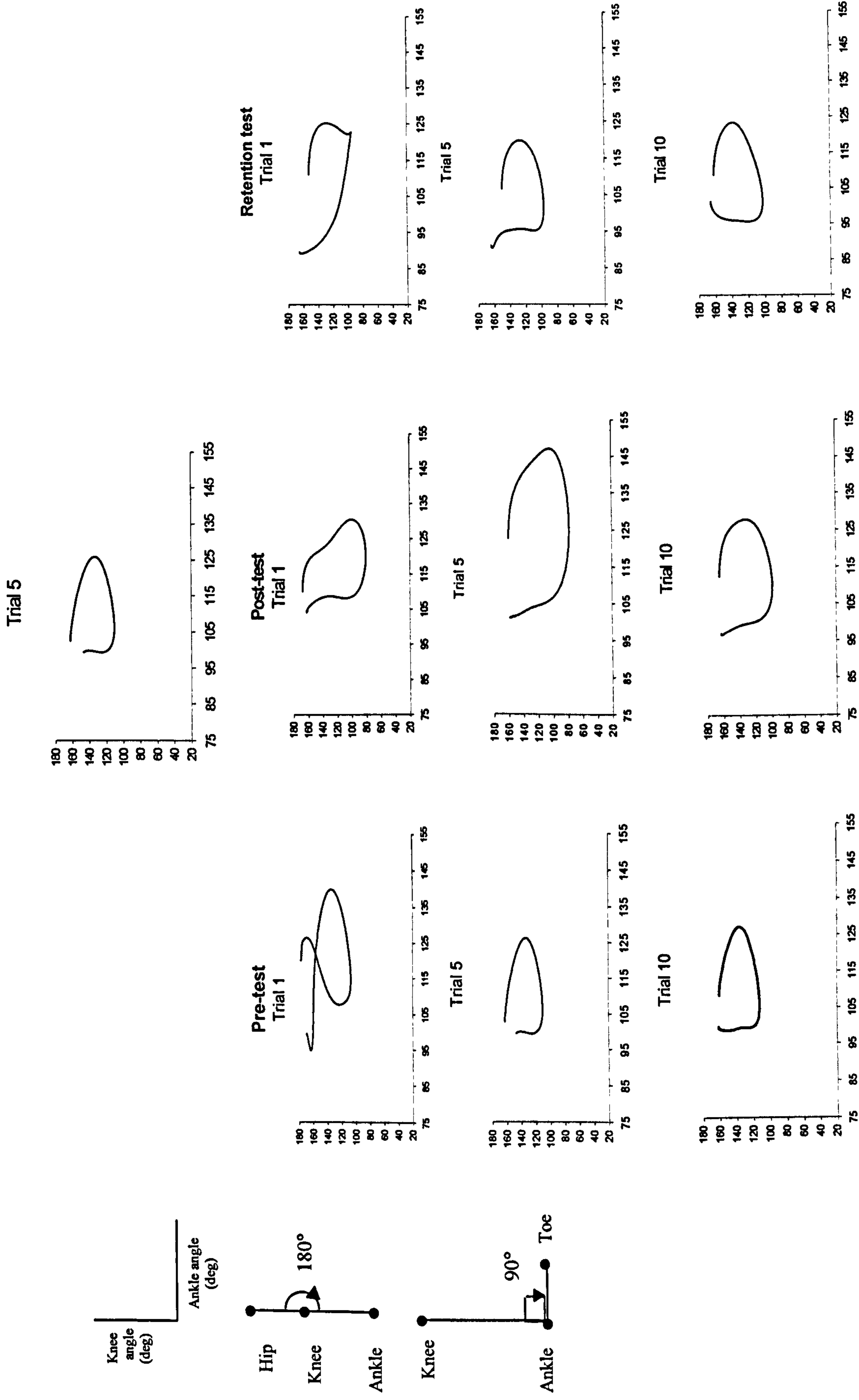


Figure 2.10. Knee-ankle angle-angle plots for the PLD participant in pre-test, post-test, and retention test.

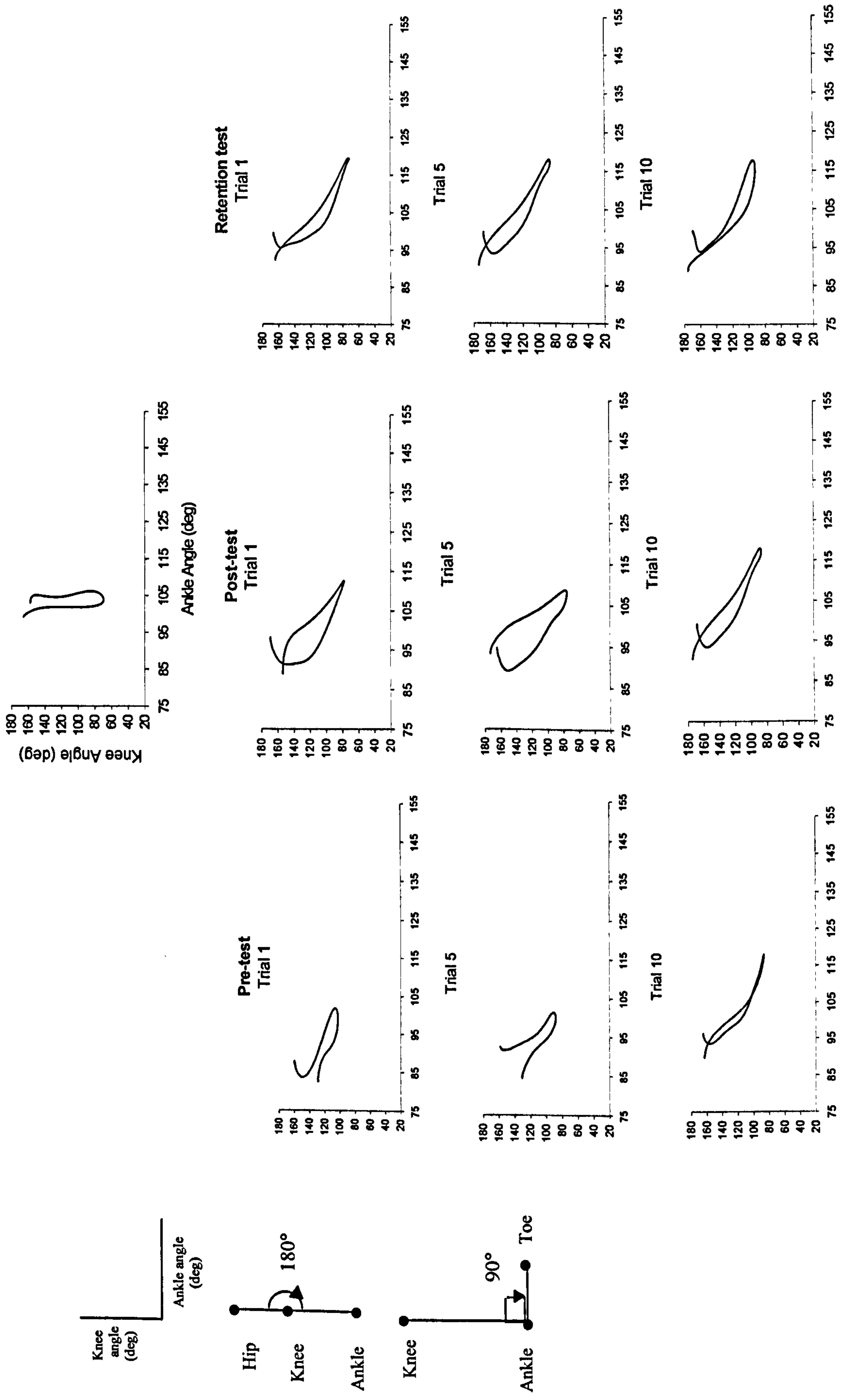


Figure 2.11. Knee-ankle angle-angle plots for the control participant in pre-test, post-test, and retention test.

Discussion

The aims of this study were to compare visual search strategies in response to video and point-light models and to examine the effectiveness of each mode of demonstration in facilitating task outcomes and correct movement form. It was hypothesised that participants observing the point-light model would learn outcomes and coordination better than those observing the video model. It was also hypothesised that participants observing the point-light display would illustrate more selective search than would those observing the video model. Furthermore, it was anticipated that search strategies would become more refined within and between successive periods of observation, regardless of viewing condition.

The results indicated an overall learning effect across all groups for outcome assessment. All three groups developed greater accuracy on the task, coupled with decreased outcome variability. However, observation of a model did not appear to facilitate the learning of task outcomes over and beyond those participants who practised the task with knowledge of results. This supports the findings of Romack (1995), while contradicting those of Landers and Landers (1973). Newell's (1985) classification of coordination, control and skill as an embedded hierarchy in stages of learning may explain the results. For the participants observing the models, the task was one of acquiring a specific and new movement topology and of scaling the new relative motion pattern in order to hit the target area. The group not using a model could explore their own, intrinsic movement patterns and scale them appropriately. It is important to note that Newell (1985) does not suggest that coordination (the assembly of a new movement topology) precedes control (the parameterisation of the movement pattern), but rather that coordination is the organisation of control. As such it would be inaccurate to suggest that the modelling groups were in a *coordination* phase of learning while the

control group were in a *control* phase of learning. It would appear that since the CONTROL group participants were adjusting their own naturally occurring kicking motions, the assembly of an appropriate topology was simpler, facilitating the organisation of control. In contrast, the participants in modelling groups tried to acquire an unnatural topology, experiencing more complex assembly of the relative motion pattern. This would result in diminished organisation of control and arguably less intrinsic links with the control of the movement. The implication for past and future research is that for tasks in which the goal for participants observing a model is to achieve a prescribed outcome and replicate a movement pattern, the benefits of the model may be offset by heightened task complexity. As such, in comparison to control groups, outcome scores for modelling groups may be similar, or worse (e.g., Romack, 1995).

No support was found for the prediction that viewing a point-light display model would be more effective in learning than observation of a video model. The fact that these groups did not differ supports the finding of Williams (1989b) with darts-style throwing. This finding suggests that neither the additional structural information afforded by video, nor the greater accessibility of relative motion in a point-light display led to superior learning.

In terms of movement kinematics, the observation of a model facilitated the acquisition of the model's global pattern of coordination. Participants who practised the task without reference to the model gradually decreased their approach to the ball, becoming less like the model, whereas those observing the video and point-light models increased their steps to match the model's three-step approach.

At a local level of analysis, the benefits of observing the model are limited to temporal factors. Participants observing the models developed closer replication of the

temporal phasing of knee flexion and extension, while the control participant became more disparate to the model. The participant observing the video model also developed a marked reduction in variability of the temporal phasing from pre-test to the retention test, whereas the PLD and CONTROL participants maintained somewhat equivocal variability.

Joint range of motion analysis provides no evidence for the benefit of observing a model. For the knee joint, range of motion increased for the control participant through practice alone. For the hip joint, again in retention, the CONTROL participant was most like the model. However, the VIDEO participant showed a distinct decrease in joint angle and variability from pre-test to retention. Finally, in retention, all participants showed similar ankle range of motion, but in achieving this the control participant became less like the model, the PLD participant maintained pre-test range of motion and the VIDEO participant decreased her range.

The angle-angle plots used in the experiment to illustrate intra-limb coordination did not show any advantage as a result of observing a model when learning a movement pattern. This finding supports that of Southard and Higgins (1987), who found participants exposed to a model performing a racketball forehand shot did not show superior adjustment of limb configuration when compared to the control group. Figures 2.6 to 2.11 show greater stability in the joint couplings of the CONTROL participant. For example, Figure 2.8 indicates that knee-hip relative motion was adjusted in the first five kicks of the pre-test (measurements taken at trials 1 and 5). By the third pre-test kick on trial 10, a movement pattern emerged which remained stable thereafter. This observation supports the notion that the control participant experienced less complex coordination of the movement pattern, facilitating the parameterisation or *control* of the movement.

The VIDEO participant shows little improvement in her pattern after observation of the model. Shallow *wells* indicated low knee range of motion, with excessive motion at the hip and ankle. The PLD participant showed somewhat more improvement. She achieved deep *wells* through better knee range of motion, but showed larger patterns due to high ankle and hip range of motion. Although coordination improved in the retention test, the patterns were not superior to the CONTROL participant.

The evidence presented in this experiment suggests that the model was beneficial only in gaining global representation and temporal phasing of the movement. Some research evidence supports the notion of preference for these features. Bertenthal (1993) found some subjective reports by observers viewing biological motion suggesting that they perceived an emergent human form rather than individual features or local relations. Following up on this, Bertenthal and Pinto (1994) found that participants could detect human locomotion (even when common motion was subtracted by walking on a treadmill) from many other moving lights during presentation for just one second. However, on inverting the display, recognition was not greater than chance. It is unlikely that absolute or local relations were extracted in the short presentation time, but instead an orientation-specific global form was perceived. It is logical that, if the visual system is tuned to global representation of form, then the global, gross pattern of coordination is more likely to be perceived and imitated. In the current experiment, the participants may have acquired the global movement pattern and then focused on task outcomes. Also, the experiment used a relatively short acquisition period. As such, the participants may not have been able to acquire the local relations or intra-limb coordination in this time. Bertenthal and Pinto (1994) also found that perturbations of the temporal features of the point-light display was more detrimental to recognising human movement than perturbation of the spatial positions. If the perceptual system is

found to be more tuned to temporal features in biological motion, it follows that these are more easily - or at least more rapidly - learned. Williams (1989d) found that when the speed of the demonstration was manipulated, participants rapidly adjusted their cadence to the display, and this did not change with practice. The participants were also most accurate at the naturally occurring speed.

The visual search analysis elicited fewer differences between the VIDEO and PLD groups than anticipated. If, as Just and Carpenter (1976) imply, fixation duration is taken as an indicator of the processing demands upon the observer, the results suggests that no greater demand was placed on the VIDEO participants with the inclusion of structural information. Fixation duration was fairly consistent at around 300-350ms. These values fall between those found in response to very familiar practice situations in golf (100 ms; Vickers, 1992) and those found in complex team sports (850-1500 ms; Williams and Davids, 1994). Some support was found for the hypothesis that observers of the point-light display would show more refined search than those observing a VIDEO model. The VIDEO model contained distracting structural information, inducing a relatively greater amount of viewing time to less informative areas of the display, such as the head and face. In an applied context, the results of this experiment suggest that using video models in teaching may induce greater levels of distraction than PLD models, but the learning process is not necessarily hindered. This finding, however, may be a function of the number of observations given. If the participants received 3-5 presentations rather than a total of 15, then perhaps the effect of sampling non-informative areas in the VIDEO group may have manifested itself in poorer learning.

The visual search data suggest the preferential perception of a global representation of movement on two counts. First, when compared to the VIDEO group, the PLD group

employed a more *synthetic* search strategy. That is, the participants directed their gaze to positions in the display from which the greatest amount of the action can be seen and grouped from a single fixation (see Ripoll, 1991). Many fixations were located behind and ahead of the model's body. Due to the abundance of rods in the periphery of the retina, the perception of both movement and light are more effective if the stimulus is located in the periphery. In this manner, the global pattern of movement can be perceived, but lower visual acuity means that the specifics of the movement are not readily picked up. Second, the fixation data illustrated in Figure 2.3 shows the marked preference for fixations to the lower body for the PLD group. These were specifically oriented toward the ankles and knees. However, the participants did not learn the correct angles or the local relations at these centres. It is likely that participants fixated these areas as a reference point to pick up information in the periphery (Rockwell, 1972). This 'visual anchor' or 'pivot' would then facilitate pick up a global representation of the movement.

The prediction that visual search would become more refined over time was partially supported. Although search rates did not change, participants fixated on successively fewer areas of the display across observation periods. This pattern of less-to-more selectivity was also evident within observation periods. Participants fixated on significantly fewer areas of the display in the last trial than in the first, second, or fourth. These results point once again to the global representation of the relative motion pattern being sought and acquired before localised, intra-limb information.

Finally some reference should be made to the role of knowledge of results. In using a shallow sand-pit to clearly mark the ball's landing position, powerful visual intrinsic feedback was available to all participants. As Swinnen (1996) noted, this intrinsic knowledge of results promotes self-initiated, error-detection and correction. In

the absence of knowledge of performance, participants lacked a clear understanding of the way in which their coordination was changing in response to the model. Therefore, knowledge of results is likely to be the motivating and constraining source of information, diminishing the impact and reliance upon the model. Future work is planned to eliminate visual intrinsic knowledge of results and it is anticipated that greater differences will be found in visual search strategies in response to VIDEO and PLD models, and that more marked changes in coordination will emerge during acquisition and retention.

The results of this study suggest that in learning a complex motor skill, a model may provide the basis for primarily gross, holistic imitation in the absence of verbal guidance or augmented feedback. The search for information on which to base this imitation also appears to proceed from wide to narrow, perhaps indicating the need to develop this holistic impression before seeking information at a localised level. The search patterns by which participants 'pick-up' this information are more refined in response to point-light models, however the structural information of video does not appear to impede the learning of relative motion patterns, when compared with point-light displays. The similarity in visual search data between PLD and VIDEO participants and the correspondence in their outcome and process measures suggests that the information picked up from video is the same relative motion that is readily available in point-light displays, as suggested by Scully and Newell (1985).

Chapter 3

**Visual Search and Coordination Changes in Response to Video and Point-Light
Demonstrations in the Absence of Intrinsic Knowledge of Results**

Abstract

This study examined the predictions of the visual perception perspective (Scully & Newell, 1985) in conditions in which participants were constrained to use the model as their primary source of information, through the absence of intrinsic visual KR. The task for 24 novice females was to chip a soccer ball 5 m to a target. Participants were matched and assigned to video (VID), point-light (PL), and no model (CON) groups. During testing, participants wore earplugs and vision was occluded at contact with the ball. Pre- and post-tests were performed, interspersed with 2 alternating periods of observation of the model and acquisition. Retention tests were performed without and then with KR 2-3 days later. Visual search behaviour was assessed during observation of the model and kinematic and outcome data were collected in all test and acquisition periods. The results showed that in the absence of intrinsic KR, participants did not learn to reduce radial error. However, participants observing the PL and VID models became immediately more like the model in terms of intra-limb relative motion and the number of steps used to approach the ball. These changes remained through retention, and were not observed for the CON group. Participants observing the PL model illustrated more selective visual search than those seeing the VID model, but this was not reflected in differences in coordination between the 2 groups. In support of the visual perception perspective, the coordination data showed that VID and PL models do convey relative motion information. However, in the absence of intrinsic KR, the saliency of relative motion resulted in more rapid changes than previously reported.

Variety in the type of task and practice conditions used in observational learning research has resulted in considerable uncertainty regarding the efficacy of demonstrations. In particular, the precise nature of information picked up and used by the learner remains unclear. Contributing to this situation has been the tendency to measure learning by outcome scores, such that it has been difficult to establish links between the precise nature of information seen, and the way in which that information mediates the movement response. The aim in the current study was to examine the observational learning of a motor skill in which changes in relative motion, or coordination, was the primary dependent measure. To facilitate our understanding of the information used, eye movements were recorded during observation of the model.

An appropriate theoretical framework within which to study the motoric changes that occur in skill acquisition is Newell's (1985) embedded hierarchy of coordination, control, and skill. In this hierarchy, Newell operationalized the concepts introduced by Kugler, Kelso, and Turvey (1980). From this perspective, coordination represents the assembly of a new movement topology, while control denotes the parameterization or scaling of the coordination function. There has been a tendency in the literature to refer to this assembly and parameterization in terms of 'coordination' and 'control' stages (e.g., Handford, Davids, Bennett, & Button, 1997). However, an embedded hierarchy does not imply serialization of processes, but rather uses Bernstein's (1967) view that coordination is the organization of control. Skill, in turn, refers to the optimization of the coordination and control synergy.

In early skill acquisition, the dominant factor in this synergy is considered to be coordination. Therein, the topological properties of relative motion (motion of limbs, segments or points in a configuration relative to each other) are deemed essential

information in assembling this coordination function (Newell, Morris, & Scully, 1985). Several authors have suggested that visual demonstrations can provide this essential motion information to the learner (e.g., Cutting & Profitt, 1982; Scully & Newell, 1985). As such, demonstrations are expected to be more effective early in the skill acquisition process, rather than later, when parameterization of an existing movement pattern is predominant.

The prevailing theoretical backdrop to observational learning research is Bandura's (1977) social learning theory. According to this theory, when observing a model, the learner forms a cognitive representation of the act via the component sub-processes of attention, retention, motor production, and motivation. This representation then guides subsequent re-enactment. Bandura's theory does not readily compliment a hierarchy of coordination, control, and skill for several reasons. First, much of the research it has inspired has utilized tasks that do not require participants to learn a new coordination pattern. The prototypical task has been one in which the goal has been to achieve an outcome irrespective of the movement pattern employed (e.g., barrier knock-down, McCullagh & Caird, 1990; computer tracking, Pollock & Lee, 1992). Heyes (2001) has criticized researchers for failing to distinguish between the processes of imitation (copying of model's bodily movements) and emulation (copying the movements of the employed object). In the aforementioned studies, the task outcomes may have been achieved by emulation, without demands on participants to replicate any component of human motion. It is particularly difficult to distinguish between these two processes when learning has only been measured by outcome or error scores. To effectively assess how demonstrations have affected learning, and specifically how they have influenced coordination and control, some measure of movement form, such as subjective ratings or kinematic analyses is needed.

An ecological alternative to Bandura's social cognitive theory, which encompasses notions of coordination, control, and skill, is Scully and Newell's (1985) visual perception perspective. This approach emphasizes what information is taken from the display, rather than how the process of imitation occurs. It has been heavily influenced by Gibson's (1950, 1979) theory of direct perception, and Johansson's (1971, 1976) biological motion studies. Johansson showed that humans are capable of rapid and accurate discrimination of different types of locomotion from point-light displays, in which only points of light are visible at joint centers. Static displays, in contrast reveal little information to the observer. More recently, researchers using point-light stimuli have found that participants are able to perceive properties such as gender from gait (e.g., Mather & Murdoch, 1994), emotion in dance (e.g., Brownlow, Dixon, Egbert, & Radcliffe, 1997), affordances for action (Stoffregen, Gorday, Sheng, & Flynn, 1999), and hidden dynamic properties such as the mass of lifted objects (e.g., Runeson & Frykolm, 1981; Shim & Carlton, 1997).

When perceiving moving point-light displays, or events, the visual system appears capable of 'automatic visual processing' (Johansson, 1973). Cutting and Proffitt (1982) showed in a series of experiments that the visual system can minimize common motion (the motion of all elements in a configuration relative to the observer) or relative motion (the motion of elements in a configuration relative to each other; for a review, see Bruce, Green, & Georgeson, 1996). Scully and Newell (1985) suggested that when observing a moving demonstration, the visual system perceives and automatically minimizes relative motion. When the learner attempts to re-enact the observed movement, this relative motion pattern acts to constrain the emergence of coordination through its informational or instructional properties (see Warren, 1990). Al-Abood,

Dauids, and Bennett (2001) suggest that these constraints guide the search for motor solutions in the 'perceptual -motor workspace'.

Scully and Newell's (1985) predictions that learners perceive, minimize, and become constrained by relative motion have rarely been directly tested. Some indirect evidence in support of the visual perception perspective has been provided by researchers who have compared groups that observe a model with no model (discovery learning) control groups. Schoenfelder-Zhodi (1992) found that participants who observed a model more closely matched the model's relative motion and outcomes (amplitude) in a ski simulator task than those left to discover the dynamics of the task without viewing a model. Similarly, Al-Abood et al. (2001) found that a model conveyed the relative motion pattern of an underarm dart throw more effectively than verbal guidance and discovery methods. Finally, Horn, Williams, and Scott (2002; Experiment 1) found that participants who observed a model perform a soccer chip showed more similarity to the model than a no-model control group. These effects were in terms of global movement parameters such as the number of approach steps, rather than the local relative motions within limbs.

Runeson (1984) has suggested that the removal of structural information via point-light facilitates the perception and recognition of motion since it removes non-essential information, leaving relative motion salient. As such, one might anticipate superior perceptual performance in response to point-light rather than video stimuli. In support of this argument, Pellechia and Garrett (1997) found that physical therapists made more reliable assessment of lumbar stabilization from point-light rather than video displays. However, in learning studies, the point-light versus video comparison has yielded largely equivocal results. For example, Romack (1995) found that participants who observed a point-light model dribbling a basketball were less accurate in their

movement outcomes (number of consecutive bounces) and form (phasing between the ball and the hand) than a no-model control group or those participants viewing a video model. In this study, the participants were young children and the kinematic measure was phasing between the hand and ball. It is questionable whether the surface information of the ball afforded by video was matched in the point-light condition. Contrasting findings were obtained by Scully and Carnegie (1998) in the learning of a ballet sequence. Participants who observed a point-light model perform the sequence were more accurate in outcome measures such as landing position. The point-light group also more closely imitated the model's angular displacement and relative timing than participants watching a video model.

Most recently, Horn et al. (2002) compared the effect of point-light and video demonstrations on learning a soccer chip. In this study, the way in which point-light and video models influenced the learning of a movement task that had both a complex form component and an objective target goal was examined. To determine what information in the demonstration was attended to, participants' eye movements were recorded during each observation. Three periods of acquisition were interspersed with three periods of observation. Learning was assessed in terms of outcome scores (absolute and variable error), and coordination at a local, intra-limb level (knee-hip and knee-ankle relative motion) and a global, participant-object level (number of steps in approach to the ball) levels. No differences were found between the video and point-light groups in outcomes or coordination.

Based on the apparent equivalence in learning between video and point-light models, it could be argued that the relative motion, which is salient in point-light displays, is readily abstracted from structured video displays. However, some important factors that may potentially contribute to the equivocal findings between video and

point-light should first be given consideration. The foremost of these factors is the presence of intrinsic knowledge of results (KR) in most of these studies. The importance of intrinsic KR is widely recognized in the motor learning literature. For example, Swinnen (1996) noted that it promotes self-initiated error detection and correction, which according to Schmidt and Lee (1999), operates relative to a reference of correctness.

Such a rich source of information may be the constraining source of information in a learning environment. In many experiments the task is to achieve an outcome while replicating the model's form (e.g., Al-Abood et al., 2001; Horn et al., 2002). In these experiments, participants may attempt to replicate the model's form immediately after viewing the demonstration. However, following the first trial intrinsic visual KR may become the primary information constraining subsequent attempts at the task (Horn et al., 2002). If the model is not the primary source of information, or it is not being used at all, then the comparison of point-light and video is undermined. The first aim of the following experiment was therefore to extend the Horn et al. (2002) study, by removing intrinsic visual and auditory feedback about the outcomes of the action.

In order to understand the interaction between intrinsic visual KR and changes in movement patterns, it is necessary to quantify coordination. Furthermore, to assess the effects of observing a model, it is important to assess similarity in the relative motion patterns of the model and the learner. Al-Abood et al. (2001) have recognized that this requirement has often been overlooked in previous research (e.g., Magill & Schoenfelder-Zhodi, 1990; Southard & Higgins, 1987). If, as suggested by Scully and Newell (1985), it is relative motion that we are attuned to, then changes in relative motion to become more like the model should be observed. Furthermore, some researchers in observational learning have also neglected to measure variability in

movement patterns (e.g., Magill & Schoenfelder-Zhodi, 1996). If early learning predominantly involves the assembly of a new movement topology, we would also expect greater variability in movement patterns early in learning rather than later, when parameterizing the movement is prioritized. Consequently, in this study, we aimed to quantify coordination in terms of both variability and similarity to the model.

Previous comparisons between point-light and video models have typically measured effectiveness by way of learning (i.e., long term retention). However, if point-light displays contain only salient topological information, we might anticipate that not only would they be more effective than video models, but also more efficient, as measured by a rate of acquisition or immediate effects. Since learning studies require many acquisition trials, differences in rate of acquisition, or immediate effects of viewing the model, are likely to be diluted. Such measures have not featured often in observational learning research. Two studies which have given some indication of the rate of changes are Williams (1989a) who used the number of trials to achieve a correct sequence, and Al-Abood et al., (2001) who examined relative motion patterns at the end of the first period of acquisition in an underarm dart throwing study. Therefore, in addition to measuring learning effects, this study aimed to examine the immediate impact of observing a model on relative motion by comparing changes in coordination from the pre-test to the first three trials of acquisition.

The final aim of this study was to facilitate understanding of what information learners pick up from a demonstration by examining visual search behaviours. It was assumed that visual search provides a reliable index of the information used to guide action. For example, the visual search of experienced and inexperienced soccer players yields different scan paths in response to the same in-game video sequences. The experience of the experts is assumed to allow them to differentiate redundant areas from

those pertinent to upcoming events (e.g., Williams, Davids, & Burwitz, 1994). In observational learning specifically, the involvement of visual search is implied by evidence that errors in modeling arm movements increased when learners observed a demonstration using eye movements unlike their typical scan paths (Williams, 1989c).

Given that visual search represents the shifting of attention to informative areas of the display, it follows that if intrinsic visual KR is the primary source of information for action, then the search for meaningful information from the model may be diminished. This may explain the findings of Horn et al. (2001) that only small differences existed in participants' visual search while observing video and point-light models. Those watching the point-light model were more selective only in terms of the number of areas of the model's body sampled, while both groups became more selective in their gaze orientation with successive trials and observation periods. In the present study, by limiting the participants' sources of information through the removal of intrinsic visual KR, differences in visual search between point-light and video groups should be accentuated.

It was predicted that the salience of relative motion in point-light displays would lead participants observing the point-light model to learn the model's relative motion pattern more effectively than those observing the video model. It was further predicted that the point-light model would induce greater immediate changes in coordination than the video model. These differences were expected to be facilitated by more selective visual search patterns in response to the point-light rather than the video the model, as evidenced by lower search rate, fixations on fewer areas of the model's body and higher relative fixation times on lower body fixations. Finally, a control group was also examined. This group did not receive any demonstration, and was included to ensure that immediate and long-term changes in relative motion were not the result of

adaptations to a new skill, rather than as a result of watching the model. Both model groups were anticipated to show greater learning and immediate changes in coordination than the control group.

Method

Participants

Twenty-four female students (M age = 22.5, SD = 4.7 years) provided informed consent prior to taking part in the study. The participants were matched on pre-test radial error scores and allocated to one of the point-light model, video model, or no model control groups ($n = 8$). All were considered novice at the task since they had never played soccer on a regular basis, and had not received formal instruction in the sport. Female participants were included to maximize task novelty as girls in the UK have, until recent years, had limited opportunity for involvement in soccer. All participants were right-side dominant.

Task and Test Films

The task was to chip a soccer ball over a barrier 0.35 m in height a distance of 5.0 m. This movement was selected as the chip is not considered an intrinsic form of kicking, but rather is a soccer-specific action. A target area was constructed of 64 x 50 cm² squares; a red cross indicated the target center. The model was a collegiate level female soccer player (age = 18.6 yr). After a period of practice, the model was filmed in a sagittal plane using a video camera (Panasonic M-40) during the performance of a successful chip. The spatio-temporal positions of 18 retro-reflective markers were registered by four infrared cameras (Pro-Reflex, Qualisys) sampling at 240 Hz. These were positioned at the conventional anatomical landmarks of the model's major joint centers. These data formed a point-light display via the Q-Trac View Motion Viewer

(Beta 2.54; Qualisys). This image was then transformed in the program to match the video presentation and converted to VHS format. Since the same model and trial was employed to create both groups' test films, the kinematic data facilitated the production of a coordination or relative motion profile for both models. This profile served as the basis for comparison with participants' kinematic profiles across groups.

Procedure and Design

A summary of the experimental design employed is provided in Figure 3.1. Participants were matched on pre-test radial error scores and assigned to one of three equal ability groups: video model (VID); point light display model (PL); no demonstration (CON).

The ball was placed on a switch embedded in the laboratory floor. As the participants made contact with the ball, the switch triggered a head mounted, polymer dispersed liquid crystal screen (Plato S-2, 1987) so that vision of the ball's flight path and landing position was immediately occluded (< 3 ms). Participants received five acclimatization trials in which they kicked the ball to an experimenter located 2-3 m away. The participants wore earplugs to minimize auditory cues from the ball.

Prior to the pre-test, retro-reflective markers were placed on the ball (size 5; 5 psi) and on the participants' right side at the 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). Finally, participants received standardized instructions informing them to approach the ball in a straight line, kick with their right foot, and keep their hands above the height of their hips.

Five trials were performed in the pre-, post-, and retention tests, and 20 trials were performed in each acquisition period. Kinematic data were collected on each trial

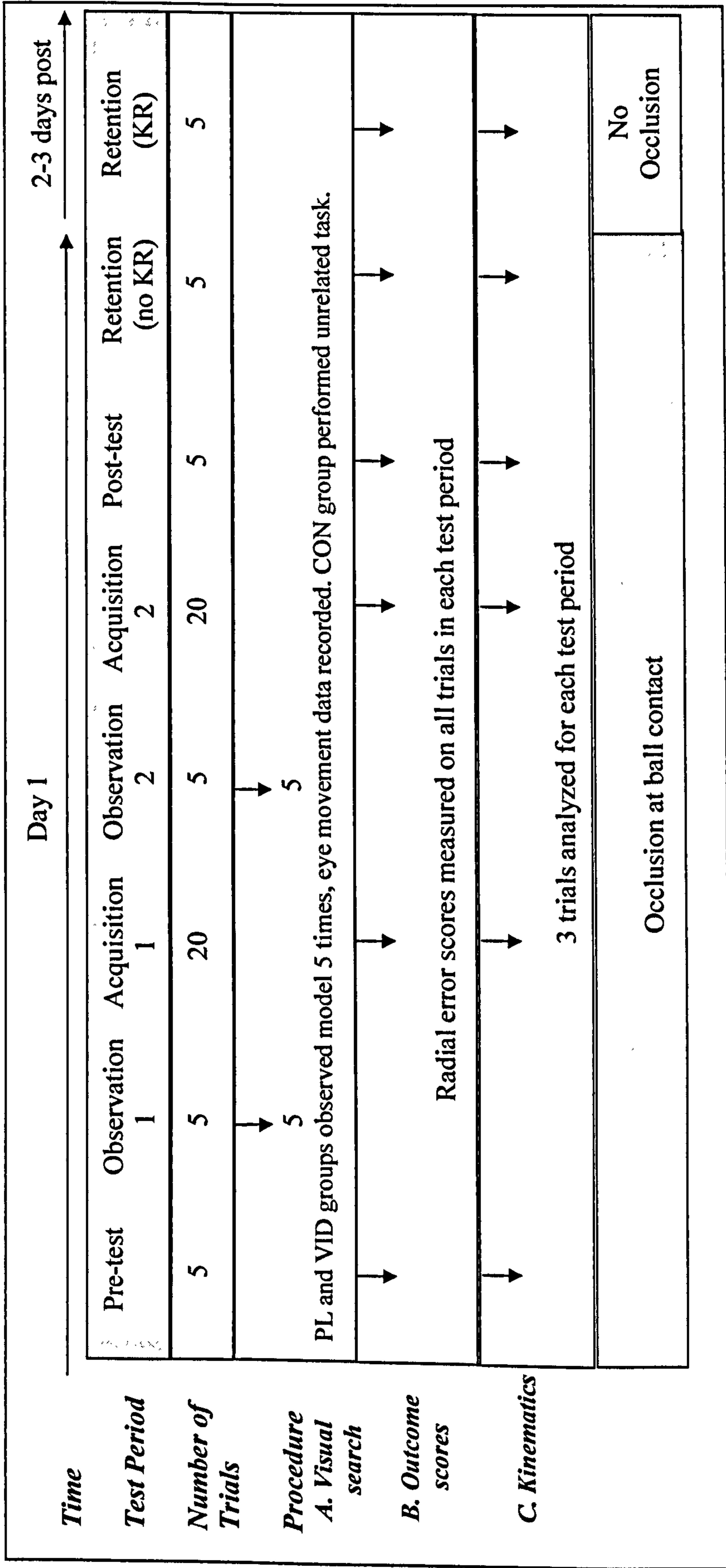


Figure 3.1. Summary of the experimental design and procedure

of pre-, post- and retention tests, and on the first three trials of acquisition using four infrared cameras (Pro-Reflex; Qualisys) sampling at 240 Hz.

Participants in the PL and VID groups were given standardized instructions prior to observing the model. These informed participants that after observing the model, they should continue to try to hit the target, by exactly replicating the model's form or style.

All demonstrations were back-projected onto a screen (Cinefold; 3.0 m x 3.5 m) placed 5 m from the participants, such that the model subtended a realistic visual angle of 18°. In each observation period, participants were presented with five repetitions of the same trial of the model's action. Visual search behaviours were recorded using an Applied Science Technologies (ASL) 4000SU eye-movement registration system and a magnetic head tracker (Ascension Technologies, Flock of Birds 6DFOB). This combined system produced accuracy of $\pm 1^\circ$ of visual angle (for details of this system, see Horn et al., 2002; Williams & Davids, 1998).

Participants in the demonstration groups also observed one repetition of the model following each of the first five trials of acquisition. This image was presented via a Sanyo Monitor. For participants in the CON group, an unrelated computer activity was performed for five minutes at times corresponding to the observation periods.

Dependent measures and data analysis

Outcome scores. On each trial, the x and y coordinates of the ball's landing position were measured from the center of the target (in centimeters). The scores were recorded to produce radial error (calculated as the hypotenuse of the triangle made from distances x and y). Means and standard deviations for radial error were then calculated for each test period.

Coordination. The data for five randomly selected participants in each group were used in kinematic analysis. The effects of viewing the models were assessed via changes in coordination in terms of immediate effects (from pre-test to the first three trials of acquisition) and learning effects (from pre-test to retention). These changes in coordination were further assessed at two levels of analysis. At a local level, intra-limb coordination was assessed in the kicking leg. This process required the start and end points of the analysis of the kick to be normalized due to large variation in approach to the ball. Analysis commenced at the initiation of knee flexion in preparation for the back swing of the kick and ended at the moment of maximal knee extension following contact with the ball. 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.

Variability in intra-limb coordination was quantified using a modified version of Sidaway, Heise, and Schoenfelder-Zhodi's (1995) normalized root mean squared error (NoRMS). The root mean squared error was calculated based on disparity of each trial from the mean trace. The score was normalized for number of trials and excursion. Since a larger movement pattern may exhibit more variability than a similar, smaller pattern, Sidaway et al. (1995) normalized for scale using total distance. However, we used an interpretation presented by Mullineux, Bartlett, and Bennett (2001), in which excursion reflects range of motion for the angles in the angle-angle plot. This is a more appropriate measure of excursion because in an angle-angle plot that has been normalized to 100 points, size is governed by range of motion.

Since our data were not linear, cross-correlation was deemed inappropriate for comparing relative motion between the model and participants. Instead, we adapted the NoRMS technique to provide an index of similarity to the model. For each test period,

the participant's average trace was replaced by the model's trace. The resulting measure was termed *normalized root mean squared difference* (NoRM-D).

At a global, participant-object level, the number of steps in approach to the ball was recorded. Error scores were calculated based on the difference between the number of steps taken by the model, and those taken by the participant.

Visual Search. The frames from each test film were converted to a bitmap image and analyzed using *Fixplot 1.1* (ASL, 1998). This program superimposes a time-scaled scan path over the bitmap images. The scan path is integrated with the calibration frame used in the collection of eye data and indicates fixation locations and durations. Fixations were parameterized within Fixplot as stable periods of no eye movement lasting 100 ms or more.

Three measures of visual search were assessed. *Search Rate* included the mean number of fixations and the mean fixation duration (in ms) per trial. *Fixation Location* reflected the relative amount of time spent fixating upon the upper body (including head/neck, shoulder, chest, trunk, arms, wrist/hand), lower body (hip, thigh, knee, calf ankle/foot), and non-bodily areas (ahead of the body, lagging the body, the ball/ball's trajectory). Finally, the *Number of Areas of the Model Sampled* assessed the mean number of areas fixated across trials. This variable was obtained by dividing the display into the following regions: head/face/shoulder; chest/trunk; arm (mid-segment); elbow; wrist/hand; hip; thigh; knee; calf/shin; right foot/ankle; left foot/ankle.

Statistical Analysis

All outcome and coordination variables were analyzed using separate factorial analyses of variance (ANOVA) in which viewing condition (VID, PL, CON) was the between-participants factor and experimental period (pre-test, acquisition 1, acquisition 2, post-test, retention test with no KR, retention test with KR) was the within-

participants factor. For the visual search measures, both the observation period (observation 1 and 2) and trials (1 to 5) were within-participants factors. The Tukey HSD test was used to follow up significant effects as appropriate ($\alpha = p < .05$). Where violations of the assumption of sphericity for repeated measures ANOVA were observed, data were adjusted with a Greenhouse-Geisser epsilon factor. Meaningfulness was calculated using omega squared (Tolson, 1980).

Results

Outcome scores

For radial error ANOVA revealed a main effect for test period, $F(2.64, 55.34) = 3.96, p < .05, \omega^2 = .44$. Post hoc analysis showed that participants exhibited significantly lower error in the post-test ($M = 126.69, SD = 54.40$ cm) and retention test with KR ($M = 133.24, SD = 57.63$ cm), compared with the pre-test ($M = 174.52, SD = 70.22$ cm). However, in equivalent conditions when intrinsic KR was not present, participants did not learn to reduce error from the pre-test to the retention test. No main effects for group or Group x Test Period interactions were observed. Radial error scores are illustrated in Figure 3.2.

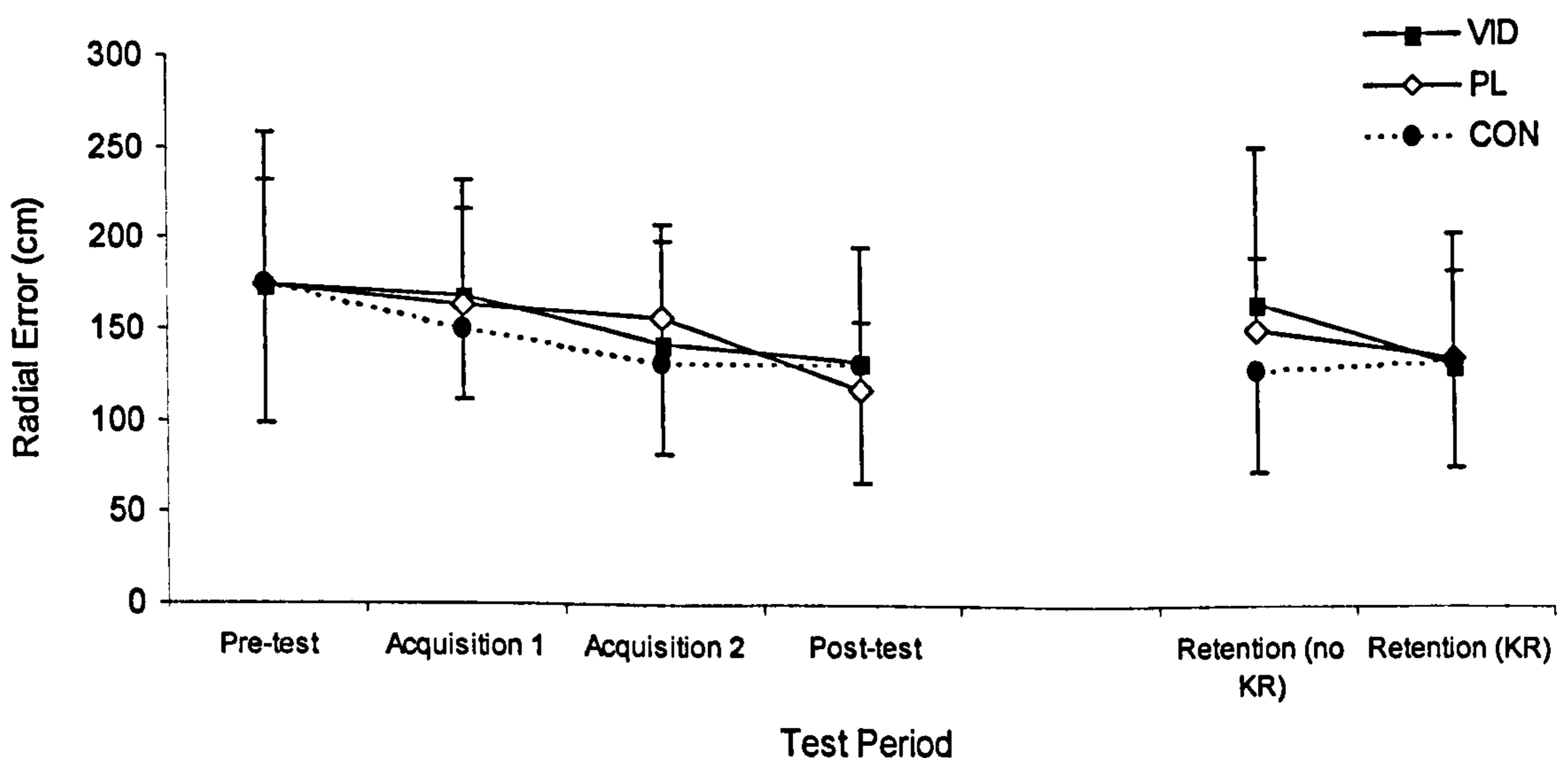


Figure 3.2. mean radial error scores across test and acquisition periods

ANOVA also revealed a main effect for test period in the standard deviations of radial error, $F(3.67, 77.07) = 2.71, p < .05, \omega^2 = .33$. Participants exhibited less variability in the post-test ($M = 61.66, SD = 30.23$ cm) and retention test without KR ($M = 60.89, SD = 39.69$ cm) than in the first acquisition period ($M = 83.30, SD = 19.74$ cm; see Figure 3.3). No long-term learning changes were present between the pre-test and retention test without KR, and no group or Group x Test Period interactions were indicated.

Intra-limb. Figure 3.4 shows knee-hip angle-angle plots across each experimental condition for a single participant from the PL group. The bold trace represents the model's criterion movement pattern. Also presented with these qualitative data are the corresponding quantified values for similarity to the model (NoRM-D) and variability (NoRMS) across conditions. A sizeable improvement in similarity to the model's relative motion is apparent from the pre-test to first acquisition (lower NoRM-

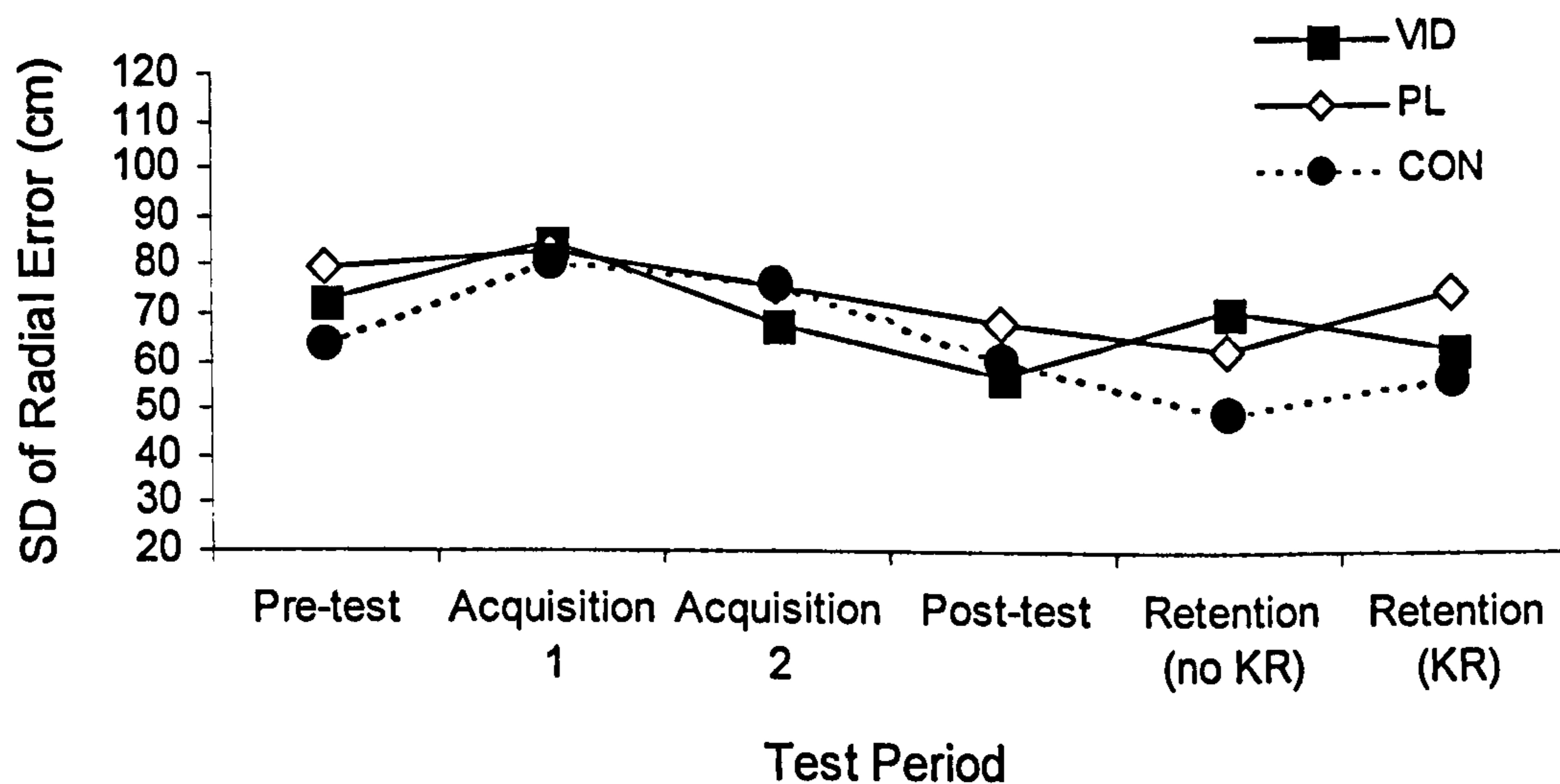


Figure 3.3. Standard deviations of radial error scores across test and acquisition periods

D represents greater similarity). The participant showed greatest proximity to the model in the second acquisition period, and this improved proximity remained throughout the conditions. Variability also decreased from the pre-test to a minimum in the second acquisition period.

Figure 3.5 shows angle-angle data across each condition for a participant from the VID group for knee-ankle relative motion. Once more a marked qualitative change in relative motion is shown from the pre-test to the first three trials of acquisition. This is reflected in a large change in NoRM-D for this period. Following this, the pattern became more stable for the remaining periods.

The NoRM-D data were also analyzed for between and within group differences, as shown in Figure 3.6. A main effect for test period was present for knee-hip relative motion, $F(5, 60) = 8.22, p < .001, \omega^2 = .41$. Participants changed their relative motion to be more like the model from the pre-test to the first three trials of acquisition. This difference was maintained in all subsequent conditions.

A Group x Test Period interaction was also observed, $F(10, 60) = 3.89, p < .001, \omega^2 = .33$. Figure 3.6 suggests that changes between the pre-test and first three trials of acquisition primarily accounts for the interaction. The CON group increased NoRM-D scores to become less like the model (from $\underline{M} = 34.70, \underline{SD} = 10.48\%$ to $\underline{M} = 37.14, \underline{SD} = 11.00\%$), the PL group moderately decreased their scores (from $\underline{M} = 44.82, \underline{SD} = 9.21\%$ to $\underline{M} = 35.78, \underline{SD} = 13.34\%$), and the VID group substantially decreased their scores to more closely approximate the model's pattern (from $\underline{M} = 45.65, \underline{SD} = 7.41$ to $\underline{M} = 24.40, \underline{SD} = 10.93\%$).

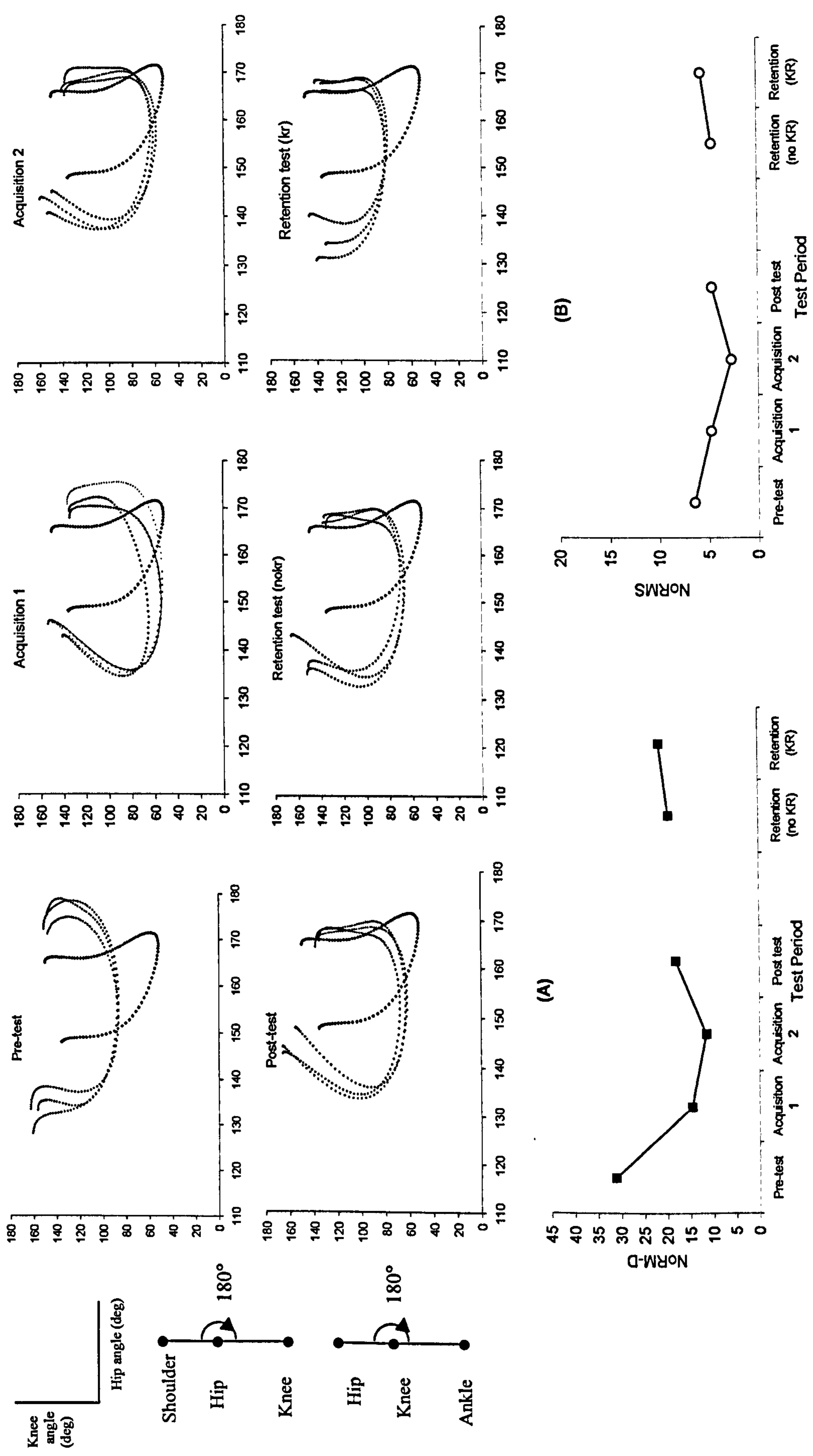


Figure 3.4. Knee-hip angle-angle plots across test periods with corresponding NoRMS and NoRM-D data for a single participant observing the PL model (for each test period, knee angle is shown on the vertical axis, with hip angle on the horizontal axis)

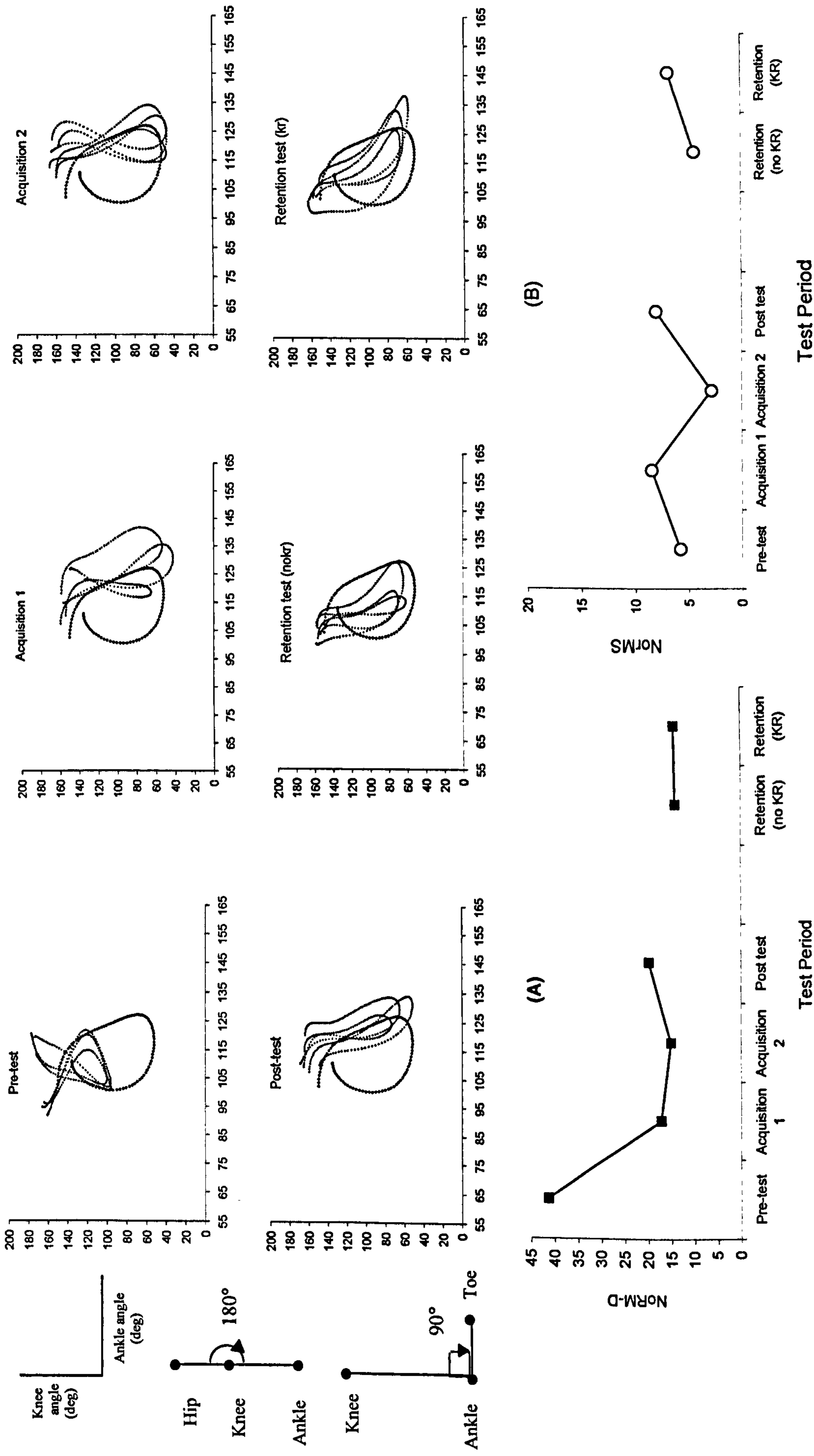


Figure 3.5. Knee-ankle angle-angle plots across test periods with corresponding NoRMS and NoRM-D data for a single participant observing the PL model (for each test period, knee angle is shown on the vertical axis, with hip angle on the horizontal axis)

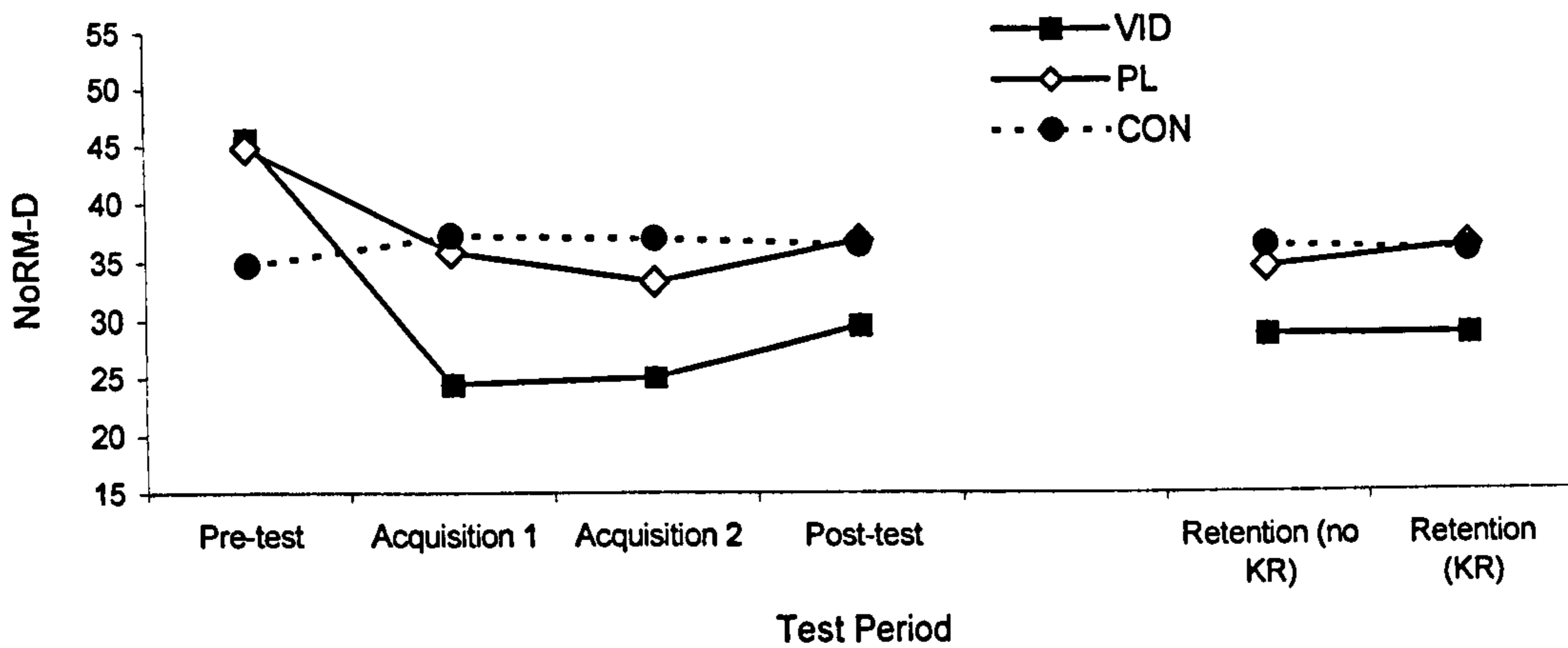


Figure 3.6. NoRM-D scores for knee-hip relative motion across test conditions

A very similar pattern was observed for knee-ankle relative motion. There was a main effect for test period, $F(2.22, 26.58) = 8.49, p < .001, \omega^2 = .43$. Participants improved their proximity to the model from the pre-test to the first three trials of acquisition. This difference was maintained in all other test periods. A Group x Test Period interaction was also present, $F(4.43, 26.58) = 3.61, p < .05, \omega^2 = .30$. As with knee-hip relative motion, the interaction was derived from different responses between the pre-test and first acquisition. Participants in the CON group did not change their NoRM-D scores (from $\underline{M} = 35.00, \underline{SD} = 8.94\%$ to $\underline{M} = 36.16, \underline{SD} = 9.99\%$), the PL group moderately decreased their scores (from $\underline{M} = 45.55, \underline{SD} = 9.34\%$ to $\underline{M} = 36.94, \underline{SD} = 12.38\%$), and the VID group substantially decreased their scores (from $\underline{M} = 46.30, \underline{SD} = 8.23\%$ to $\underline{M} = 26.59, \underline{SD} = 10.41\%$).

For knee-hip and knee-ankle variability (measured by NoRMS), participants did not alter the variability in their movement patterns across test periods. There were also no group main effects or interactions.

Participant-object coordination. For error in steps taken in approach to the ball, ANOVA indicated a main effect for test period, $F(2.85, 34.14) = 3.63, p < .05, \omega^2 = .20$. Participants reduced this error from the pre-test to the first acquisition period. This improvement was maintained in all periods except the retention test without KR. No differences were found between the other test periods. There was also a Group x Test Period interaction, $F(5.69, 34.14) = 2.51, p < .05, \omega^2 = .22$. Figure 3.7 shows that participants in the CON group did not change the number of steps in their approach

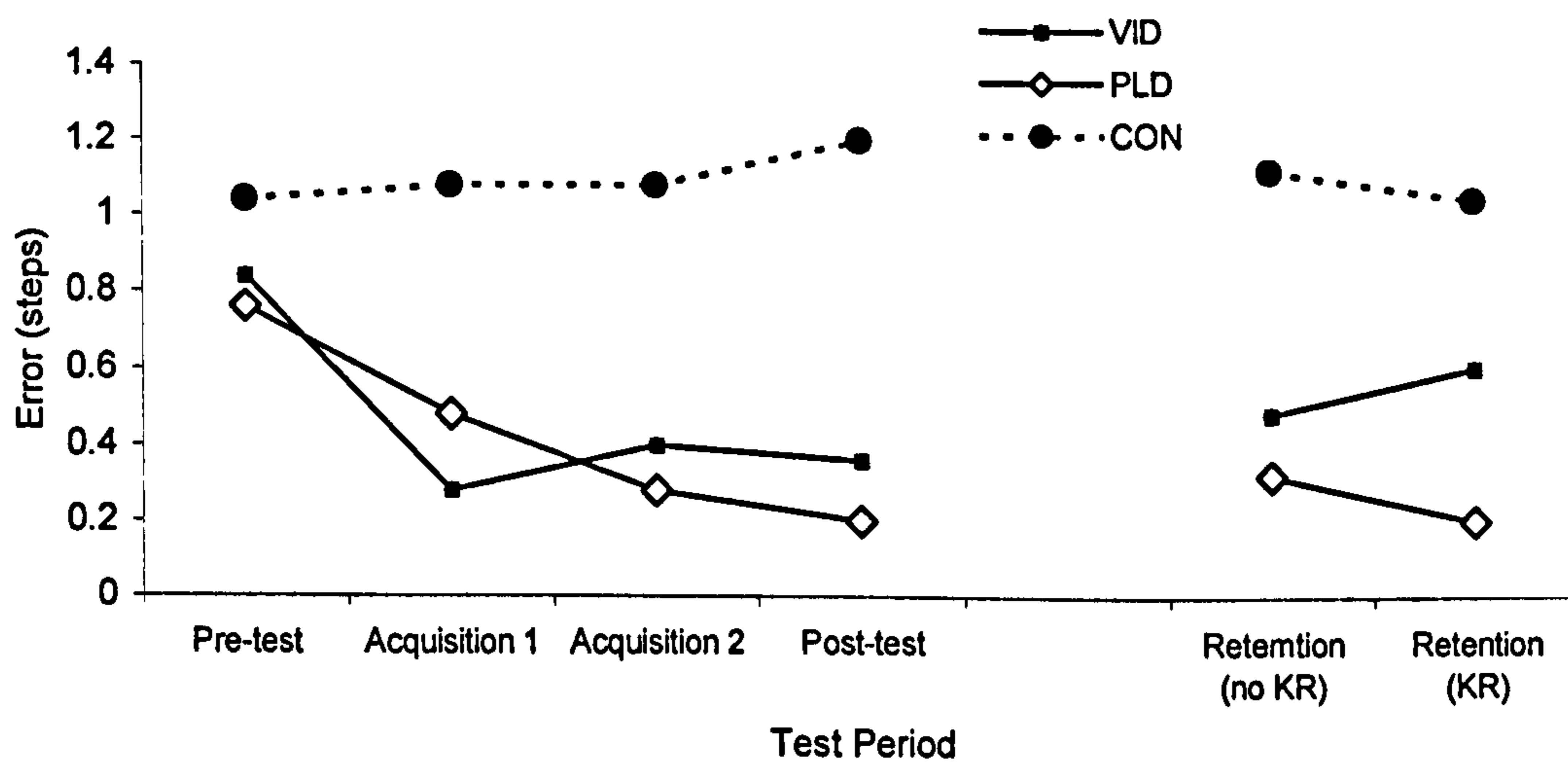


Figure 3.7. Error in steps in approach to the ball across test conditions

across test periods. Conversely, the PL (from $\underline{M} = .76, \underline{SD} = .43$ to $\underline{M} = .48, \underline{SD} = .50$) and VID (from $\underline{M} = .84, \underline{SD} = .26$ to $\underline{M} = .28, \underline{SD} = .44$) participants reduced their error by the first three trials of acquisition, and maintained this improvement across test periods.

Visual Search

Search Rate. A main effect for group was observed for mean number of fixations per trial, $F(1,14) = 6.24, p < .05, \omega^2 = .43$. The PL group had less fixations per trial (\underline{M}

= 8.19, SD = 1.86) than the VID group (M = 9.29, SD = 1.81). For fixation duration, there was a Group x Observation Period interaction $F(1,14) = 6.12, p < .05, \omega^2 = .27$. The participants viewing the PL model increased the mean duration of their fixations from the first observation period to the second. Conversely, those observing the video model decreased their fixation duration in the second observation period. The search rate data are summarized in Table 3.1.

Table 3.1. The mean (\pm SD) number of fixations and fixation duration for the video and point-light model groups across observation periods

Group	Observation 1		Observation 2	
	Number of Fixations	Fixation Duration (ms)	Number of Fixations	Fixation Duration (ms)
VID	9.0 (1.8)	278 (56.4)	9.6 (1.8)	260 (65.8)
PL	8.4 (1.9)	289 (68.7)	8.0 (1.9)	338 (100.9)

Number of areas sampled. A main effect for group was observed, $F(1,14) = 6.90, p < .05, \omega^2 = .42$. The VID group sampled a greater number of areas of the model's body per trial (M = 4.46, SD = 1.40 areas) than the PL group (M = 3.78, SD = 1.19 areas). Differences in the breadth of the search between participants observing the point-light and video models are illustrated graphically in Figure 3.8. Scan paths of a representative participant from the VIDEO group (A) and the PL group (B) are presented. The lines represent saccades between fixations, and the fixations in turn are indicated by circles. Duration of fixation is indicated by size of circle, where larger

circles indicate longer fixations. In response to the video model, Figure 3.8 clearly indicates a broad search originating at the hips (corresponding to previous bitmap images), moving to the head, returning to the hips and ending around the ankles. In response to the point-light model, search is confined to the area of the ankles throughout.

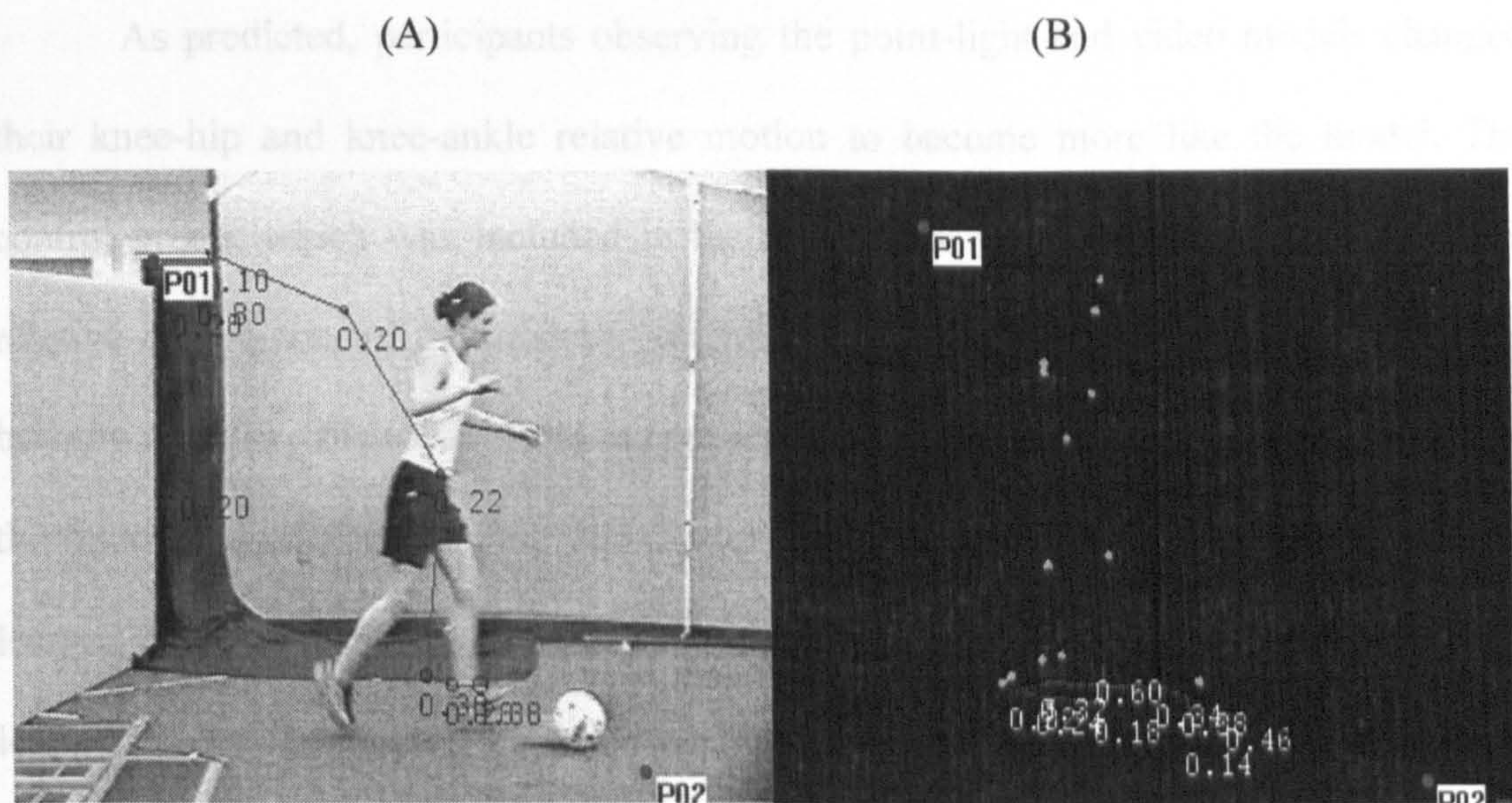


Figure 3.8. Scan paths to indicate breadth of visual search for representative participants in the VIDEO (A) and PL (B) groups.

Relative fixation time per location. No between or within group effects were observed for the relative temporal distribution of fixations per location, $p > .05$.

Discussion

This study tested predictions arising from Scully and Newell's (1985) visual perception perspective, under conditions in which the model was the participants' constraining source of information. We predicted that participants observing video and point-light models would show immediate and permanent changes in relative motion to

closely imitate the model, while the control group would show no improved proximity. Also, we anticipated that the salience of relative motion in a point-light model would facilitate greater immediate and learning effects than observing a video model. This saliency was further expected to be portrayed in more selective visual search patterns in response to the point-light compared with the video model.

As predicted, participants observing the point-light and video models changed their knee-hip and knee-ankle relative motion to become more like the model. The control group, which was included in the experiment to ensure that such changes in relative motion toward the model's patterns did not occur merely by practice, did not become more like the model from the pre-test to the retention test. These results support the findings of Al-Abood et al. (2001) who showed that participants observing a model learned the relative motion patterns more effectively than those in a no-model discovery learning group. It appears, as proposed by Cutting and Profitt (1982) and Scully and Newell (1985), that demonstrations convey the topological properties of relative motion to the learner. Given the limited alternative sources of information present with the removal of intrinsic KR, the learners appear to have adapted their relative motion to be more like the model, through the informational constraints it imposed.

The salience of relative motion information in the demonstrations was such that the aforementioned changes appear to have occurred immediately after watching the model. From the pre-test to the first three trials of acquisition, participants observing the point-light and video models showed an improvement in relative motion toward the model's pattern. These changes were not present for the control group. Previous studies have measured rate of acquisition of relative motion by, for example, number of trials to achieve a correct movement sequence (Williams, 1989a), or by comparing pre-test scores with scores at the end of acquisition periods (e.g., Al-Abood et al., 2001;

Schoenfelder-Zhodi, 1992). Whilst our results support these studies, they also provide a clearer indication of how rapidly changes in relative motion occur. According to Scully and Newell (1985), learners may perceive information in the demonstration that cannot necessarily be realized immediately in attempts at re-enactment. In contrast, our results suggest that under constrained conditions, the learner can acquire the relative motion pattern within three trials. Since we used three trials rather than one, this precludes us from concluding that relative motion information can be acquired *pre-practice*. However, this evidence provides some support for Bandura's (1969) concept of observational learning as 'no-trial learning'.

Although our findings require corroboration, the implication that demonstrations convey relative motion with minimal requirement on practice may be considerable. Typically, ecological accounts of early learning emphasize the concepts of 'search' and 'assembly' of coordination (e.g., Newell, Kugler, van Emmerik, & McDonald, 1989; Handford, et al., 1997). In observational learning specifically, Al-Abood et al. (2001) describe the informational or instructional constraints imparted by the model's relative motion pattern, guiding the learner's 'search for task-optimal solutions in the perceptual-motor workspace'. However, data from this study leads to the suggestion that when learning from a model, the process may be less transitory than suggested by Al-Abood and colleagues. If learners are capable of pre-assembling, or at least rapidly assembling the relative motion, early practice may concern refining an existing solution rather than broadly 'searching' for one per se. It could be that demonstration constrained the search to a localized, appropriate region of the perceptual-motor workspace.

In ecological terms, the rapid changes from the pre-test to the first three trials of acquisition found in this study may be seen as 'soft assembly' of body segments. This infers that the changes are temporary and representative of an approximate solution to

the problem, which needs to be refined (Handford et al., 1997). However, since the participants viewing the models maintained their proximity to the model after the first trials of acquisition, whilst showing no significant fluctuation in the variability of their movement patterns across experimental periods, this does not support a concept of 'soft assembly'. The comparison of results obtained when intrinsic visual KR was present (Horn et al., 2002; Experiment 1) with the results of this experiment also sheds light on the synergistic nature of coordination and control. In both these experiments, the task for participants observing a model was to achieve an outcome whilst employing a novel movement pattern. Therefore, there were demands on the learner in regard to both the organization of the movement topology (coordination) and its parameterization (control).

Using Newell's (1985) concept of an embedded hierarchy, coordination and control are implicitly linked. Changes to one may therefore impact the other. With intrinsic visual KR present in Experiment 1, the demands on scaling the movement pattern appear to have been at the cost of imitating the movement pattern. That is, an improvement in performance outcomes was observed whilst movement form remained stable. In the present study, without intrinsic KR, there was a paucity of information that the learners could use to parameterize the movement. As a result, though participants showed some improvement during practice, they did not *learn* to reduce error in outcomes. However, as the demands on coordination were less 'shared' with control, greater changes in relative motion resulted.

The immediate effects of observing the model were also present at a more global level of analysis. The participants in the control group did not alter the number of steps in their approach to the ball from the pre-test to the first period of acquisition. However, participants viewing the models altered the number of steps to more closely match the

model. There is some existing evidence for the perception of global properties of human form rather than local relations when biological motion is embedded in point-light displays (Bertenthal, 1993). Experiment 1 found that participants only learned to imitate global properties of the model's movements when visual intrinsic KR was present. It was concluded that participants may first form a global concept of the movement, whilst the refining of local relations in movement required extended acquisition. The present study, however, demonstrates that in the absence of other constraining sources of information (i.e., intrinsic KR) these local relations can be acquired without extended practice. The fact that improvements in the approach to the ball were not maintained in retention perhaps suggests that the acquisition of the model's global pattern occurs early, and diminishes with acquisition.

The prediction that point-light demonstration would facilitate greater immediate and prolonged learning effects than video was not supported. There were no differences between these groups in any aspect of locally or globally defined relative motion, similar to the findings of Williams (1989a) and Experiment 1. Given the constraint to use the model as the primary source of information, these results allow us to more confidently suggest that the relative motion salient in point-light displays is easily abstracted from video. If video does indeed contain distracting structure as suggested by Runeson (1984), it does not appear to be reflected in action responses.

The visual search patterns observed in this study imply somewhat more refined search in response to the point light model than the video model, supporting the evidence of Experiment 1. Participants observing a point-light model sampled fewer areas of the model's body than those who observed video. In addition, the participants observing the point-light model sampled these areas at a lower search rate. However, this study did not replicate two findings of Experiment 1. First, the two model groups

did not differ in the distribution of fixation time allotted to the upper and lower body. Second, participants did not refine their search from the first observation period to the second. The latter contrast may reflect the impact of removing KR. In the first experiment, the participants appeared to become increasingly dependent on visual intrinsic KR to guide their performance. Therefore, in later observations of the model, the search for information may have diminished. In the present study, without KR, the model remained the only relevant source of information to guide participants, and similar search patterns ensued. Overall, the differences in visual search between the groups were less than anticipated, considering the constraint imposed on participants to use the model. Furthermore, similarity between groups in both visual search and coordination changes precludes attributing any relative motion differences between these groups to variations in the manner in which participants sought information.

In summary, this study indicates that video and point-light demonstrations can convey relative motion information that is rapidly adopted and learned by the observer. Moreover, it points to the impact of the learning environment on observational learning and the synergy of coordination and control. The decision to remove visual intrinsic KR was based on the findings of a previous study where it was proposed that KR constrained the choice of movement and diminished the influence of the model. The results of this experiment support this claim. In comparison to the findings of the first experiment, without intrinsic KR, participants did not learn to reduce error, but did learn the model's relative motion pattern. The presence of KR appears to encourage the parameterization of the movement. If coordination and control exist as a functional synergy, these changes in control from trial to trial brought about by KR may impact on changes in relative motion. This process may be perceived as the transitory 'search' for an optimal coordination function. However, in contrast, the immediate changes in

relative motion induced by the demonstration remained stable throughout the remaining test periods when intrinsic visual KR was not available.

Chapter 4

Demonstration as a Scaler:

On the Facilitative Role of Demonstration in Early Skill Acquisition

Abstract

Previous research has failed to clarify the rate of changes in coordination in response to a model. This study examined trial-by-trial changes in intra-limb coordination in participants who observed a video model (MODEL), or practiced a task based only on initial verbal guidance (CONTROL). The task for 16 male novices ($n = 8$) was a back-handed throw that mimicked a reversed baseball pitch. Participants aimed at a large target, and threw for maximal velocity. Participants in the MODEL group were instructed to exactly replicate the model's movement pattern. It was predicted that participants in the MODEL group would demonstrate immediate changes in relative motion to more closely resemble the model's relative motion pattern. In opposition to the predictions of proponents of discovery learning, the MODEL group were anticipated to maintain this movement pattern throughout the 18 acquisition trials. In support of Scully and Newell (1985), after seeing the demonstration the MODEL group showed significant changes in knee-hip and elbow-shoulder relative motion in the first trials of acquisition. This change in proximity to the model (as measured by NoRM-D; Horn et al., 2003) was maintained across the acquisition period, and mirrored significant changes in ball velocity. These findings suggest that participants were not using an inappropriate and temporary movement solution as suggested by Handford et al. (1997). The CONTROL group showed no changes in coordination or velocity across acquisition. This study clarifies the role of demonstration as a rate *scaler* in early acquisition.

A review of observational learning literature suggests that demonstrations vary considerably in their effectiveness in facilitating skill acquisition. Traditional explanations for this incongruence centre around the type and novelty of the tasks employed (e.g., Gould & Roberts, 1982; Southard & Higgins, 1987), and the informational content of the demonstration, in terms of the conveyance of a strategy for action (e.g., Burwitz, 1975), the extent of redundancy (e.g., Newell, 1981), and load (Gould & Roberts, 1982).

More recently, Horn and Williams (2003) have presented an alternative interpretation of the inconsistency of demonstration effects. They suggested that the use of traditional research designs coupled with our concept of the role of demonstration may have limited understanding of its benefits. The efficacy of demonstrations has typically been gauged in research designs by employing retention measures after long periods of acquisition. These designs may have two effects. First, they typically ignore the changes in motor performance that occur early in the skill acquisition process. Therefore, if demonstration proffers any advantage in early learning over discovery learning, or verbal guidance, this may go undetected. Second, this potential advantage may be lost or diminished over prolonged practice. For example, Martens, Burwitz, and Zuckerman (1976) found that observation of a model facilitated performance on a ball-roll-up task only in the early stages of learning, and that the task relevant information presented by a model in early learning could be also be acquired by a period of physical practice.

Horn and Williams (2003) raised an important question in the skill acquisition process: is it significant that demonstration may act as rate enhancer, imparting immediate effects in acquisition if long-term benefits are not apparent? Horn and Williams (2003) state that although it could be argued that long-term changes are the

benchmark for skill acquisition, there are important implications for accelerated early acquisition. Practice sessions rarely mimic learning experiments. Coaches and teachers of motor skills use feedback, verbal guidance, and many different types of practice (see Borrie & Knowles, 2003; Williams, Horn, & Hodges, 2003). In realistic learning environments, the efficiency of demonstration may put learners in a position to receive further augmented information or coaching to guide skill acquisition earlier than those not receiving demonstration (Horn & Williams, 2003). Moreover, in realistic learning environments, the learner may have only a limited time to practice a new skill before its context is changed or advanced. Those whose skill acquisition is more efficient in this short time may be better prepared for such changes.

In theoretical terms, the role of demonstration in accelerating the rate of skill acquisition is certainly not a novel concept. Cognitive accounts of observational learning have emphasized the formation of a *blueprint* (Sheffield, 1961) or cognitive representation (Bandura, 1969) to guide action. In the absence of higher cognitive processes, Bandura (1965) considered that in early development, modelling is confined to instantaneous imitation. This process has been shown to be present by the twelfth day of human life (e.g., Meltzoff & Moore, 1977), and suggests that the ability to immediately organize new behaviour in response to the actions of others is a fundamental human ability.

In older humans with more advanced cognitive development, it has been proposed that demonstration accelerates acquisition by conveying structure and the underlying rules of behaviour (Carroll & Bandura, 1985). This approach is consistent with Fitts and Posner's (1967) stages of skill learning, which views early learning as the *cognitive stage*. At this time, the learner is preoccupied with understanding the characteristics and requirements of the task (Williams, Horn, & Hodges, 2003). Bandura

(1965) considered that demonstration held such potency that behaviour could be observed on one occasion, and re-enacted later, in the absence of a model. Bandura's (1965) concept of 'no-trial learning' suggests that observation of a demonstration may essentially replace physical practice.

Ecological and dynamic accounts of early learning perhaps view the role of demonstration as a rate enhancer in early acquisition less optimistically. Scully and Newell's (1985) *visual perception perspective* suggests that observers pick up the model's relative motion, and in later re-enactment, become constrained by the informational or instructional constraints it imparts (see Warren, 1990; Newell & McDonald, 1992). Scully and Newell (1985) do not directly suggest that demonstration acts to increase the rate of skill acquisition. Instead they predict that the model's effects are greatest in early learning, evoking Newell's (1985) hierarchical view of coordination, control, and skill. In Newell's account, early learning emphasizes the assembly of a new movement topology (i.e., *coordination*).

Scully and Newell (1985) suggest that in early learning the perception of the model facilitates the pick up of relative motion between body parts. Later in the learning process, when the parameterization of the movement pattern dominates (i.e., *control*), the influence of the model is assumed to subside. Scully and Newell's (1985) limited confidence in demonstration as an immediate impact on coordination is reflected in a caveat stating that the information picked up from a model may not be immediately realized in attempts to imitate the movement.

Dynamic accounts of early learning have promoted the idea of *searching* for task solutions in the *perceptual-motor workspace*. First used by Thelen (1995), this is a metaphorical depiction of the emergence of coordination as a dynamical system flows through the potential range of degrees of freedom by which it can be configured

(Williams, Davids, & Williams, 1999). Al-Abood, Davids, and Bennett (2001) suggest that observation of a demonstration guides the learner's search for optimal task-solutions in the workspace. The dynamic accounts of early learning have emphasized collapse and rebuilding of unstable regions of behaviour, and although abrupt changes in behaviour do occur (i.e., switches from one attractor state to another), this represents 'soft assembly' of movement patterns. These are considered to be temporary and inaccurate solutions to the movement problem (Handford, Davids, Bennett, & Button, 1997).

Research evidence for accelerated changes in motor performance after observation of a model has not been forthcoming, due to the experimental designs used. To ascertain the coordinative effect of a model in early acquisition, a design has four requirements. First, it must measure changes on a trial-by-trial basis. It should also measure movement kinematics to appropriately compare the kinematics of the model and learner. Third, it requires a comparison between pre-test (pre-observation) and acquisition (post-observation) data. Finally, it requires a comparison with a no demonstration control group.

Considering the first requirement, many studies provide a single mean score to represent the first block of acquisition (e.g., Blandin, Proteau, & Alain, 1994; Herbert & Landin, 1994, Weeks & Anderson, 2000; Wuyts & Buekers, 1995). This allows little inference of either the immediate effect of the model, the rate of acquisition, or variability in early acquisition.

It has been argued that the preference for measuring outcome data has led to indifference to the trial-by-trial changes in performance that reflect the search for solutions in learning (Newell & McDonald, 1991). Of the studies showing trial-by-trial changes in performance, most have measured outcome data or ratings of form. For

example, Pollock and Lee (1992) observed changes in performance on a computer tracking task over 15 trials. Similarly, Doody, Bird, and Ross (1985) tracked trial-by-trial changes in a barrier knock-down task.

McCullagh and Meyer (1997) assessed trial-by-trial changes in a free-weight squat lift using outcome and perceived form scores. Participants' observing a learning model with and without feedback, a correct model with feedback, and those just practicing with feedback all showed improvement across trials 1-4 in acquisition. The performance of participants watching a model was not superior to those just practicing.

Gray, Neisser, Shapiro, and Kouns (1991) also assessed learning of a ballet sequence using ratings of form over five acquisition trials. Participants observing a static or moving model improved across acquisition in *local* measures such as arm and leg position and *global* measures such as coordination, balance, and movement flow. The authors also assessed immediate effects of viewing condition. Analysis of the first acquisition trial showed significantly higher ratings for movement flow and hesitation for those observing a dynamic video model compared with those observing static images. Importantly, however, neither Gray et al. (1991) nor McCullagh and Meyer (1997) used pre-observation tests to allow comparison with post-observation early acquisition trials.

It is difficult to assess the predictions of the visual perception perspective without directly measuring kinematics. However, few studies have indicated rate of acquisition or immediate effects of the model on measured movement kinematics. Williams (1989) used the number of trials to reach the correct sequence of a dart-throwing movement. Williams and Thompson (1994) found immediate changes in joint angles in performance of a leg lift after observation of a model. The model group were also found to maintain the new coordination in a delayed retention test. In contrast,

participants in a no-model control group did not change in acquisition or retention. Scully and Carnegie (1998) found that for a ballet sequence, little change in measures such as relative timing and movement form occurred over ten acquisition trials. The authors concluded that observers pick up and reproduce the movement pattern almost instantaneously, and presumably maintain those changes. However, pre-test to early acquisition trial changes are not reported to corroborate this stance.

Three recent studies have attempted to quantify participants' coordination relative to the model. Al-Abood, Davids, Bennett, Ashford, and Martinez Marin (2001) examined changes in relative motion of the upper and lower arm segments in an underarm dart throw. Data were assessed in acquisition over ten blocks of ten trials. No trial period effect was found, and with no pre-observation measures of coordination, the immediacy of model effects on coordination were not shown. The same applies to a further study employing the same task by Al-Abood, Davids, and Bennett (2001). However, this study did reveal that participants became more like the model across acquisition.

Horn, Williams, Scott, and Hodges (2003; Experiment 2) assessed changes in knee-hip and knee-ankle coordination relative to a model in a soccer-chipping task. Kinematic data were collected in batches of three trials in a pre-test, in the first three trials of acquisition (immediately after observation of the model), at the start of a second acquisition period, and in post- and retention-tests. Coordination was quantified for variability using normalized root mean squared error (NoRMS; Sidaway, Heise, & Schoenfelder-Zhodi, 1995) and for proximity to the model using an adapted version of NoRMS (NoRM-D; Horn et al., 2003). Participants observing a point-light or video model changed their relative motion to become more like the model from the pre-test to the first three acquisition trials, and then showed little change thereafter, with lower

variability. In contrast, a no-model control group showed less proximity throughout acquisition, and did not change across test periods.

Horn et al. (2003) questioned ecological explanations of early skill acquisition. They argued that if a demonstration constrains learners to rapidly assemble a new relative motion pattern which in turn stays consistent in its proximity to the model, then early learning may not be about a broad search for task solutions as suggested by Newell et al. (1989) and Handford et al. (1999). Instead, the constraints of the model appear to act as a rate enhancer or *scaler* (see Haywood & Getchell, 2001), allowing the learner to *refine* rather than broadly *search*.

The study of Horn et al. (2003) is currently the closest to meeting the aforementioned requirements for expounding the role of demonstration in early skill acquisition. This study aims to extend upon their research in two key ways. First, their study constrained participants to use the model as a dominant source of information by removing intrinsic visual knowledge of results at contact with the ball. Based on comparison with a previous study that did allow intrinsic visual KR and saw relatively small coordination changes, removing intrinsic KR may have afforded participants with faster and larger coordinative changes. This study aims to measure early acquisition changes in a task that allows intrinsic KR, but has low accuracy constraints. Second, Horn et al. (2003) used intermittent clusters of kinematic trials, rather than assessing coordination on all trials. This meant that they were able to measure immediate changes in coordination after viewing a model, but were unable to gain a complete representation of the stability in movements. In this study this limitation is overcome by collecting and quantifying kinematic data on all trials.

It was predicted that the demonstration group would show a significant change to more closely approximate the model's relative motion patterns from the pre-test to

the first three trials of acquisition. After this immediate change, it was predicted that the participants in the demonstration group would not change their proximity to the model for remainder of acquisition trials. The participants in the model group were also predicted to show this pattern for variability. In contrast, the no-model control group was predicted to show no change in proximity between the pre-test and first three trials of acquisition, but were expected to show an overall effect of practice, resulting in a difference between coordination from the pre-test to the last trials of acquisition. Variability was anticipated to remain higher in acquisition for the control group than the model group, reflecting the participants' search for an optimal movement solution. Finally, for movement outcomes it was predicted that since the model demonstrated the optimal movement pattern, the model group would show a significant change from pre-test to early acquisition, and significantly higher velocity in acquisition than the no-model control group.

Method

Participants

Sixteen male participants (M age = 31.93, SD = 10.20 yrs.) provided informed consent to take part in the experiment. Participants were randomly allocated to a MODEL or CONTROL group (n = 8). All participants were considered novice at the task and were right-side dominant.

Task and Test Films

The task was to throw a ball to a 1.7 m² vertical target placed 5.0 m away. The target was unmarked. The model was a 28-year-old male. After several days of practice, a throw was conceived that would be novel to the participants. The throw was considered a reversed, backhand baseball pitch. In baseball, for a right-handed thrower,

the left knee and hip flex to bring the left leg across the body and the left shoulder points to the target. In this task, for a right-handed thrower, the ipsilateral foot crosses the body with hip and knee flexion, pointing the right shoulder to the target. This puts the thrower in position to throw backhand. The arm is then pulled through with the elbow leading toward the target. As the right arm comes through, the back of the hand faces the target until release.

Several other factors indicate that this technique mimics a reversed mature baseball pitch. As with a baseball pitch, the thrower takes a long forward step to increase the distance over which force can be applied. In the current task the long step was with the ipsilateral foot. The thrower also utilises the open kinetic chain. The forearm segment lags to reach peak velocity after the upper arm segment, when the trunk has rotated forward. The trunk in turn shows differentiated rotation, with the lower portion rotating forward before the upper trunk. This combination of differentiated rotation and arm lag allows high velocity to be imparted on the ball, and after comparing with other techniques (e.g., backhand darts-throw) this technique was found to be optimal.

During a successful throw, the model was filmed in a sagittal plane using a video camera (Panasonic M-40). The spatio-temporal positions of retro-reflective markers were simultaneously registered using 4-infra-red cameras (Pro-Reflex, Qualisys) sampling at 240 Hz. The video of the model's throw was edited and repeated on tape eight times.

Procedure and Design

On arrival for testing participants were assigned to the MODEL or CONTROL group. The difference between the treatments was that participants in the CONTROL group performed all trials without observing a demonstration. Participants in the

MODEL group observed five demonstrations of the model immediately after the pre-test, and one demonstration after each of the first five trials of acquisition. The video of the model was projected as a life-size image onto a 3.5 m x 3.0 m screen (Cinefold). Both groups performed all trials without augmented feedback.

Before the pre-test, retro-reflective markers were placed on each participant's right side at the acromion process (shoulder), lateral epicondyle (elbow), ulnar process (wrist), greater trochanter (hip), lateral condyle of the femur (knee), and the lateral malleolus (ankle). Two markers were also placed on the ball to provide a reference point for ball release.

Prior to the pre-test the participants were also given standardized instructions and were positioned with their feet on two floor markings, 35 cm apart. They were told that the task was to throw the ball for maximum velocity, ensuring that the ball hit the target. They were then given additional task constraints. First, to ensure that an intrinsic throwing pattern could not be used, they were told that the back of the hand should face the target until ball release. Second, they were told that they were free to move how they wanted as long as they did not step over the line placed 1 m in front of them. Third, to prevent underarm throwing, the participants were told that the ball should be released from a position in which the wrist was located above the height of the elbow.

After three pre-test trials, the MODEL group observed five repetitions of the demonstration. Prior to this they were informed that after seeing the model, they should continue to throw at the target for maximal velocity, while trying to exactly replicate the model's form in all subsequent trials. Participants in both groups performed 18 acquisition trials. This number was selected to mimic typical practice ecologies. Normal practice environments for maximal tasks are unlikely to exceed this number in a single session. Also, a greater number of trials may produce changes in technique as a result of

fatigue, which could inappropriately be charged to instability in movement form.

Outcome and kinematic data were collected on all trials.

Dependent Measures and Data Analysis

Outcome scores. Ball velocity was assessed with a JUGS Doppler radar gun (Decatur Electronics). This measured ball velocities from 32 to 320 kph via a microwave transmitter. Accuracy was tested on each day of testing using a calibration fork, vibrating at 110.6 kph. Across all test days, maximum error did not exceed 0.4 kph. This was within the acceptable range of 1.5 kph of error. During each trial, an experimenter stood with the radar gun next to the target to minimize the angle between ball approach and radar direction. This minimized radar error and allowed the gun to pick up the ball throughout its flight until just before contact with the target. The experimenter also kept track of the number of times the thrower missed the target.

Coordination. The data from 5 randomly selected participants in each group were used for a kinematic analysis. The effect of viewing a model on the immediacy and stability of changes in coordination was assessed at a local, intra-limb level of analysis. At a local, intra-limb level, coordination was assessed as relative motion between the right shoulder and elbow, and the right knee and hip. For the elbow-shoulder relative motion, the start and end points of the analysis were normalized to start at the initiation of shoulder flexion, and end after ball release at maximal elbow extension. For knee-hip relative motion, normalization also ended at maximal elbow extension, since this represented the end of the meaningful portion of movement. However, to account for differences in movement technique, knee-hip motion was normalized to start at the initiation of knee flexion. Data were smoothed with a recursive 4th order Butterworth filter with a cut-off frequency of 7 Hz. A linear interpolation was then performed on the qualitatively normalized, filtered data, to quantitatively normalize this period to 100

data points. This process did not alter the relative motion pattern as indicated in angle-angle plots.

Intra-limb coordination was quantified in two ways. First, variability was assessed using a modified version of Sidaway, Heise, and Schoenfelder-Zhodi's (1995) normalized root mean square error (NoRMS). In the original version of this technique, root mean squared error is calculated based on disparity of each trial with the mean trace pattern. Then, the data is normalized for number of trials and the excursion of the pattern. The reason for this is that a larger movement pattern may exhibit greater variability than an equivalent, smaller plot. An interpretation of the NoRMS technique presented by Mullineux, Bartlett, and Bennett (2001) used range of motion as the measure of excursion. Horn et al. (2003) considered this to be a more appropriate measure of excursion, since for a plot normalized to 100 data points, its size is a product of its range of motion.

For proximity to the model's relative motion pattern, we used an adapted version of NoRMS in which the participant's mean trace is replaced by the model's trace. The resulting measure was termed normalized root mean squared difference (NoRM-D) by Horn et al. (2003).

Statistical Analysis

All outcome and coordination variables were analyzed using separate factorial analyses of variance (ANOVA) in which group (MODEL; CONTROL) was the between-participants factor and experimental test period was the within-participants factor (pre-test, A1-3, A4-6, A7-9, A10-12, A13-15, A16-18 or post-test). Trials were not used as the within-participants factor since NoRM-D and NoRMS data require a cluster of trials for the analysis. Therefore, each trial represented by these measures

would contain data from two other trials (this is similar in principle to a moving average) and is best illustrated graphically.

Significant effects were followed up where appropriate using the Tukey HSD ($\alpha = p < .05$). Where violations of the assumption of sphericity for repeated measures ANOVA were observed, data were adjusted with a Greenhouse-Geisser epsilon factor. Meaningfulness was calculated using omega squared (Tolson, 1980).

Results

Velocity/outcomes

For velocity, ANOVA revealed a main effect for test period, $F(2.86, 39.98) = 5.95, p < .05, \omega^2 = .47$. Post hoc analysis indicated that participants showed a significant increase in velocity from the pre-test ($M = 37.17, SD = 5.04$ kph) to all subsequent acquisition periods (A 1-3: $M = 40.71, SD = 5.33$; A4-6: $M = 41.35, SD = 6.01$; A7-9: $M = 42.02, SD = 4.61$; A10-12: $M = 42.09, SD = 4.61$; A13-15: $M = 42.75, SD = 4.59$; A16-18: $M = 42.38, SD = 5.16$ kph). A significant group effect was also present, $F(1, 14) = 7.23, p < .05, \omega^2 = .10$. The model group illustrated higher velocity ($M = 43.51, SD = 4.87$ kph) than the CONTROL group ($M = 38.90, SD = 4.69$ kph). ANOVA also presented a Group x Test Period interaction, $F(2.85, 39.98) = 2.95, p < .05, \omega^2 = .18$. Figure 4.1 illustrates that differential changes in velocity from the pre-test to the first three trials of acquisition primarily account for this effect. The CONTROL group shows minimal change in velocity over this period, followed by a trend for a slight overall increase in velocity across remaining test periods. The MODEL group shows a large increase in velocity from the pre-test to first three acquisition trials and little change in velocity thereafter.

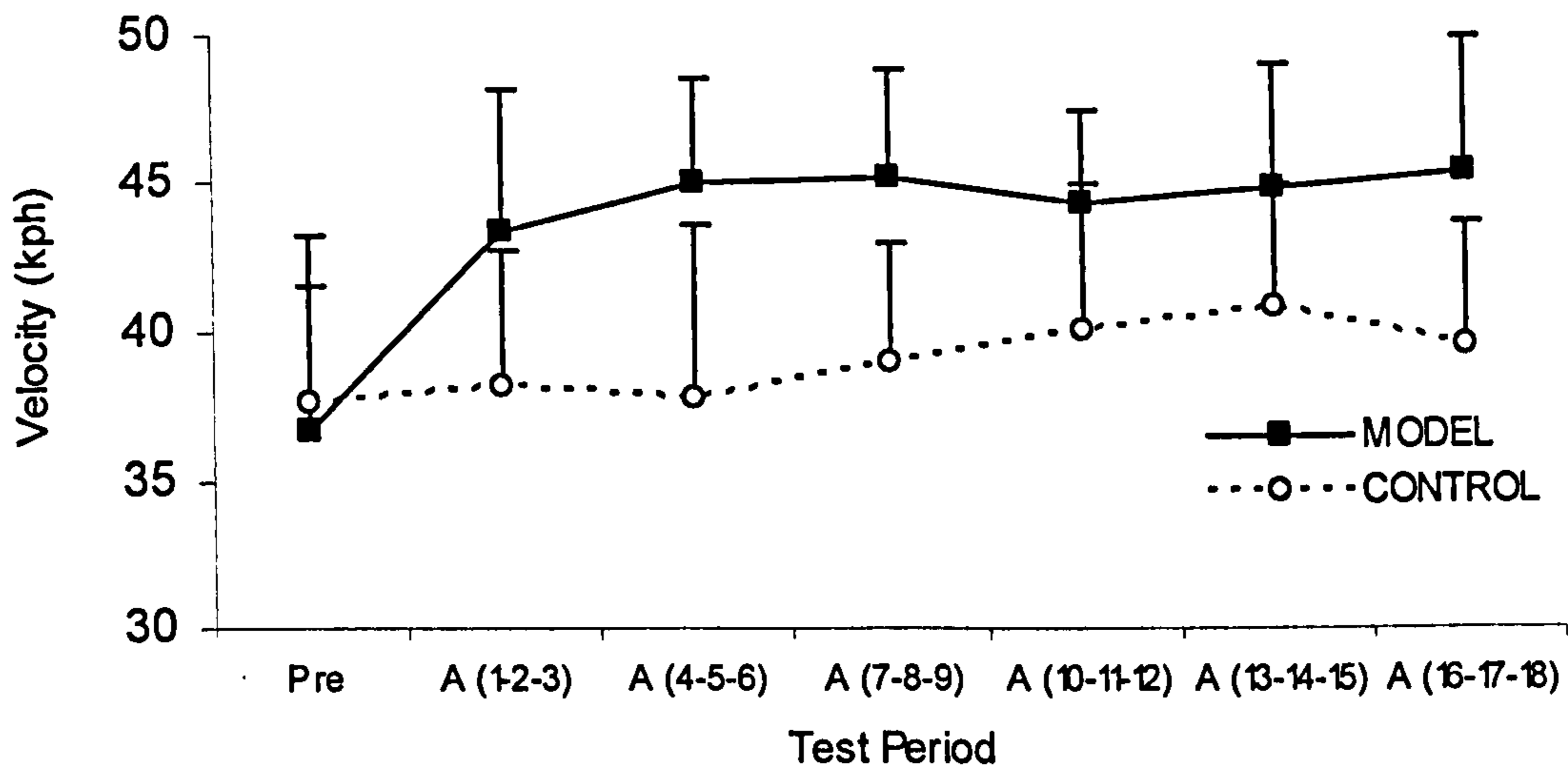


Figure 4.1. Ball velocity values for both groups across acquisition

Proximity to Model's Relative Motion – NoRM-D.

Elbow-shoulder relative motion. Figures 4.2 and 4.3 show elbow-shoulder relative motion plots across all test conditions for a single participant from the MODEL group and CONTROL group respectively. In Figure 4.2, the participant's three trials per period are shown against the model's movement pattern (dark trace). It shows a clear change in elbow-shoulder relative motion to more closely resemble the model's pattern from the pre-test to first period of acquisition. This pattern then remains stable throughout the remaining practice trials. For the CONTROL group participant in Figure 4.3, there is little change across trials and no apparent increase in proximity to the model's preferred relative motion pattern.

For proximity to the model's elbow-shoulder relative motion, ANOVA revealed a significant main effect for group, $F(1,8) = 11.66, p < .05, \omega^2 = .22$. The MODEL group illustrated elbow-shoulder relative motion that was closer to the model's relative motion pattern, as indicated by lower NoRM-D scores ($\underline{M} = 27.10, \underline{SD} = 6.49\%$) than the CONTROL group ($\underline{M} = 39.59, \underline{SD} = 8.33\%$). Figure 4.4 suggests that observation

of the model accounts for this effect. Pre-test scores for both groups are shown to be close in value (MODEL \underline{M} = 36.74, \underline{SD} = 8.58; CONTROL \underline{M} = 40.58, \underline{SD} = 7.88 %), but become markedly different in the first three trials of acquisition (MODEL \underline{M} = 25.61, \underline{SD} = 6.50; CONTROL \underline{M} = 41.57, \underline{SD} = 10.49 %). A test period effect was also present for elbow-shoulder NoRM-D, \underline{F} (6, 48) = 4.37, $p < .05$, $\omega^2 = .42$. Participants as a whole decreased their NoRM-D scores from the pre-test (\underline{M} = 38.66, \underline{SD} = 8.03 %) to more closely approximate the model's RM pattern in acquisition periods A7-9 (\underline{M} = 32.20, \underline{SD} = 9.46 %), A12-15 (\underline{M} = 29.75, \underline{SD} = 8.00), and A16-18 (\underline{M} = 29.97, \underline{SD} = 8.37 %).

Knee-hip relative motion. Figures 4.5 and 4.6 show the knee-hip relative motion patterns of one member of the MODEL and CONTROL groups respectively across each period. Once again the participant observing the model (Figure 4.5) shows a substantial change in relative motion from pre-test to the first three trials of acquisition. This pattern is then refined in subsequent periods, but changes relatively little. The participant performing the throws without observation of the model appears to change neither range of motion (indicated by the size of the plots) nor relative motion (indicated by shape) across acquisition (Figure 4.6).

ANOVA for proximity to the model's knee-hip relative motion, as measured by NoRM-D, indicated a main effect for Group observed, \underline{F} (1,8) = 37.15, $p < .05$, $\omega^2 = .18$. The MODEL group showed greater proximity to the model's knee-hip relative motion pattern (\underline{M} = 35.41, \underline{SD} = 12.69 %) than the CONTROL group (\underline{M} = 55.55, \underline{SD} = 5.50 %). A main effect for test period was also present, \underline{F} (2.86, 22.85), = 14.25, $p < .05$, $\omega^2 = .40$. Participants lowered their NoRM-D scores to more closely imitate the model from the pre-test (\underline{M} = 57.17, \underline{SD} = 9.87 %) to all subsequent acquisition periods (A1-3: \underline{M} = 41.00, \underline{SD} = 13.53; A4-6: \underline{M} = 40.02, \underline{SD} = 12.00; A7-9: \underline{M} = 41.24, \underline{SD} = 11.04;

A10-12: $\underline{M} = 42.78$, $\underline{SD} = 12.33$; A13-15: $\underline{M} = 40.32$, $\underline{SD} = 11.40$; A16-18: $\underline{M} = 41.84$, $\underline{SD} = 12.33$ %).

A Group x Test Period interaction was also present, $F(2.86, 22.85) = 12.93$, $p < .05$, $\omega^2 = .36$. Figure 4.7 shows group data for knee-hip NoRM-D across test periods. It suggests that the response of the MODEL group to the demonstration accounts for both the group effect and the interaction. The CONTROL group showed almost no change across test periods, and almost identical scores in the pre-test ($\underline{M} = 52.13$, $\underline{SD} = 4.43$ %) and the last period of acquisition ($\underline{M} = 54.00$, $\underline{SD} = 5.20$ %). The MODEL group shows a large change from the pre-test ($\underline{M} = 62.21$, $\underline{SD} = 11.66$ %) to the first three trials of acquisition ($\underline{M} = 30.29$, $\underline{SD} = 8.75$ %), and then maintains a similar level of proximity until the end of acquisition ($\underline{M} = 30.93$, $\underline{SD} = 4.07$ %).

Variability in Relative Motion - NoRMS

Elbow-shoulder. For elbow-shoulder relative motion, there were no main effects or interactions.

Knee-hip. ANOVA revealed a significant main effect for time, $F(1.88, 15.02) = 6.28$, $p < .05$, $\omega^2 = .72$. Post-hoc analysis indicated that participants reduced variability in all periods after the pre-test. This pattern is illustrated in Figure 4.8. No main effect for group or Group x Test Period interaction was present. Figure 4.8 however indicates that variability fell substantially for the MODEL group from the pre-test to first acquisition period. Throughout acquisition, variability appears slightly lower for the MODEL group than the CONTROL group. Interestingly, the standard deviations of NoRMS (i.e., the extent of variability in variability) are markedly lower for the MODEL group than CONTROL group throughout acquisition.

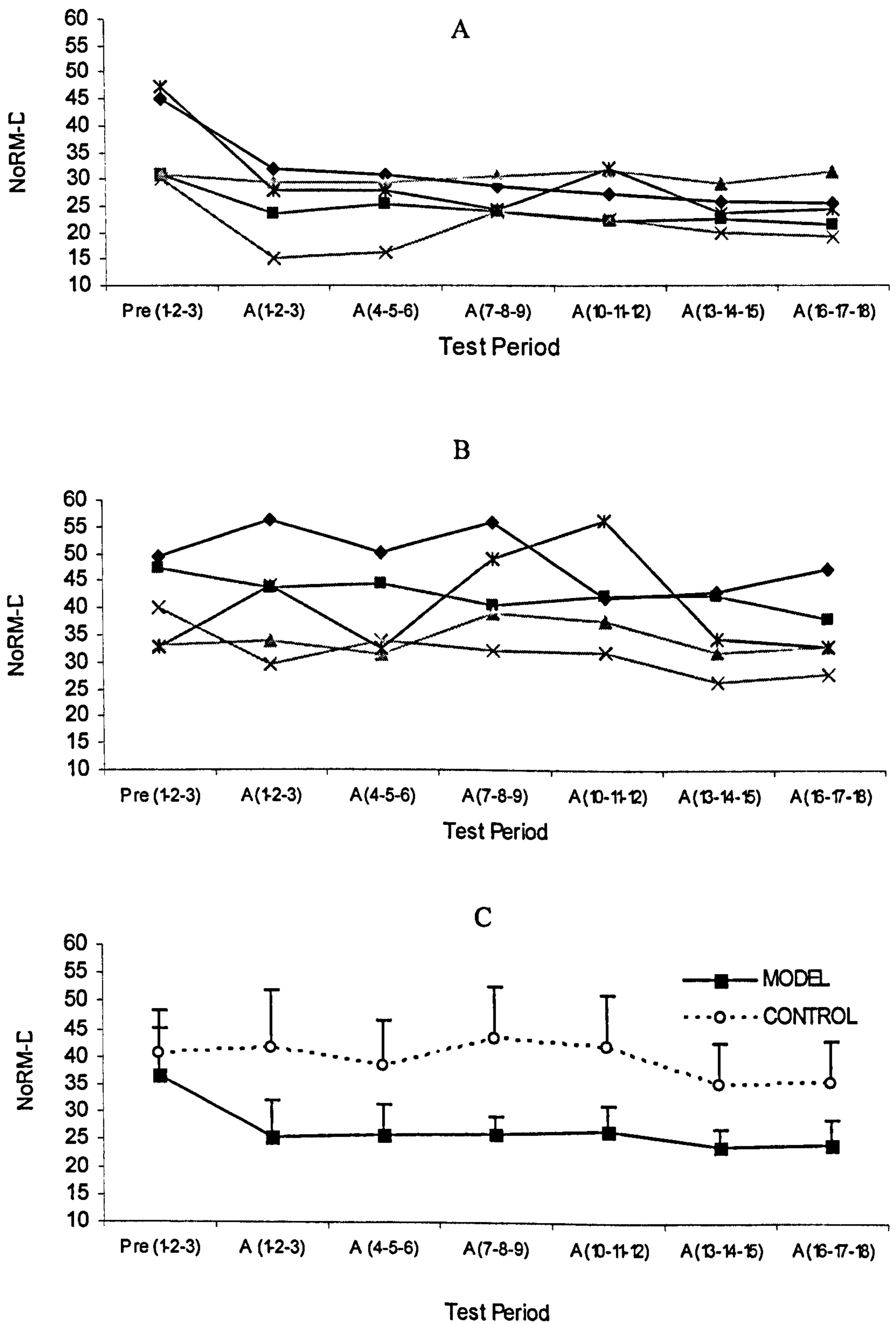


Figure 4.4. Elbow-shoulder NoRM-D (%) scores for the MODEL group (A), CONTROL group (B) and group averages (C) across acquisition

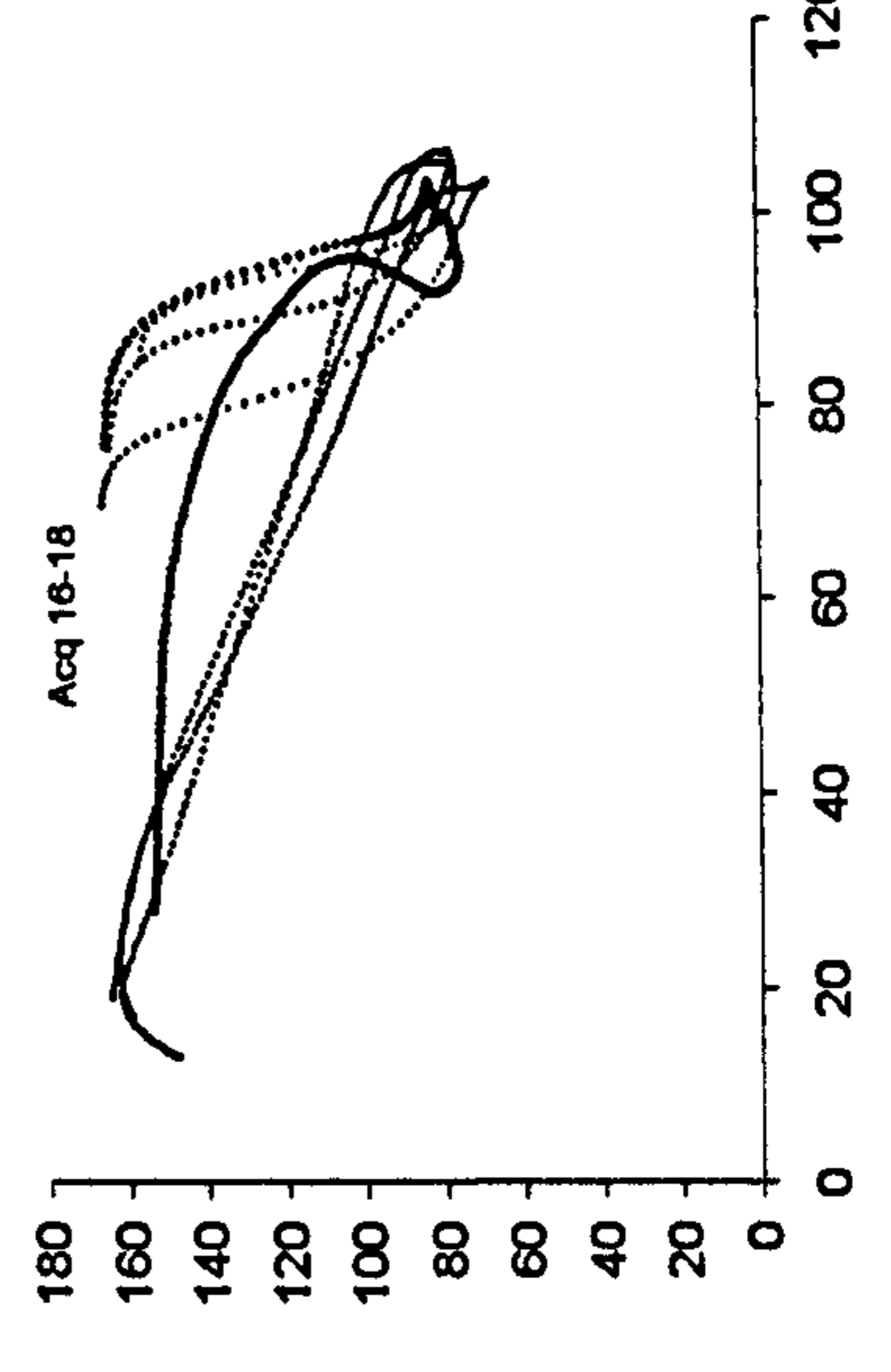
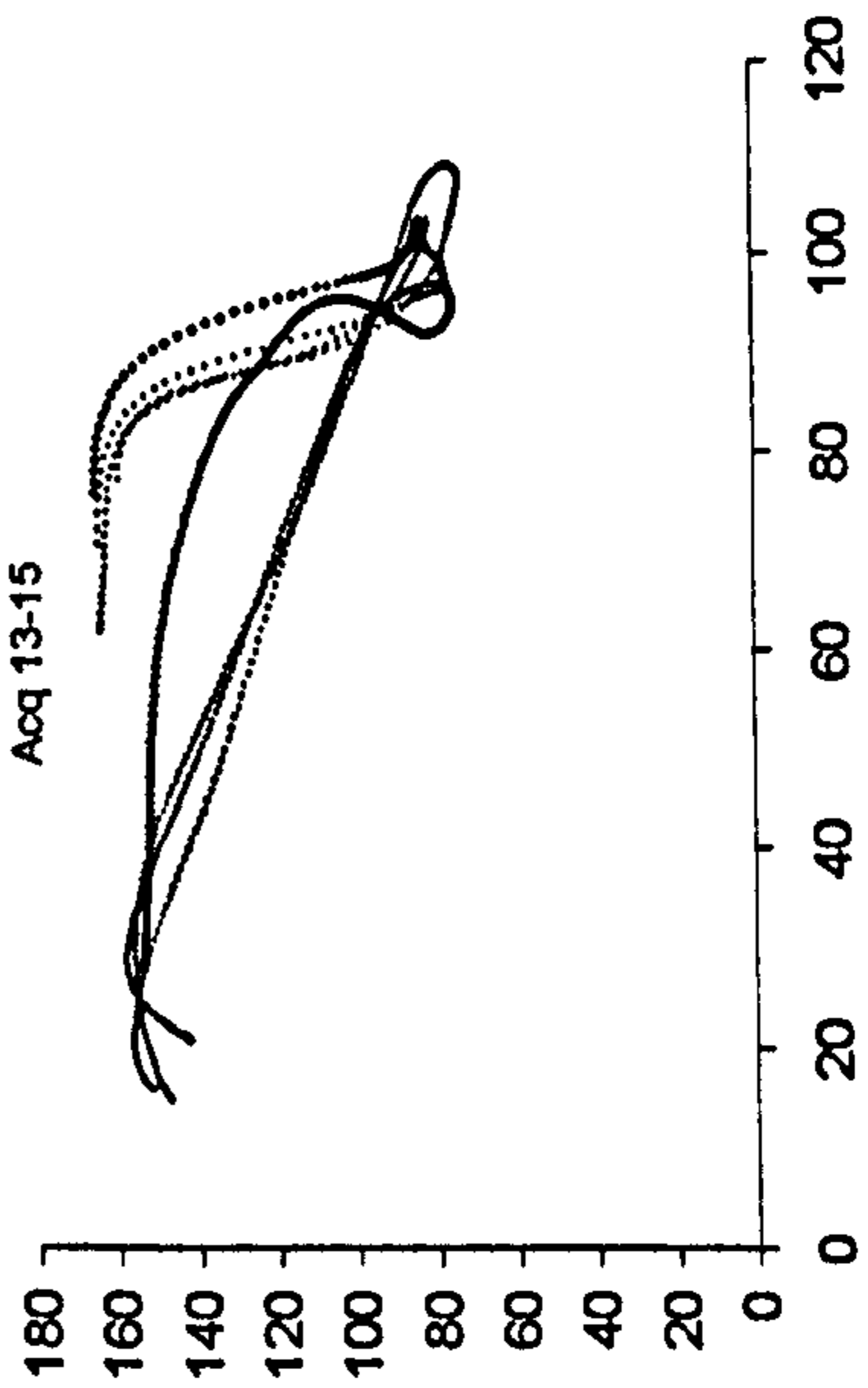
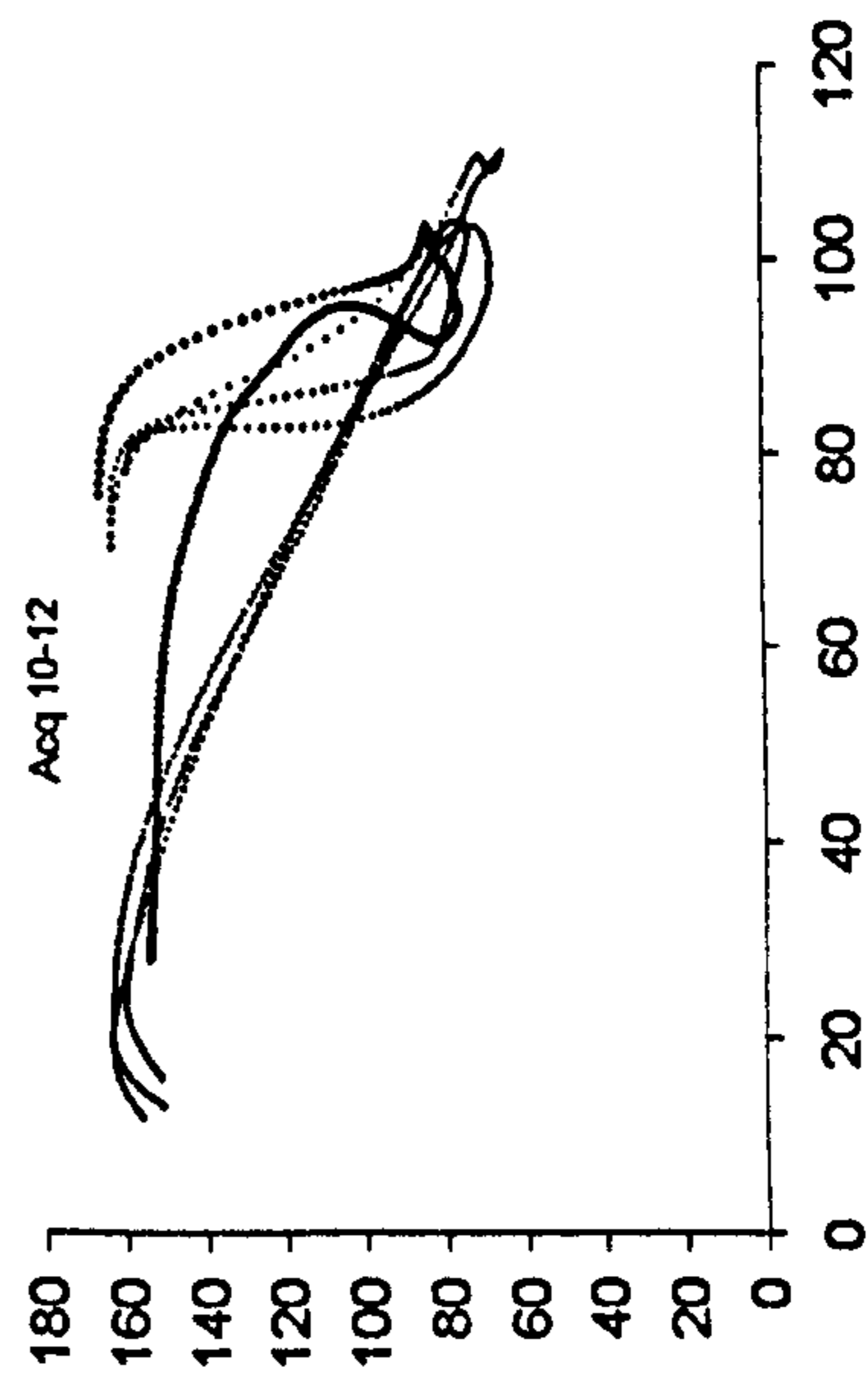
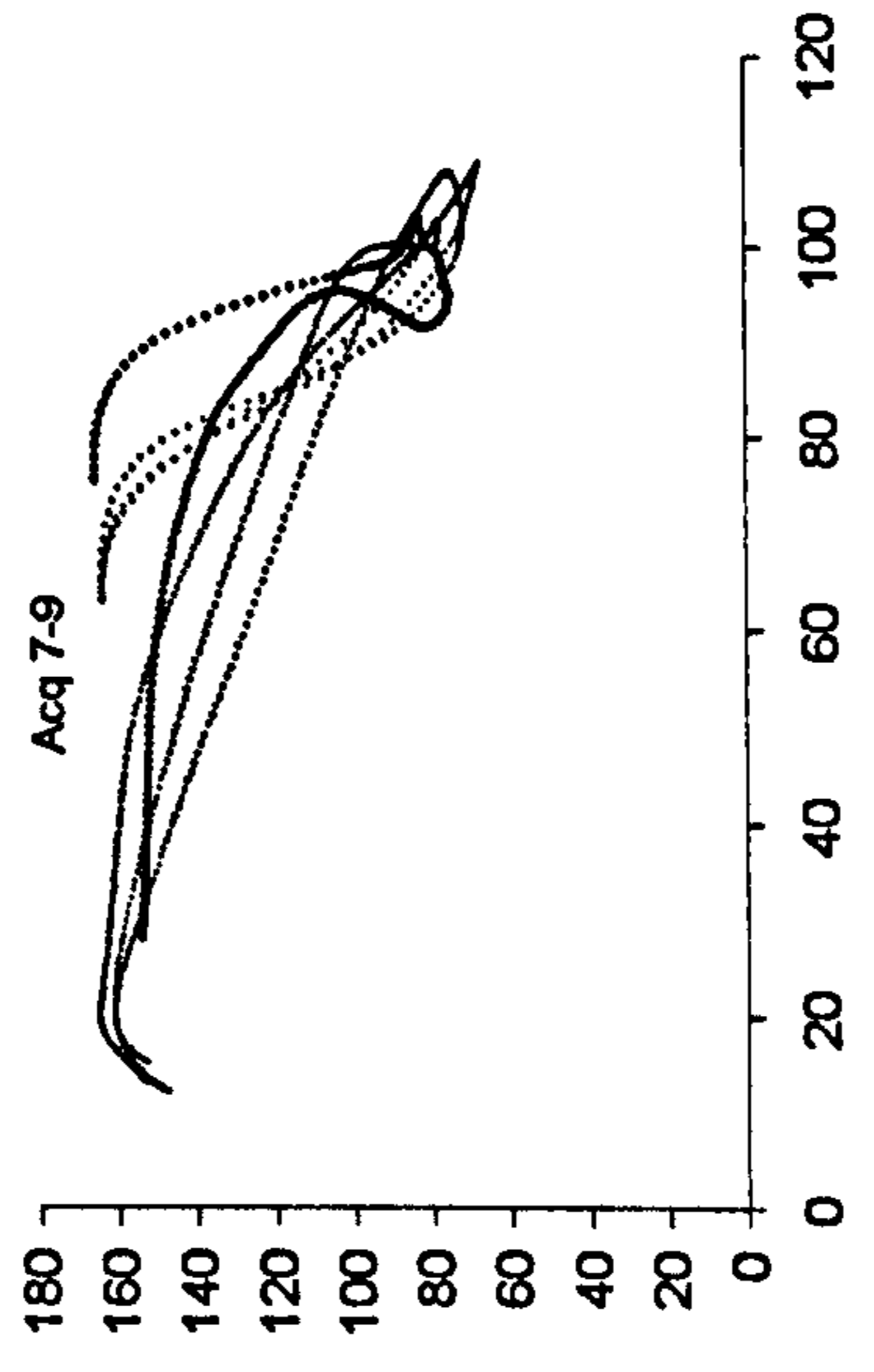
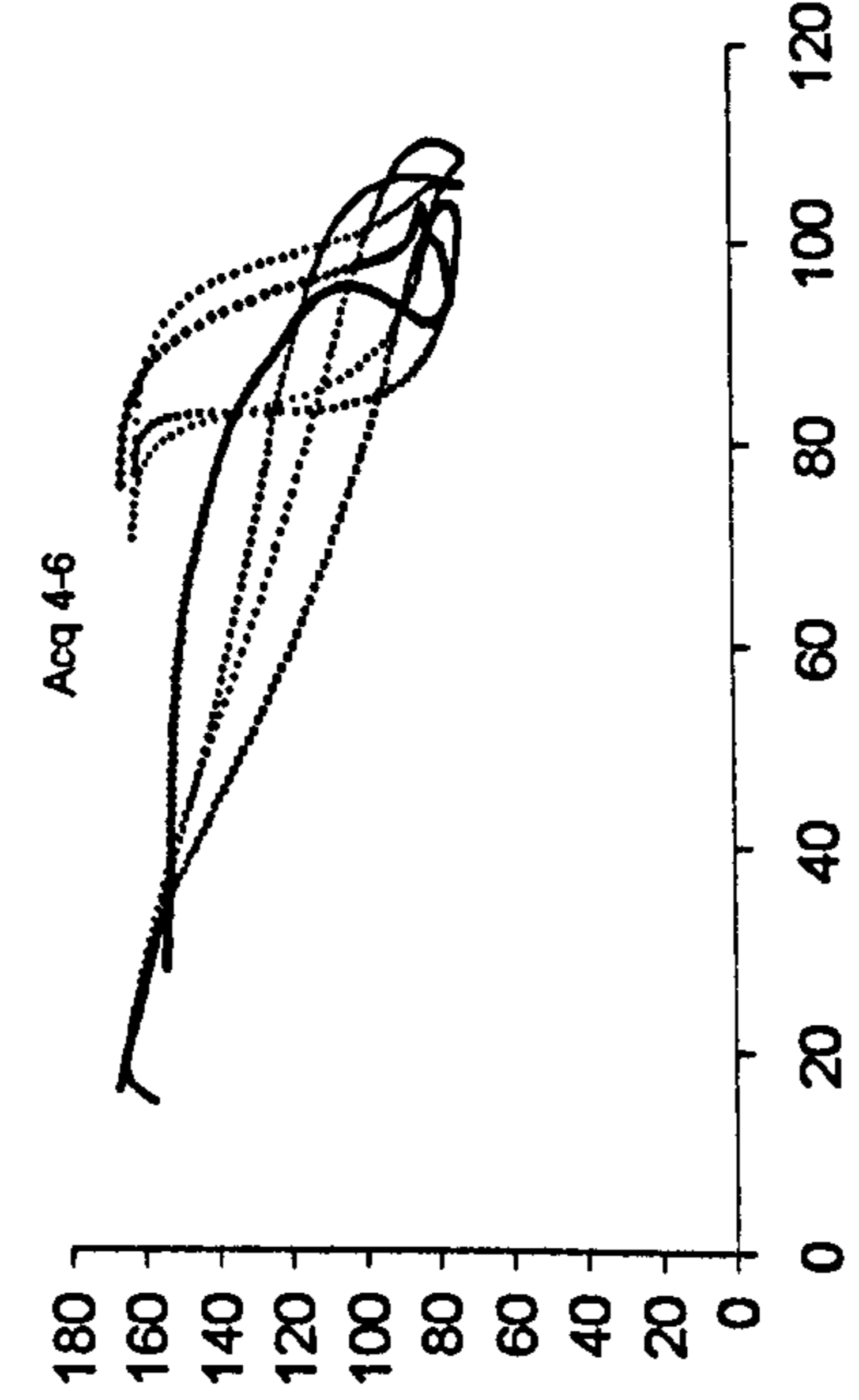
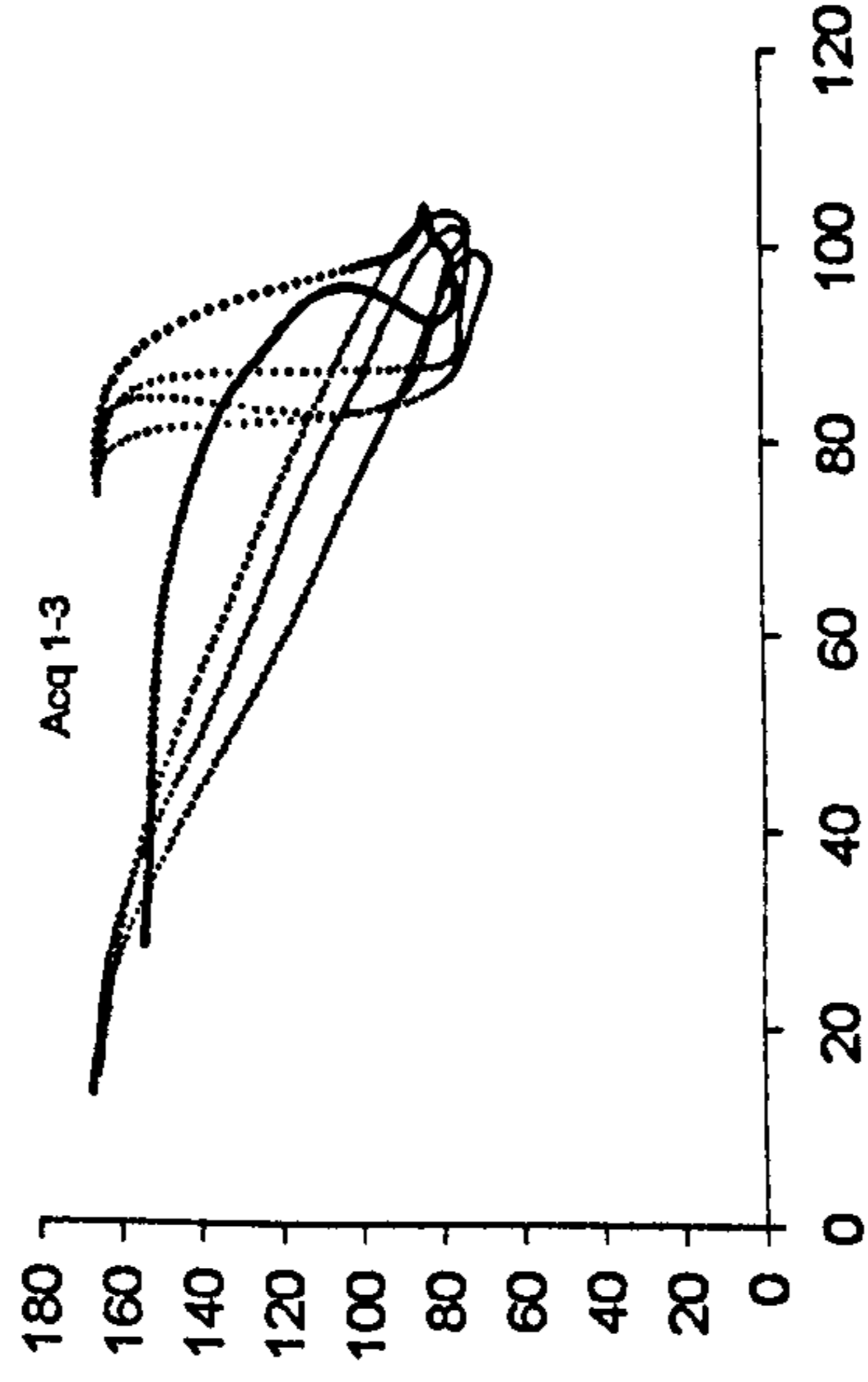
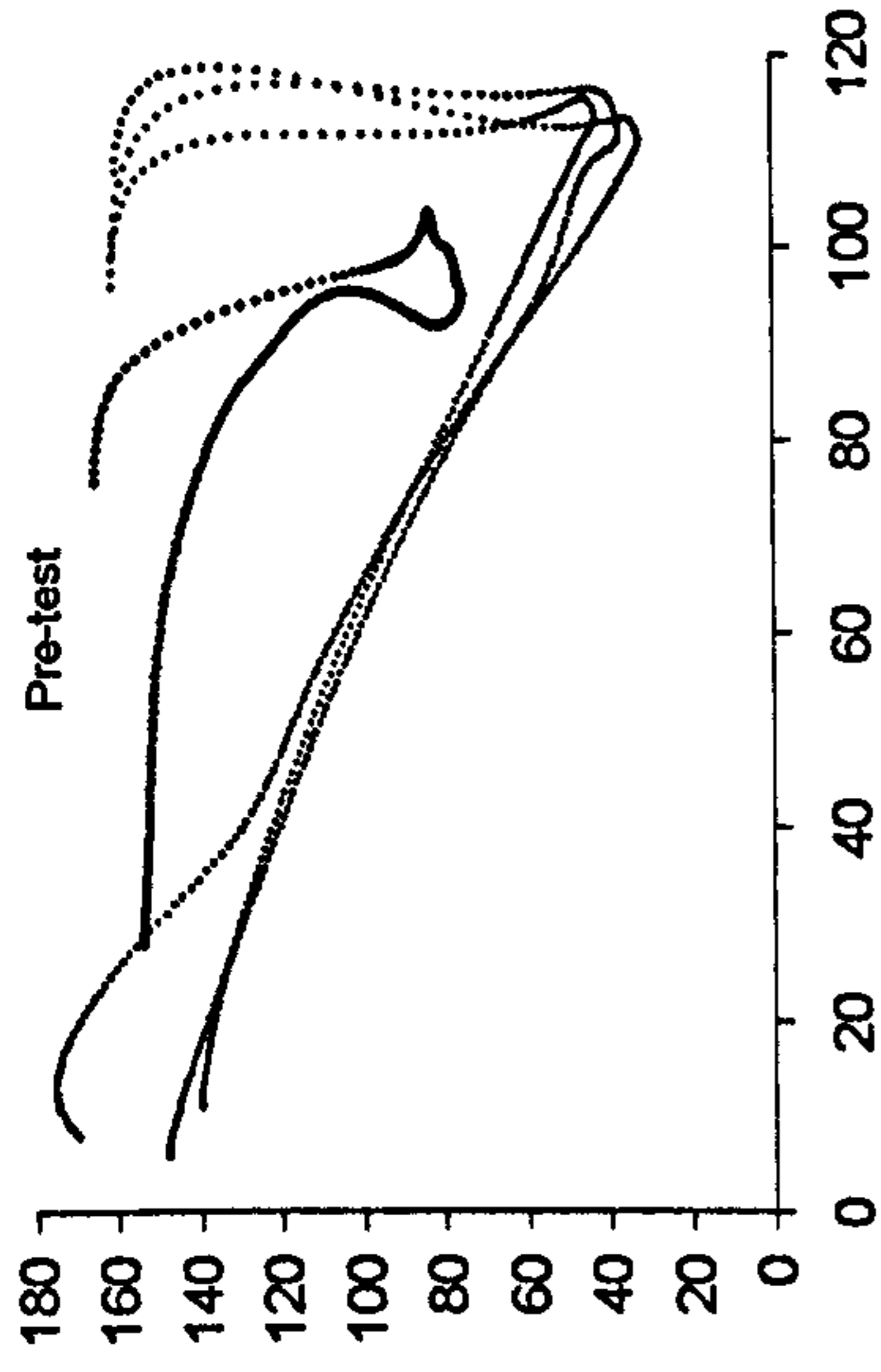
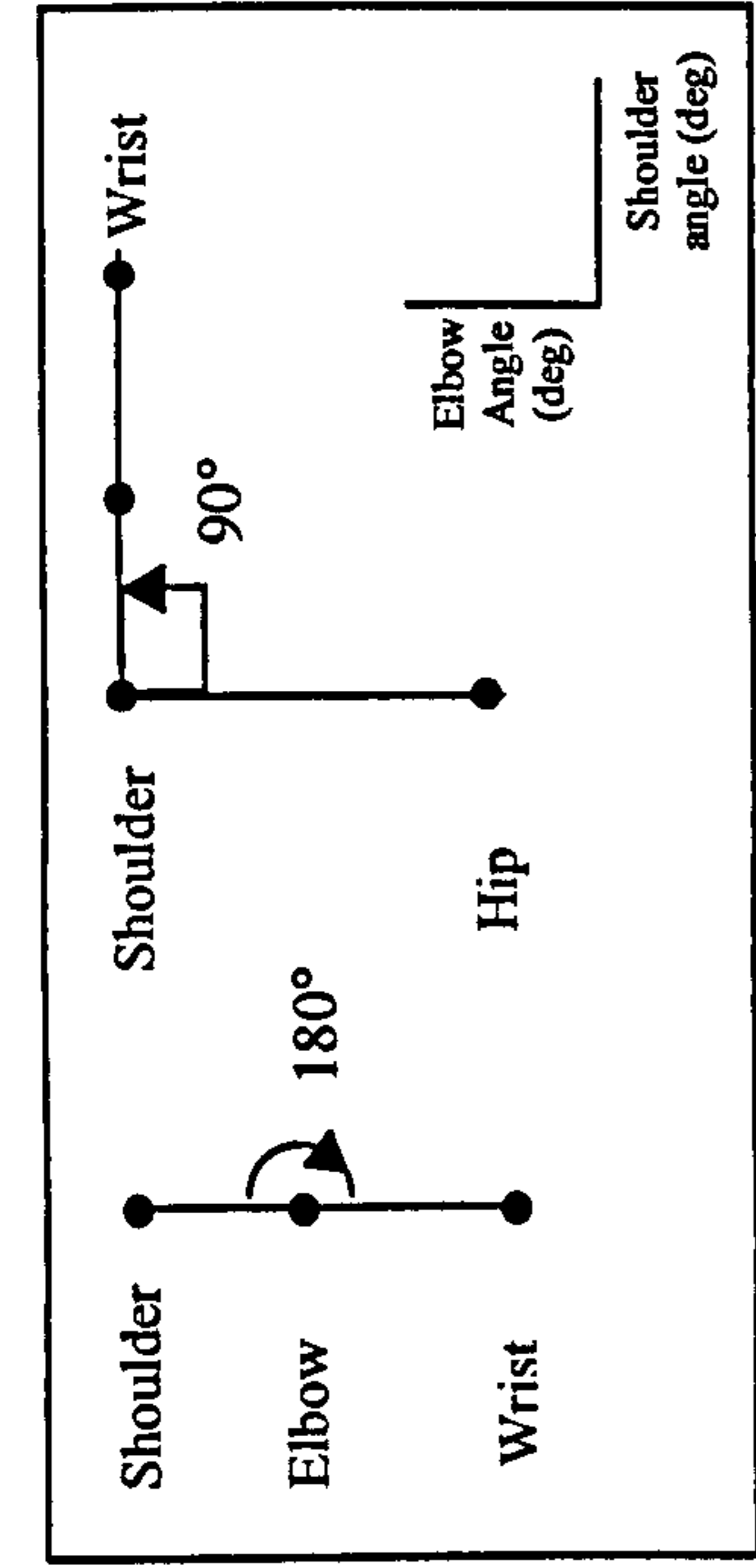


Figure 4.2. Elbow-shoulder relative motion across acquisition for a representative participant from the MODEL group (dark plot = the model's pattern; 3 lighter plots = participant's patterns).

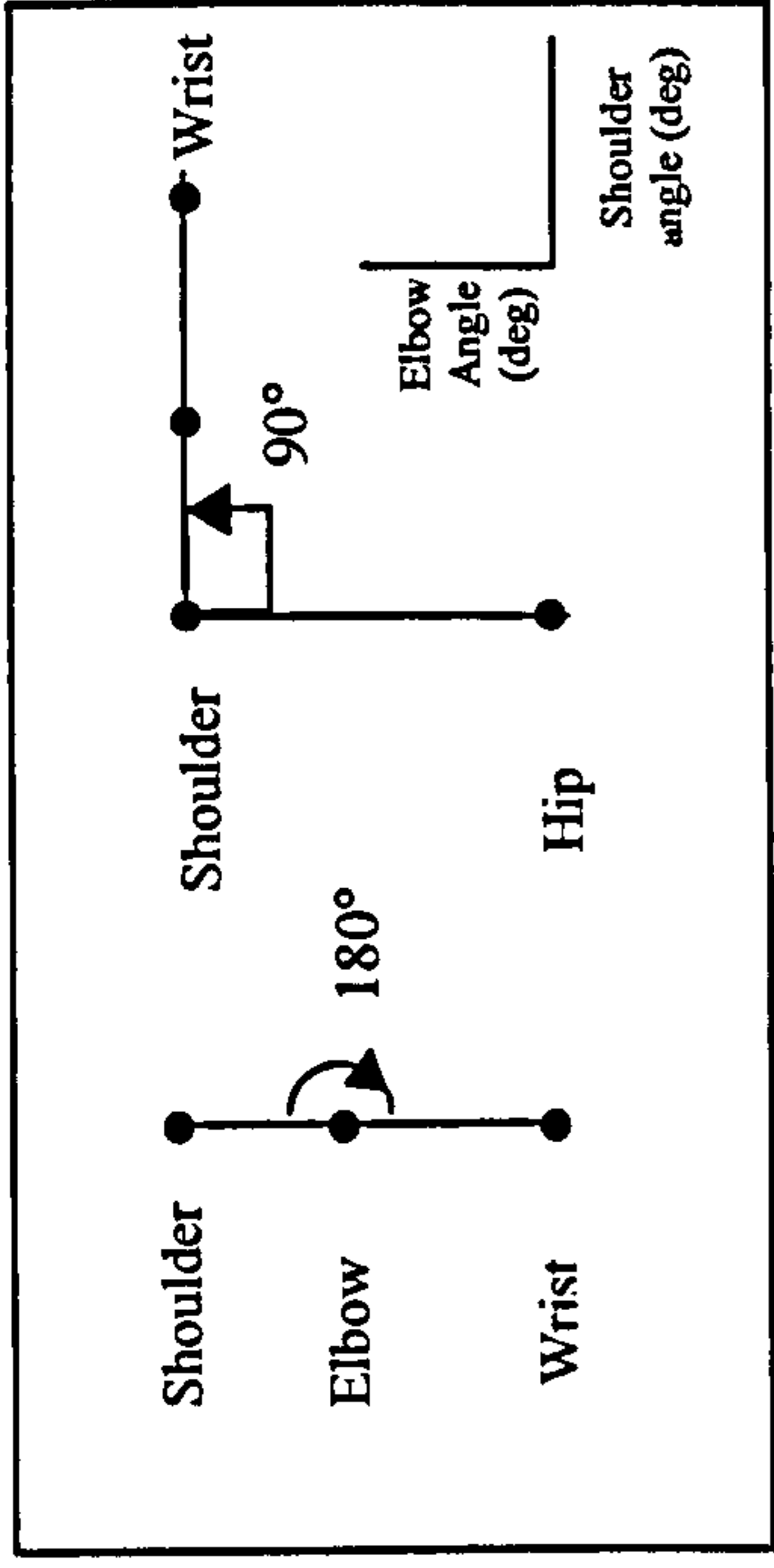
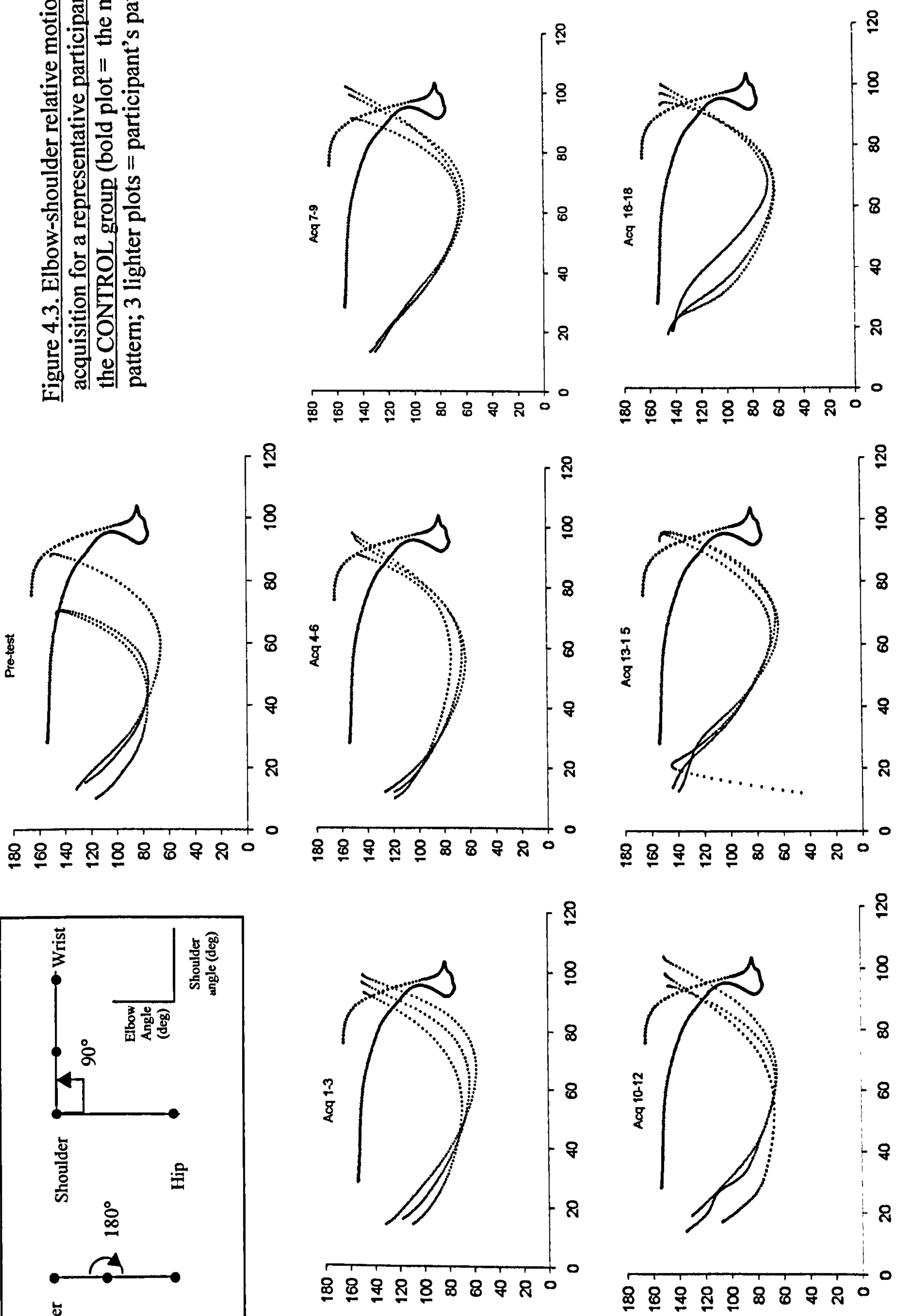


Figure 4.3. Elbow-shoulder relative motion across acquisition for a representative participant from the CONTROL group (bold plot = the model's pattern; 3 lighter plots = participant's patterns).



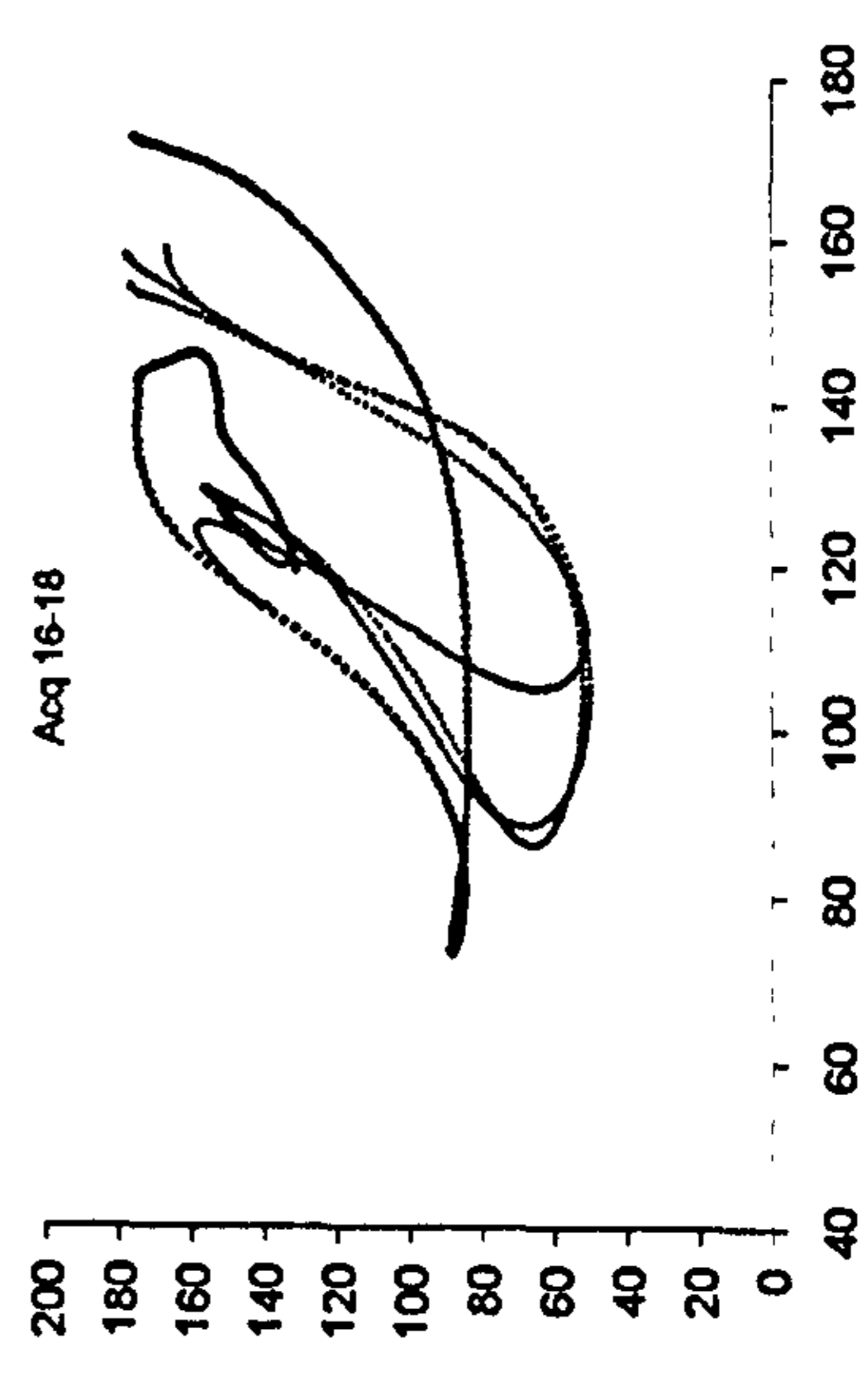
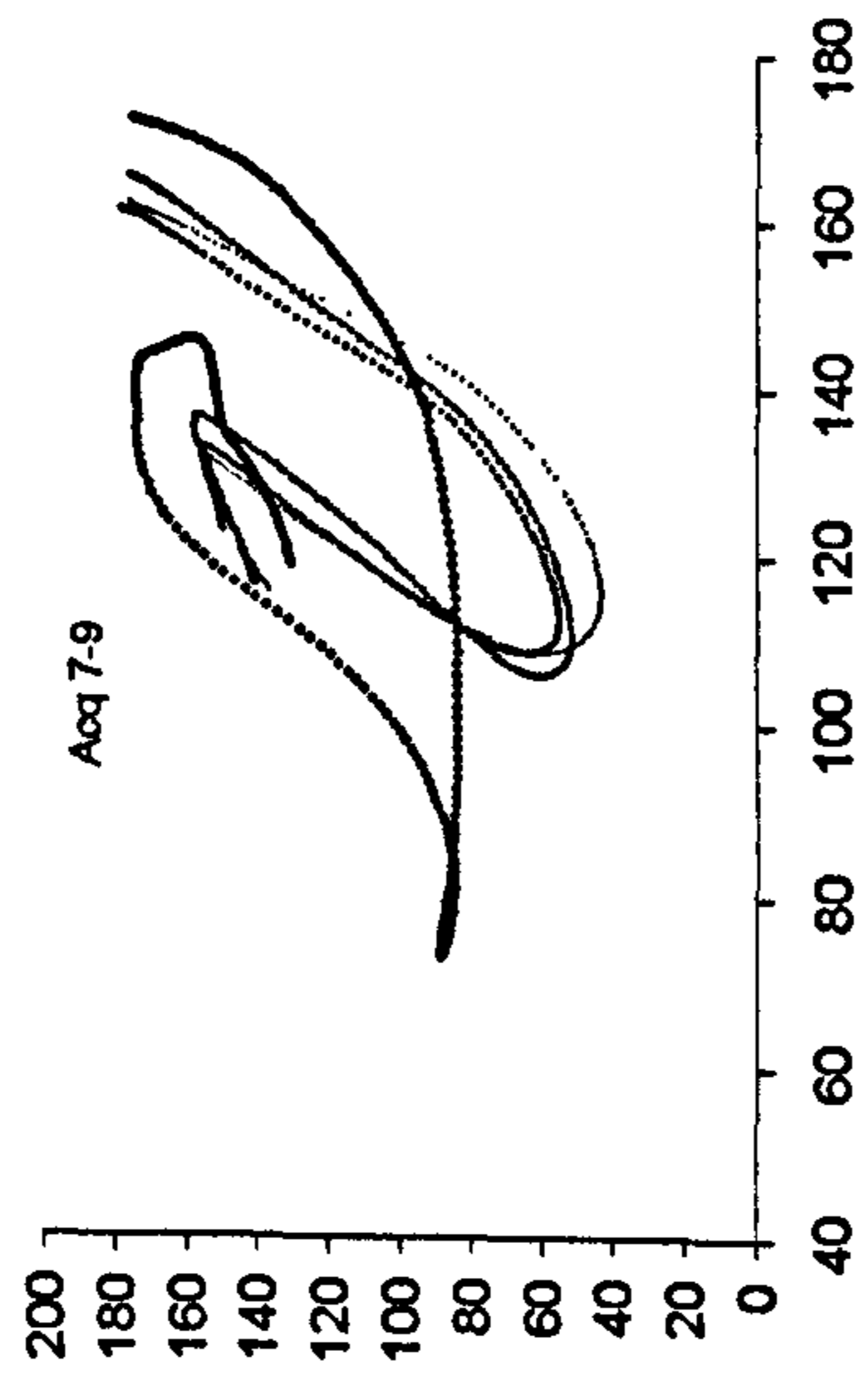
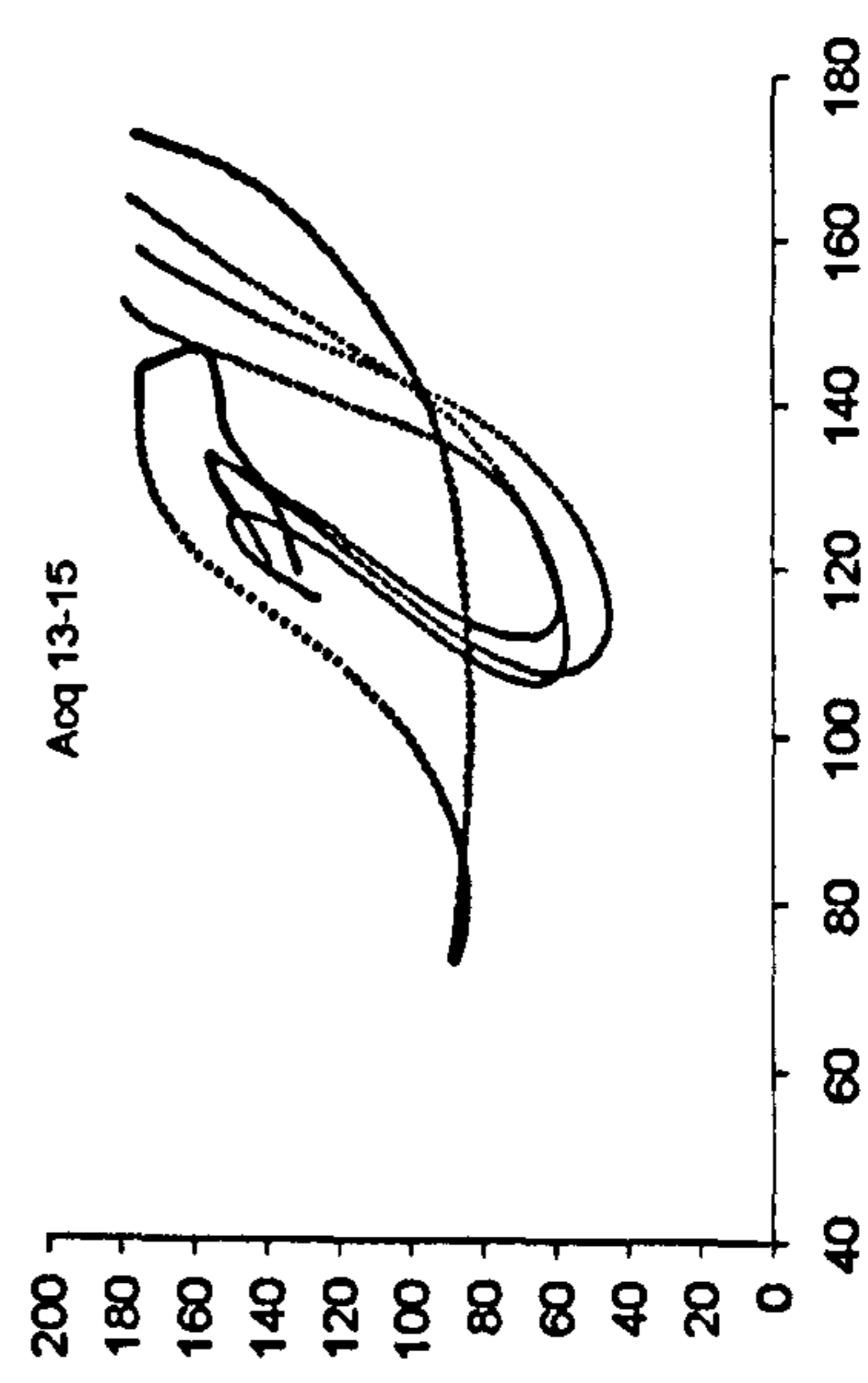
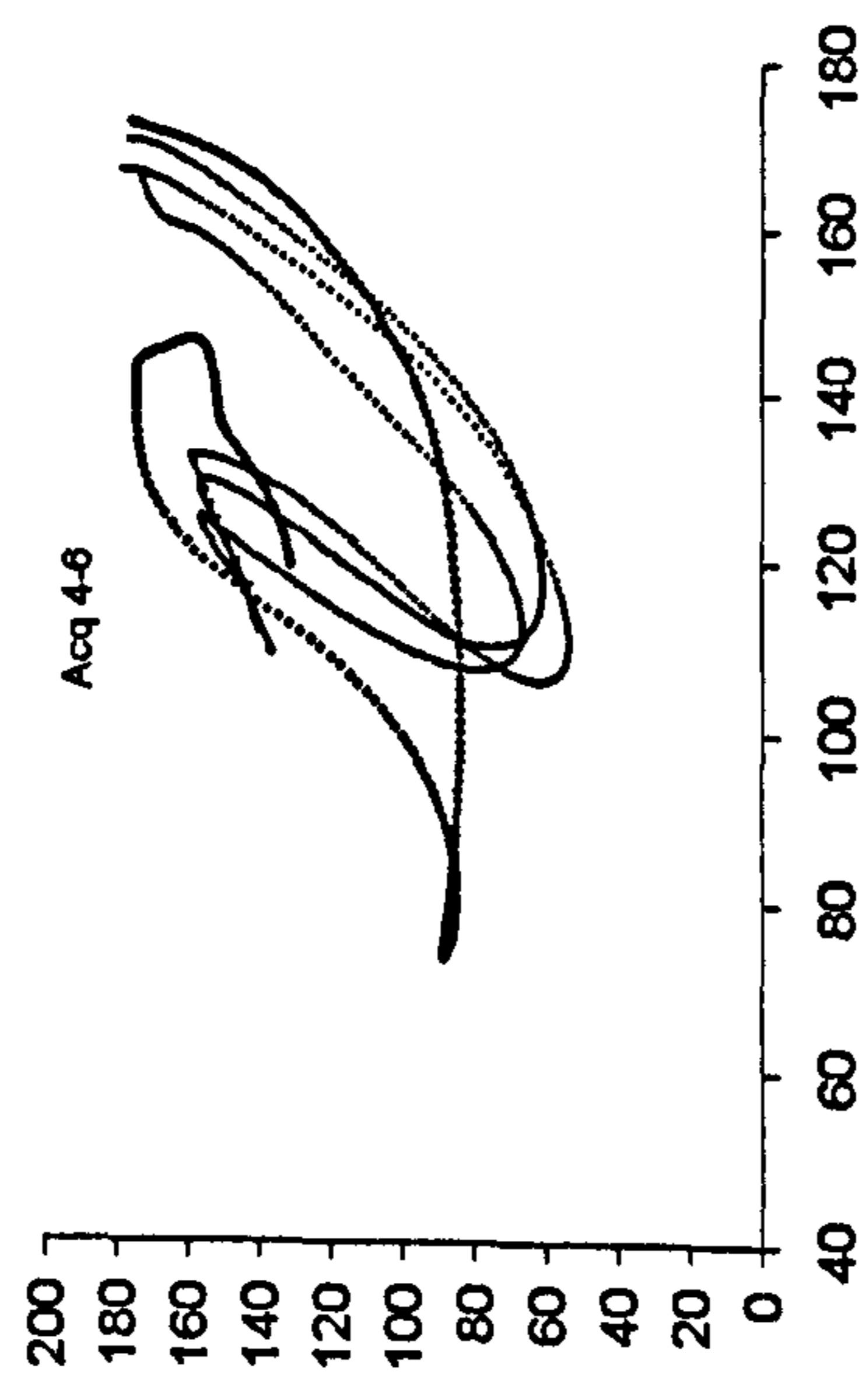
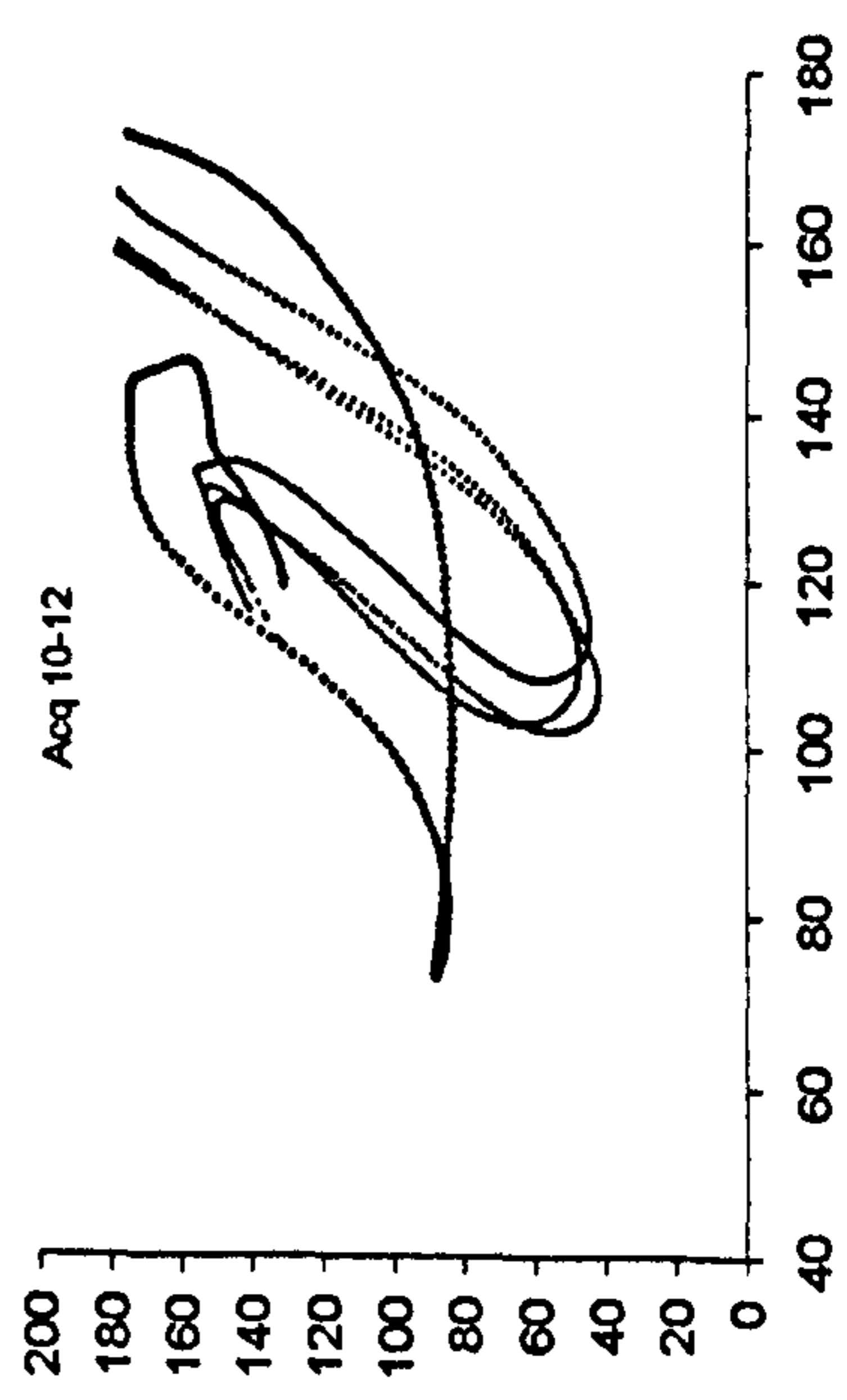
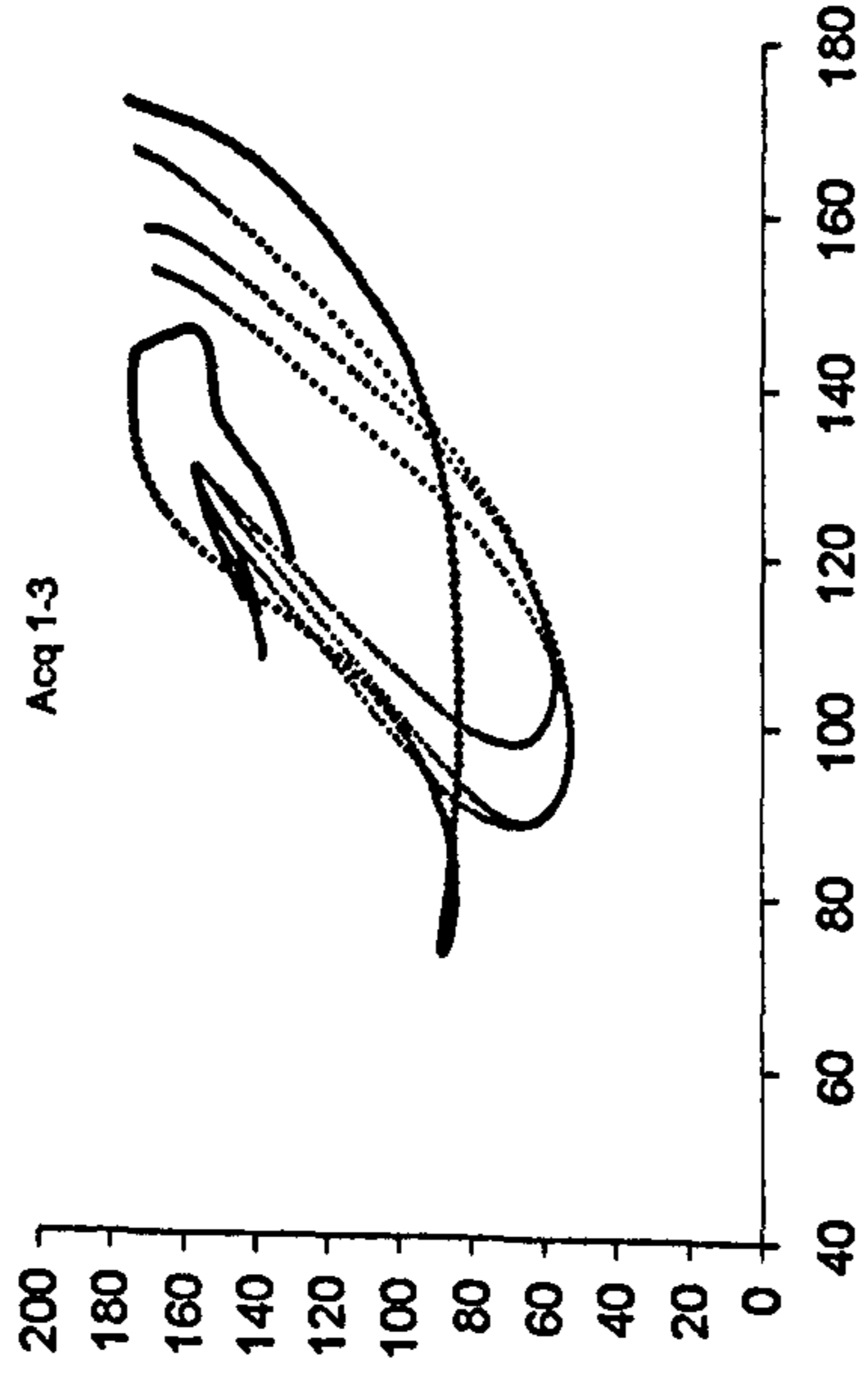
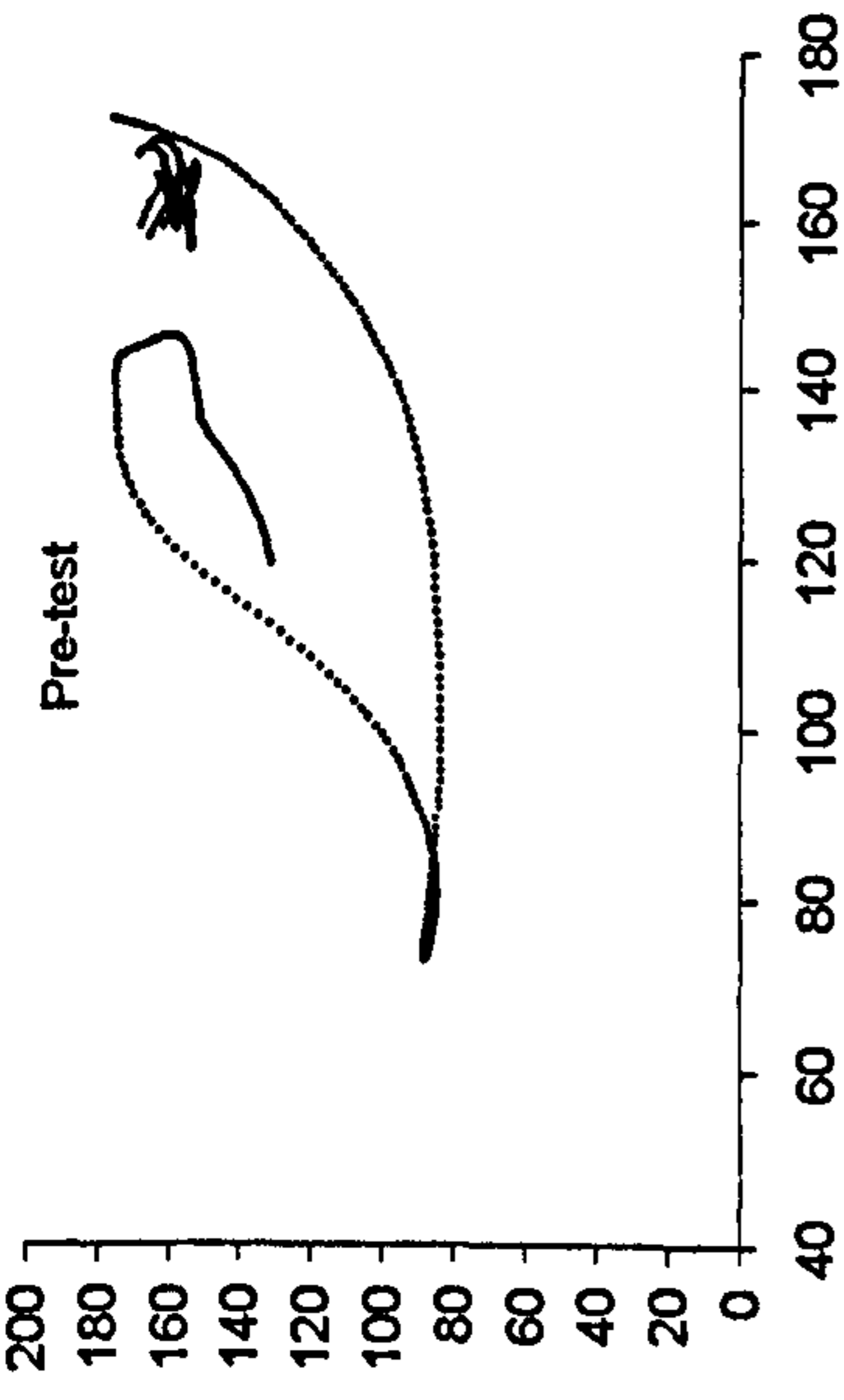
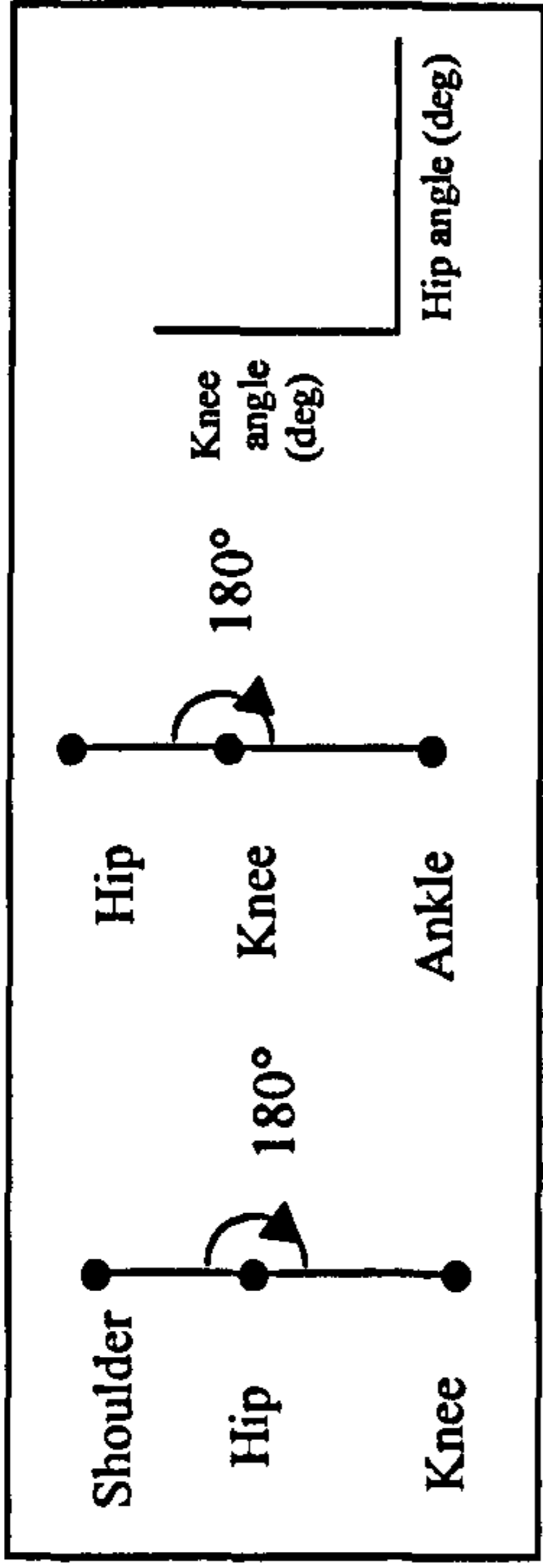


Figure 4.4. Knee-hip relative motion across acquisition for a representative participant from the MODEL group (bold plot = the model's pattern; 3 lighter plots = participant's patterns).

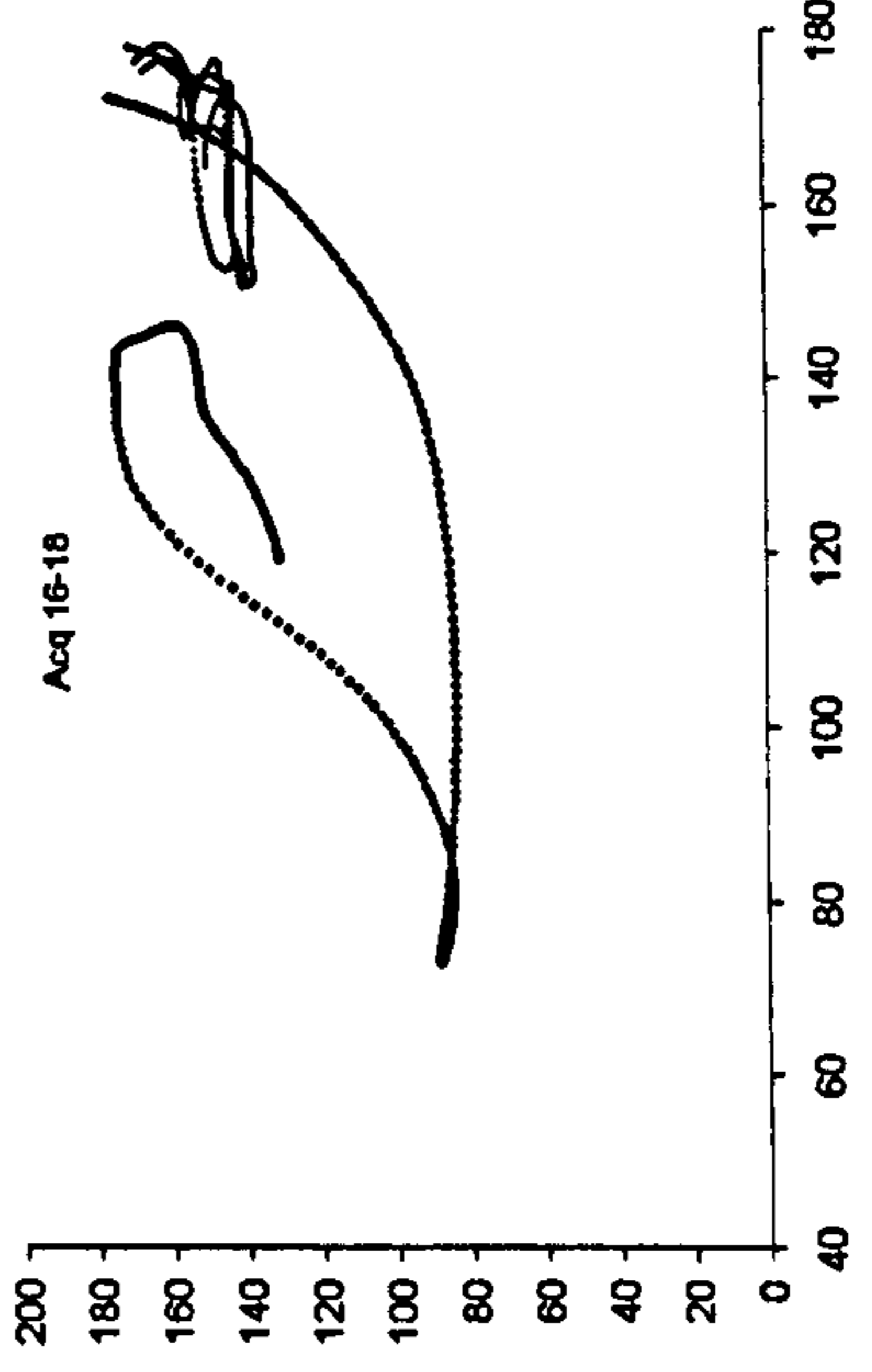
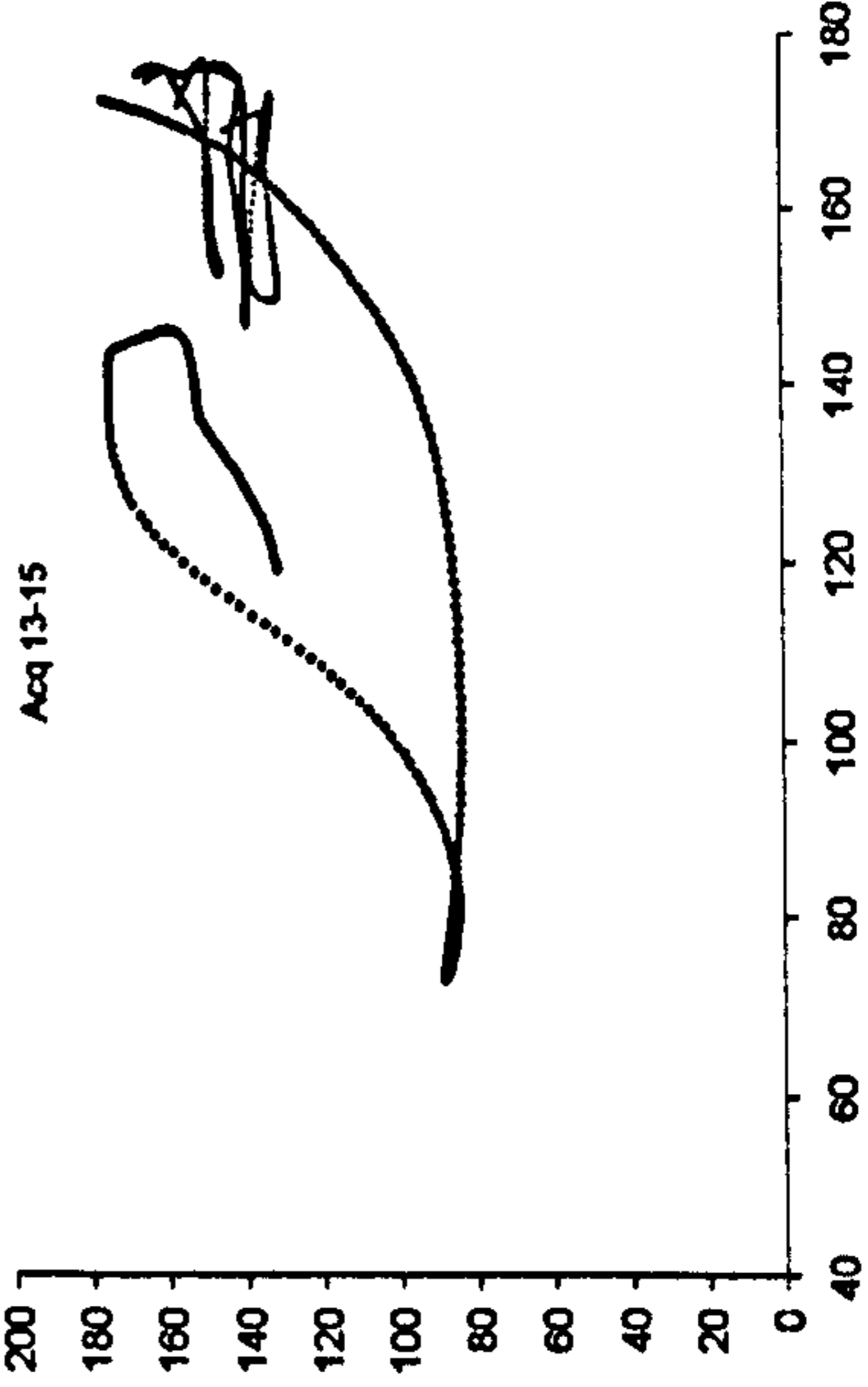
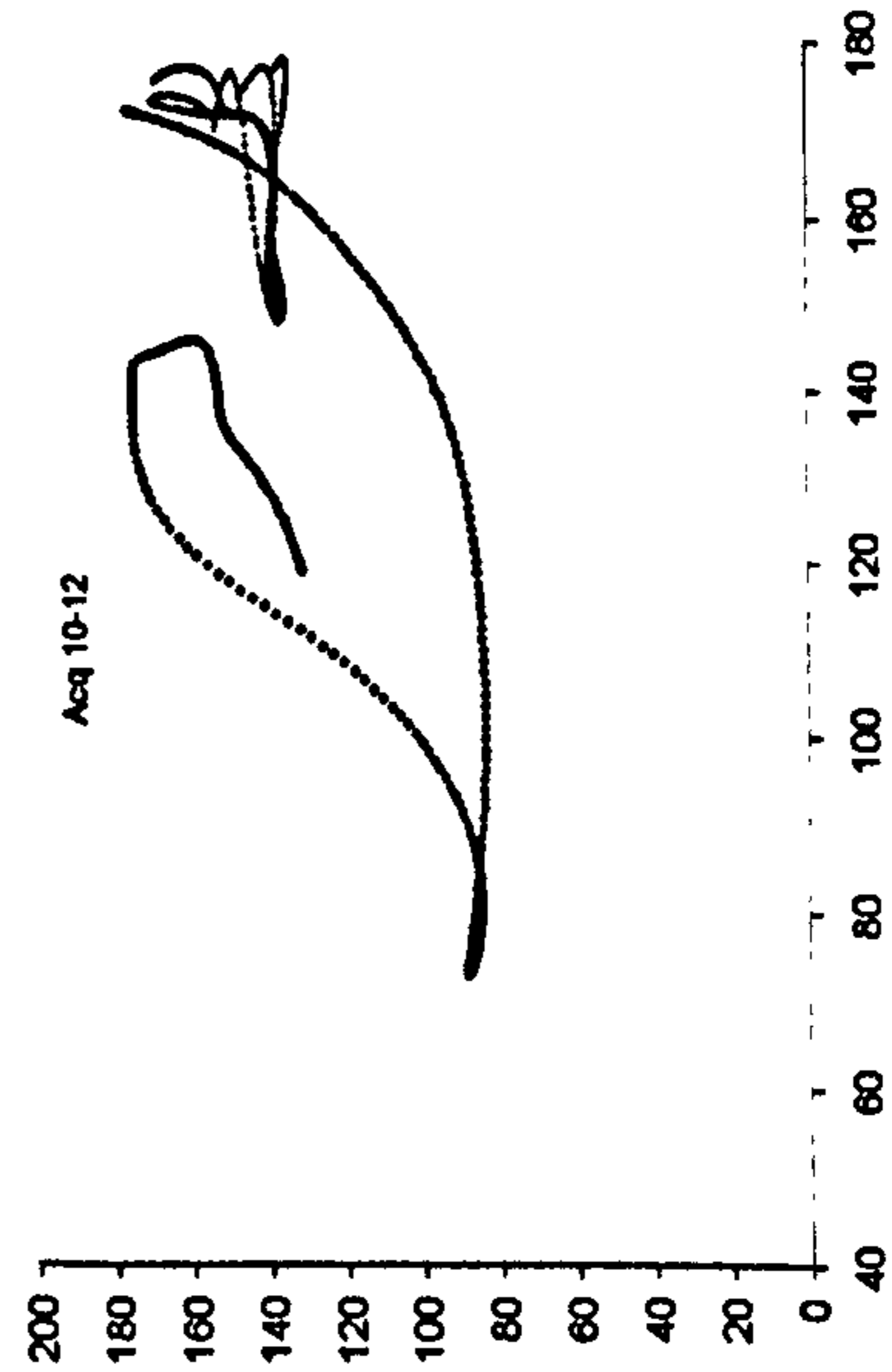
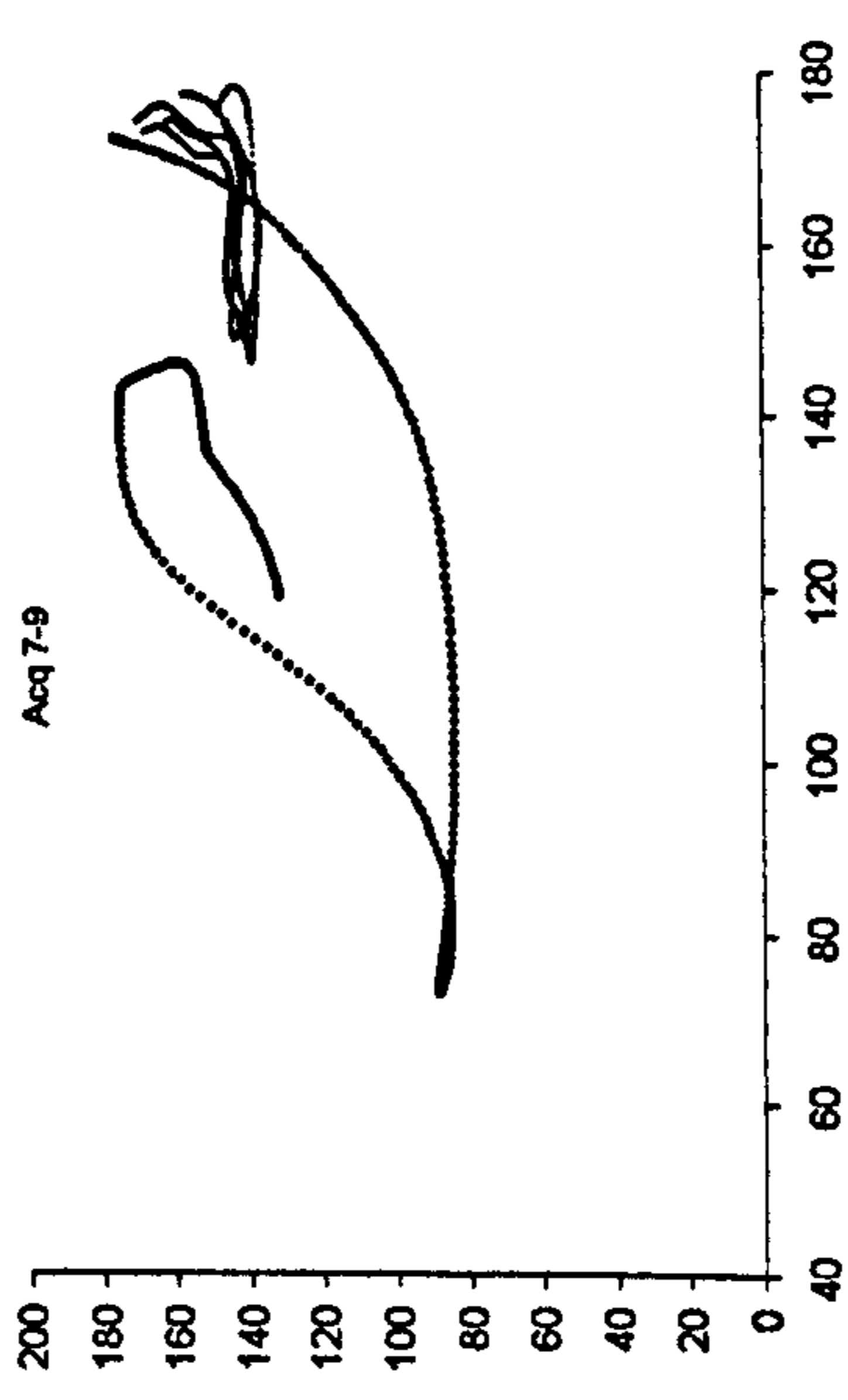
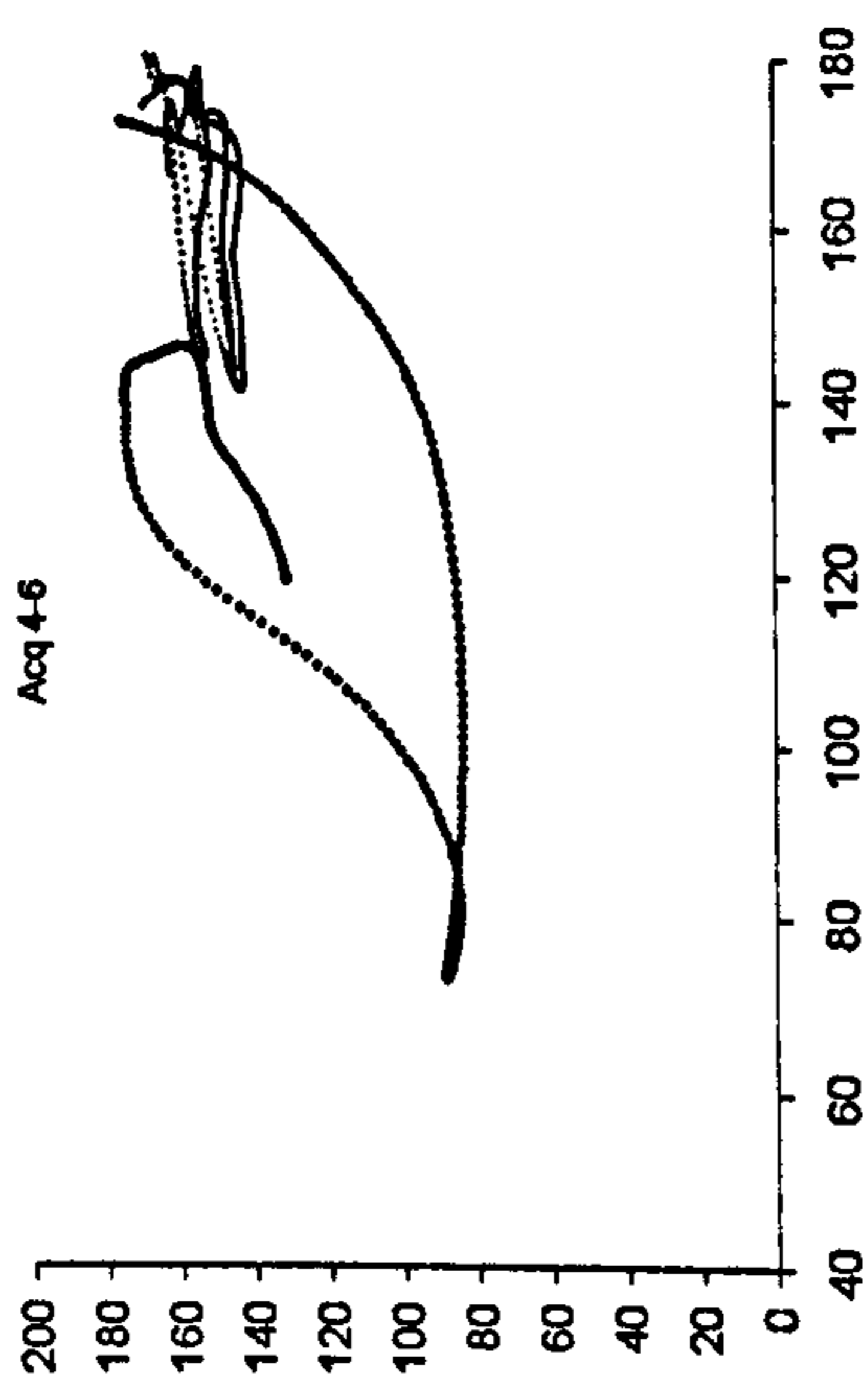
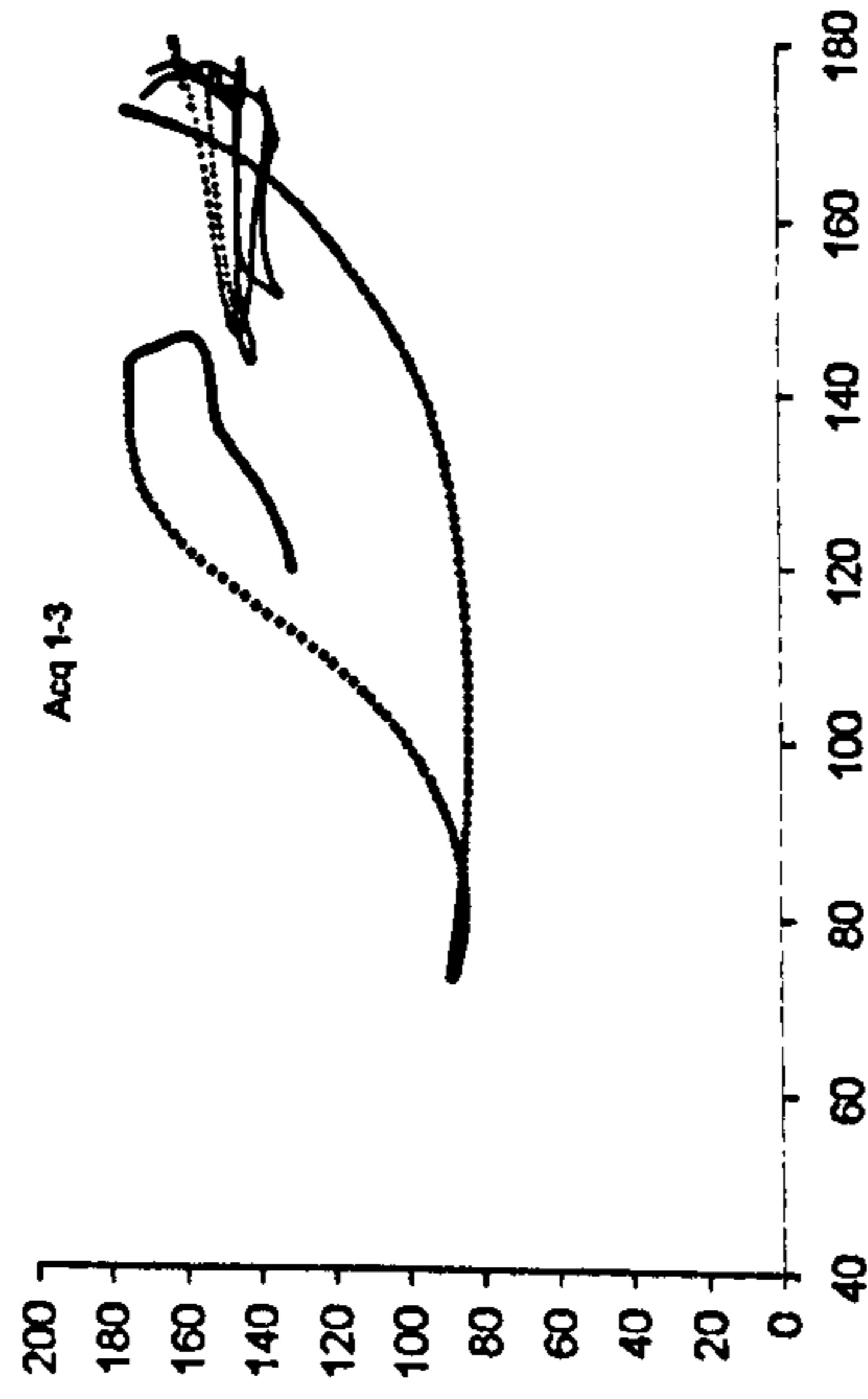
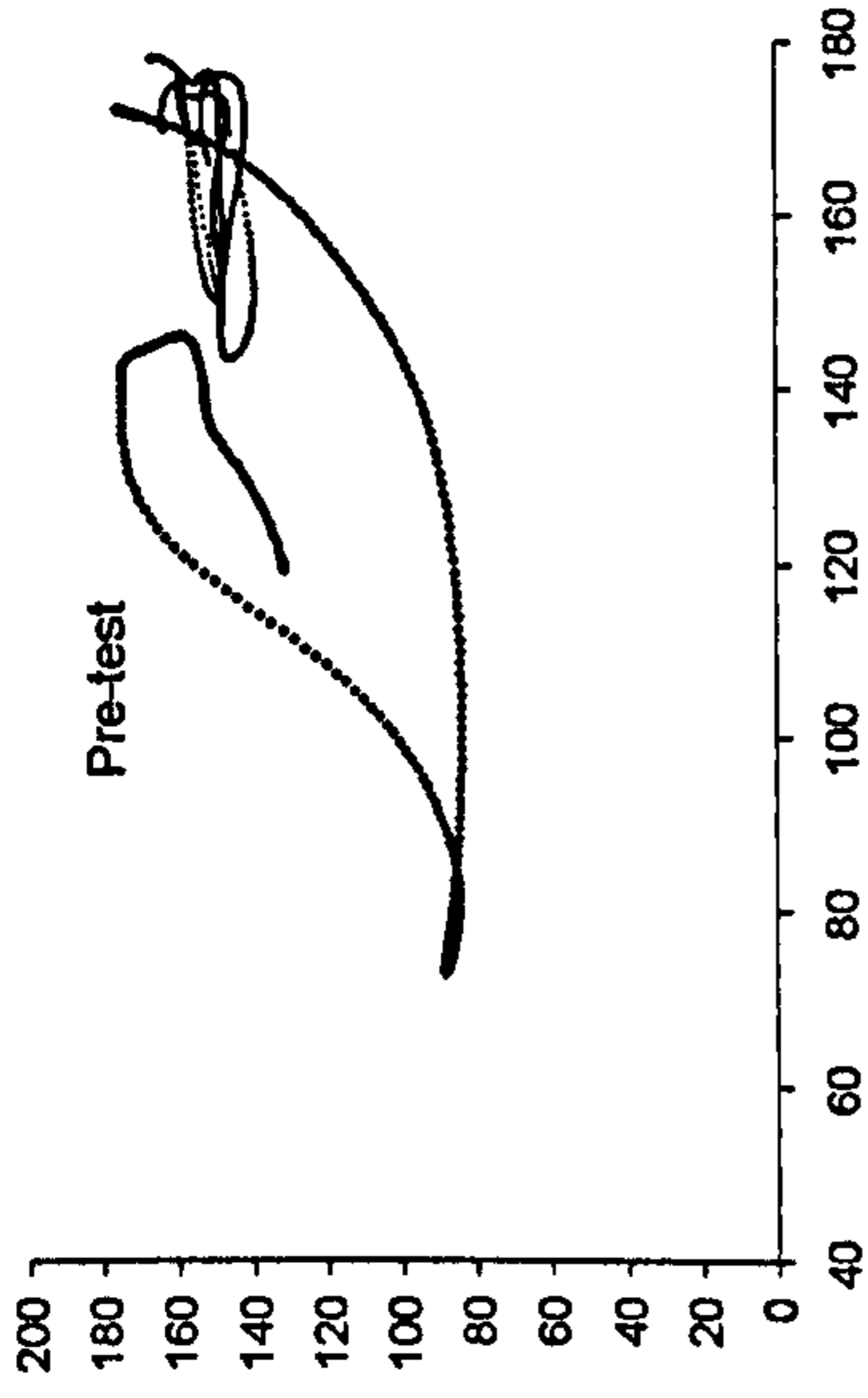
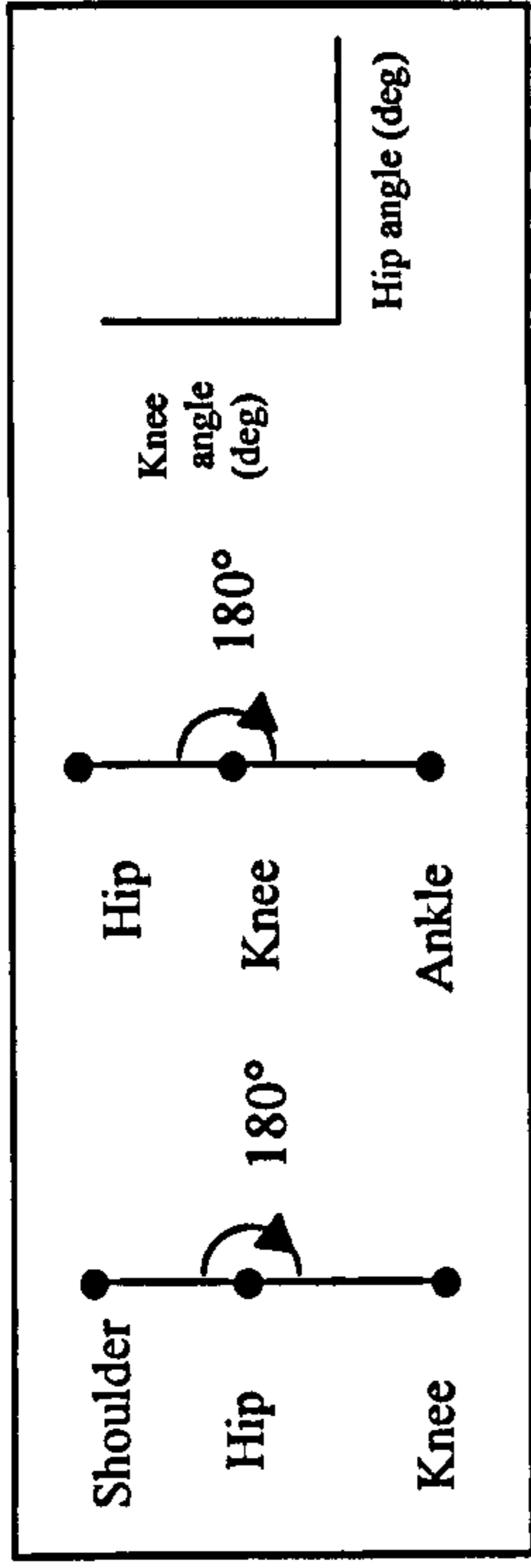


Figure 4.5. Knee-hip relative motion across acquisition for a representative participant from the CONTROL group (bold plot = the model's pattern; 3 lighter plots = participant's patterns).

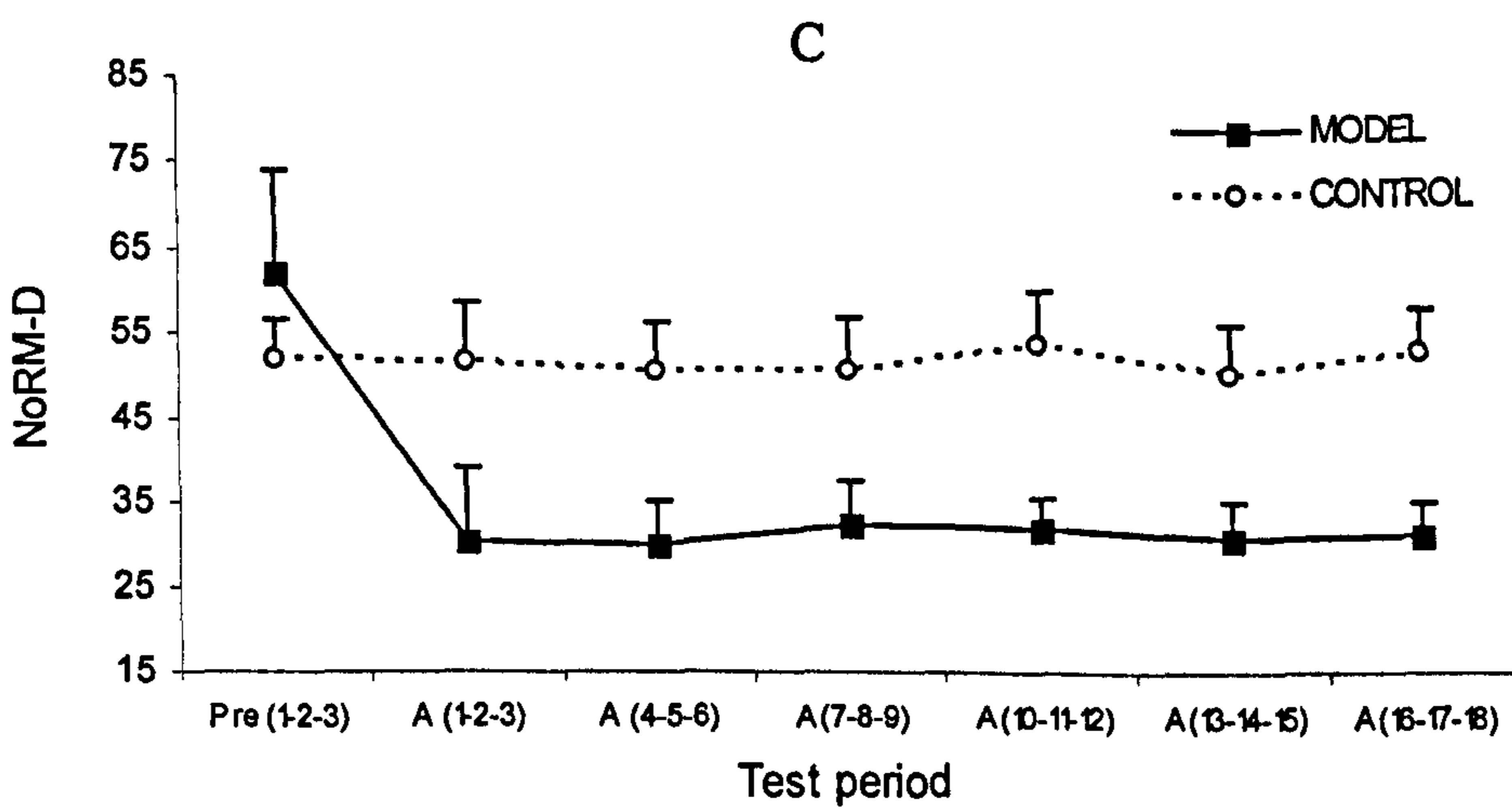
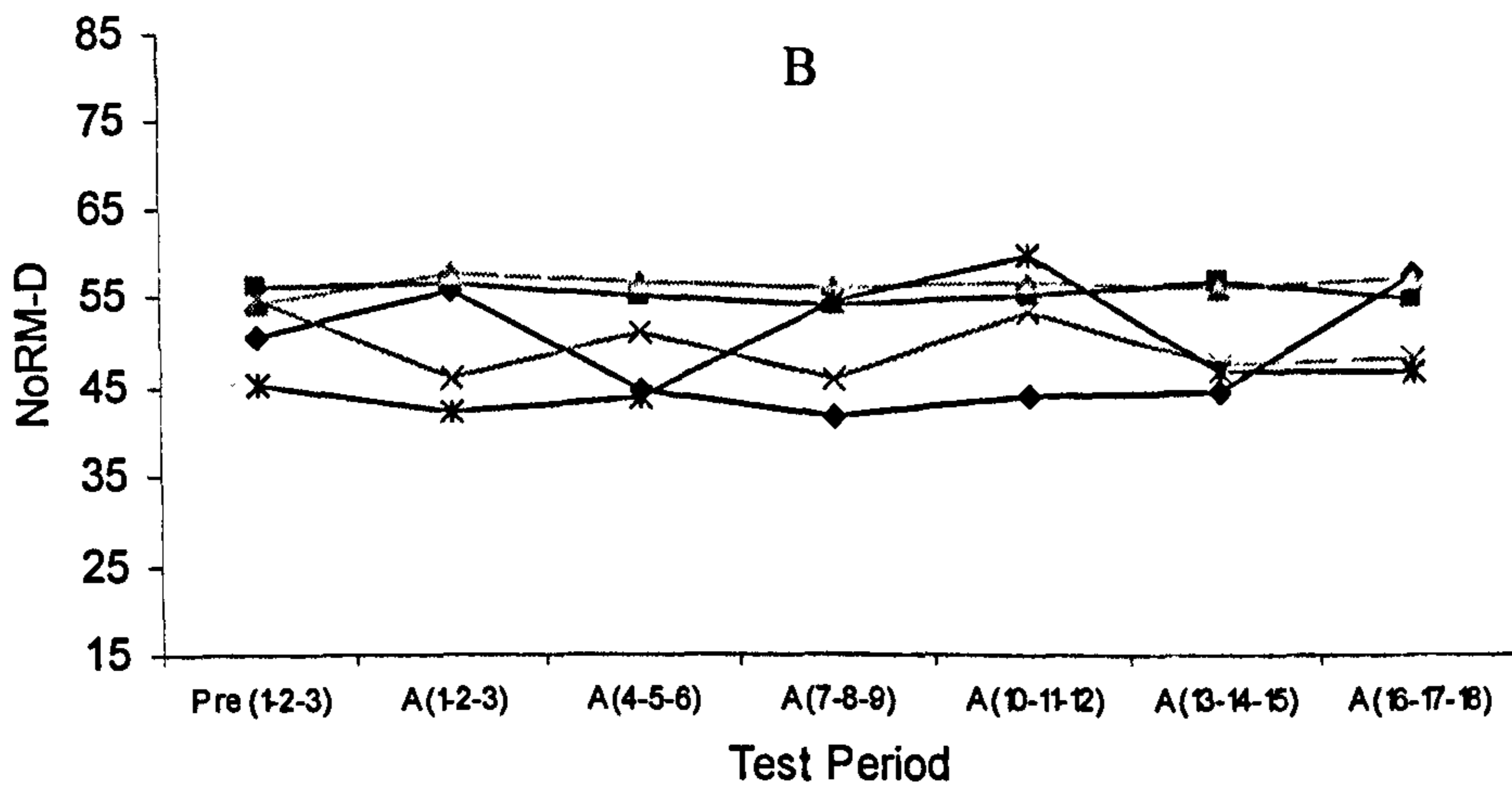
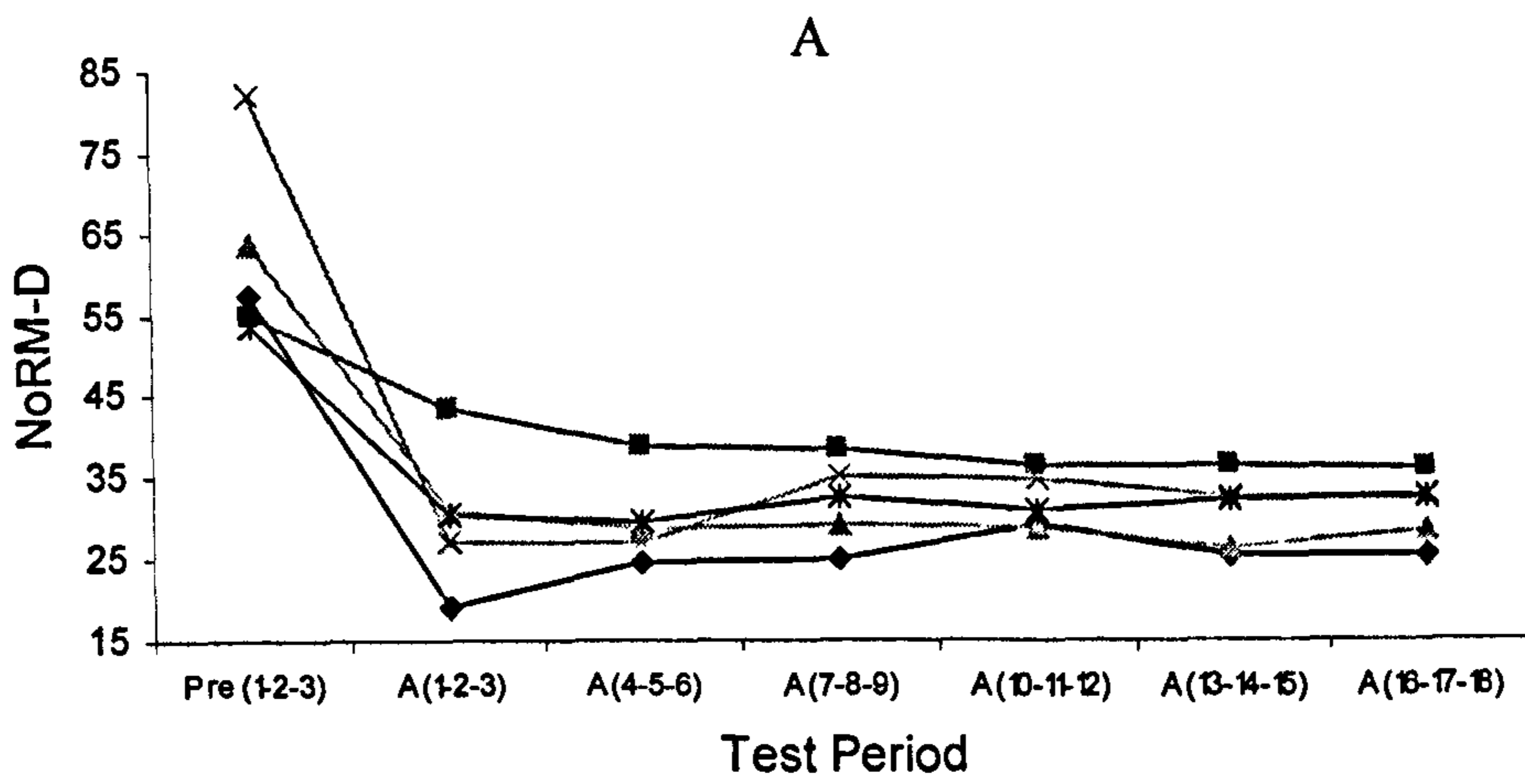


Figure 4.7. Knee-hip NoRM-D (%) scores for the MODEL group (A), CONTROL group (B) and group averages (C) across acquisition

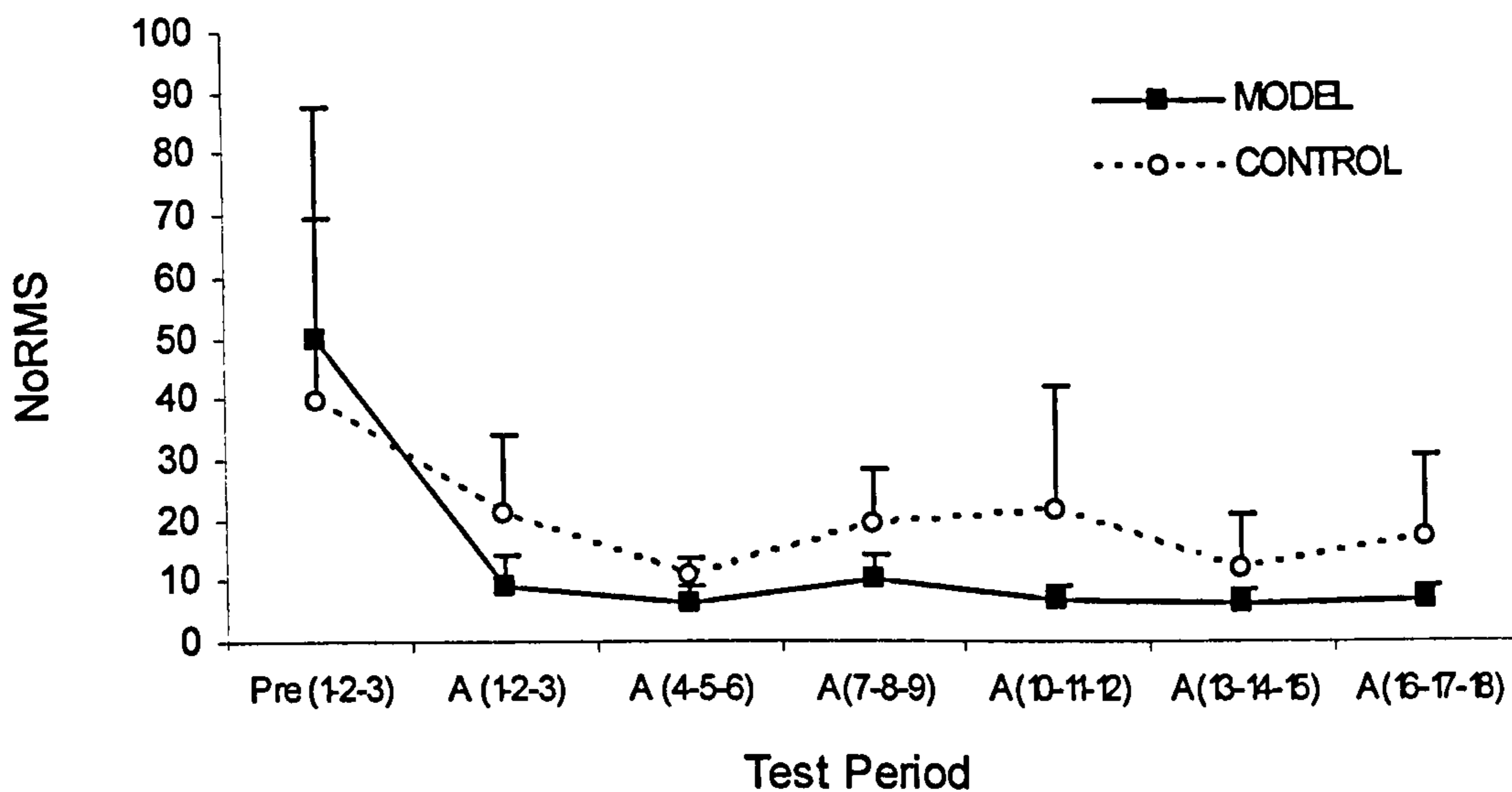


Figure 4.8. Knee-hip NoRMS across the acquisition period

Discussion

The adage ‘a picture paints a thousand words’ has oftentimes been applied to observational learning to illustrate the efficiency with which demonstration conveys information for action. Yet paradoxically, research designs have not thoroughly investigated the coordinative changes that occur in response to demonstration in early acquisition. This paper aimed to address this limitation by comparing the changes in relative motion in the first 18 trials of acquisition in participants observing a demonstration and those learning through unguided discovery.

It was predicted that those observing a model would show immediate changes in relative motion to more closely imitate the model’s coordination. These changes were predicted to remain throughout acquisition, with only small refinements ensuing. The adoption of the model’s movement pattern was also anticipated to facilitate faster ball velocity for the MODEL than the CONTROL group. The CONTROL group was

predicted to show greater variability in acquisition, lower ball velocity, and only small changes in coordination relative to the model between the pre-test and the end of practice.

Support was found for the first hypothesis. For both knee-hip and elbow-shoulder relative motion, the MODEL group became more like the model from the pre-test to the first three trials of acquisition. The CONTROL group showed no change across this time. Given that the participants in the MODEL group were not superior in their coordination in the pre-test, this finding directly indicates the role of the model in changing coordination.

The results corroborate the findings of previous studies that report immediate coordination changes from kinematic measures (e.g., Horn et al., 2003; Scully & Carnegie, 1998; Williams 1989; Williams & Thompson, 1994). However, the data provide a more detailed picture through trial-to-trial measures. In particular, the data advances the findings of Horn et al. (2003; Experiment 2). Their study also found immediate changes in coordination for those observing a soccer chipping task, but data were not collected on all trials. Also, their participants were constrained to use the model in the absence of intrinsic visual KR. As such they it remained unclear whether such immediate changes were possible when intrinsic visual KR was available. The present study clearly illustrates that even with intrinsic information available, coordination changes can be immediate.

The changes in relative motion present in the MODEL group supports the ecological view that observers of a demonstration perceive, minimize, and become constrained by the topology of the model's relative motion (Scully & Newell, 1985). The data add to previous evidence for relative motion changes in observational learning (Al-Abood et al., 2001a, b; Horn et al., 2003; Schoenfelder-Zhodi, 1992). The specific

role of those constraints has received only modest research attention, and it is suggested to influence behaviour through informational (Warren, 1990) and instructional (Newell & McDonald, 1992) properties. The current data suggest that it specifically acts to as a rate enhancer or scaler. In motor behaviour, rate controllers have typically been confined to developmental changes in, for example, the onset of walking (e.g., Thelen, 1986). It appears to be an equally appropriate concept for skill acquisition.

This role of demonstration as a scaler in early acquisition has theoretical and practical implications. Using Newell's (1985) embedded hierarchy of coordination, control, and skill, the dominant function in the synergy between coordination and control in early learning is assumed to be coordination. Control in turn is assumed to become dominant once the topological relations between body parts are assembled. It appears logical that by accelerating the acquisition of the new topology through demonstration, the learner is able to explore the dynamics of the task earlier than those acquiring skill by discovery or *guided discovery* methods (e.g., Mosston & Ashworth, 1986). This process facilitates the parameterization of a technically appropriate movement pattern with less practice trials. In the current experiment the relative motion at the knee-hip and elbow-shoulder shown by the CONTROL group after 18 acquisition trials was not close to the levels achieved on the first three acquisition trials for the MODEL group.

Support was also found for the second hypothesis. In addition to rapidly acquiring the model's relative motion, participants in the MODEL group sustained that improvement over the entire acquisition period. This finding suggests that the constraints imposed by the model were enduring. Although only 18 acquisition trials were employed to minimize the effects of fatigue on relative motion, the data is supported by the research of Horn et al. (2003) with soccer chipping. Their study found

that proximity to the model did not change from the first three trials to the end of 40 acquisition trials, and remained stable after a 48-hour retention period.

Collectively, these studies provide evidence against advocates of discovery learning, who propose that interventions in early learning produce only temporary, emergency solutions to the movement problem (e.g., Handford et al., 1997). They further argued that since the 'soft assembled' coordinative structures acquired may be inappropriate, they may delay the parameterisation of the movement. This argument is refuted on two grounds. First, the data suggest that the changes were not temporary but long-term adaptations to the task constraints. Second, if the model portrays the appropriate movement topology, parameterization is attained earlier, not later. The current data suggest that the model's coordination was both optimal and directly linked to successful outcomes. In support of this hypothesis, the MODEL group demonstrated faster ball velocity than the CONTROL group, and demonstrated velocity changes in tandem with coordination changes: large changes in relative motion from the pre-test to the first trials of acquisition were accompanied by greatest increases in velocity. Stable relative motion patterns were associated with only small variations in velocity.

In opposition to discovery methods of learning, over the course of acquisition the participants in the discovery group neither increased ball velocity nor changed their relative motion in reference to the model's pattern. This corroborates the findings of Al-Abood et al. (2001a) for an underarm dart throw, and Horn et al. (2003) for a soccer chip. Conversely, Schoenfelder-Zhodi (1992) found that discovery learners' relative motion did become more like the model after five days of practice (albeit at a slower rate than the model group). However, this finding has been explained in terms of the high level of constraint imposed by the apparatus (Al-Abood et al., 2001a).

Finally, Horn et al. (2003) alleged that if observing a model immediately changes a learner's relative motion, then early acquisition becomes a time of refinement, rather than the broad search for movement solutions as suggested by Newell and McDonald (1991). Although the proximity data for the MODEL group supports the concept of refinement, variability should also be considered. The predictions regarding variability were only partially supported. Most significantly, the MODEL group decreased knee-hip variability from the pre-test to the first trials of acquisition, and then maintained this level throughout acquisition. This supports the concept of refinement, as broader search for movement solutions would have been indicated by prolonged, high variability. For elbow-shoulder variability, both groups showed an overall trend for reducing variability but this did not reach significance. There were no differences between groups in variability as measured by NoRMS. However, the MODEL group showed less variability in knee-hip NoRMS in each period of acquisition.

In conclusion, this study clarifies the role of demonstration as a rate scaler in early acquisition. The trial-by-trial analysis extends previous research, and supports the findings of Horn et al. (2003) that observation of a model affords learners with constraining information to facilitate immediate and enduring changes in relative motion. This effect was not present in the absence of a model. The coordinative changes resulting from demonstration were associated with improved ball velocity. These results negate discovery learning as a preferred method of skill acquisition, and imply that learning from a model may not be a soft-assembled emergency solution, but an efficient and stable behavioural change.

Chapter 5

The contribution of relative motion to the perception and replication of dynamics

Abstract

The kinematic specification of dynamics (KSD) principle states that optical information revealed in movements specifies the causal factors in events. Although research evidence supports this principle, the contribution of relative motion to the perception of dynamics is unknown. This experiment addressed this issue, examining participants' perception and replication of the unseen distance traveled by a projected ball. Video and kinematic data were simultaneously collected as a trained model bowled a medicine ball to four approximately equally spaced points. The model's kinematics were then examined to elucidate which variables illustrated systematic variation upon which the perception of dynamics could be based. Forty male participants comprised groups observing the model in normal speed video (VN), normal speed point-light (PLN), half-speed point light (PLHS), or as static point-light images (PLst). The results showed that participants' perceived and re-enacted distances were highly correlated with the model's projected distances. However, the results imply that relative motion does not contribute to the perception of dynamics on 2 counts: first, the model's angle-angle plots showed no systematic variation across distances. Second, participants' performance was significantly poorer for the PLHS group than the PLN group, despite the fact that relative motion remains intact with reduced velocity.

When people watch demonstrations of skills such as throwing or kicking a ball to a target they face a complex problem. In order to quickly and successfully imitate the movement pattern, they must 'pick up' the relative motion that describes the movement's topology (Scully & Newell, 1985). Furthermore, to parameterize their movement response and achieve accurate outcomes with the ball, they must perceive the underlying dynamics of the task. Recent evidence suggests that observers can pick up a model's intra-limb relative motion, resulting in significant changes in coordination by the end of the first period of practice (Al-Abood, Davids & Bennett, 2001), and even within three trials (Horn, Williams, Scott, & Hodges, 2002). Although the nature of the information used in the perception of dynamics has been examined (e.g., Bingham, 1987; Shim & Carlton, 1997), the specific role of the model's relative motion pattern to the perception and replication of dynamics has not been explored.

The nature of the information used to guide action is of considerable interest in the process of skill acquisition. In this regard, ecological and dynamic theories of motor behaviour are indebted to J.J. Gibson (1950, 1979) for introducing the concepts of direct perception of motion, invariants, and affordances in the visual array. Gibson's work has encouraged the concept of perception-action coupling through the notion of mutual interdependency, in which the information we perceive is functionally specific for ensuing action. These ideas suggest that when we see a demonstration of a skill, the topological properties of the motion, and the relationship between the dynamic properties of the action and the way they relate to our intrinsic dynamics are directly perceived.

Gibson's influence is apparent in more recent accounts of observational learning. Scully and Newell's (1985) *visual perception perspective* provides an alternative to Bandura's (1969) Social Learning Theory, based on ecological principles. According to

Scully and Newell (1985) when observing a demonstration the learner perceives and minimizes relative motion (the motion of components in the display relative to other components), which later constrains the reproduction of the model's coordination.

Scully and Newell's (1985) approach refers specifically to the acquisition of the *topological* properties of movement. That is, the spatial and geometric invariant properties which describe coordination. However, Runeson, Juslin, and Olsson (2000) suggest that it is arguably more meaningful to perceive the underlying *dynamic* rather than the kinematic properties of movement. The basis of their argument is that the causal dynamics contain action-relevant information that is more enduring in nature. For example, when a learner observes a demonstration of a kick or throw, the specific coordination presented by the model is evanescent. When the model is no longer present, the kinematic reproductions of the task are influenced by the learner's cognitive, physical, and emotional constraints (Newell, 1986). Yet, our understanding of the force production properties and the mass of the object to be used is withstanding. In Gibsonian terms, affordances in the environment, which specify what can be done with, or expected from objects (i.e., the ball in this example), are primarily dynamic rather than kinematic in nature (Runeson & Frykolm, 1983).

If dynamic properties are of great importance to the learner, then a key question is exactly what causal information can be perceived directly from kinematic events? Specifically, does relative motion at a global (whole body) or local (intra-limb) level contribute to the perception of dynamics as well as to the imitation of movement patterns? The science of mechanics illustrates that kinematics (concomitants of displacement in time; Gildea, 1991) are derived from dynamic conditions. If mechanical properties shape movements, then this relationship may be perceivable. Runeson (1977) showed that hidden, causal properties of inanimate objects become apparent when they

are involved in events. When objects of unknown mass were involved in linear collisions, their relative weight and the damping effect of their material composition were specified. These studies influenced the formation of the kinematic specification of dynamics (KSD) principle (Runeson & Frykolm, 1983), which simply states that the optical information revealed in movements specify the causal factors in events. This principle follows Gibsonian theory in that the ambient information within the environment is revealed with changes in the optic array (Gilden, 1991). According to Runeson and Frykolm (1983), the process does not require inference or the solving of equations on the part of the observer (Gilden & Proffitt, 1989).

Runeson and Frykolm (1981) first extended the study of inanimate objects to human behaviour. In the first manipulation, a model presented in point-light format lifted a box from the floor, carried it a few steps and placed it on a table. The dynamics of the task were manipulated by varying the weight of the sandbags concealed within the box. The results showed that participants' estimates of the weight were highly correlated with the actual weights. Shim and Carlton (1997) later replicated this finding when only the lift phase of movement was available.

An alternative explanation for the perception of dynamics has been presented by Gilden and Proffitt (e.g., 1989; Proffitt and Gilden, 1989; Gilden, 1991). These authors suggested that humans are not sensitive to dynamic invariants, but instead use commonsense notions concerning the way in which objects operate in the environment. These notions are believed to form the basis for heuristic judgments of dynamics. For example, in their studies of planar collisions Gilden and Proffitt (1989) found that the basis for the perception of relative mass were heuristics that faster moving objects are less massive than slower moving objects, and an object ricocheting backward at impact with another object is less massive than the object it hit.

The points of departure between the KSD and heuristic camps, though conceptually clear, may not be easily tested. Hecht (1996) has suggested that the argument may be moot since the approaches cannot be empirically distinguished and are immune to falsification. Indeed, even if judgments of dynamics are based on heuristics rather than direct specification per se, the kinematics of the event still forms the basis of the decision. Thus they differ primarily in terms of the necessity for inference.

Given the arguments of Hecht (1996), the present study follows the lead of Shim and Carlton (1997) by not attempting to empirically test these theories, but to elucidate the nature of information that may specify dynamics. To do this, two methods appear appropriate for this task. One is to manipulate the type of information available and examine effects on performance. The other is to profile the kinematics of the model as dependent measures at the different experimental weights or distances of the independent variable.

The former technique has typically been used to examine the relationship between the advance cues proffered by the actor's movement and the observer's ability to perceive a component in the outcomes of the movement such as direction of a badminton shot (Abernethy and Russell, 1987), a squash shot (Abernethy, 1990) or a soccer penalty kick (Williams & Burwitz, 1993). The latter approach was initially employed by Bingham (1987) to profile the differences in the kinematic patterns of two actors performing bicep curls with dumbbells of five different weights. Phase plane portraits at the elbow revealed very similar patterns for each weight. Only a drop in peak angular velocity at an angle of around 90 degrees for the heavy weight differentiated the patterns. For angular acceleration versus displacement, the data also showed great similarity across weights. Peak angular velocity showed little difference between lighter weights, but fell considerably for the heaviest weight. Bingham concluded that velocity

was critical in the perception of lifted weight, though as Shim and Carlton (1997) noted, there was limited evidence on which to base this interpretation. More convincing evidence was provided by Shim and Carlton (1997) who examined the kinematics of four models lifting boxes of five different weights. They found that phase planes (for the shoulder) revealed little difference between weights. Instead the results indicated that lift velocity, hip angle, and dwell time (time spent in position ready to lift) were key variables. When manipulating these variables, participants were found to be most effected by changes in lift velocity. This finding supports the position of Runeson and Frykolm (1983) and Bingham (1987) that in lifting, velocity rather than position is the key source of information.

The data reported by Bingham (1987) highlighted differences between the kinematic variables at various weights. However, in searching for a variable that could contribute to the perception of dynamics, the variable should illustrate not only difference, but *systematic order* and *pattern*. Clearly, it is not sufficient for the angle-angle or phase plane portraits of the highest weight to appear different from the lightest weight, if the patterns for the intermediate weights do not maintain the pattern. Shim and Carlton (1997) improved upon Bingham's approach, plotting different patterns together to illustrate systematic variation. However, many of their variables showed only limited order (i.e., the data was not in perfect systematic order from lowest to highest weight, or was in order for just part of the movement pattern). It is logical that the kinematic variables illustrating clearest order and pattern between the levels of the independent variable are more likely to contribute to the perception of dynamics.

Also contributing to the lack of systematic pattern in the data of Bingham (1987) and to a lesser extent, Shim and Carlton (1997) was that they assessed kinematic patterns across the whole movement. Given the argument of Hecht (1996) that the

heuristic versus KSD argument is moot, rather than attempt to distinguish between simple optical cues or heuristic judgments, a more appropriate analysis is to ascertain whether the kinematic properties contributing to the perception of dynamics are derived from entire movement patterns (such as relative motion throughout the movement) or cues abstracted from the whole pattern at key moments in the movement (in our example, at ball release). Consequently, the first aim of this experiment was to profile the kinematics of a bowler projecting a medicine ball to one of four unknown distances. Data were examined for order and pattern across the whole movement, and in detail at ball release. It was predicted that the kinematic profile would isolate variables most likely to contribute to the perception of dynamics, and that relative motion (indicated by angle-angle plots) would be among the systematic variables.

In addition to profiling the intra-limb kinematics at each projected distance, we aimed to assess the role of globally defined relative motion in the perception of dynamics by manipulating the visual information available to the observer. This technique is the basis of, for example, the occlusion paradigm which has been used to assess the types of advance cues used by experts and novices to anticipate future events (e.g., Williams and Davids, 1998). We used two manipulations. The first was to compare the perception of dynamics from video and point-light (in which only lights at the major joint centers are visible). Examinations of the KSD principle typically employ point-light displays, such that results cannot be explained by the presence of additional structurally based cues. Originally attributed to Marey (1895/1972), Johansson (1973) popularized their use in studies of biological motion. While static images in point-light form offer little information to the perceiver, in motion participants could rapidly identify different types of locomotion. Runeson (1985) argued that the geometric and mechanical proportions of, for example a walker's body, are

dynamical properties that shape movement. When participants observe point-light displays, this accounts for their ability to recognize various types of whole body motion (e.g., Johansson, 1973; Dittrich, 1993).

Researchers examining the KSD principle have not compared the perception of dynamics from video and point-light models. However, this has become a common manipulation in the observational learning literature. Based on Scully and Newell's (1985) predictions, if it is relative motion that we perceive and use, then observation of a point-light model should be at least as effective as learning from video, since this also contains distracting structural information (Runeson, 1986). As an example, some recent evidence suggests that the perception of lumbar stabilization by physical therapists was facilitated by the removal of structural information (Pellechia & Garrett, 1997). In learning studies, the results are largely equivocal (see Horn, Williams, & Scott, 2002; Romack, 1995; Scully & Carnegie 1998; Williams, 1989). If the addition of structure in video also adds distracting information, this may result in diminished perception of dynamics. Therefore, it was predicted that perception of dynamics would be more accurate in response to a relative motion only (point-light) model than a video model.

The second way in which this experiment aimed to assess the involvement of relative motion in the perception of dynamics was by comparing performance in response to normal point-light, half-speed point-light, and static point-light images. If the spatial organization of the relative motion pattern provides KSD information, changes in original speed should not effect the perception or replication of force. Clearly, the relative motion pattern illustrated in angle-angle plots is unaffected by a change in movement speed. However, the disruption of relative motion in static images should be detrimental. This manipulation also allowed us to examine Runeson and Frykolm (1983) and Bingham's (1987) prediction that velocity information is

fundamental to the perception of dynamics. If the perception of the dynamics in an event is velocity-dependent, changing the original speed should be detrimental to perception.

Finally, this paper extended upon previous tests of the KSD principle by advancing into the action domain. Curiously, previous KSD studies have only measured perceptual responses. This is at odds with the Gibsonian theory on which it was based. In Gibsonian terms, perception is about information for action. The nature of affordances implies that we perceive action in 'action-relevant' terms, based upon what it allows or demands the performer to do (Williams, Davids, & Williams, 1999). As such the more ecological measure is an action response. Although previous studies do show a remarkable propensity for the perception of causal properties, is this information readily available for action? Furthermore, by measuring action responses, the data may forge links between the perception of dynamics and the learning process. Shim and Carlton (1997) have recognized this shortcoming, highlighting the need for greater understanding of the link between perception and action with reference to KSD. More specifically Runeson et al. (2000) recognized that a major limitation has been the failure of researchers to apply the KSD principle to skill acquisition.

The significance of extending KSD research into the action domain is considerable. Gibson (1979) and Runeson (1988) predicted that information picked up in the array becomes more advanced and accurate with practice. If so, awareness to and use of dynamic information should be trainable and should distinguish groups based on experience or expertise. In support of this argument, Scully (1986) found that the ability to perceive the aesthetic quality of biological motion was different in expert and novice gymnastic judges. Similarly, Ille and Cadopi (1995) found expert dancers significantly better than novices at extracting and repeating the relative motion, fluency, and rhythm

of choreographed walks. As evidence for trainability, Michaels and de Vries (1998) found that participants learning to judge the pulling force exerted by stick figures became progressively more reliant on higher order variables with training and feedback. Likewise, Jacobs, Runeson, and Michaels (2001) found that participants' changed the variables employed to judge relative mass in collisions and improved their estimations with practice and feedback.

Considering the above, our final aim was to examine not only the perception of force production, but the ability to *reproduce* that force. In order to examine this question, the conventional study of lifted weight is inappropriate as there is no obvious action response. Instead we used the perception of the distance of a projected object (as employed by Runeson and Frykolm, 1983). The task chosen was an underarm bowling action involving a medicine ball. It was hypothesized that the information in the model's action was readily available for action, as evidenced by significant correlation between the model's actual bowled distances and the participants' re-enacted distances

Method

Participants

Forty male participants (aged 20-32 years) were recruited and gave informed consent to participate in the study. All were right-side dominant for everyday activities and were naive to the purpose of the study. Participants were randomly assigned to one of four viewing conditions: Video Normal Speed (VN); Point-light Normal Speed (PLN); Point-light half-speed (PLHS); and, Point-light Static (PLSt).

The Model and Test Films

The dynamic task selected was to bowl a medicine ball of 2-kg weight to four specific distances. This was similar to the throwing task of Runeson and Frykolm

(1983). However, the movement pattern was considered to be more novel. The task was also selected on the basis of it being a closed, whole body movement. The model was a 21 year old male student. He practiced the task until he reported that they felt his form had become consistent. The model fixated on a mark on the floor to encourage a constant head position throughout practice and testing. The resulting movement pattern was a one step approach with the left foot and ball release from the right hand.

In order to compare force production from video and point-light demonstrations, video and kinematic data were recorded simultaneously. Consequently, retro-reflective markers (18 mm) were placed at the following locations: the left and right lateral malleolus (ankle); the left and right 5th metatarsal (toe); the left and right lateral condyle of the femur (knee); the left and right greater trochanter (hip); the left and right acromion process (shoulder); the left and right styloid process (wrist); the 1st thoracic vertebrae (base of the neck); and, the occipital bone (base of the skull). Five retro-reflective circles were placed on the ball to enable detection of the moment at which the ball was released from the hand. Test films were generated for bowls representing short (2.86 m), medium short (4.54 m), medium long (6.49 m), and long (8.55 m) distances. During each of these movements, the model was filmed with a Panasonic M-40 camera from a sagittal plane to show the model's right side. In the video condition a screen was placed behind the model to minimize distracting information. Kinematic data were simultaneously recorded with 6 infra-red cameras (Pro-reflex; Qualisys) at 240 Hz. The test films were edited with the Media 100 system (*i-finish* software). The video presentation film was edited to occlude at the moment the ball left the model's hand. The point-light test film was temporally and spatially matched to the video test film using Q-Trac View (Beta 2.4; Qualisys). The resulting point-light display showed white points on a uniform black background. The video condition also used the uniform

background of a curtain. The PLHS presentation condition was created in Q-Trac View by playing the demonstration at 120 frames/second. The PLst condition comprised of 10 frames of the model's movements. Frames 1 and 240 represented the first and last, with the remaining 8 taken at equidistant intervals in-between. Rather than presenting these in picture form, the images were presented in video form to match the other conditions. Each frame was presented with a 1-second gap between frames. Finally, the size of the model was kept constant at approximately 70% of the screen in each condition.

Profiling the Model's Intra-limb Kinematics

The model's data were smoothed using a 4th order Butterworth Filter with a cut off frequency of 7 Hz. The filter was passed recursively to avoid phase lag, as recommended by Winter (1990). The data were then normalized to a period beginning with the initiation of the foreswing and ending at maximal shoulder flexion in the throwing arm. The moment of ball release was also marked. From this normalized period, three broad categories of variables were examined. First, for variables that describe the angular pattern of movement, angular displacement at the shoulder of the right (throwing) arm, angle-angle plots at the right shoulder and elbow, and phase portraits (velocity versus displacement) at the right shoulder were examined. Phase portraits add to the angle-angle plots used in studies 1, 2, and 3 in that they illustrate coordination with respect to both position and speed of movement. This provides a geometrical representation of the actor's *state space* (Clark, 1995). Second, for variables describing speed of movement, angular velocity at the right shoulder, and linear velocity at the right wrist were examined. Finally, for variables describing temporal control of the movement, time to peak shoulder angular velocity, time to peak wrist linear velocity, and time from the initiation of the foreswing to ball release were examined.

Procedure

The laboratory floor was first marked with tape. A line marked the point from which participants would bowl the ball. A second line was placed parallel to the throwing line at a distance of 10 m. This represented the end line. A 2 m-wide channel connecting the throwing line and end line was also marked with tape. Participants were informed that in all the demonstrations the ball would stop somewhere within this marked channel, between the two parallel lines.

On arrival in the laboratory, participants were given a standardized information sheet and provided informed consent. Participants were told that they would be observing demonstrations of a person bowling a ball. Those observing a point-light model were informed that they would see only white circles representing the model's joint centers. They were also informed that the demonstrations would end the moment the ball left the model's hand, such that they would not see the resulting movement of the ball. Participants were informed that they had to reproduce the action of the model, bowling the ball to make it stop at the point at which they believed the model's delivery had stopped. They were also required to place a marker on the floor at the point they perceived the model's ball would have stopped.

Participants were randomly assigned to one of the VN, PLN, PLHS or PLst groups. Two familiarization trials were presented in the appropriate form on a 22" Sanyo CE32 monitor. The familiarization trials represented a mid-scale standard (5.5 m) and their inclusion was consistent with the procedure employed in previous KSD studies (e.g., Runeson & Frykolm, 1983). These trials helped to verify that participants observing a point-light model had recognized the movements they had seen. After viewing the demonstration, participants were shown a mark on the floor to represent where the ball had ended on the demonstration trial. The participants then had three

attempts to bowl the ball to the reference marker, thereby providing a uniform amount of familiarization with both the task and weight of the ball.

Before commencing data collection, participants were informed that they would be observing bowls to four separate distances, and that these would be presented in a random order. They were told that the demonstration to each distance would be shown four times and that they would immediately attempt to reproduce what they had seen before observing the next distance. They were reminded that they should focus on the model's movements and try to gain as many cues as to how far the ball was being rolled. Also, in repeating the actions, they were asked to attempt to replicate the model's movement form.

Participants observed the demonstration from a standardized seated position. After the four demonstrations, the participant was given the ball and stood behind the throwing line. Following each of the participant's throws, the distance travelled by the ball (from the throwing line) was measured with a 10 m tape. When each participant had completed their three throws and the ball had been removed, they then placed the marker at the point at which they estimated the model's ball had stopped. This distance was then measured and recorded and the process repeated for the remaining three distances.

Dependent Measures and Data Analysis

Action. The first of the two dependent measures employed was absolute error scores for the action response. This measure was calculated as the absolute difference between the distance the model projected the ball and the mean distance of the participants' reproduced distance.

Perception. The second measure was absolute error scores for perception responses. This measure was calculated as the absolute difference between the distance

the model projected the ball, and the distance the participant estimated the ball to have travelled.

Absolute error scores were analyzed with 4 x 4 Analysis of Variance (ANOVA), where viewing condition (VN, PLN, PLHS, PLst) was the between-participants factor and distance (2.86, 4.54, 6.49, and 8.55 m) was the within-participant factor. Where violations of the assumption of sphericity occurred, adjusted degrees of freedom and Greenhouse-Geisser epsilon factors are presented. Significant differences were followed up with the Tukey HSD post hoc test, and meaningfulness was assessed using omega squared (Tolson, 1980). Finally, the degree of relationship between the distance of the model's actual projections of the ball, and those perceived and re-enacted by the participants were assessed by a separate Pearson Product Moment correlation (1-tailed) for each group.

Results

Absolute Error

Action. ANOVA produced a significant main effect for Group, $F(3, 36) = 14.16, p < .01, \omega^2 = .33$. The VN and PLN groups produced significantly less error than PLHS and PLst groups, while no differences were found between the VN and PLN conditions, $p > .05$. These findings are presented in Figure 5.1.

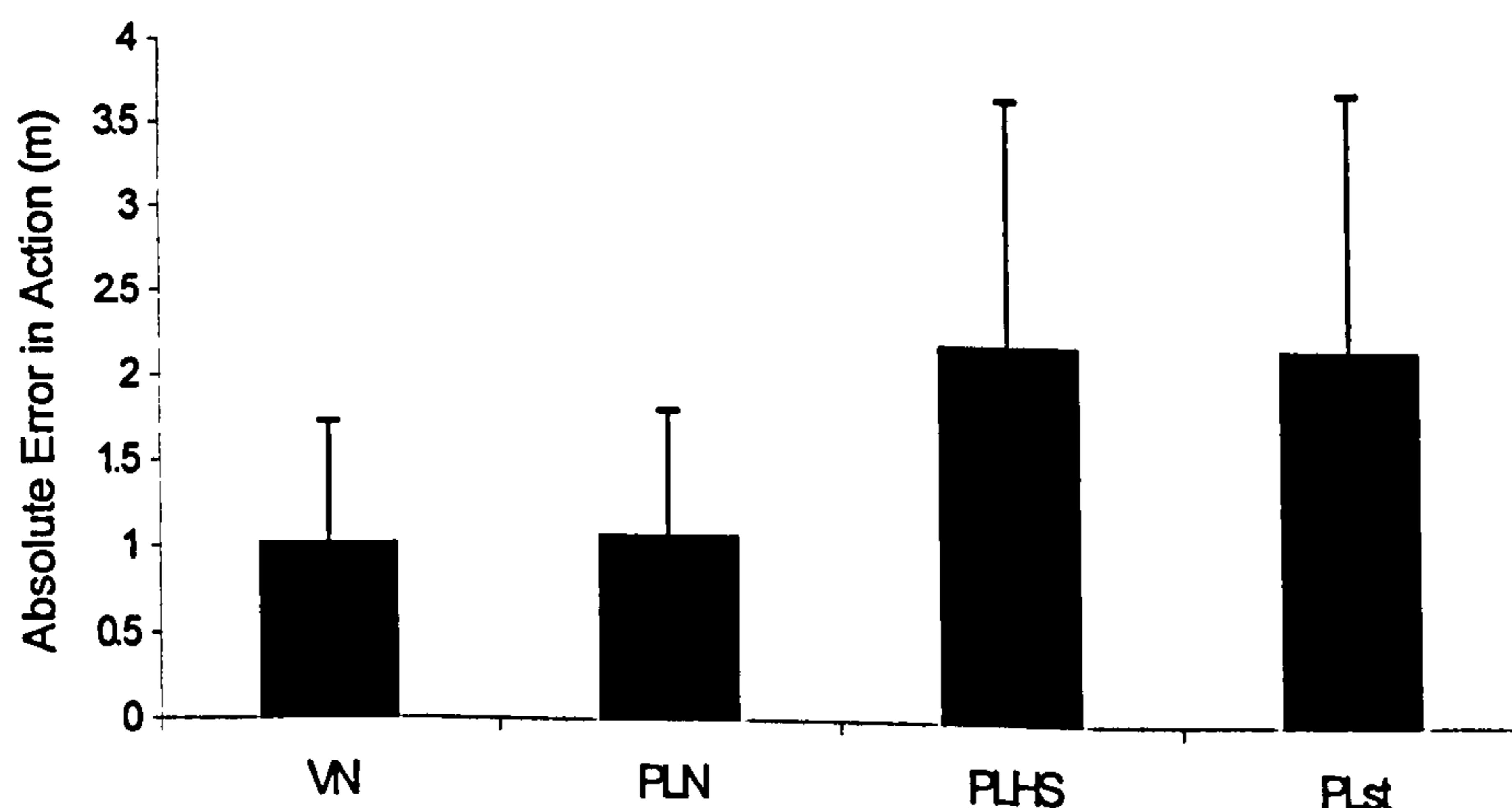


Figure 5.1. Mean absolute error with standard deviations for the action response across groups

A significant main effect for Distance was revealed, $F(2.38, 85.75) = 6.21, p < .01, \omega^2 = .13$. Absolute error was higher for the longest distance (8.55 m) than the medium-short (4.54 m) or medium-long (6.49 m) distances. A Group x Distance interaction was also found, $F(7.14, 85.75) = 3.93, p < .01, \omega^2 = 0.22$. The VN and PLN groups showed uniform levels of error across the four distances, while the PLHS and PLst groups showed increased error for the short and long distances.

Perception. ANOVA yielded a significant main effect for Group, $F(3,36) = 18.30, p < .01, \omega^2 = .37$. The VN and PLN groups exhibited significantly less error than the PLHS and PLst groups, $p < .05$. No differences were found between the VN and PLN conditions. These findings are presented in Figure 5.2. A significant effect for Distance was also observed, $F(3, 108) = 7.67, p < .01, \omega^2 = .14$. The error produced at

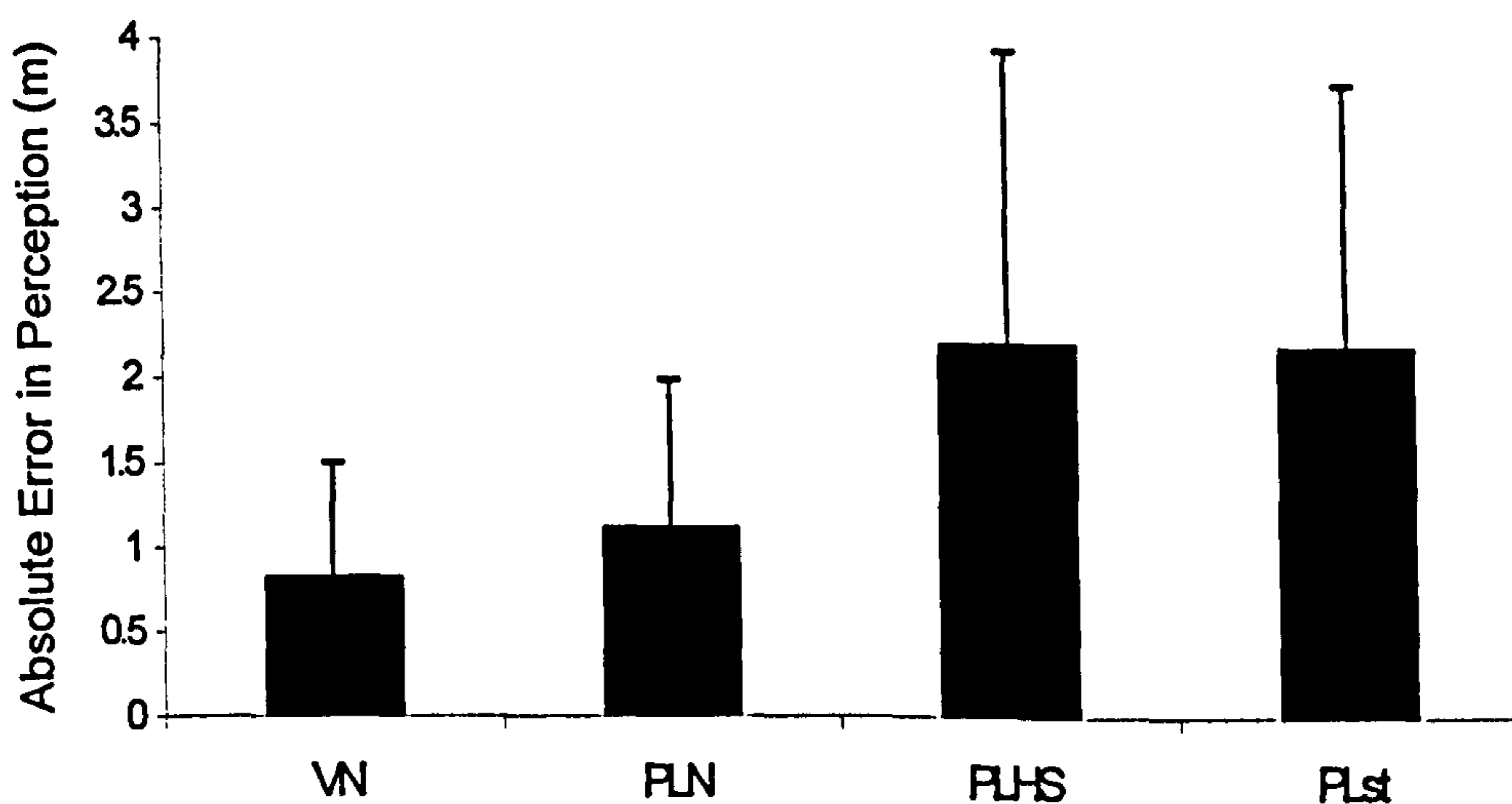


Figure 5.2. Mean absolute error with standard deviations for the perception response across groups

both the shortest and the longest distance were significantly higher than for the two middle distances, $p < .05$. A significant Group x Distance interaction was also present, $F(9, 108) = 4.23, p < .01, \omega^2 = .21$. Like the action scores, error remained somewhat

constant across all distances for the VN and PLN groups. In contrast, absolute error was greater in the shortest and longest distances for the PLHS and PLst groups, $p < .05$.

Correlation between Actual and Estimated Distances

Pearson product moment correlations are shown in Table 5.1. The perceived and re-enacted distances of the VN and PLN groups were significantly correlated with the actual distances the model projected the ball. No relationship was found between the model's actual distances and the action and perception based estimates of the PLHS and PLst groups. These data are presented in Figure 5.3. Participants were more accurate in perceiving and re-enacting the model's behaviour for the deliveries made to the middle two distances.

Table 5.1. Correlations and coefficients of determination (in parentheses) between participants' perception and action estimates and the model's actual distances
(Note: * denotes significant findings at $p < .01$).

Group	Perception	Action
VN	.89 * (.79)	.90 * (.81)
PLN	.77 * (.59)	.81 * (.66)
PLHS	.06 (.00)	.17 (.03)
PLst	.16 (.03)	-.01 (.00)

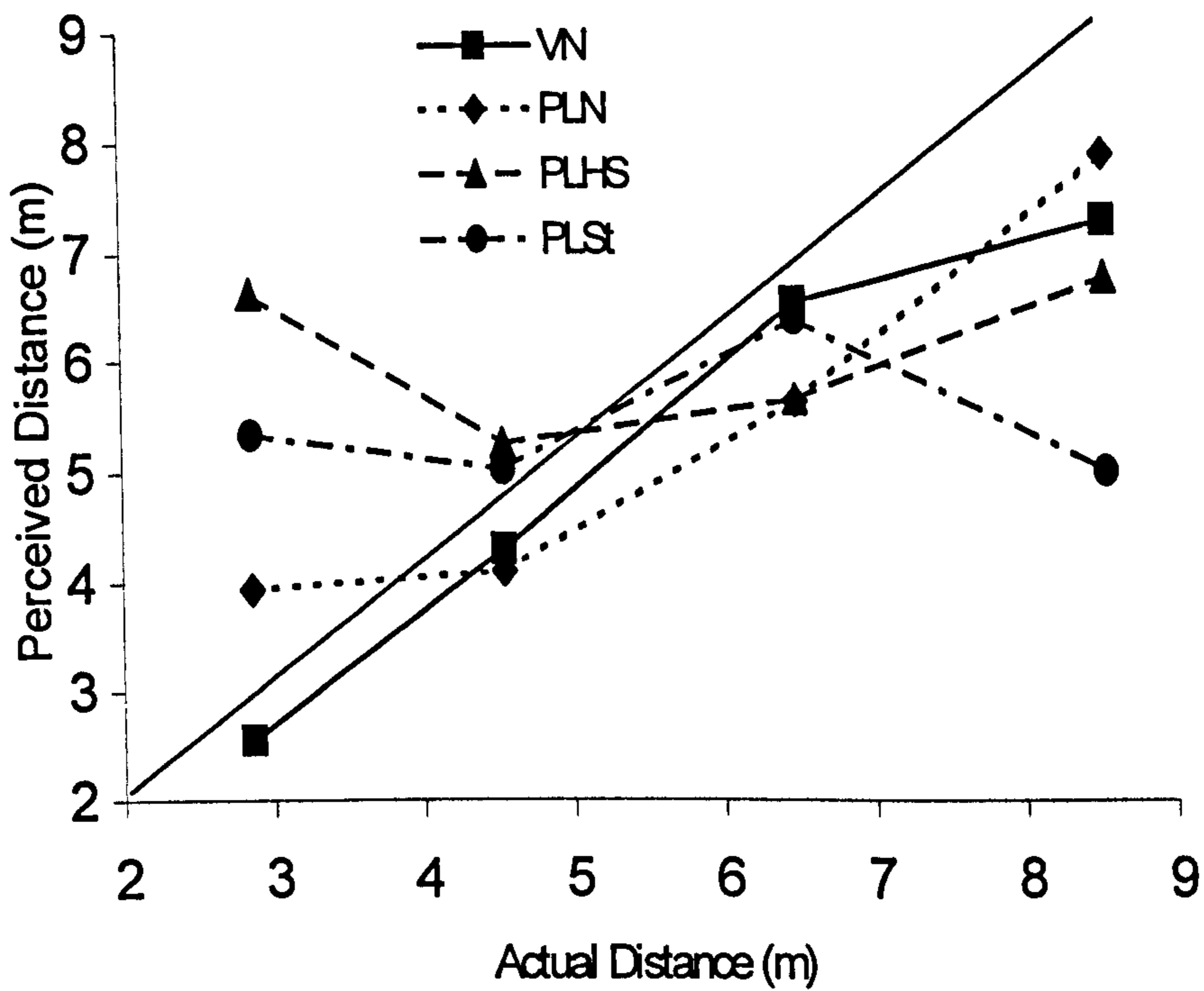
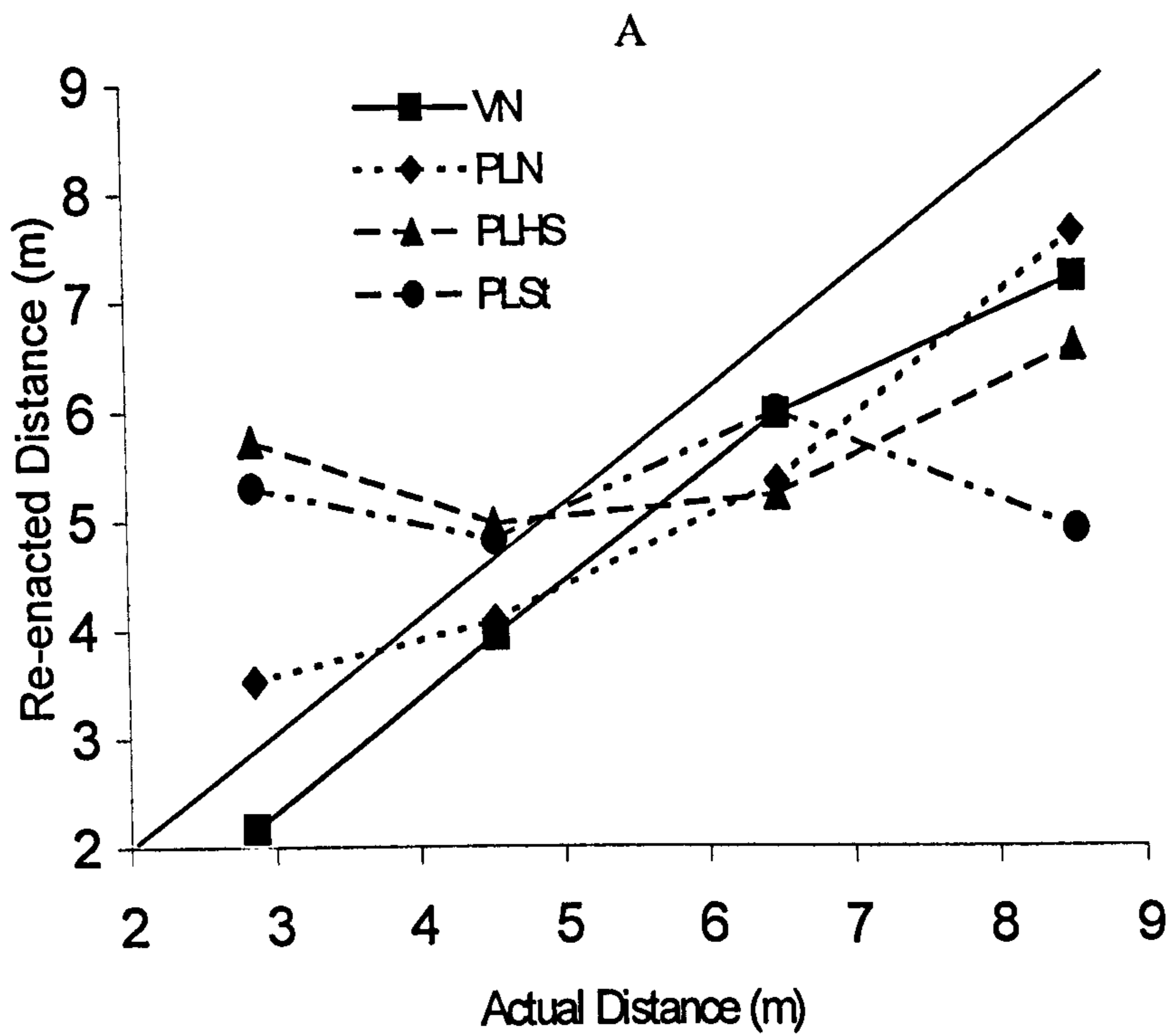


Figure 3. The relationship between participants' re-enacted (A) and perceived (B) distances and the model's actual distances.

The Model's Intra-limb Kinematic Profile

Figure 5.4 shows the model's angular displacement at the shoulder, across each bowled distance. It can be seen that across the entire foreswing, there is great similarity between the four patterns. However, when normalized to the time of ball release, the two shorter distances are differentiated from the longer distances. There is greater flexion in the shoulder for the shorter distances, suggesting later release in the foreswing of the movement.

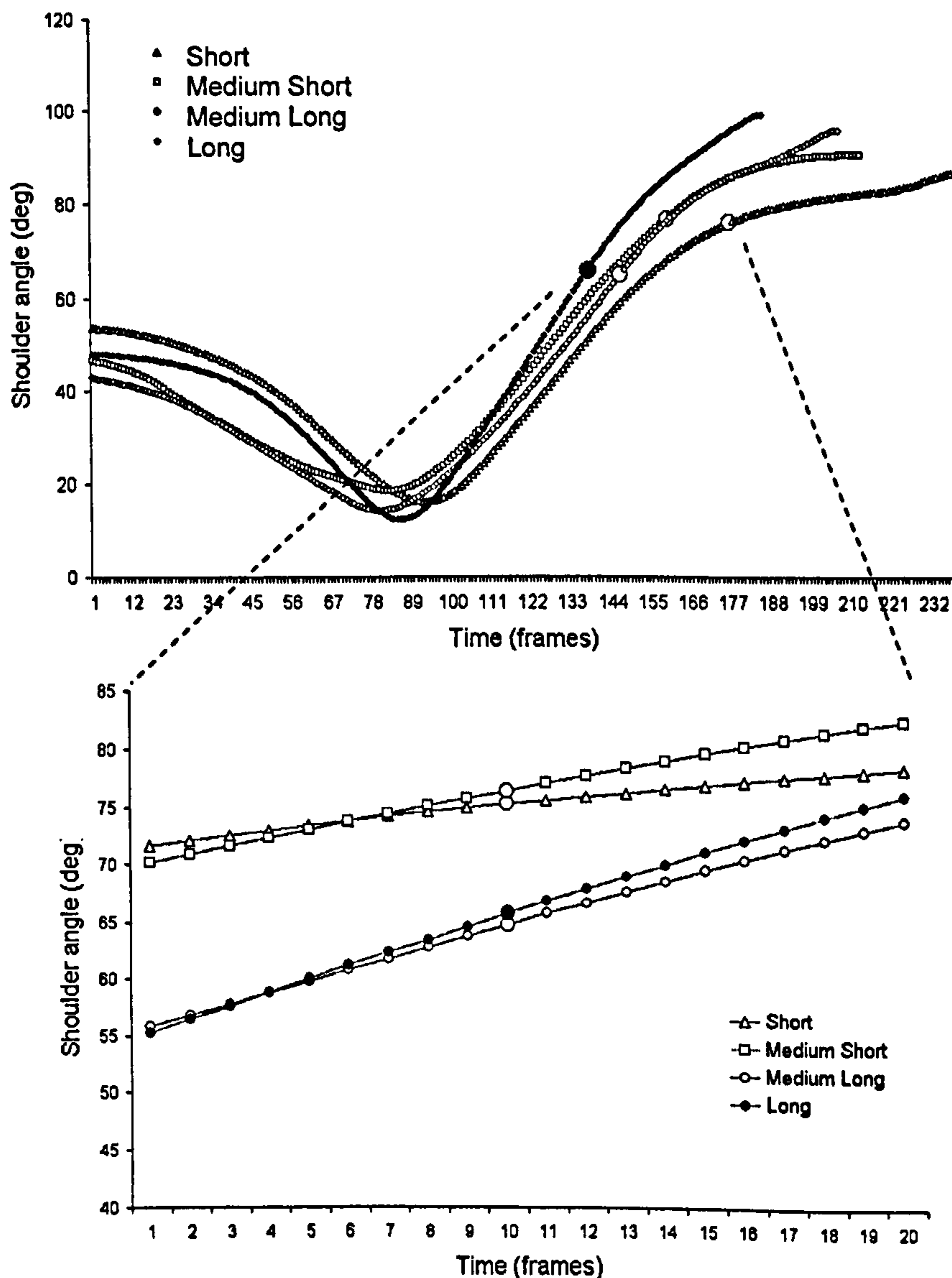


Figure 5.4. The model's angular displacement at the shoulder from the initiation of the foreswing to the end of shoulder flexion (inset are 20 frames normalized around ball release, which is marked by larger data points).

Intra-limb relative motion is shown in Figure 5.5. Considering the whole movement, the figure illustrates that while the relative motion demonstrated for the shortest distance is clearly different than at the longer distances, there is no systematic order to the four patterns shown. At ball release, the relative motion pattern shows order across the short, medium short, and medium long distances, but this is not maintained at the longest distance.

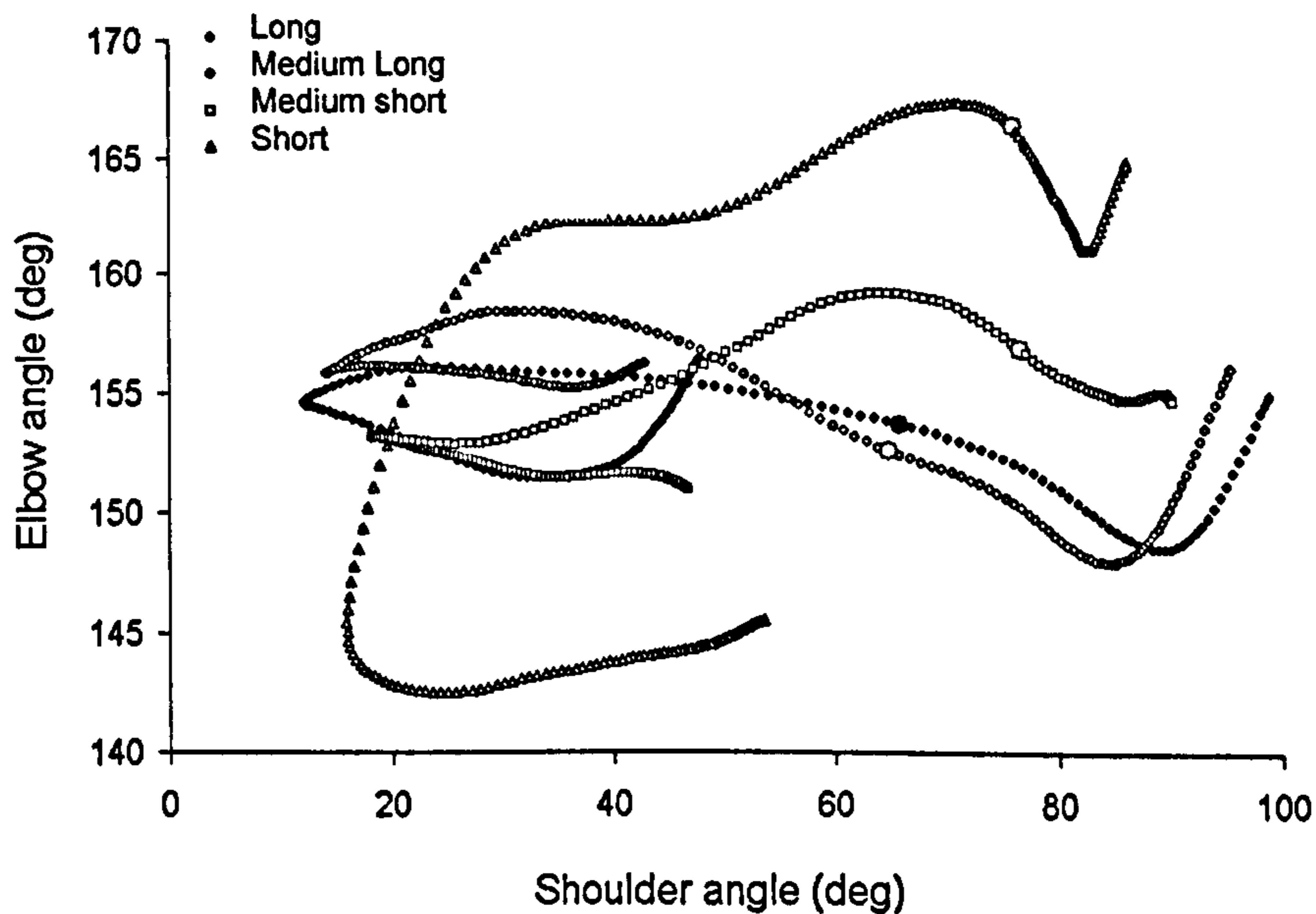


Figure 5.5. The model's elbow-shoulder relative motion for each bowled distance from the initiation of the foreswing to the end of shoulder flexion.

The phase plane portrait presented in Figure 5.6 shows shoulder velocity against position. These diagrams are typically used for cyclical data (the patterns shown here are not cyclical as the model does not return to the start position). They are included here to illustrate that when velocity data is introduced clear order is present. This systematic pattern is most apparent in the frames immediately preceding, and including, ball release. Angular velocity at the shoulder is also shown in Figure 5.7. A clear pattern between the four distances is not present when the whole foreswing of the movement is shown, but emerges when the normalized frames around ball release are studied. Of all

variables studied, this data shows the most distinct order and pattern among the four distances bowled.

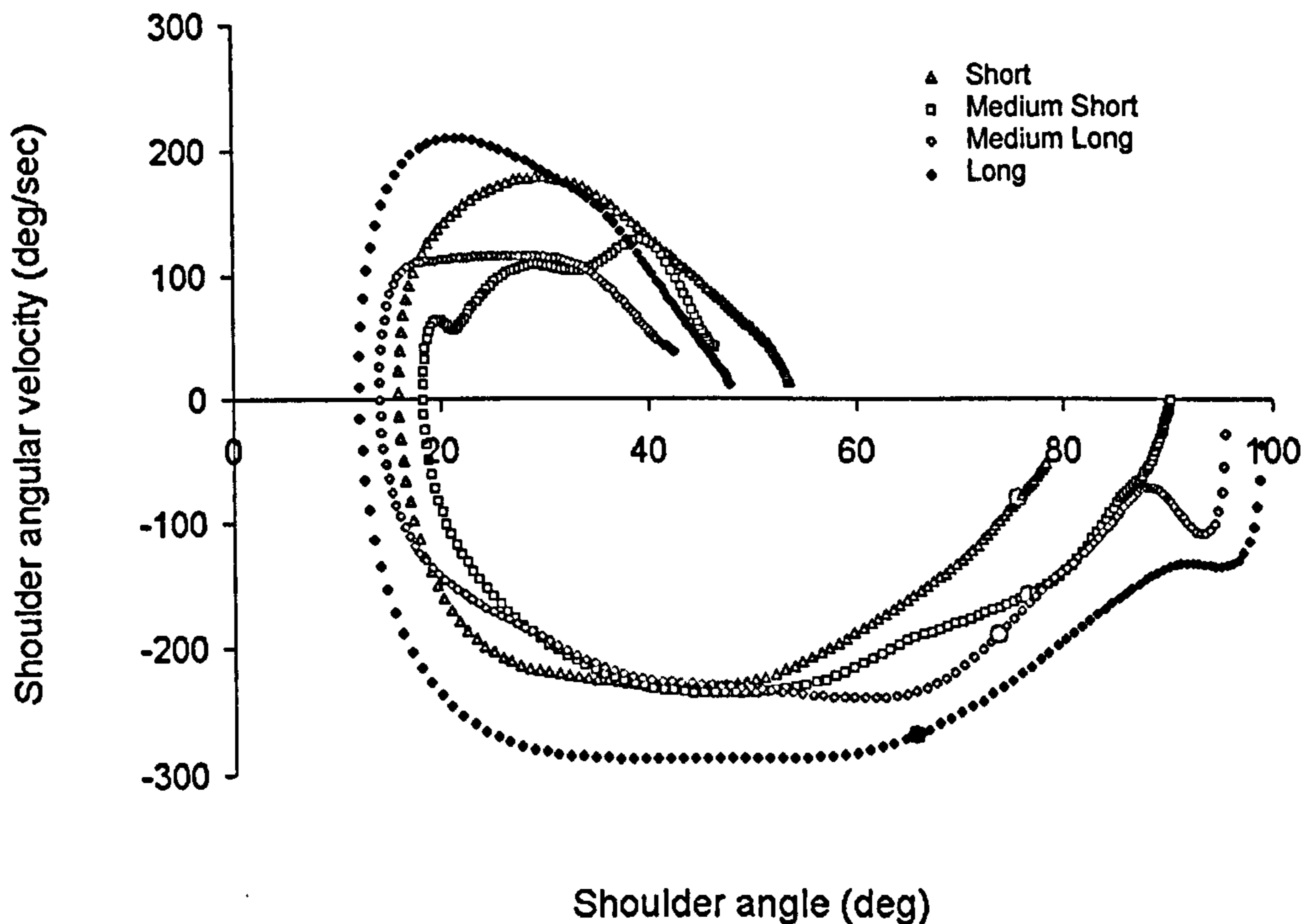


Figure 5.6. The model's shoulder phase plane portraits for each bowled distance from the initiation of the foreswing to the end of shoulder flexion.

For linear velocity at the distal end of the throwing arm, Figure 5.8 shows that the distance bowled was not simply a product of peak wrist velocity. While the longest distance also showed highest peak velocity, this pattern was not maintained across the distances. Higher peak velocity was found at the shortest distance than at the medium short distance, but the peak for the short distance was considerably before release. Around ball release, linear velocity differentiated the two longest from the two shortest distances. The short and medium short distances show similar values. This finding implies that release of the ball at lower shoulder angular velocity (Figure 5.5) and greater shoulder flexion (Figure 5.4) for the short distance in Figure 5.4 accounts for a different release angle and less distance travelled.

Finally, for temporal variables, time from the initiation of foreswing to ball release shows most systematic variation across distances (Figure 5.9). With increasing distance bowled, the time for the foreswing is progressively less. Table 5.2 indicates that no systematic patterns were present for time to peak angular velocity at the shoulder, or time to peak linear velocity at the wrist.

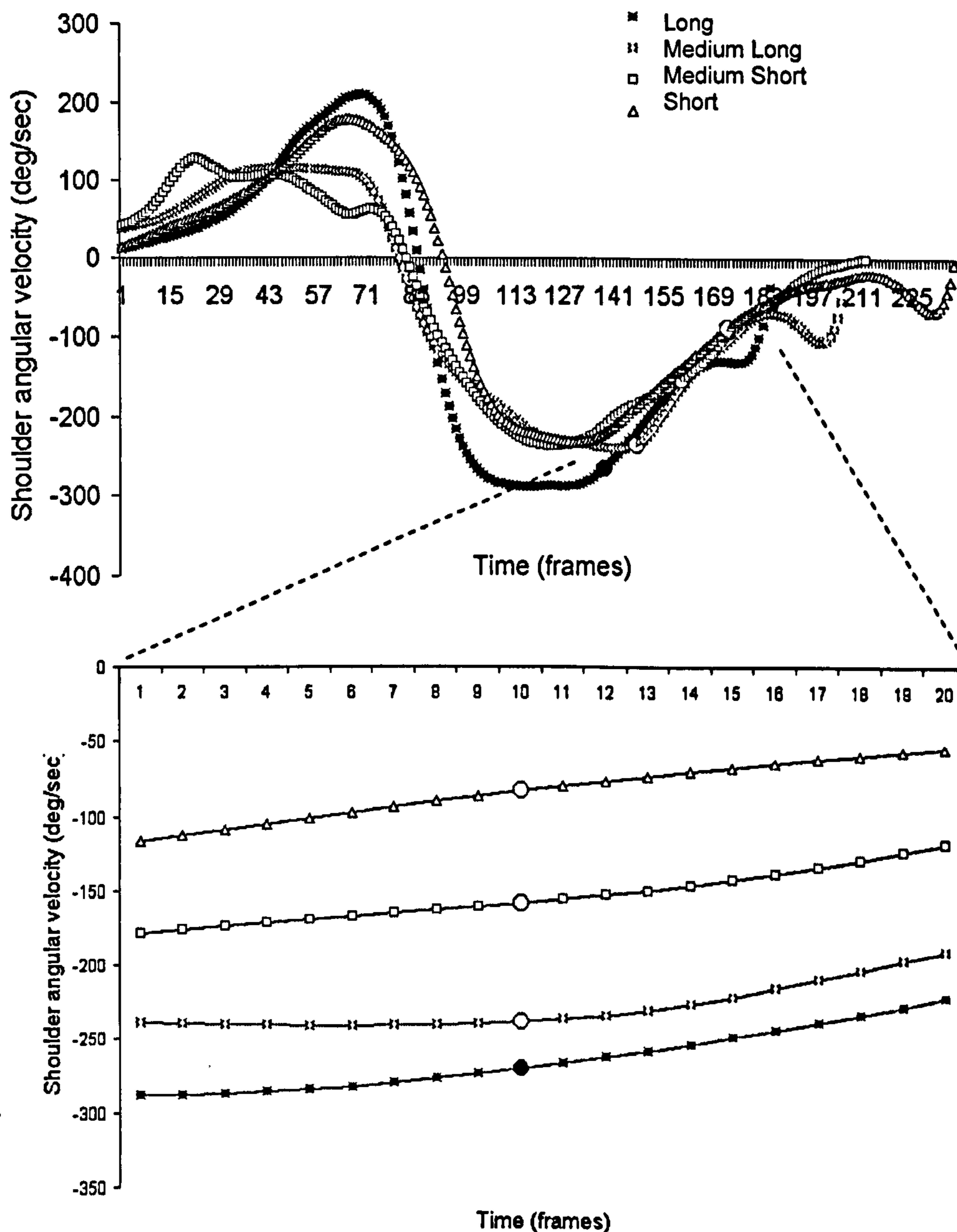


Figure 5.7. The model's angular velocity at the shoulder for each bowled distance from the initiation of the foreswing to the end of shoulder flexion (inset are 20 frames normalized around ball release, which is marked by larger data points).

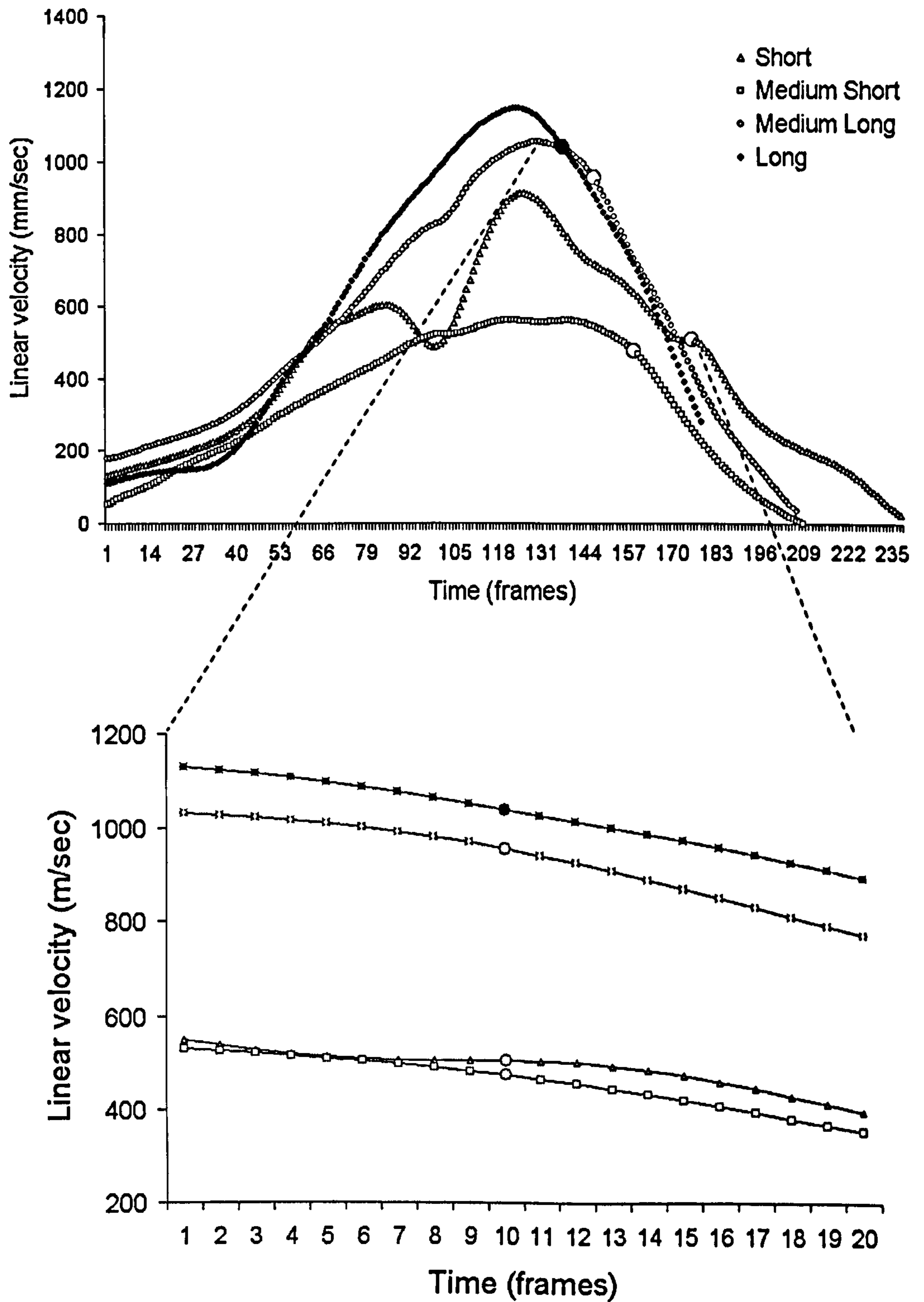


Figure 5.8. The model's linear velocity at the wrist for each bowled distance from the initiation of the foreswing to the end of shoulder flexion (inset are 20 frames normalized around ball release, which is marked by larger data points).

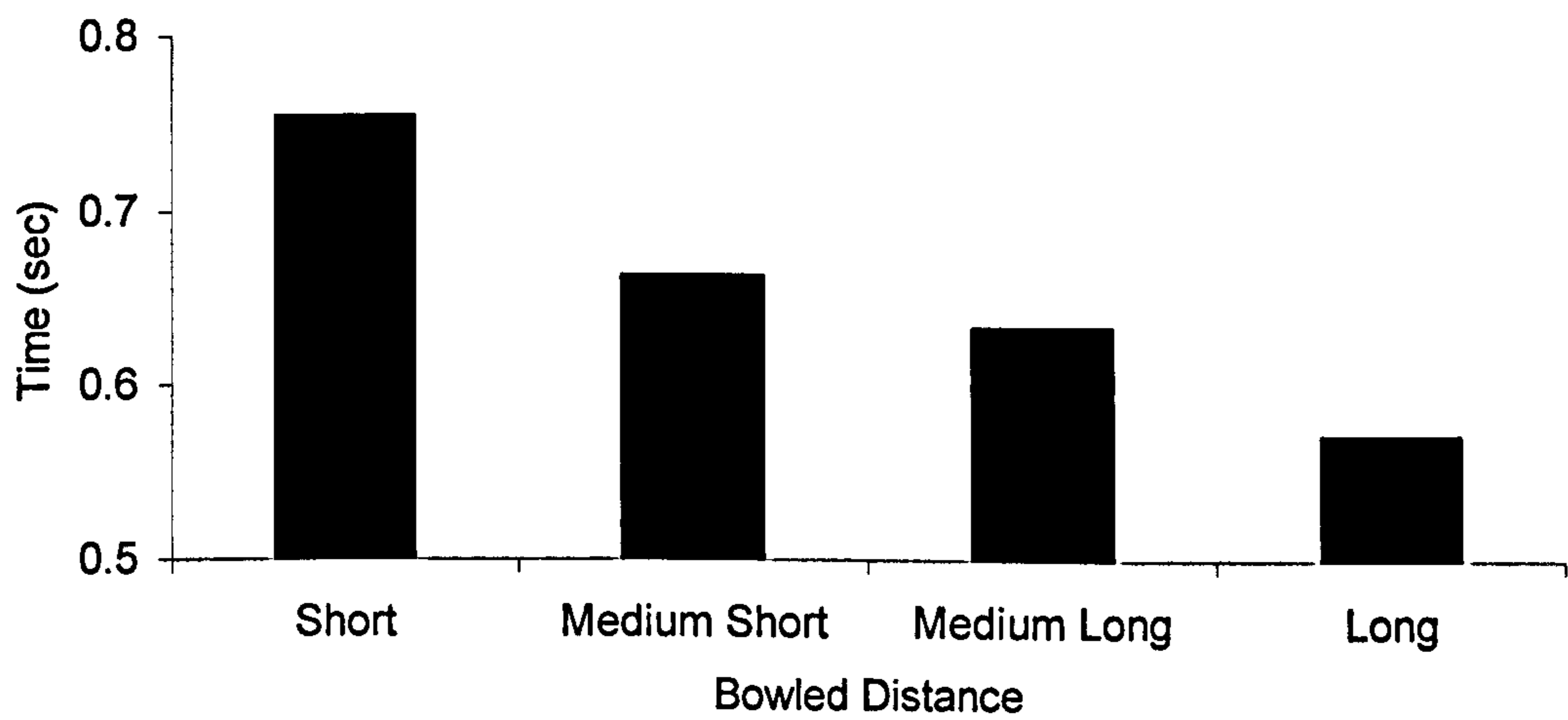


Figure 5.9. Time from the initiation of the foreswing until ball release across the four distances.

Table 5.2. Time (seconds) to (A) peak angular velocity at the shoulder and (B) peak linear velocity at the wrist.

	Distance			
	Short	Medium Short	Medium Long	Long
(A)	.54	.52	.60	.48
(B)	.53	.51	.54	.52

Discussion

The aim in this experiment was to examine the contribution of the model's relative motion pattern to the perception and replication of the causal properties of an underarm bowling task. A profile of the model's kinematics was created for each distance bowled, and the data were examined for systematic patterns. It was predicted that relative motion would be among the variables showing a systematic trend on which the perception of dynamics could be based. The role of whole body relative motion was also examined in the comparison of performance from real-time video and point-light displays, and half-speed and static point-light images. High correlations were anticipated between the perceived and replicated distances of those participants observing real-time displays and the model's actual distances. Participants were predicted to perform better in response to point-light models than video displays, as the pertinent kinematic information is more readily accessible. It was also anticipated that the manipulation of relative motion in static images would be more detrimental to perception and action than in half-speed images, as these maintained the spatial description of relative motion.

As predicted, participants observing the point-light and video models in real-time displayed highly accurate perception and replication of the model's action. This finding corroborates previous research for the perception of lifted weight by point-light (e.g., Runeson & Frykolm, 1981; Shim & Carlton, 1997) and video models (Valenti & Costall, 1997), and for distance thrown by point-light models (Runeson & Frykolm, 1983). Support was therefore found for the specification of dynamics from kinematic sources. Moreover, the results extend previous work, as it appears that the dynamic information in the kinematic display of underarm bowling is not only perceivable but also readily available for emulation through action. This finding lends support to the

ecological perspective presented by Gibson (1950, 1979), suggesting that information in the environment is specific for the action it affords. By taking the study of the KSD into the action domain, the measures have greater ecological validity, and progress toward examining the role of perceived and replicated dynamics in skill acquisition.

No differences were observed between the abilities to perceive or reproduce force from the real-time point-light and video models. It appears that both formats present the pertinent information for perception and action. In essence the kinematic information in point-light appears to be that used in video even when additional structural information is present. Since the absolute motion of points in the display is rarely perceived in human movement (Scully & Newell, 1985), the relative motion available in point-light accounts for the perception of the bowler in point-light form. The added structure of video neither provides additional cues nor distracting sources of information to effect performance. This finding reflects mounting evidence in similar comparisons between point-light and video models in observational learning (e.g., Horn, Williams, & Scott., 2002: Experiment 1; Horn, Williams, Scott, & Hodges, 2002: Experiment 2; Williams, 1989).

When the point-light model was presented at half-speed or as still images, no relationship was found between participants' estimations or replications of force and the model's actual performance. Poor performance in response to static images was predicted and supports previous work on the preparation and early phase of lifting by Valenti and Costall (1997). However, against expectations, no difference was found between the participants' responses to these stimuli. This result clearly implies that the spatial organization of the model's global relative motion pattern does not account for the perception of dynamics. The relationship between joints and segments in the movement was unaltered by reducing the speed of the display, yet the detriment in

performance was similar to that in response to static images. This finding suggests that velocity was the key source of information contributing to the perception of dynamics, as suggested by Runeson and Frykholm (1983) and Bingham (1987). The profile of the model's kinematics at each bowled distance also implies the importance of velocity information, but only at the most pertinent period of the movement. Angular and linear velocity data across the whole foreswing revealed little systematic pattern on which the perception of dynamics could be based. However, for the 20 data points around ball release, wrist linear velocity differentiated the two shortest from the two longest deliveries, and shoulder angular velocity differentiated all four into a systematic, ordered pattern. Directly related to this velocity data was time from initiation of the foreswing to ball release, where a systematic pattern was also observed.

A dependence upon velocity information for accurate performance is also predicted in the skill acquisition literature. Newell's (1985) embedded hierarchy of coordination, control, and skill predicts that while the coordination of a movement pattern is unhindered by slow motion demonstrations, parameters for control of a movement pattern are affected. Several researchers have supported this concept. For example, Scully and Carnegie (1998) found that slow motion marred the reproduction of peak landing force and total movement time. Similarly, Al-Abood, Davids, Bennett, Ashford, and Martinez (2001) found participants observing a slow motion demonstration of an underarm dart throw were less accurate in reproducing elbow velocity at release and movement time.

As reported for velocity data, the angle at the shoulder was found to be similar across distances when the whole foreswing was considered. However, around ball release it differentiated the two shortest from the two longest deliveries. Variations in the model's intra-limb relative motion at the elbow and shoulder did not appear to

contribute to the perception of dynamics. No pattern emerged across distances throughout the foreswing or around release. In addition to our findings for the spatial organization of whole body relative motion, intra-limb relative motion appears an improbable source of causal information. Contrary to the KSD principle, the data presented here could be seen as providing simple heuristics for the perception of dynamics (such as faster angular rotation of the shoulder at release specifies greater distance, and shorter time from initiation of foreswing to release specifies greater distance). However, following Hecht's (1996) contention that the KSD and heuristic explanations may not be empirically differentiated, this argument indeed appears somewhat moot. Whether participants used heuristics based on experience and inference, or used direct optically specified cues, the basis for the perception of dynamics was kinematic changes with movement. More significant is that most variables which could not differentiate the distances through the whole forward movement of the arm, showed greater systematism at the key moment of ball release. The perception and replication of dynamics was therefore likely to have been the result of picking up significant information at a brief moment, embedded in the whole movement.

In summary, in this study we have provided further evidence for the availability of dynamic information in kinematic displays. More significantly, our findings extend previous KSD research by illustrating that dynamic information is action-relevant and readily imitated. Scully and Newell's (1985) prediction that relative motion is crucial to the observational learning of movement patterns, does not appear to apply to the perception of dynamics in the model's display. Though participants could perceive dynamics equally effectively from point-light as from structured video, variations in relative motion patterns were not sufficiently systematic to account for the perception of

dynamics. Instead the information for the perception and replication of dynamics was abstracted from the whole movement at the key moment of ball release.

Chapter 6

Epilogue

Since Bandura presented his Social Learning Theory in 1969, a host of research has examined the way in which models' characteristics influence observers' learning. Considerable evidence has also been presented to imply cognitive involvement in observational learning. Increased repetition of the modelled act, the use of memory tools, and increased cognitive load in environments mimicking high contextual interference have all been shown to facilitate learning. Nonetheless, research borne out of Social Learning Theory has often utilised cognitively based, contrived tasks which provide limited understanding of the process of learning complex coordinative actions. As such, this research has offered minimal guidance to coaches and teachers on the use of demonstration to facilitate the acquisition of movement technique and form.

In addition, the cognitive perspective on observational learning has not addressed the nature of information picked up by the observer during the demonstration (Scully & Newell, 1985). In redressing this shortcoming, Scully and Newell (1985) proposed that observers perceive the model's relative motion, which in turn constrains later attempts to imitate the movement. To date Scully and Newell's predictions have been met by a paucity of research studies, perhaps due to the necessity to examine movement behaviour by kinematic analysis. Some evidence indicates that those watching a model change their relative motion patterns to become more like the model over practice (e.g., Al-Abood et al., 2001 a, b; Schoenfelder-Zhodi, 1992). However, of critical importance is that since these studies did not measure coordination *prior* to observation of the model, a true representation of the immediate and long-term impact of the model is not possible. This thesis aimed to provide the most comprehensive test of the predictions and questions raised by the visual perception perspective thus far. Four experiments were conducted and the key research papers they examine, their key findings and their flow are summarized in Figure 6.1.

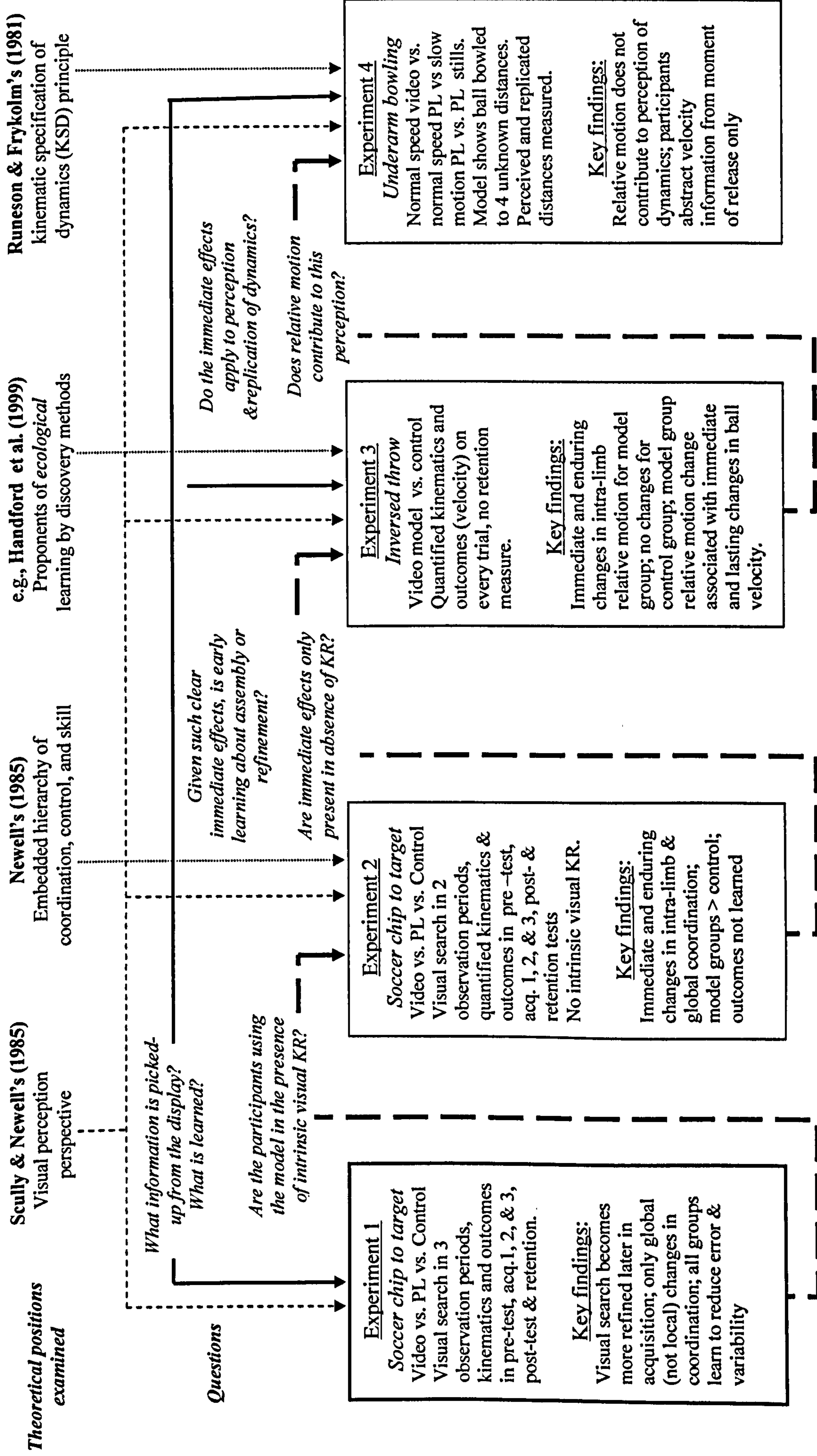


Figure 6.1. Diagram to illustrate the structure, purpose, flow, and key findings of the four experiments.

The Impact of Demonstration on Globally and Locally Defined Coordination:

Key Findings and Implications

Global changes in coordination

Several authors have suggested that imitation of action primarily operates in a manner described variously as *holistic* (e.g., Scully & Carnegie, 1998), *global* (e.g. Bertenthal & Pinto, 1994; Horn et al., 2002) or *program* level (Russon & Byrne, 1998). For Russon & Byrne, in program level imitation, the observer copies the structural organization of the action, but specific details are added on a trial-and-error basis. This process is assumed to account for the majority of imitation occurring on an everyday basis. Surprisingly, few research studies have pursued this concept. In these experiments, approach to the ball was an ideal index for global imitation, because in kicking, it represents the organization of how many steps to take, which foot to start with, and to an extent, the appropriate start position. Experiments 1 and 2 provide evidence for imitation of a model at this *global* level of analysis. In both experiments, participants changed their approach to the ball to become more like the model by the post-test (Experiment 1) or by the first three trials of acquisition (Experiment 2). Those participants not seeing a model showed no change, or became less like the model with practice.

Our data supports preferential modelling at a global level, but with a proviso: *the effect occurred only when visual intrinsic knowledge of results (KR) is present*. When participants were constrained to use the model in the absence of visual intrinsic KR, they changed their coordination at both global and local level. These findings imply that perception of relative motion in a localized sense may either be less developed than global perception, or is more susceptible to the distraction of outcome information. In corroboration with the former point, Oram and Perrett (1994) found cells in the anterior

temporal lobe that were sensitive only to whole body motion and not localized motion in single arm articulation. The authors suggested that sensitivity to biological motion is not readily accounted for in terms of isolated patterns of relative motion.

Local changes in coordination

Experiments 1, 2, and 3 examined local changes in relative motion at an intra-limb level. This allowed direct assessment of the predictions of the visual perception perspective. If learners perceive and become constrained by the model's relative motion, then their coordination should change to become more like the model. Experiment 1 did not find support for this position. Although those participants observing the point-light and video models showed positive changes in temporal phasing of joint flexion and extension, they did not change their knee-hip or knee-ankle relative motion to become more like the model. This contradicts the findings of Schoenfelder-Zhodi (1992) and Al-Abood et al. (2001) for relative motion, but supports the recent comment of Hodges and Franks (2002) that there exists little evidence that pre-practice information via demonstration facilitates the acquisition of complex movement tasks. However, in contrast, we found stark evidence for the facilitative effects of demonstration when the model was the participants' constraining source of information.

The interaction of demonstration and intrinsic visual KR: a reflection of the synergy of coordination and control. KR is considered to be a powerful source of information for skill acquisition, and in its intrinsic form it is typically available. As such it may compete with the model as the constraining source of information guiding learning. Therefore, to effectively test Scully & Newell's (1985) prediction that observers pick-up and become constrained by the model's relative motion, it was considered necessary to ensure that the model was acting as the constraining source of

information. This was achieved through visual occlusion at ball contact, and the results were pronounced. In the first study, with KR available, participants decreased error in their outcomes, at the expense of failing to change their movement pattern relative to the model. In the follow-up study, with intrinsic visual KR occluded, the exact opposite occurred. Participants learned to more closely match the model's coordination, but failed to learn to decrease error on their outcomes. As an illustration, the angle-angle plots (i.e., inter-limb coordination) for one participant from each of the studies are shown in Figure 6.2. Graphs (A) and (B) show the participant's closest attempts at reproducing the model's knee (vertical) – ankle (horizontal) relative motion (represented by the dark plot) in the pre-test and retention test. Note that there is little change in relative motion for the participant with KR available in (A), whilst in (B) considerable improvement occurs without KR.

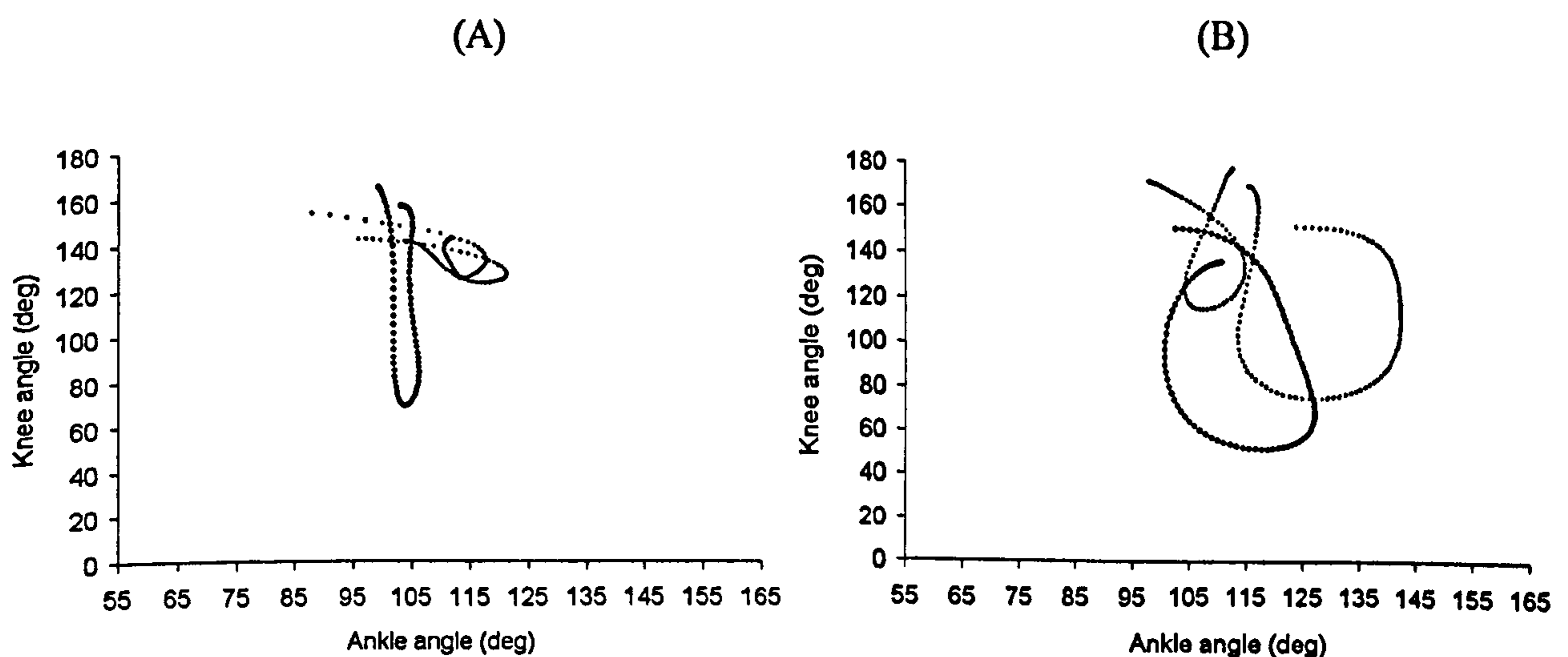


Figure 6.2. Pre-test to retention test changes in knee-ankle relative motion to match a model from in the presence (A) and absence (B) intrinsic visual knowledge of results (for each test period, the vertical axis = knee angle, horizontal axis = ankle angle).

By adapting a measurement tool used to quantify variability in movements, these experiments employed a new measurement system (NoRM-D; Horn et al., 2003) to

directly quantify the proximity of learner's relative motion to the model's motion. This facilitated the most direct assessment of Scully and Newell's (1985) predictions to date. NoRM-D values indicated that both the point-light model and the video model facilitated immediate and long-term changes in relative motion. Those in the CONTROL group showed no change in relative motion.

Although the combined findings of Experiments 1 and 2 support Scully and Newell's predictions for relative motion, they are best explained in the context of Newell's (1985) hierarchy of coordination, control, and skill. Contrary to recent interpretations of this hierarchy, Newell adopted Bernstein's (1967) view that coordination (the assembly of a new movement topology) is the organisation of control (the parameterisation of the pattern). As such the two are synergistically linked, and constraints imposed on one will also affect the other. When a learner has to simply learn a movement outcome regardless of technique (or vice-versa), this synergy is maintained. However, in learning environments where learners must achieve an accurate outcome with a specific technique, there are demands placed on both coordination and control. This may be seen as *competition replacing synergy*. If intrinsic visual KR is the constraining source of information, the parameterisation of movement (control) dominates at the expense of the appropriate movement pattern (coordination). Conversely, if the model is the constraining source of information, coordination is emphasized at the expense of control. In Experiment 3, when visual information was naturally available to the learner (i.e., they could see where the ball went), but was not usable as a source of outcome information (i.e., velocity), the assembly of the movement pattern was again facilitated by the model's demonstration.

These results may also have far reaching practical implications. They imply that in order to facilitate immediate and lasting changes in technique, the instructor needs to

assess the presence of intrinsic visual KR. If the movement task has a definitive technique and powerful, usable information is present (e.g., soccer and American Football kicking, basketball shooting, cricket bowling, baseball pitching, bowling), the instructor may need to minimize that information to constrain the learner to use the model. Hodges & Franks (2002) state that when a movement response is not part of the learner's repertoire, movement demonstrations portraying an optimal technique proffer little benefit to learning. The results of Experiments 1 and 2 suggest that this conclusion is somewhat premature. Instead the results indicate that movement novelty is in fact, less significant than the presence of other constraining information for learning.

The evidence presented for an interaction between demonstration and intrinsic visual KR may also contribute to current understanding on equivocality in observational learning. A review of observational learning literature suggests that demonstrations are not always effective in facilitating skill acquisition. Previously posited accounts for this include variations in task type and novelty used (e.g., Gould & Roberts, 1982) and the learning of pre-existing movement patterns (Southard & Higgins, 1987). Also, the nature of information has been proposed to account for equivocal findings. The extent to which the demonstration conveys a strategy for action (Burwitz, 1975), the degree of redundancy in information provided (Newell, 1981), and informational load (Gould & Roberts, 1982) have all been proposed as factors contributing to the degree of efficacy of a demonstration. In light of the results of Experiments 1 and 2, the availability of powerful KR, and the potential for interaction between demonstration and feedback should also be considered.

Immediacy and stability of coordinative changes in response to model

One of the most salient results obtained in the absence of intrinsic visual KR was the rate of change in relative motion for those observing a model. Experiments 2 and 3

provided the clearest indication to date of the rate of changes in intra-limb coordination that may occur in the absence of usable KR. This makes a substantial contribution to the literature because until now, researchers have employed designs that largely ignore early acquisition trials in favour of long term assessments. Those researchers assessing changes in early acquisition have not provided clear data on the rate of change because they did not compare coordination before and after observation of the model (e.g., Al-Abood et al., 2001 a,b; Gray et al., 1991), or they used a single measurement to represent a whole acquisition period (e.g., Wuyts & Beukers, 1995).

In Experiments 2 and 3, those observing a model showed large, immediate changes in relative motion in the first three trials of acquisition. This new level of proximity is then maintained throughout the remaining trials. These results oppose both the theory and the purported benefits of learning by discovery methods. Several authors have recommended that allowing learners to explore the intrinsic dynamics of the task may be superior to learning from a model (e.g., Handford et al., 1997; Hodges & Franks, 2002). This discovery learning method may guide the learner's search to optimal areas of the *perceptual-motor workspace*, while the use of demonstration and coach interventions are assumed to provide 'soft assembly' of a temporary, inaccurate solution as an emergency (Handford et al., 1997). The combined data from Experiments 2 and 3 clearly indicate that the 'solution' provided by the model was neither temporary nor inaccurate. This thesis proposed that in the absence of usable KR, the model immediately allows the learner to *refine* rather than *broadly search* for movement solutions. In Experiment 3, discovery learners in the CONTROL group showed no signs of changing their relative motion to facilitate increased ball velocity across the 21 trials.

The practical implications of these findings relate to efficiency in typical learning environments. Here, learners often receive a limited number of trials before the

context, or *regulatory conditions* (Gentile, 1972) of a skill are changed. The results of Experiments 2 and 3 suggest that using demonstration would support this type of coaching environment, while discovery learning is unlikely to be effective within these time constraints. Further research is planned to examine whether participants using models in early learning are better equipped (or equipped sooner) to adapt to coaching changes and the addition of augmented information.

Point-light versus video models

In all three experiments comparing coordination responses to point-light and video models, the differences between the groups were minimal. This supports the work of Williams (1989b) for a dart-like throwing action. In Experiment 1, with intrinsic visual KR, no differences were found between groups for globally or locally defined coordination. In Experiment 2, the removal of intrinsic visual KR was anticipated to accentuate any differences between groups, as participants were more dependent on the model for information. However, no differences were found. These results were taken to indicate that if video does add distracting structure, as suggested by Newell and Walter (1981) and Runeson (1984), this does not effect perception and replication of the event. It appears that relative motion, which is salient and readily picked up from point-light models is easily extracted from an embedded video display. At present, these studies suggest that there is no benefit to using point-light images as a demonstration tool.

‘What’ Information, Visual Search Strategy, Perception of Motion and Dynamics:

Key Findings and Implications

Visual search strategy

Three key results were obtained for visual search analysis. First, search strategies support theories of the perception of a global representation of the movement.

Second, there is evidence for refinement of search over time. Finally, visual search strategy appears to be influenced by presence or absence of visual intrinsic KR.

Evidence for the predominance of global perception of movement. Analyses of visual search strategies in Experiments 1 and 2 indicated that the joint centres of the lower limb (hip, knee, ankle) were the primary areas of interest for participants observing both the video model and the point-light model. However, local coordination analyses indicated that observers were not improving their coordination around these sites. Therefore, this suggests that these fixation points were a reference point, or visual anchor around which to pick up peripheral information (Rockwell, 1972). Since acuity is low in the periphery, but movement perception is potent, this supports the perception of an overall, global concept of the movement, at the expense of detail. This 'synthetic' search strategy was especially evident in response to the point-light model.

In the only comparable study of visual search in observational learning, Mataric and Pomplun (1998) found that participants fixated primarily on the end-point of the moving segment (hand and fingers). This was reported as evidence that participants gain information for performing the task by tracking the trajectory of the end-point, as outlined in theories of end point control (e.g., Latash, 1990). However, Experiments 1 and 2 found little evidence to support fixation upon the end-point of the kicking leg.

Evidence for refinement in visual search. Experiment 1 showed that the breadth of visual search narrows over successive observation periods. This was taken as evidence for the priority of acquiring a global representation of the movement first, before refining later in learning. As indicated by the coordination data, the acquisition of global properties of movement was attained, but the refinement of search later in acquisition did not facilitate local coordination changes. Initially, this was attributed to an insufficient period of acquisition. However, the marked local coordination changes in

Experiment 2 negate this idea. Instead they point to further effects of intrinsic visual KR on visual and coordinative search.

The influence of intrinsic visual KR on search strategy. Experiment 2 did not substantiate the refinement of visual search over time. Nevertheless, this data fits well with the position that without intrinsic visual KR, a model facilitates the immediate *refinement* of movement rather than broad search for movement solutions. It is theorized that participants did not progressively narrow their visual search during acquisition in Experiment 2 because their search was immediately narrow to support the early refinement of movements.

The perception and replication of dynamics

Experiment 4 investigated two aspects of the visual perception perspective. First, it examined Scully and Newell's (1985) prediction that since early learning emphasizes the assembly of movement patterns, a model is likely to facilitate coordination rather than the parameterization of movement. Second, it examined whether relative motion, which appears to be central to imitating coordination, also contributes to the perception of dynamic properties.

In support of Scully and Newell's (1985) position, Scully and Carnegie (1998) found learners could replicate angular properties but not landing and take-off forces in a dance routine. The results of Experiment 4, however, indicate that observers of point-light and video demonstrations were able to accurately perceive and *replicate* the unknown distances of a ball bowled by a model. This extends past research on three fronts. First, previous research into the kinematic specification of dynamics (KSD) has only measured perceptual responses (e.g., Runeson & Fryholm, 1981, 1983). By measuring action responses, this experiment more closely follows Gibson's (1950) position that perception is *for action*. It also bridges the gap between KSD and

observational learning literature. Finally, it indicates that similar to the results for coordination in Experiments 2 and 3, the model afforded learners with the opportunity to *immediately* perceive and parameterize the movement response.

The results of Experiment 4 found no evidence for the contribution of relative motion to the perception and replication of dynamics. When the modelled act was presented in slow motion, observers showed much greater error in parameterizing the movements even though relative motion was intact. A systematic analysis was also conducted to elucidate patterns in the model's movement patterns when bowling to four equally spaced distances. Building on the techniques of Bingham (1987) and Shim and Carlton (1997), the data revealed that relative motion plots provide no systematic pattern on which the perception of dynamics could be based. Instead, observers appeared to grasp velocity data from just a small window of time around ball release.

Considerations for Future Research

The studies presented in this thesis provide a strong foundation for future research down several avenues. For example, the visual search analyses presented here require further elaboration. An analysis of visual search on a trial-by-trial basis in acquisition in tandem with coordination changes (NoRM-D and NoRMS) would clarify the nature of refinement in search over time, and provide stronger links between perception and action responses in observational learning.

The strong interaction between demonstration and intrinsic visual KR on coordination and outcome changes also merits further attention. Research designs using ecologically valid interventions (e.g., regular changes in practice context rather than countless identical acquisition trials) are encouraged to explore this issue. Further

research is required to establish the ideal use of demonstration to encourage the adoption of the optimal movement technique, while maintaining successful outcomes.

Of considerable theoretical interest is Scully and Newell's (1985) concept that observational learning occurs if the learner's relative motion matches the model's pattern within certain 'bandwidths'. The experiments reported in this thesis measured and quantified imitation based on locally defined coordination in angle-angle plots. Currently, we do not know the sensitivity of human perception to subtle variations in relative motion. Is this the appropriate level of analysis? We clearly cannot imitate what we cannot perceive. If we do predominantly imitate at a holistic or program level, as suggested by Byrne and Russon (1998) and others, then measures that reflect the global organisation of the task (e.g., number of steps taken in approaching a ball) may be more likely to be sensitive to demonstration than measures reflecting higher, localized levels (e.g., intra-limb relative motion during the kick). A threshold-based analysis of sensitivity of the system to localised relative motion using the techniques of psychophysics is encouraged.

Finally, the measurement tool devised and used to quantify coordination (NoRM-D) appears an excellent vehicle to apply to special groups. For example, the condition *developmental coordination disorder* is currently receiving research interest centred around postural control and proprioception (e.g., Smyth & Masson, 1998). Some researchers have even investigated methods of intervention (e.g., Sigmundsson, Pedereson, Whiting, & Ingvaldsen, 1998). Yet the patterns of coordination (stability and proximity to criteria) shown by these children in gross inter-limb tasks remains have not been quantified. This seems a necessary precondition for understanding the nature of deficits, and the extent of progress in intervention programs.

Chapter 7

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Appendix

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