EXTERNAL FOCUS FEEDBACK FOR MOTOR SKILL ACQUISITION AFTER STROKE

By

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Abstract

Feedback which induces an external focus of attention, about movement effects, has been found to promote motor performance in healthy subjects. It is unknown what attentional focus of feedback therapists induce when retraining reach to grasp after stroke, or whether inducing an external focus of attention is more beneficial to motor performance.

This thesis adopted a mixed methods paradigm to explore the attentional focus of feedback used by therapists. Where feedback was used it predominantly induced an internal focus of attention, about body movements.

The next study compared feedback inducing an internal or external focus of attention during the motor performance of reach to grasp after stroke. A counterbalanced design was used and reaching movements were recorded using motion analysis. Support was found for adopting an external focus of attention compared with an internal focus of attention, although an interaction between feedback type and order was also found. Finally, the influence of the level of arm and memory impairment on feedback type was explored. Neither the level of arm or memory impairment was found to influence feedback type.

This study highlights the complexities of providing feedback after stroke and suggests that adopting an external focus of attention may be beneficial to improving motor performance after stroke.

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Corrective Feedback: Information which provides knowledge on how to improve the next movement based upon the previous movement attempt. It does not provide information regarding movement errors.

External focus of attention (EF): Attention directed to focus on the movement effects within the environment.

Extrinsic feedback: Extrinsic feedback is information from an external source, such as a therapist giving verbal information to a patient about what and how to change a movement.

Information feedback: Information provided as a result of a movement, intended to improve the subsequent movement. Information feedback is commonly referred to as feedback.

Instructions: Information which directs a movement and is given before or during a movement**.**

Internal focus of attention (IF): Attention directed to the body movement**.**

Intrinsic feedback: Information available during the performance of a movement and comes from the body's sensory system.

Invariant features: A unique set of characteristics that defines a generalised motor programme where these characteristics do not vary from one performance of the action to another in healthy subjects.

Knowledge of Performance (KP): Refers to information about the movement dynamics.

Knowledge of Results (KR): Refers to information about the outcome of the performance.

Motor performance: Refers to the execution of a motor skill at a specifc time and in a specific situation.

Motor learning: Refers to a change in capability of a person to perform a motor skill. It is a permanent improvement of that motor skill.

Trajectory: The path taken by the arm during motion.

CHAPTER 1 – INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

The primary aim of this thesis was to examine extrinsic feedback in the retraining of reach to grasp after stroke, and in particular the effect of directing attention to either the body movements or the task. As an introduction to the thesis this chapter provides a brief overview of current stroke rehabilitation techniques used to improve motor function and follows with how application of findings from the motor learning literature in healthy subjects, can benefit therapy treatments. As this thesis focused upon reach to grasp, a section will detail the kinematics of reach to grasp in healthy people. This will be followed by an account of kinematics commonly seen after stroke. The role of feedback in motor learning and the types of feedback in both healthy subjects and people with stroke will then be discussed to inform design decisions within the study. Next the literature detailing the effects of focusing attention either to the body (internal focus) or to the task (external focus) will be outlined in both healthy subjects and people with stroke. Finally the influence of experience of a skill or the level of impairment will be discussed, as will the influence of working memory capacity on motor performance. The search strategy used to find relevant studies can be found in Appendix B.

1.2 Theoretical background

1.2.1 Current status of research in stroke rehabilitation

Practice and feedback are both key components to motor learning in healthy subjects (Enebo & Sherwood 2005) and people with stroke (Platz et al. 2001). It is however the importance of practice which has dominated stroke rehabilitation research. These include studies highlighting the need for repetitive functional activity (Butefisch et al. 1995;Dean & Shepherd

1997;Duncan 1997;Hanlon 1996;Kwakkel et al. 1999;Parry et al. 1999;Winstein et al. 1999) with an emphasis on task orientated training (Nelles et al. 2001;van Vliet et al. 1995;Wu et al. 2000). This has led to the development of treatments including constraint induced therapy (Bjorklund & Fecht 2006), Functional electrical stimulation (FES) (Alon et al. 2007;Mackenzie-Knapp 1999) bilateral training (Stewart et al. 2006), motor imagery (Crosbie et al. 2004) and robotic and virtual reality training interventions (Woldag & Hummelsheim 2002). The success of these rehabilitation techniques may however be limited unless feedback on performance is provided. The use of feedback to promote motor recovery has however received little attention in stroke rehabilitation research (van Vliet & Wulf 2006).

1.2.2 Stroke rehabilitation and motor learning

There are vast quantities of literature in healthy subjects, detailing methods of delivering information to learners about their motor performance. In the field of sports this research in particular has led to more efficient and effective training regimes (Magill 2007). These findings have had a minimal affect on clinical treatments as the examination of the transferability of these methods to stroke rehabilitation has been limited (de Bruin et al. 2009;Marchant et al. 2007;Winstein 1991). This is a missed opportunity and one that needs rectifying with a view to increasing the effectiveness of therapy, particularly given the time constraints under which therapists work, and the growing economic difficulties within the health service. To improve the effectiveness of therapy treatments, it seems logical to examine whether the results of motor learning research in healthy subjects can be applied to the delivery of treatment techniques in stroke rehabilitation. Currently it is unclear whether the results of studies in healthy subjects can be transferred to people with stroke. Specific research within the stroke population is therefore required. In the meantime it is deemed acceptable to use the principles of motor learning in healthy subjects to the rehabilitation setting (Winstein 1991). These principles as they relate to feedback are discussed later in this chapter (section 1.4).

1.2.3 Motor relearning after stroke

To understand how the delivery of information may influence people with stroke it is useful to understand the pathology of stroke and the basis by which motor relearning occurs. Following stroke the brain has a remarkable capacity to regenerate neural pathways although the extent of recovery depends upon many factors. These include the size and location of the lesion as well as the experiences of the individual and the environment they are exposed to (Shelton & Reding 2001). Following infarction there is a core ischaemic area and a region known as ischaemic penumbra. The core ischaemic area is where neurons have necrosed as a result of inadequate supply of oxygen and glucose. This results in the permanent loss of those neurons. The region known as penumbra represents areas that have reduced blood flow but without collapse of cerebral blood volume (Fisher & Ginsberg 2004). Collateral arteries can be used to perfuse this area and hence the development of treatments such as thrombolysis to prevent permanent damage (Murphy & Corbett 2009). The infarct also results in oedema which can raise intracranial pressure, another cause of irreversible cell death. Much of the improvement seen during early rehabilitation is due to the effects of the oedema decreasing, absorption of necrotic tissue debris and from improved perfusion to the brain cells through the opening of collateral channels. This it thought to take place over a 3-4 week period (Lee & van Donkelaar 1995). Beyond this point the primary process responsible for functional recovery is the reorganisation of neural mechanisms, a process known as neuroplasticity (Cramer & Riley 2008). These processes include changes in membrane excitability, growth of new connections, unmasking of pre-existing connections and removal of inhibition and activity dependent synaptic changes (Murphy & Corbett 2009). Physiotherapists can take advantage of the capability of cortical reorganisation through the practice of effective and efficient movement patterns, and through reducing the impact of dysfunctional movement patterns (Murphy & Corbett 2009). The type of practice which assists the reshaping of the cortex matters (Small & Solodkin 1998). To understand the factors which constitute optimal practice conditions, it is useful to have a theoretical understanding of how motor control and learning occurs.

1.2.4 Theories of Motor Control

Theories surrounding how the motor system is controlled, that is how muscles and limbs are coordinated to find an optimum solution to a motor problem is much debated (King 2003;Newell 2003;Schmidt 2003;Shea & Wulf 2005). The concepts developed are based upon the ground breaking work of Bernstein (1967) who described the coordination of movement to involve controlling the number of degrees of freedom that exist within the body (Bernstein 1967). The main theories of motor control which relate to this thesis are dynamical systems approach (Kelso 1995) and schema theory (Schmidt 1975). The dynamical systems approach describes movement solutions that emerge from the environment utilising movement synergies (Kelso 1995). It also has a basis from Gibsonian theories of perception and action. Gibson’s view was that perception and action are integrally coupled with the ability to attain functionally relevant information directly from the task (Gibson 1979). It also accounts for the physical laws of movements and as such the dynamical systems model is characterised by three main areas: self organisation, stability and constraints (King 2003). The self organisation component deals with the interaction between an individual’s movement and the environment (King 2003). This aspect is important in relation to inducing an external focus of attention in an individual as it suggests that focusing upon the environment while performing a movement may directly affect movement dynamics. The issue of attentional focus and the research which has examined the effect of focusing attention externally will be explored later (Section1.5).

The issue of stability relates to the idea that the body prefers stability with the suggestion that after a perturbation, the system will return to a stable state. This highlights the dynamic nature of movement and how with practice a different movement solution can become the stable state, an important concept to improving movement patterns (King 2003).

The issue of constraints highlights how factors within the individual, task and environment influence movements, with the body adopting the most efficient pattern of movement within the constraints placed upon it. When considering people with stroke this aspect of the dynamical systems theory highlights how individual impairments influence movement output, but also offers a solution to how movement patterns can become more effective. Movements can be optimized by utilising the environment, and task selection, to enable an individual to use effective muscle synergies. For example to aid reaching in the presence of weak shoulder muscles, the effect of gravity on the arm could be reduced by performing the reaching movement in side lying.

Taken together the dynamical systems theory suggests an individual can be supported to move more efficiently, through an improved movement pattern utilising the environment. This is an important concept within this thesis as it suggests a role for inducing attention towards the environment and to encourage interaction between the individual and the environment which could improve motor control.

In contrast Schmidt's schema theory (Schmidt 1975) describes the existence of motor programmes as a solution to controlling the degrees of freedom within the body. Motor programmes are described as being a memory representation that stores information enabling an action to be performed quickly. Schmidt described the concept of the generalised motor programmes which comprise of invariant movement components for movements of the same class, for example reaching movements. The invariant features for reach-to-grasp are described in section 1.3.2. The invariant features were initially thought to include the order of events and the relative timing and relative force, although following subsequent research the idea of relative force in a class of movements being invariant is now questioned (Schmidt 2003).

In addition to the general motor programme, Schmidt (1975) also described the concept of schema, which allowed a movement to be scaled to the environment and the specific requirements of the task. Schemata are 'an abstract representation of rules governing movement' (Magill 2007 pg 91). Schmidt described two types of schemata, recall and recognition schemata. Recall schemata are associated with the relationship between parameters used during a performance and the outcome achieved by the motor programme for that performance (Schmidt 2003). Recognition schemata evaluate the effectiveness of the response, acting as a reference to allow comparison of the actual movement with the desired movement (perceptual identification) (Sherwood & Lee 2003). The concept of a generalised motor programme and schemata suggested a role of information processing in motor control. Following a stimulus, a response requires the selection of a motor programme based upon the desired outcome. The motor programme used can also be adjusted based upon the feedback generated both during and after the movement, another cognitive process. Schema theory incorporated the idea of two memory compartments, the selection of a motor programme prior to movement initiation, an open loop or feed-forward system, and a closed loop or feedback driven system whereby feedback is responsible for evaluating the effectiveness of a movement. The emphasis of the role of feedback in schema theory and the cognitive aspect of the theory is relevant as augmented feedback was the treatment used to influence the motor performance of people with stroke in this thesis. It suggests that providing feedback can influence the attainment of efficient movements.

Both theories have their strengths and limitations. One key problem with Schema theory surrounds the omission of being able to explain movement as dynamic, as well as the issue of storage capacity and how the motor programmes are developed (Newell 2003;Sherwood & Lee 2003). Evidence however remains for the idea of a pre-programmed response to help constrain the degrees of freedom to movement (Shea & Wulf 2005;Wulf et al. 1999c). The main criticism to the dynamic systems theory surrounds the lack of acknowledgment to a cognitive aspect of motor control and learning. Both theories however offer theoretical underpinning to this thesis, with the dynamical systems theory emphasis towards the individual and their interaction with the environment. Schema theory offers a role for providing feedback and the role of cognition in motor control. It is anticipated that in the future a new theory encompassing a perceptual-cognitive framework for motor control will be proposed (Schack & Tenebaum 2004).

1.2.5 Application of motor learning theory to stroke rehabilitation

Schema theory also provides a good basis to understand the principles of rehabilitation after stroke (Nativ 1993). Depending on the extent of stroke, damage to the motor programmes and motor schema may occur, so some or all aspects of movements such as reach to grasp may need to be relearned. Rehabilitation needs to emphasize the relearning of invariant features of a movement where motor programmes are damaged, and guidance towards the correct parameter selection where schemata are damaged (Hodges & Franks 2002). To promote the development of motor schemata both practice and feedback are required. The importance of practice for motor learning has been outlined above (Section 1.2.1). The role of feedback will be discussed in detail later (Section 1.4).

1.3 Performance of reach-to-grasp

1.3.1 Reach to grasp

This thesis focused on reach to grasp as it is one of the most common upper limb movements needed in everyday life (Ingram et al. 2008) and arm impairment affects 77% -85% of people with stroke (Lawrence et al. 2001;Nakayama et al. 1994) with only approximately 56% regaining functional use (Nakayama et al. 1994). Arm and hand movements are therefore a major contributor to disability after stroke (Sveen et al. 1999) resulting in a significant impact upon lifestyle, affecting personal, domestic and work related activities (Mudie & Matyas 1996). To improve functional arm movement an understanding of motor control is essential as it provides important knowledge which can be used to develop and improve rehabilitation techniques. Next the motor control of reach to grasp will be outlined including the invariant features of reach to grasp and the spatial representations and temporal sequencing.

1.3.2 Motor control of reach to grasp

Reaching in front of the body comprise of invariant features, that is, movement components which occur with every forward reaching movement in healthy subjects. These are: shoulder forward flexion, protraction and lateral rotation of the scapula, shoulder external rotation, elbow flexion and extension, supination of the forearm, wrist extension, wrist radial deviation, abduction and opposition at the carpel metacarpal joint of the thumb, extension of the fingers at the metacarpal phalengeal joint with flexion at the interphalangeal joints, conjunct rotation of the fingers towards the thumb for reach and flexion of the metacarpal phalengeal joints of the fingers, adduction of the carpal-metacarpal joint of the thumb and flexion at the interphalengeal joint of the thumb for grasp closure. These invariant features provide focus when assessing and retraining arm movements (Carr & Shepherd 1989;Carr & Shepherd 2003).

To produce efficient reaching movements spatial and temporal coordination are also important. The spatial representations and temporal sequencing of reaching will now be discussed as they occur in healthy subjects followed by deviations from normal commonly seen after stroke.

1.3.3 Kinematics of reach to grasp in healthy subjects

Reach to grasp has typically been described as consisting of two components, transport and grasp, and controlled by two separate visual motor channels (Jeannerod 1981). The transport component refers to bringing the hand to the target object, while the grasp component refers to the opening and closing of the fingers and thumb around the object that leads to grasping of the object (Alberts et al. 2002). These 2 components with now be discussed as they occur in healthy subjects.

1.3.4 Transport

The velocity profile of the hand of a pre-planned reaching action has consistently been found to be bell shaped consisting of one acceleration and one deceleration phase (Jeannerod

1984;Latash & Anson 1996;Morasso 1981). The amplitude of peak velocity has been found to depend upon factors such as task difficulty (Wagner et al. 2007) and can be negatively affected by the removal of environmental cues (Churchill et al. 2000) and age (Bennett & Castiello 1994). The relative timing of wrist peak velocity has been reported to occur between 30 to 50% of movement duration (Hu et al. 2005) with task accuracy requirements (Marteniuk, Leavitt & Mackenzie 1990), removal of vision (Churchill et al. 2000) and age contributing to the variability. Peak velocity has been found to occur early where a task requires precision (Jeanerod 1984) and later where there are no accuracy constraints (Marteniuk, Leavitt & Mackenzie 1990). The removal of vision causes a reduction in the percentage time to peak velocity, resulting in a longer deceleration phase (Churchhill et al. 2000), and age has also been found to reduce the percentage time to peak velocity (Bennett & Castiello 1994).

After velocity reaches a peak, a deceleration phase begins. Peak deceleration represents a positioning or target-acquisition phase which has been found to occur around 70% of total movement duration (Jeanerod 1984).The deceleration phase is increased with increased accuracy requirements as more online adjustments are required to successfully complete the task (Marteniuk et al. 1987).The transport phase has been found to follow a straight hand path (Morasso 1981) as the object constrains the reach causing a direct path towards the object (Flash et al. 1992).

1.3.5 Grasp

Grasp formation, or the pre-shaping of the hand and fingers, starts at the onset of arm movement (Rosenbaum et al. 1999). Aperture between the fingers and thumb increases smoothly reaching a single clear peak. Then a few centimetres short of the target, aperture reduces slowly until the object is grasped (Haggard & Wing 1998;Jeannerod 1981;Marteniuk et al. 1987;Wing et al. 1986). The time of maximum aperture has been found to occur between 60-80% of movement duration (Jeannerod 1984;Marteniuk et al. 1990;Paulignan et al. 1991;Rand & Stelmach 2000;Smeets & Brenner 2002;Wallace et al. 1990;Wallace & Weeks 1988). Others however have found variation of this based upon the type of grip used, with a precision grip resulting in an earlier maximum aperture (Gentilucci 1991) and the absence of vision has been found to reduce the percentage time to maximum aperture to be as little as 45% (Schettino et al. 2003). The variance of the timing of maximum aperture indicates there are at least two control mechanisms at work during hand pre-shaping, an early predictive phase during which grip selection is attained regardless of the availability of visual feedback, and a late responsive phase during which subjects may use visual feedback to optimize their grasp. These finding suggests a complex system of control coordinating transport and grasp.

1.3.6 The coordination between transport and grasp

The general consensus is that the transport and grasp phases of reaching are coordinated. The mechanisms for this coupling vary, with views that have evolved over time in the light of further research. Initially Jeannerod (1984) described temporal coordination between the transport and grasp components, with his finding that the timing of maximum aperture was invariant, occurring around 70% of movement duration, and closely correlated to peak deceleration also reported to be around 70% of movement duration. Following the findings of studies involving perturbations whilst reaching, this view required modification (Gentilucci et al. 1992;Paulignan, Jeannerod, Mackenzie, & Marteniuk 1991). To account for the coupling of the reach and grasp components it was suggested feedback of the predicted duration of each component, led to coordination of the two visuomotor channels, resulting in a continuous synchronization throughout the movement (Hoff & Arbib 1993). This model could not however account for delays to the pre-shaping of the hand when reaching in a curved path towards an object. For example when an additional object obscured the direct path to the desired object the predicted duration of the grasp component was unable to accommodate the presence of the additional object which resulted in asynchrony.

The current view and where the weight of evidence lies is with respect to a spatial coupling between transport and grasp, where the grip aperture is modulated based on the distance between the hand and the object (Alberts, Saling, & Stelmach 2002;Haggard & Wing 1998;Rand et al. 2006). In other words the distance of the hand from the object where aperture begins to close has been found to be invariant (Alberts et al. 2002; Rand and Stelmach 2005) but the distance travelled by the wrist prior to maximum aperture varies under different task constraints. For example, where precision grip is required, maximum aperture occurs earlier so the wrist travels a shorter distance prior to maximum aperture (Bennett & Castiello 1994). So despite the view that the correlation between maximum aperture and peak deceleration is robust it does appear to depend upon the task with some even failing to detect a correlation (Hesse & Deubel 2009). For example where the deceleration phase is prolonged, peak aperture has been found to occur proportionally later, such that there is no correlation between peak deceleration and peak aperture (Churchill et al. 2000).

1.3.7 Measures of upper limb kinematics

Kinematic variables enable detection of subtle deficits in movement coordination (Cirstea et al. 2003a). This helps to discern how movements differ between healthy subjects and people with stroke which in turn can inform the development of rehabilitation techniques (McCrea et al. 2002). Peak velocity, time to peak velocity, relative time to peak velocity, movement duration, time to peak deceleration, relative time to peak deceleration and hand path curvature are all common kinematic measures used to evaluate movement performance. Joint angles are also commonly collected either in absolute terms (Kamper et al. 2007; Wagner et al. 2007) or so the coordination between the joints can be examined (Cirstea et al. 2003a).

1.3.8 Upper limb kinematics after stroke

Studies examining reaching after stroke have reported numerous kinematic differences compared with healthy subjects.

Common findings are:

- **Increased movement duration** (Archambault et al. 1999;Cirstea et al. 2003b;Cirstea et al. 2003a;Cirstea & Levin 2000;Kamper et al. 2002;Lang et al. 2005;McCrea & Eng 2005;Michaelsen et al. 2009;Michaelsen et al. 2004;Platz et al. 1994;Roby-Brami et al. 1997).
- **Decreased peak velocity** (Roby Brami et al. 1997, Archambault et al. 1999, Fasoli et al. 2002).
- **Increased deceleration phase** (McCrea & Eng 2005, Michaelsen et al 2009).
- **Decreased active joint range of motion** (Kamper et al. 2002, Cirstea et al. 2003a; Cirstea, Ptito & Levin 2003b).
- **Increased path curvature** (Archambault et al. 1999; Kamper et al. 2002; Lang et al. 2005; Levin 1996; McCrea & Eng 2005; Reisman & Scholz 2006).
- **Increased trunk displacement -**This compensates for decreased shoulder forward flexion and elbow extension (Cirstea, Ptito, & Levin 2003b;Levin et al. 2002;Michaelsen et al. 2001;Roby-Brami, Fuchs, Mokhtari, & Bussel 1997;Roby-Brami et al. 2003).

- **A change in aperture -**This could result in either an increased or decreased aperture relative to healthy subjects (Nowak et al. 2007). In this study as most subjects had moderate upper limb impairment, a decreased aperture was seen as abnormal so an increase in aperture was seem as an improvement (Lang et al. 2005).
- **Increased time to maximum aperture** (Michaelsen et al. 2009).
- **Increased movement units - **A movement unit can be defined as a ‘single acceleration followed by a single deceleration, thus delineating a stop-start or discontinuous motion when two or more units are combined.’ (Fetters & Todd 1987). After stroke multiple movement units are common (Roby Brami et al. 1997, Cirstea, Ptito, Levin 2003b).
- **Increased variability of the kinematic variables listed above** (Archambault et al. 1999; Cirstea & Levin 2000; van Vliet et al. 1995).

Movement duration is thought to increase in people with stroke for a multitude of reasons. These include increased visco-elasticity of muscles and longer time to recruit motor units (McCrea & Eng 2005). There can also be an increased reliance upon feedback control (Trombly 1992) due to the inability to form appropriate representations of movement (Beer et al. 2000). This can result in a prolonged deceleration phase and can increase the absolute and relative time to peak deceleration, (McCrea & Eng 2005) and thus increase movement duration. The acceleration phase can also be increased reflecting increased time to implement the motor programme (Archambalut et al. 1999; Reinkensmeyer et al. 2002). An increased acceleration phase can increase the absolute time to peak velocity compared with healthy subjects but when taken in conjunction with the prolonged deceleration phase the relative time at which peak velocity occurs is proportionally earlier (Michaelsen et al. 2009).

The magnitude of peak velocity is lower compared with healthy subjects due to a reduced ability to produce sufficient muscle torques (Fasoli et al. 2002;Reinkensmeyer et al. 2002), reduced distance travelled (Jeannerod 1984) and muscle weakness (Bohannon 1991;Boubonnais & Vander Noven 1989). Muscle weakness is considered a primary factor for reduced active range of motion at the shoulder and elbow, and is compensated for by increased trunk flexion (Archambault et al. 1999; Michaelsen et al. 2004; Roby-Brami et al. 1997). Others however report a large contributory factor to slow movements due to impaired interjoint coordination (Beer, Dewald, & Rymer 2000;Cirstea, Ptito, & Levin 2003b;Cirstea & Levin 2000;Levin 1996) which presents as deviation from the straight line path (Archambault et al. 1999;Kamper et al. 2002;Levin1996;McCrea & Eng 2005,Reisman & Scholz 2006) resulting in less smooth movements (Levin 1996;Roby- Brami et al.1997;Archambault et al. 1999;Cirstea, Ptito & Levin 2003).

Hand opening has also been found to occur just before the object is reached in people with stroke rather than at the onset of the transport phase, resulting in an increased time to maximum aperture, but it can also result in an early time to maximum aperture (Lang et al. 2005, Michaelsen et al. 2009). The magnitude of aperture has either been found to be much wider than the object diameter or smaller reflecting a difficulty activating the fingers to shape the hand to object size (Lang et al. 2005). Correlation between percentage time to peak velocity (TPV) and time to maximum aperture (TMA) have been found in both sub-acute (van Vliet & Sheridan 2007) and in chronic stroke (Michaelsen et al. 2004) although this interdependence between these two components have been found to be less tight (van Vliet & Sheridan 2007).

The compensations adopted are considered maladaptive as non-optimal movement patterns result which can induce maladaptive brain plasticity and can limit functional recovery (Cirstea & Levin 2007). Rehabilitation of movements is required to encourage the recovery of the lost movement elements (Levin 1996; Levin et al. 2002; Michaelsen et al. 2006). Practice alone may only reinforce faulty movement. To adjust the motor control elements of the reaching movements, the use of sufficient feedback is required to promote more optimal movement patterns (Winstein 1991).

1.4 Feedback

1.4.1 What is feedback?

Feedback is considered critical for motor learning (Magill 2007). Broadly, feedback is input to the sensory system which provides information about a movement (Magill 2007). It is the process where individuals can compare their actual movement with the desired movement (Balzer et al. 1989) thereby guiding optimum movement form (Park et al. 2000). The desired movement template is a pre-planned internal representation which is selected to best suit the task.

One method to promote motor performance and learning is through the use of feedback. Without adequate information it is nearly impossible to develop a motor programme/ motor representation for a task (Guadagnoll & Lee 2004). Where a task is unfamiliar, refinement to the motor schema is required. Feedback provides information regarding the actual movement and enables the system to make adjustments where the actual movement either does not match the pre-planned movement, or changes to the motor programme are required to achieve a more efficient movement.

1.4.2 Types of feedback

Feedback has two main sources, intrinsic and extrinsic. Intrinsic feedback refers to the information available during the performance of a movement and comes from the body's sensory system. For example, the visual system provides information about whether an object has been reached, and tactile and proprioceptive information informs a person whether a jar has been touched. Extrinsic feedback is information from an external source, such as a therapist giving verbal information to a patient about what and how to change a movement (Magill 2007). Extrinsic feedback is additional to intrinsic feedback and is also referred to as augmented feedback.

1.4.3 Role of extrinsic feedback

Primarily extrinsic feedback assists interpretation of intrinsic feedback (Guadagnoll & Lee 2004) and is particularly beneficial when it provides information which is not perceivable to the learner. For example the distance of a driving shot in golf. Other benefits of extrinsic feedback include: increasing the rate of skill acquisition, promoting more efficient movements and encouraging persistence to learn (Magill 1994).

1.4.4 Is extrinsic feedback always beneficial?

The benefit of feedback has been widely accepted for many years with the view that it provides improved knowledge about a task leading to improved motor performance. As previously highlighted in section 1.2.1, feedback, along with large amounts of deliberate practice, have been associated with motor learning (Enebo & Sherwood 2005) but some have questioned the benefit of feedback (Kluger & DeNisi 1992). Some have suggested that sufficient practice without guidance may improve learning (Green & Flowers 1991;Hodges & Lee 1999) suggesting the use of direct information may be unnecessary. More commonly extrinsic feedback has been found to enhance learning (Young & Schmidt 1992) but as mixed views exist, including positive, negative and indifferent results to feedback, studies showing the disparate effects of feedback will now be briefly outlined (Kluger & DeNisi 1992).

1.4.5 Effects of feedback vs no feedback

Some studies have examined the effect of extrinsic feedback relative to no extrinsic feedback and have found a positive effect of feedback (Croce et al. 1996;Kawashima et al. 2000;Mononen et al. 2003;Perez et al. 2009;Shea et al. 1999;Thorpe & Valvano 2002). Kawahima et al. (2000) compared receiving feedback against no feedback in a line drawing task. A benefit to feedback was found which perhaps was not surprising as vision was excluded thereby increasing the demand for extrinsic information. Some studies have failed to find a benefit of a feedback intervention. Such studies however used feedback which was already inherent in the task, leading to the conclusion that where intrinsic feedback from performing a task provides an indication of the response, extrinsic feedback is probably redundant (Buekers et al. 1992) thereby showing no additional benefit (Schmidt & Young 1991). For example Platz et al. (2001) trained arm movements after brain injury. The training included keeping an arm steady while manipulating small objects, and included receiving visual feedback indicating individual progress. Although improvements were seen after training, the provision of feedback 'was not associated with a statistically significant differential on improvement'. This was accounted for by patients being aware of their performances and progressed independent of the extrinsic feedback. Others argue however that feedback even in the presence of sufficient intrinsic feedback, can be useful for a motivational effect (Kilduski & Rice 2003).

1.4.6 Negative effects of feedback

Some studies have reported negative effects of extrinsic feedback (Swinnen etl al. 1990; Puttenmans et al. 2004). These studies have provided feedback which caused performance decrements when the extrinsic feedback was removed. For example where feedback is provided immediately after a movement, it is thought to interfere with an individuals ability to independently detect errors. Dependence with the feedback develops such that when the feedback is removed, it causes performance decrements (Swinnen et al. 1990). Feedback which prevents or affects the use of intrinsic feedback has a negative effect on learning. In summary for feedback to serve as an important tool to aid motor performance and learning, it needs to be carefully selected (Puttemans et al. 2004). Factors to consider when choosing how to deliver feedback effectively will now be discussed.

1.4.7 Content of extrinsic feedback

One factor when choosing how to provide feedback is the content of feedback. This in itself comprises of many components. These include: providing information about errors; corrections; errors and corrections; feedback about the performance or movement outcome, and the specificity of the feedback. These styles will now be outlined with an emphasis on the issues that need consideration when choosing feedback content for people with stroke.

Prescriptive, descriptive or corrective extrinsic feedback?

Traditionally prescriptive feedback detailing the error made, and the correction required, has been considered optimal when providing extrinsic feedback (Magill 2007). This suggestion has mainly applied to sport situations where subjects are often young with good cognitive abilities, and are well motivated. Such detailed information can however have drawbacks, including the possibility of information overload (Guadagnoll & Lee 2004) which can inhibit learning (Enebo & Sherwood 2005). This is a particular consideration when providing feedback to the stroke population where cognitive impairments are common, as the amount of information which can be processed can be limited (Guadagnoli & Lee 2004). In contrast increased cognitive effort associated with providing information about movement errors (Koehn et al. 2008), has also however been associated with increased motor learning (Cirstea & Levin 2007;Lee et al. 1994), albeit at a slower task acquisition rate (Hodges & Franks 2000). In the case of people with stroke a slower task acquisition rate may increase the risk of developing secondary complications, such as muscle length problems, as some muscles may be used ineffectively while the correct movement structure for the task is developed.

It seems prudent to carefully consider individual characteristics, for example cognitive ability, to gauge the amount and style of information used. Descriptive feedback, which describes only the error made during performance, would reduce cognitive load but this type of feedback can be perceived as being negative which could be detrimental to practice (Wiswede, Munte & Russler 2009). Feedback however can also be used to guide the learner to the adjustment required to improve performance, and can be classified as corrective feedback. This type of information accommodates for attentional capacity and working memory difficulties by limiting the amount of information. It is possible that providing the correction may cause dependency as a learner may rely upon the corrective feedback to improve performance rather than relying upon intrinsic mechanisms (Lee, Swinnen, & Serrien 1994), although feedback which directly informs what to do next as opposed to feedback about the completed response is still considered valuable (Kernodle 1992).

Knowledge of results and knowledge of performance

Another classification of extrinsic feedback is knowledge of results (KR) and knowledge of performance (KP). Knowledge of results refers to the outcome of the performance whereas knowledge of performance refers to the movement dynamics (Gentile 1972;Gentile 1998). Traditionally in the feedback literature KR has been used most frequently, but more recently the use of KP has increased on the premise that it is more useful to provide information which the learner is unaware. Kernodle & Carlson (1992) compared feedback based upon the biomechanical analysis of optimal reaching (KP) and KR, and found KP improved movement technique and distance in a throwing task. However, the KP group received more sources of FB: video and verbal, whereas the KR group only received verbal feedback. The improvement seen could therefore reflect increased cognitive effort within the KP group (Lee, Swinnen,Serrien 1994), or may relate to the outcome measures used, with improvements seen in the areas trained (den Brinker et al.1986;Tzetzis et al. 1997;Zentgraf & Munzert 2009).

1.4.8 Specificity of extrinsic feedback

Some research has found that the inclusion of encouragement while providing extrinsic feedback has a positive effect on learning (Kilduski & Rice 2003). This may be associated with a positive effect on mood which may assist sustaining motivation for continued practice of a task (Chiviacowsky & Wulf 2007;Mouratidis 2008). Information feedback has however been found to be more effective than just providing verbal encouragement with phases such as ‘well done’, ‘keep going,’ as it provides more specific information (Fredenburg et al. 2001;Wallace & Hagler 1979). Although therapists have reported stating that sustaining patient motivation is important (Demain et al. 2006), more specific feedback is thought to be necessary where guidance to the correct movement form is required (Chen & Rikli 2003).

1.4.9 Scheduling

Another consideration when incorporating feedback into rehabilitation programmes is the scheduling, that is, the timing and frequency of the feedback. Insight with regard to the scheduling of feedback after stroke can be gained from the literature in healthy subjects as little research has been conducted in the stroke population (van Vliet & Wulf 2006). After stroke, the timing of feedback needs to consider the possible presence of cognitive impairments and the frequency of feedback requires careful consideration and may require a different approach to that advocated in healthy subjects. These issues surrounding the scheduling of feedback will now be outlined with an emphasis on how it applies to people with stroke.

Timing of feedback

Extrinsic feedback can be provided during or after a movement. Concurrent feedback however has been found to be detrimental (Park et al. 2000;Schmidt & Wulf 1997;Vander Linden et al. 1993) whereas terminal feedback, feedback provided after a movement has been found to be more beneficial (Schmidt & Wulf 1997). Concurrent feedback is thought to become incorporated within the internal representation of a movement causing dependency upon the feedback, whereas terminal feedback is thought to encourage the learner to self analyse their own movement performance using intrinsic feedback mechanisms (Lee, Swinnen, Serrien 1994; Sherwood & Lee 2003). Giving terminal feedback immediately following a movement has however been found to degrade learning, as instantaneous feedback is thought to detract learner from interpreting their intrinsic sources (Lee, Swinnen, & Serrien 1994; Swinnen et al. 1990; Swinnen et al. 2006; Winstein 1991). Providing feedback after a short delay of a few seconds, can increase the use of intrinsic feedback and is considered optimal (Lui & Wrisberg 1997;Swinnen et al. 1990). This is likely to be relevant after stroke as providing feedback after a motor performance and after a delay of a few seconds will assist the remembering of the information provided yet will also encourage the use of intrinsic feedback mechanisms.

Frequency of feedback

Providing feedback after every trial compared to reduced frequency has been found to have a negative effect on learning (Adams et al. 2002;Croce, Horvat, & Roswal 1996;Swinnen et al. 2006) as it is thought to detract attention away from intrinsic feedback (Anderson et al. 2005;Wulf et al. 1993). Increased frequency has however been found to improve performance (Croce et al. 1996). Such close guidance, known as the 'guidance effect' can however be counterintuitive as a dependency can form which can negatively affect performance once the feedback is withdrawn (Ishikura 2008;Konttinen et al. 2002;Salmoni et al. 1984;Wrisberg & Wulf 1997). Despite this it has been acknowledged that there is a place for frequent feedback, in particular in low skilled subjects where error detection and correction mechanisms are being developed (Guadagnoli et al. 1996;Vickers et al. 1999) and where the task is complex (Wulf,Shea,Matschimer 1998). So although reduced frequency feedback has been found to be more effective as it increases the use of intrinsic feedback (Anderson et . 2005) for optimal feedback frequency, task complexity and skill level need to be considered. It is likely that increased frequency of feedback will be more beneficial, particularly for improved motor performance. These considerations are likely to affect the most beneficial feedback frequency after stroke. A simple task for a healthy subject may be considered difficult for a person with stroke and hence reduced feedback frequency may not therefore be advantageous after stroke (van Vliet & Wulf 2006).

1.4.10 Role of feedback after stroke

Studies in healthy subjects demonstrate feedback has a role to facilitate motor performance and learning. The role of extrinsic feedback for skill acquisition and learning may be even more compelling after stroke. Lesions of the sensorimotor areas of the brain can cause damage to intrinsic feedback mechanisms (Fisher et al. 2000). This reduces individual's ability to make ongoing movement adjustments which are necessary for effective movements (Cirstea et al. 2006; van Dijk et al. 2005; Winstein 1991). Stroke can damage motor programmes and cause an inability to form or implement schema/ internal models, the sensory motor mappings used by the nervous system to anticipate the force requirements of a movement for a given task (Beer et al. 2004;Beer, Dewald, & Rymer 2000;Mercier et al. 2004).Without the ability to form or use internal representations, a person with stroke will struggle to learn to perform tasks efficiently especially ones which involve a dynamic environment such as reaching towards an object (Takahashi & Reinkensmeyer 2003). Therefore extrinsic feedback becomes important to develop an improved internal representation of a movement resulting in improved function (Fisher et al. 2000).

Another common problem after stroke is the use of compensatory movements which often develop due to muscle imbalances. Practice alone is therefore not considered sufficient to optimise motor recovery as this may just reinforce compensatory mechanisms (Cirstea, Ptito, & Levin 2003b;Cirstea & Levin 2000;Levin 1996) and result in incorrect internal representations being formed. This may allow the execution of relatively simple tasks but are not conducive to the execution of more complex tasks (Hodges & Franks 2000). Feedback enables a pre-existing movement to be changed (Hodges & Franks 2000) enabling the development of optimal movement patterns.

1.4.11 Application of extrinsic feedback after stroke

A role for extrinsic feedback after stroke appears clear but this method of regaining efficient movement requires cognitive and perceptual processes, which are commonly impaired after stroke (Cirstea et al. 2006;Mercier et al. 2001). Efficient movement form is developed through the 'accumulation of increased perceptual processes and the information provided is acted upon using cognitive processes' (Sherwood & Lee 2003). To optimise feedback interventions it is advisable to account for impaired processes. The effects of verbal feedback following stroke has however received little attention (Cirstea, Ptito, & Levin 2006; Cirstea & Levin 2007; Hanlon 1996; Platz et al. 2001; van Vliet & Wulf 2006; Winstein 1991; Wulf et al. 2009) so although the application of the principles attained from studies in healthy subjects is considered appropriate (Winstein 1991), direct application to the stroke population should be viewed with caution. Cognitive and perceptual deficits need to be accommodated (Cirstea,Ptito & Levin 2006; Mercier et al. 2001) as well as co-morbidities such as depression, as these can negatively affect recovery (Rijntjes 2006). Processing ability needs to be accounted for. It is therefore likely to be more useful to provide information about the correction required, as it informs the learner and aids the development of crucial movement features (Puttenman et al. 2004). In terms of when to deliver feedback, feedback after a movement has been completed, is considered best as it is less likely to interfere with intrinsic feedback mechanisms, and the development of internal models (Cirstea & Levin 2007;Hanlon

1996, Platz et al. 2001). In terms of feedback frequency after stroke, more frequent feedback could be favourable to accommodate for the absence or inefficient motor programmes and schemata (van Vliet & Wulf 2006).

1.4.12 Do therapists use verbal feedback in stroke rehabilitation?

Although it is easy to argue the importance of feedback after stroke and suggest how it is best implemented, the question is: Do therapists use verbal feedback in clinical practice? and Do people with stroke benefit from receiving feedback to enhance their motor performance? The evidence suggests therapists rely on their intuition and clinical experience as a method to maximising motor performance and learning (McNevin et al. 2000). Where verbal feedback is used, it is either subjective or ‘soft’ with phrases such as ‘well done’ or ‘a little bit more’ being used (Parry 2005), possibly because therapists place much emphasis on the emotional state of their patients (Demain 2006). Information feedback where used often relates to movement dynamics, namely how the body movement needs to be adjusted (Winstein 1991) and is associated with providing error information which has been associated with negative effects on the affective state (Allen & Howe 1998;Amorose & Weiss 1998;Wiswede et al. 2009). This potentially may affect motivation to practise the task, however feedback which offers encouragement compared with specific feedback may have limited value (Fredenburg, Lee, & Solmon 2001).

The literature suggests therapists interchange feedback and instructions (Parry 2005) so it is useful to distinguish the two. Instructions can be defined as information which directs a movement and is given before or during a movement (Magill 2007) whereas information provided as a result of a movement, intended to improve the subsequent movement is considered information feedback (Wulf et al. 2002).

1.5 Attentional focus

1.5.1 Definition

It is the consideration of attentional focus as it relates to the delivery of feedback after stroke that forms the main focus of research within this thesis. Attentional focus can be defined as ‘the directing of attention to specific characteristics in a performance environment, or to action preparation activities’ (Magill 2007). Attention directed to focus on the tasks or the movement effects within the environment is known as external focus (EF), whereas attention directed to the body movement is known as internal focus (IF). For example, to encourage greater extension of the elbow in a reach-to-grasp movement, one could say ‘next time, straighten your elbow more’ (internal focus) or ‘next time, move closer to the jar’ (external focus). Researchers have utilised two different approaches when studying this area: verbally directing a focus of attention, or through a dual task methodology, where focus is indirectly influenced by distracting subjects with a secondary task. The studies which relate to the attentional focus of feedback in healthy subjects, followed by studies which relate to the attentional focus of instructions in healthy subjects will now be discussed. This will be followed by reviewing the studies in subjects with neurological impairments, including stroke.

1.5.2 Feedback and attentional focus

Attentional focus has been reported as being an important qualifying variable for the effectiveness of feedback interventions when performing and learning motor skills (Kulger & DeNisis 1992; Wulf et al. 2002). Shea & Wulf (1999) gave two groups the same concurrent feedback on a computer screen while they learned to balance on a stabilometer. One group was told that the feedback represented their own movements (internal focus - IF) whereas the other group was told it represented movement of the lines that were marked on the platform in front of the performer's feet (external focus - EF). The results showed the EF group demonstrated significantly improved balance during practice and learning compared with the internal focus group. The interesting aspect of this study was that the feedback was identical. The only difference was what the subjects were told it represented. In a similar experimental setup de Bruin et al. (2009) trained balance in subjects over 70 years, two days a week for five weeks. The IF group were informed the feedback on the visual display represented the body's centre of gravity, and were told to focus on the 'belly' whilst looking at the screen, whereas the EF group were told the visual feedback display represented an air bubble like that which could be found on a spirit level which was positioned in front of their feet. Angular displacement and weight shift through medio-lateral stability were measured but unlike Shea and Wulf (1999) no differences were found between the groups. This different result could be accounted for by the presence of impairments in attention, movement adjustments and muscular activity. These may have limited the individual's ability to balance automatically and hence may have minimised a benefit of an external focus, which is thought to promote automatic control (Wulf, McNevin, Shea 2001a). Using a more functional activity, a volleyball serve, Wulf et al. (2002) also examined feedback which induced either an internal or external focus of attention. The results showed that serve accuracy increased in the EF group compared to the IF group during both practice and in a retention test, performed one week later when no feedback was given. Interestingly however both groups were assessed as having similar improvements in movement form, as assessed by the use of expert performance ratings, of a volleyball service. The EF group however did not specifically direct focus upon movement form.

1.5.3 Instructions and Attentional focus

The effects on motor performance and learning when varying the type of attentional focus, has also been examined whilst using instructions. Many of these studies have been conducted by Wulf and colleagues who have consistently found that inducing an external focus of attention is more beneficial to motor learning than inducing an internal focus of attention. This finding extends to a variety of tasks, and has also been replicated by other authors. These show evidence that EF is more beneficial on balance tasks (Chiviacowsky et al. 2010;Maxwell & Masters 2002;McNevin et al. 2003;Totsika & Wulf 2003;Wulf et al. 2001b;Wulf et al. 2001a;Wulf et al. 2003b;Wulf et al. 2004;Wulf 2008;Wulf et al. 1998b;Wulf et al. 2007b) whereas other studies have shown that external focus is more beneficial for complex tasks including golf (Bell & Hardy 2009;Wulf et al. 1999b;Wulf et al. 2000;Wulf & Su 2007), basketball (Al-Albood et al. 2002;Zachry et al. 2005), juggling (Zentgraf & Munzert 2009), running (Udewitz 1993), tennis (Maddox et al. 2000) jumping (Wulf et al. 2007a;Wulf et al. 2010), dart throwing (Lohse et al. 2010;Marchant, Clough, & Crawshaw 2007), soccer (Wulf et al. 2003a), acrobatics (Wulf 2008) and performing bicep curls (Marchant et al. 2009;Marchant et al. 2008).

1.5.4 Theories of attentional focus

To explain the consistent finding for a benefit of inducing an external focus Wulf and colleagues proposed the 'constrained action hypothesis theory' (McNevin, Shea, & Wulf 2003;Wulf, McNevin, & Shea 2001a). This states that an internal focus of attention promotes conscious control of movements, interfering with automatic motor control processes which would normally control the movement, whereas external focus is thought to allow movements to be executed more automatically, without the interference from conscious control and so promote motor learning.

Although this theory specifically addressed the effects induced by adopting a particular attentional focus, the proposition that focusing on remote effects is more beneficial to motor learning was not new. Back in the nineteenth century a relationship was identified between performing an action and the perceivable effects (James 1890). For example, when an action is performed, close perceivable effects, such as tactile sensations can occur. Equally more remote effects can be perceived, such as awareness that a light has been turned on as the result of turning on a light switch. Subsequently the common coding hypothesis was developed which proposed a common representation between perception and action such that actions are best planned in terms of their distal effects, as this was considered the format which allowed for the commensurate coding of perception and action (Prinz 1990). This idea was adopted and developed by others (Hommel et al. 2001;Prinz 1997) with Prinz (1997) labelling the proposition that actions are best planned and controlled by their intended effects as the 'action effect principle'.

1.5.5 The use of attentional focus after stroke

More recently the use of different types of attentional focus in people with stroke has been explored as it is unclear whether the motor performance and learning behaviour seen in healthy subjects can be transferred to people with stroke (Dancause et al. 2002;Levin, Michaelsen, Cirstea, & Roby-Brami 2002). Fasoli et al. (2002) examined the effects of internal and external focus instructions on three upper limb tasks: removing a can from a shelf, placing an apple into a basket and moving a coffee mug onto a saucer. Movement performance improved significantly with external focus instructions, compared with movement performance following internal focus instructions. This was shown by decreased movement time, increased peak velocity and less movement units, in all three tasks under the external focus condition. Time to peak velocity was not however significant between the conditions indicating that movements in both the internal and external groups were similarly determined. A requirement for this study however was the ability to perform the tasks. As the tasks all required a high level of upper limb function this could account for both conditions adopting a similar pre-planned movement strategy. It is likely that the subjects stored an appropriate motor programme and were able to retrieve it and so benefited from instructions which guided automatic movement control. The study does however provide evidence supporting the use of external focus instructions after stroke, in people with sufficient motor ability to reach forwards and grasp the task objects. This study only however used 16 stroke subjects, which although was based upon a power analysis from pilot data, and was sufficient to find statistical significance, it did not allow generalization to the stroke population.

Other studies have disputed the benefit of inducing an external focus after stroke (McNevin & Wulf 2003). McNevin & Wulf (2003) examined the effects of internal and external focus instructions on postural control after stroke and found internal focus instructions were more beneficial. Static standing balance was examined, with a task that required stroke subjects to remain standing still, whilst lightly touching a curtain with their fingertips. Postural sway was used to measure the difference between internal and external focus instructions. Although both conditions resulted in a reduction in postural sway relative to baseline measures it was the internal focus instructions which corresponded to increased frequency of adjustment which was suggested to be a better movement strategy.

More recently Cirstea and colleagues have used knowledge of results (KR) and knowledge of performance (KP) which in this situation have similarities to the attentional focus classification. Knowledge of results was used to represent feedback about movement precision. This represented movement effects and therefore could be considered akin to external focus. Knowledge of performance related to feedback about joint movement which represented body movements and so can be likened to inducing an internal focus of attention. (Cirste,Ptito & Levin 2006;Cirstea & Levin 2007). It is worth noting however that the correlation between attentional focus and KR and KP does not always follow. Feedback can be often be phrased either internally or externally for measures of performance (KP) although this transference of attentional focus terms does not happen readily for measures of outcome (KR). Cirstea and colleagues (2006) examined a pointing task using the hemiplegic arm and provided information either about joint motions or movement precision. Movement precision improved when feedback related to precision whereas it was found movements were more consistent when feedback related to joint motions. Overall Cirstea and colleagues concluded that knowledge of performance (KP) resulted in improved motor outcomes, because when feedback was given about joint motions this correlated with improvement in clinical and cognitive scores. Evidence for this was seen in subjects with moderate to severe upper arm impairment.

Cirstea & Levin (2007) also found KP provided most gains in subjects with more severe arm impairments. This study also examined pointing movements of the impaired arm and found that KP improved joint range and inter-joint coordination compared with the knowledge of results (KR) group. An alternative explanation for these results could relate to a specificity effect, that is, improvements were seen in the aspect of movement about which the learner received feedback (den Brinker et al. 1986;Tzetzis et al. 1997;Zentgraf & Munzert 2009).

1.5.6 Attentional focus and other Pathology

The research examining the effect of attentional focus and stroke does not appear to reach a consensus so it useful to review studies which have examined other neurological pathologies. Landers et al. (2005) tested 22 subjects with Parkinson disease, 10 of which had a history of falls, on three balance tasks. The IF group were asked to focus upon their feet, whereas the EF group were asked to focus on rectangular pieces of paper placed under their feet. When subjects focused upon the external rectangles, postural sway was reduced, in subjects with a history of falls, in the most challenging balance task: when the surface they were standing upon moved. No such benefit was found in subjects without a history of falls which could suggest the tasks were not sufficiently challenging. It was unclear however whether subjects focused as directed as this was not included within the design, a common criticism of the attentional focus studies which have adopted the instruction paradigm, where focus was directed verbally (Bund et al. 2007;Castaneda & Gray 2007;Gray 2004;Poolton et al. 2006). The results do however suggest that EF was beneficial when subjects were challenged. Canning (2005) also explored the effect of attentional focus in subjects with mild to moderate Parkinson's disease. This study used a dual task methodology. Subjects were asked to perform four walking tasks: to walk independently without any instructions, to walk whilst carrying a tray of glasses without instructions, to walk whilst carrying the tray of glasses and instructions to focus on their walking, and to walk whilst carrying the tray of glasses whilst focussing upon the tray and glasses. The variables measured were the number of glasses which remained upright on the tray, and variables associated with walking including velocity, stride length and cadence. Although this study found that focusing on walking produced a more favourable walking pattern, the design used need to be examined to consider whether it is comparable to the studies which directly compared external focus with internal focus. For example, can distracting attention away from the body movement be considered the same to studies which have more actively induced an external focus of attention? Wulf et al. (2000) & McNevin, Shea & Wulf (2003) found that it is not EF per se which is beneficial to motor performance and learning, but an external focus of attention which relates to the movement effects. However in the Canning study the focus was directed towards the tray. This did not relate to walking and therefore could not be considered as directing attention to movement effects. Focusing on the glasses however resulted in 100% accuracy with regard to maintaining the glasses upright compared to 94% when subjects focused on walking. This indicates a specificity effect, in other words subjects showed most improvement in the measures where attention was directed, a similar findings to that shown by Cirstea and Levin (2007).

1.5.7 Outcome measures and attentional focus

Overall there is substantial support for the benefit of adopting an external focus of attention for motor performance and learning, although it is possible a specificity effect could be a factor as shown during the discussion of Cirstea & Levin (2007) and Canning (2005) (section 1.5.5 & 1.5.6). It is possible that improvements in performance may relate to which aspect of the movement/task the focus of attention was directed. For example Zentgraf & Munzert (2009) found that when focus was directed to upper body displacement and the arm, in a juggling task, a desirable trait of reduced elbow displacement was found. When focus was directed to ball flight, improvement was found for ball height.

Success of completing a task usually relates to the outcome of the movement. Many studies have used accuracy as an outcome measure and perhaps based on the specificity argument it is not surprising that focusing externally has been found to produce more favourable task performance compared with focusing internally (Al-Abood et al. 2002; Poolton et al. 2006; Wulf, Lauterbach & Toole 1999; Wulf et al. 2000; Wulf et al. 2003b; Wulf& Su2007a; Wulf et al. 2010; Zachry et al. 2005). Over-emphasis on task outcome has been a criticism to the attentional focus literature with a suggestion that it would be useful to also focus upon the amplitudes of joints and motor control (Peh et al. 2010;Vuillerme & Nafati 2007). The suggestion is that the benefits of inducing an external focus of attention could be accounted for by the selection of performance markers used (Maurer & Zentgraf 2007). The main goal of a task is to improve task outcome so it is not unreasonable to focus on this area, however some authors have addressed this criticism and have found a benefit of external focus extends to improved movement efficiency. Using EMG, less activity has been found when adopting an external focus (Marchant,Greig & Scott 2009; Vance et al. 2004; Wulf et al. 2010, Zachry et al. 2005). This evidence suggests inducing an external focus is more beneficial than inducing an internal focus of attention and it goes beyond effects which can be explained by a specificity effect.

1.5.8 Attentional focus and skill level

Some research has found an interaction with skill level and attentional focus such that where subjects are novice to a task, a benefit has been found when adopting an internal focus of attention (Beilock et al. 2002;Castaneda & Gray 2007;Ford et al. 2005;Gray 2004;Gray & Beilock 2007;Perkins-Ceccato et al. 2003).The majority of these studies used a dual task methodology and therefore did not focus upon movement effects but relied upon distraction from the body movements to induce an external focus. This could partially explain the results from other studies which used subjects novice to the task and found a benefit from adopting an external focus. The skill by focus interaction findings have been explained by traditional theories of motor learning where it has been suggested that individuals novice to a task need to attend to the step by step processes of a performance (Anderson 1982;Fitts & Posner 1967). Ford et al. (2005) suggested that IF may be preferred or naturally adopted by less skilled subjects but that as subjects practise a task this could change. Castaneda & Gray (2007) conducted a study which incorporated both the instruction paradigm and dual task paradigm. They examined eight skilled and eight less skilled subjects on a baseball batting simulation task. All received audio visual feedback but instructions given differed in a counterbalanced design. Skilled subjects were found to benefit from focusing on which direction the ball travelled, an external focus regarding the effect of movement, a similar finding to the Wulf studies. The less skilled subjects benefited from focusing on the instructions which guided subjects how to perform the skill. Additionally two skill relevant instructions were given, one relating to the position of the hands, thereby inducing an internal focus, whereas the other related to the position of the bat, an external focus. Interestingly there was no significant difference between the two skilled focus conditions (hands or bat) for the less skilled subjects, despite the data showing a slight benefit to adopting EF compared with IF. This finding can be likened to the findings of Wulf et al. (2000) where novice golfers benefited more from focusing their attention towards the golf club compared with focusing on the trajectory of the ball. Wulf et al. (2000) also found a benefit to focusing on the golf club over the group which focused upon their hands.

The consistent finding regardless of paradigm adopted is that subjects skilled at a task are able to perform at a higher level if they focus away from their performance (Beilock et al. 2007;Beilock et al. 2002; Bell & Hardy 2009; Wulf et al. 2002; Wulf 2008; Wulf & Su 2007). It is thought focusing externally accentuates visual information about spatial and temporal properties of a task which are often important in learning (Ehrlenspiel & Maurer 2007;Peh, Chow, & Davids 2010) and could explain why the benefit of focussing upon environmental cues is more evident in retention trials than after practice trials (Bund,Wiemeyer & Angert 2007). In less skilled subjects it is possible that inducing an external focus of attention promotes the utilization of automatic processes, but where there is limited or no motor programme, it is conceivable there may be a benefit to receiving information which defines the movement form (Schmidt 2003) which may induce an internal focus of attention.

1.5.9 Attentional focus and working memory

Explicit information includes the use of instructions and feedback and has been found to enable subjects to verbally report rules governing a movement or task (Maxwell et al. 2000). It has been questioned whether this conscious control which can increase the load upon working memory is beneficial (Lam et al. 2009;Maxwell et al. 2003;Orrell et al. 2009). Conscious control of movements have been found to be detrimental to performance and learning, particularly when subjects are under stress or are required to perform a secondary task (Masters 1992). Others however have found a benefit to providing explicit information

(Boyd & Winstein 2001;Castaneda & Gray 2007). Either way there is some debate regarding the benefit of explicit information due to the increase on working memory load. In relation to attentional focus and explicit information some interesting suggestions have been proposed. For example when an external focus is induced it is thought to focus attention towards the environment e.g. a ball. When an internal focus is induced it is thought to require the subject to focus upon the body, but also on the task so the task can be executed (Wulf et al. 2003b). This has been associated with an increased load on working memory while adopting an internal focus. Maxwell & Masters (2002) directly compared internal and external focus instructions in a balance task. It was predicted that an inferior performance would be seen when subjects were provided with internal focus instructions as it would increase the processing of explicit information in working memory. Although no differences were found between the groups as result of practice and learning, the EF group were able to perform the secondary task more successfully. It was therefore suggested that adopting an external focus acquired less explicit information and was therefore likely to place less demands on working memory, a proposition supported by Poolton et al. (2006). Poolton et al. (2006) used a golf putting task with subjects either being instructed to focus internally or externally. Both groups improved in a similar manner after practice and retention trials but the IF groups showed decreased performance when asked to perform a secondary task. This finding was explained by the suggestion that the IF group experienced attentional overload and hence showed performance decrements. It therefore appears that the direction of attentional focus may affect the amount of declarative information gained, which could be an important factor when considering people with stroke and the associated memory impairments that can exist.

1.5.10 Summary of attentional focus literature

In the attentional focus literature where studies have directly compared focusing attention either to body movements (IF) or the effect of the movements (EF), it has been consistently found that adopting an external focus of attention is more beneficial to motor performance and motor learning, than focussing upon the body movements (IF). A finding which extends to both subjects novice to a task and subjects with experience of a task.

The main theory proposed to explain the benefit of adopting an external focus of attention is the constrained action hypothesis (Wulf, Shea, McNevin 2001). This proposes a benefit to adopting an external focus of attention, as it promotes automatic movements without conscious control processes interfering with performance.

Others have suggested a benefit of adopting an external focus is due to its effect on attentional load, such that focusing away from the body (movement effects) reduces the load on working memory (Poolton et al. 2006). None of the hypotheses can explain all the literature on attentional focus although it is conceivable that individual characteristics such as skill level and working memory may help explain some of the inconsistencies seen within the literature and help identify the most efficient focus of attention in individuals after stroke.

Currently from the literature, it is unclear what the most effective type of attentional focus to use is when delivering feedback after stroke, in order to improve motor performance.

This thesis looked to address this issue through the following aims.

1.6 Aims

The aims of this thesis were:

1. To explore the focus of attention therapists induce when providing feedback whilst retraining reach to grasp after stroke.

2. To examine whether feedback inducing an external focus of attention was more effective compared with feedback inducing an internal focus of attention, in the motor performance of reach to grasp after stroke.
3. To explore the influence of the level of arm impairment and working memory on the delivery of feedback and attentional focus type in the motor performance of reach to grasp after stroke.

Two separate studies and analyses were devised to achieve the aims, as follows:

Study 1 – Exploring the use of the attentional focus of feedback while retraining reach to grasp after stroke

The first study explored the attentional focus of information used during the motor performance of reach to grasp after stroke. Specific emphasis was given to the attentional focus of feedback. An additional aim was to identify feedback statements used in clinical practice to inform study 2, which compared feedback inducing either an internal or external focus of attention. Study 1 adopted a multi-methodology paradigm which used video, semi-structured interviews and a therapist questionnaire to identify the use and attentional focus of feedback.

Study 2 – Attentional focus of feedback for improving performance of reach-to-grasp after stroke: a pilot study**.**

This study examined whether feedback inducing an internal focus or external focus of attention was more effective during the motor performance of reach to grasp after stroke. A within subject, counterbalanced design was adopted and the experimental hypothesis was that feedback inducing an external focus (EF) of attention differs from feedback inducing an internal focus (IF) of attention in improving motor performance of reach to grasp after stroke. The null hypothesis was there would be no difference in the motor performance of reach to grasp after stroke when feedback induced either an internal or external focus of attention.

Further analysis of data from study 2 – Exploring the interaction of impairment level and working memory level with attentional focus in the motor performance of reach to grasp after stroke

Further analyses were performed which explored the relationship between attentional focus of feedback with level of arm impairment and level of working memory impairment in the motor performance of reach to grasp after stroke. It was predicted that an interaction effect where the effectiveness of the focus used would moderate with the amount of arm impairment, with feedback inducing either an internal or external focus of attention being more effective in people with greater arm impairment after stroke.

It was also predicted that for participants with poor working memory either inducing an internal or external focus of attention would be more beneficial for the motor performance of reach to grasp after stroke.

Each of these studies will now be presented in turn with the addition of one published paper and one paper currently under review. The first paper reports the findings from study 1 and the second the findings from study 2 and the work concerning the influence of the level of arm impairment and working memory capacity.

CHAPTER 2 - STUDY 1: EXPLORING THE USE OF ATTENTIONAL FOCUS OF FEEDBACK IN RETRAINING REACH TO GRASP AFTER STROKE- METHODS

2.1 Introduction

This chapter briefly discusses the relevant literature related to the provision of information, instructions and feedback, in people with stroke. This is followed by background information about the methods used in study 1, the detail of which are not included in the published paper (Chapter 3), but were important for design decisions. The study was overseen by a steering group committee. This consisted of the research team, including myself, the supervisory team, a professor of psychology, a consultant geriatrician, a clinical physiotherapist and also a patient representative. The group met once in relation to study 1 to discuss the results.

The first study aimed to explore the focus of attention therapists induce when providing feedback whilst retraining reach to grasp after stroke. A key role for therapists is to support motor relearning after stroke but the methods used to achieve this broad aim of rehabilitation are unclear, with some suggesting that suboptimal methods are being used (Orrell et al. 2006;Wulf & Prinz 2001). Previous research has indicated that therapists tend to focus upon the arm movements rather than the task and movement effects, as efforts are directed towards improving the movement pattern (Wulf & Prinz 2001). This is contrary to what has found to be effective in the delivery of instructions after stroke (Fasoli et al. 2002). Fasoli et al. (2002) compared the effect of external focus (EF) with internal focus (IF) *instructions* on movement kinematics in patients with stroke during functional reaching tasks. The results were significantly shorter movement times and greater peak velocities during the EF condition, indicating an improvement towards to normal performance. It is unclear however what type of focus therapists induce when providing feedback while retraining reach to grasp after stroke. The amount of feedback used by therapists has previously been explored and use of information feedback has found to be limited (Talvitie 2000; Parry 2005). Parry (2005) reported that the information therapists used was more suited to a social setting as opposed to a rehabilitation setting. Parry (2005) found therapists were reluctant to express ‘direct criticism, disagreement or correction’ of a mistake which meant therapists often used instructions rather than feedback to tackle movement errors. It was argued that this approach helped to foster patient participation in the rehabilitation process, but the lack of information feedback providing details about how to correct movement errors does not support the acquisition of skills (Talvitie 2000).

The primary purpose of this first study was to explore the attentional focus of feedback used by therapists while retraining reaching movements after stroke. In light of the evidence of reduced use of information feedback (Talvitie 2000; Parry 2005), in the event of low use of information feedback, instructions would also be included in the analysis to provide a complete picture of the use of attentional focus. This would gain insight into the current ways therapists induce patient’s attention and increase their awareness of the focus used during rehabilitation of reach to grasp after stroke.

The study was an exploratory trial, designed to help the modelling of the next study, and corresponded to a Phase I trial on the framework for the design and evaluation of complex interventions (Campbell et al. 2000)

2.2 Research Questions

This first study explored the following primary question:

-Was the attentional focus used by therapists retraining reach to grasp after stroke primarily internal or external?

Additional questions were:

- What was the frequency of information feedback?

-What feedback statements do therapists use while retraining reach to grasp after stroke?

2.3 Proposition

Therapists would predominantly induce an internal focus of attention while retraining reach to grasp after stroke.

2.4 Methods

2.4.1 Design

A choice of design was needed which would provide both depth and completeness, encompassing both the type of attentional focus used by therapists in current practice but also to elicit feedback statements used in the training of arm function after stroke. The pragmatic view, that research should focus upon the research questions which drive the research design was considered appropriate (Creswell 2009;Robson 2002;Sale et al. 2002). This approach allowed the use of different methods and techniques to meet the purpose of the research and as such is the philosophical basis for the mixed methods approach to research (Creswell 2009). Mixed methods research can be defined as ‘an approach to inquiry that combines or associates both qualitative and quantitative forms of research. It involves philosophical assumptions, the use of qualitative and quantitative approaches, and the mixing of both approaches in a study.’(Creswell 2009 pp 230).

A mixed methodology was considered most suited to encompass the complexities of the therapist/patient interaction. Video recording physiotherapy treatments of the upper limb was used to gather data of actual interactions while retraining reach to grasp. In addition, separate face to face semi-structured individual interviews of therapists and patients were used, (a) to explore reasons behind therapist’s use of attentional focus in the feedback delivered in the videoed treatment session and b) to explore the patient’s perception of the attentional focus provided during the recorded treatments. In light of the reported infrequent use of information feedback in the literature (Talvitie 2000, Parry 2005), which might have resulted in relatively little feedback being used in the recorded sessions, a therapist questionnaire was also used to explore the attentional focus of feedback therapist perceive they use in their *routine* practice of training reach to grasp after stroke.

The methods chosen were associated with both qualitative and quantitative designs. Video recordings and interviews were considered qualitative, where an understanding through peoples actions were searched (Maggs-Rapport 2001). The questionnaire was considered both qualitative and quantitative as it included the use of both open and closed questions. Traditionally these two paradigms represent two totally different assumptions that are not usually mixed (Pope & Mays 2000;Sale, Lohfeld, & Brazil 2002). Quantitative assumptions are objective and can be designed a-priori, searching for a single truth with the researcher maintaining independence from the research (Robson 2002).

Qualitative assumptions on the other hand include having an evolving design, presentation of multiple realities with the researcher as an instrument of data collection, and a focus on participant's views. It employs one or more existing traditions of enquiry with the idea of seeking an understanding, not causal relationships (Robson 2002). To accommodate for the differences, Johnstone (2004) suggests describing the different paradigms adopted.

In this study the primary paradigm chosen was a logical positivist standpoint and was considered quantitative whereas the secondary paradigm was of a naturalistic enquiry and was considered a qualitative approach.

Logical positivism as a research paradigm

Logical positivism assumes the reality as being objective and predictable. It enables a study to be designed in full a priori with variables and hypotheses set, with the researcher being independent of what is being researched (Johnstone 2004). Aspects of this approach were used in this study, as it enabled boundaries to be set to ensure that the research questions could be answered. For example the therapist questionnaire used mostly closed questions which specifically addressed the attentional focus of feedback statements used by therapists (please refer to Appendix C: Feedback Questionnaire pp 209).

The data analysis produced predefined key areas, namely the type of feedback statements used (Appendix D: Framework analysis pp 235). That is aspects of the data were analysed deductively based upon a prior frame of understanding (Johstone 2004). This approach allowed distance between the researcher and participants which helped to elicit interactions between patient and therapist as they occurred in the rehabilitation sessions, and therefore assisted minimising any bias from the researcher (Johnstone 2004).

Naturalism as a research paradigm

The assumptions of a naturalistic enquiry on the other hand include seeking an understanding of the phenomenon in a subjective way, whilst eliciting the complexity of views. It therefore seeks to process the interaction and presents relationships and events exactly as encountered (Maggs-Rapport 2001). In this study the relationship being explored was that formed during the communication between a patient and their therapist. Naturalism also focuses on a specific context, which in this study was the use of attentional focus of feedback during the performance of reaching movements. It also develops themes inductively which was incorporated into the analysis of the current study (Creswell 2009), and requires any biases to be acknowledged as it is believed that the observer interacts with the participants. This interaction can be seen as advantageous as the relationship can increase the understanding of the phenomenon being studied (Onwuegbuzie & Leech 2005).

Justification of paradigms used

To answer the research questions (section 2.2) the logical positivism paradigm focused the study upon feedback statements and attentional focus as well as including a method to increase the number of feedback statements identified through the use of a therapist questionnaire. A naturalistic enquiry assisted identifying feedback statements as they occurred in the treatments, through the video recordings. Both the video and interviews were used to identify the attentional focus therapist's use, with a benefit of being able to explore additional aspects of the therapist/ patient interaction. So taken together a mixed methods approach allowed all aspects of the phenomenon to be encompassed which provided a more complete understanding (Miller & Fredericks 2006;Sale, Lohfeld, & Brazil 2002).

Concurrent Mixed methods

The mixed methods design adopted was concurrent triangulation as it allowed for 'both quantitative and qualitative data to be collected which could then be compared to determine if there was convergence, differences, or a combination' (Creswell 2009 pg228), providing a comprehensive analysis of the research problem. Data was collected simultaneously, and then the information was integrated into the interpretation of the overall results (Creswell 2009;Sandelowski 2000).

The benefits and drawbacks of each of the methods used in the concurrent triangulation will now be outlined.

2.4.2 Data collection

Video camera recordings as a research method

The main benefit of using video camera recordings was that it captured physiotherapy treatment of the upper limb after stroke as it occurred in everyday practice. It provided an actual record of events producing rich data of both visual and aural information. It also reduced observer fatigue as it provided an accurate record. It was possible however that the presence of the video and researcher affected the treatment session with both the therapist and patient potentially acting differently (Robson 2002). Where participants behaviours are affected by the presence of the researcher, it is known as the 'Hawthorne effect' (Polit & Hungler 1993;Roethisberger & Dickson 1939). An example is that participants may try and create a good impression and behave in a way that they think the researcher is searching for, or alternatively the observation may cause apprehension, thus increasing self consciousness (Adomat 1999;Bowling 1997). This potential effect questioned the naturalistic nature of the treatment captured by the video recording so measures were taken to reduce this effect.

Although the observer's presence could not be fully eliminated, it was acknowledged that subjects would struggle to sustain a change of behaviour over extended periods of time (Robson 1993) and the effect could be minimised following a period of acclimatisation (Adomat 1999). Therefore efforts were made by the observer to familiarise themselves to the patient and therapists. Both were met on previous occasions. During the video recording, interaction between the observer and participants were kept to a minimum by measures such as the avoidance of eye contact. However due to the small portal size of the video camera, low voices and background noise, the video was moved around as required which may have heightened awareness of the video's presence. Habituation was considered through the possibility of multiple video sessions. It however became apparent that therapists were not keen to be recorded over multiple sessions and indeed this only occurred with one participant where the treatment from one session was below the predetermined treatment time of 30 minutes. Initially it was considered to ask the therapist to habituate to the video by treating an impairment unrelated to the upper limb followed by treatment to the arm. This however was considered too prescriptive which would not align with a naturalistic enquiry.

The video recording provided a 'snapshot' of each participant's rehabilitation programme which may or may not have been representative of other treatment sessions.

Interviews

To support the observational data semi-structured interviews were conducted separately with the patient and therapist (please refer to Appendix C: interview questions guidance pp 206). It was envisaged that this would place the observations in context and would offer insights into the meaning of feedback and attentional focus to individual participants. This would not have been achieved from the video data alone. The interviews also allowed enquiry about the effect of the video presence which was useful to be able to evaluate the credibility of the observation (Robson 2002). The interview also helped to gain an understanding of how the observed treatment compared to others treatment sessions the therapist had with the participants. The interviews were given some structure to provide the researcher with some control over the line of questioning, so an emphasis could be given to the use of feedback and its attentional focus. The interviews consisted of open questions to allow the participants to expand upon their views about feedback and its attentional focus. Prompts were also used to elicit responses about feedback and attentional focus and were adapted to the participant's individual needs. The order of the questions varied to allow participants to define in their own way the experience of receiving feedback. Each interview was concluded with the interviewee summarizing the main themes discussed. This was done to increase accuracy in terms of how the researcher interpreted what was said, although it remained uncertain whether the message conveyed during the interviews represented the participant's total truth on the topic (Onwuegbuzie & Leech,2005).

Patient interviews

The patient interviews relied upon each participant's ability to articulate and be perceptive about the treatment session which they had received. This may have been challenging for some of the patients so efforts were made to minimize this potential factor by interviewing the patients immediately after the video recording was completed, in an environment that was comfortable for each patient.

Therapist interviews

The therapist interviews were carried out after up to one week between the video recording of treatment and the therapist's interview. This was necessary to accommodate for time constraints of the therapists and to allow time for the researcher to review the recording and transfer the video recording to disc. It was considered possible that the responses from therapists during their interviews may have reflected what the therapists say they did, rather than what actually happened within the video recording. Efforts however were made to mitigate this potential issue by offering therapists the opportunity to view the video recording either in part or full, at the beginning of the interview, to act as a reminder of the actual events.

Questionnaire

Questionnaires are considered useful when data cannot be obtained by other means (Sinclair 1975) and thereby acted as a method to generate more feedback statements. The questionnaire consisted of one open question and eight closed questions (Appendix C pp 212). The advantages of the closed questions was it provided clarity regarding the response given and eased the analysis process. These questions required therapists to select a feedback statement which related to improving reach to grasp. Therapists were required to indicate whether they tended to use a statement which induced an internal focus, about body movements, an external focus, about the task and effects of the body movement or a mixed focus of attention, where both internal and external focus elements were combined. The decision to include statements with a mixed focus of attention evolved from the observations of treatment sessions during the collection of video data, where therapists sometimes combined information inducing an internal and an external focus of attention, in one statement. Such statements were included in the questionnaire to ensure all the possible responses were covered. Additionally therapists were able to include their own feedback statements in an open question. To ensure the questions were clear and that responses matched those anticipated, the questionnaire was piloted by two research physiotherapists. This resulted in the removal of two open questions, leaving one open question, to increase the emphasis upon feedback and attentional focus.

The questionnaire acted as a means to corroborate data from other sources. There was however no direct relationship between the questionnaire and the video and interview data. It did however provide another dimension reflecting therapists' perceived use of feedback and their attentional focus.

Sampling strategy

Participants were purposively selected from hospitals around the surrounding area. This approach is a common qualitative sampling method and was adopted to include the gathering of important information from participants who were likely to provide rich data on the phenomenon being explored (Sale, Lohfield, Brazil 2002). To include a quantitative aspect to the selection process participants were chosen based upon inclusion and exclusion criteria (Chapter 3: Methods pp 66). This sampling decision was driven by the research objective and purpose and not the predominant research paradigm (Onwuegbuzie & Leech 2005).

It enabled participants to be included to represent breadth of the population, providing a more complete picture. In total eight therapists and eight corresponding patients were included. This number was considered sufficient to incorporate a wide range of responses. The decision was supported by the simultaneous collection of data and analysis which found that no new themes were identified as data collection progressed.

2.4.3 Clinical assessments

Clinical assessments were carried out as a means to check that the participants met the inclusion/exclusion criteria set and to assess individual characteristics of the patients. The selection of the measures used included searching for valid and reliable measures which were easy to administer in a short time frame. Each measure is listed below with details of why it was chosen and the reliability and validity of the measure:

<u>The upper limb section of the Rivermead Motor Assessment (RMA) (Lincoln & Leadbitter 1979)</u>

The upper limb section of the Rivermead Motor assessment was chosen to measure arm function because it covers a wide range of arm movements and can be administered in a short timeframe. It uses 15 items and has been found to be both a valid (van de Winckel et al. 2007) and a reliable measure (Cronbach's $\alpha = 0.88$) (Kurtais et al. 2009). A score range of 6-13 was initially chosen for the inclusion criteria. This decision was made as it was felt that this would ensure patients had sufficient arm control which would allow good coverage of a range of issues related to reach to grasp. This was later changed to 3-13 to be more inclusive and ease patient recruitment.

<u>The Rivermead Assessment of Somatosensory Performance (RASP) (Winward, Halligan & Wade (2002)</u>

To measure sensation the Rivermead Assessment of Somatosensory Performance (RASP) was chosen as it uses specific instrumentation which increases the standardisation of the measure and is stroke specific. It consists of seven subtests of sensation, four of which were used in study 1 (Chapter 3: Methods pp 67). It has been found to have excellent reliability, both intra-rater reliability (Pearson's correlation coefficient r = 0.92) and inter-rater reliability (Pearson's correlation coefficient r = 0.92) (Winward et al. 2002), and is considered to be valid as it measures similar subtests to other sensation tests where validity has been established (Winward, Halligan & Wade 2002).

The Sheffield Speech Test for Acquired Language Disorders (SSTALD) (Syder et al. 1993)

The receptive speech section of the Sheffield Speech Test for Acquired Language was used to test patients' ability to understand verbal information. This was considered important so patients were selected who were able to respond to the interview questions. It is a hierarchical measure with a maximum score of nine. It is an easy measure which can be used by therapists who are not speech and language therapists. It also does not require any special equipment and the test is not affected by visual neglect (Alkhawaja et al. 1996). It has been found to be valid and is also stroke specific (Blake et al. 2002).

Birmingham University Cognitive Screen –BUCS (Humpreys et al. 2009)

The Birmingham Cognitive Screen includes sections covering language, memory, praxis and attention, areas considered relevant to the study so they could assist exploring whether such impairments affected motor performance and the focus of attention used by therapists. The BUCS was chosen over individual tests of cognition and perception as it provided a comprehensive overview of impairments in a short timeframe. It is stroke specific and accommodates for factors such as aphasia and neglect when testing other components. It also is standardised and has age-matched normative data for each subtest.

Hospital Anxiety and Depression Scale (HAD) (Zigmond & Snaith 1983)

Similarly anxiety and depression was measured so it could be explored whether the presence of either condition may have influenced the attentional focus therapists used. The hospital anxiety and depression scale is a 14-item questionnaire and measures both anxiety and depression. Each item is scored on a four point scale with zero representing no presence of anxiety or depression and 3 representing a considerable presence. A score of ≥ eight is considered indicative of either anxiety or depression with a score of ≥ 11 indicating probable existence of a disorder (Bjelland et al. 2002). It has been found to be valid (Bjelland, Dahl, Hauq, & Neckelmann 2002;Olsson et al. 2002) and internal reliability has also found to be very good (Cronbach's $\alpha = 0.78$ for anxiety and $\alpha = 0.83$ for depression) (Bjelland et al. 2002).

10 Hole Peg Test (Turton & Fraser, 1986)

The 10 Hole Peg Test involves timing subjects transferring ten pegs, one at a time, and moving them eight inches forward to form a new parallel row of pegs. It was used to provide an indication of arm function. It is considered a valid and reliable tool for dexterity (Wade 1992) and is stroke specific. It does however have a floor effect meaning a certain level of arm movement is required to be able to complete the task (Verity & Tallis 1996).

Pain (McGill short form pain questionnaire) (Melzack, 1987)

A measurement of pain was included to provide insight into possible differences in the patient/therapist interactions due to pain. McGill's short form pain questionnaire was used as it can be administered in a short timeframe and is considered valid and reliable (Cronbach's $\alpha = 0.91$) (Dworkin et al. 2009;Melzack 1987;Wright et al. 2001).

Details of the scoring sheets and guidance notes of the clinical assessments used can be found in Appendix D (pp 212).

Full results of the clinical assessments can be found in the Appendix F (pp 237).

2.4.4 Data Analysis

The use of mixed methods provided a challenge with respect to how best to analyse the data. When the research objective is exploratory, it has been suggested that both quantitative and qualitative data analyses such as descriptive statistics and thematic analysis can be used (Onwuegbuzie & Leech 2005).

Triangulation involves reviewing and analyzing evidence from multiple sources such that a study's findings are based on the convergence of that information (Johnstone 2004). Many types of triangulation have been described. These include the collection of data from different sources, using different methodological approaches and at the data analysis stage (Denzin 2003). Data triangulation was used in this study as it allowed differences between the data sets to be reconciled which added rigour by compensating for weakness in any single strategy. This in turn allowed for a more in-depth analysis and increased the trustworthiness of the findings as the process had the capacity to neutralize any bias inherent in a particular data source (Johnstone 2004; Pope & May 2000). Sale and colleagues (2002) however suggested that it is best to describe the area of interest from different perspectives rather than taking the strengths of each method, giving an additive outcome for the separate research entities (Sale, Lohfield & Brazil 2002). This approach removes the problem of discovering multiple findings which otherwise would make it difficult to clarify the truth (Silverman 1993).

Therefore in this study data triangulation was used for exploration of whether active (video recordings), reflective (interviews) and theoretically (therapist questionnaire) perspectives were complimentary so decisions about the most insightful data source did not need to be made.

The process of coding data

Codes 'organize the material into chunks or segments of text in order to develop a general meaning of each segment' (Creswell 2009 pp 227). Traditionally in qualitative data analysis codes emerge during the analysis. However an increasingly popular method in the health sciences is the use of predetermined codes, codes which are based on the theory being examined (Cresswell 2009 pp187). This approach is commonly referred to as the 'framework approach' and considered to sit between an inductive and deductive approach to data analysis (Pope & May 2000). Predetermined codes developed from the aims and research questions of the study were considered deductive, but inductive codes were also included. The apriori codes focused upon exploring the use instruction, feedback and attentional focus. Additionally codes which emerged from the transcripts were used to reflect as many nuances in the data as possible (Pope and May 2000). Figure 2.1 shows the process followed to code the video data. After immersion with the early video transcripts, it was discovered that there was paucity of feedback statements. It was therefore decided to include the attentional focus of instructions in addition to the attentional focus of feedback in the predetermined codes.

All video transcripts were transcribed verbatim and were examined line by line, searching for occurrences of feedback statements and instruction. For those codes three sub-codes were identified: an internal focus (IF), pertaining to body movements, an external focus (EF), pertaining to the environment or a mixed focus (M), a combination of information relating to the body and the environment. Figure 2.2 show the predetermined codes. Quantising the data, that is converting the qualitative data to quantitative data (Onwuegbuzie & Leech 2005) was possible as each code had one meaning (Sandelowski 2000). Appendix E (p 235) details the process used for the assigning of codes to the video data.

Analysis of the interviews and the data analysis process are described in full in Chapter 3.

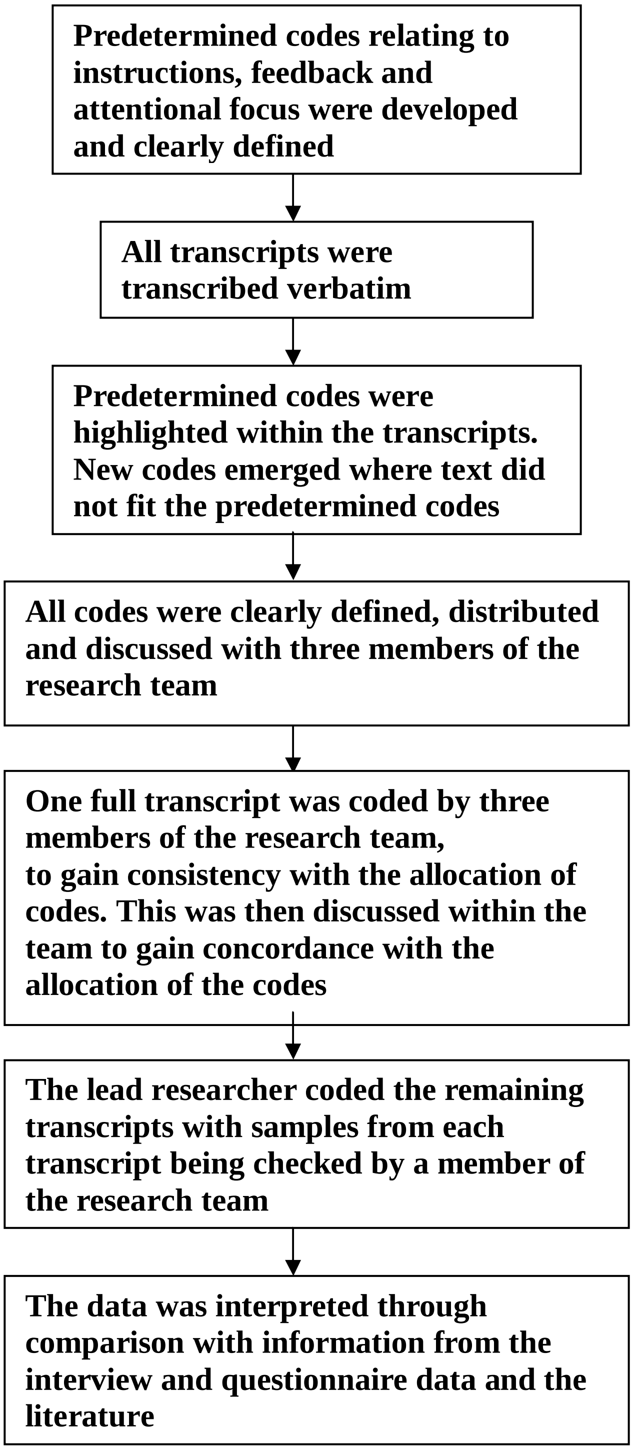


Figure 2.1 Coding process of the observational video data

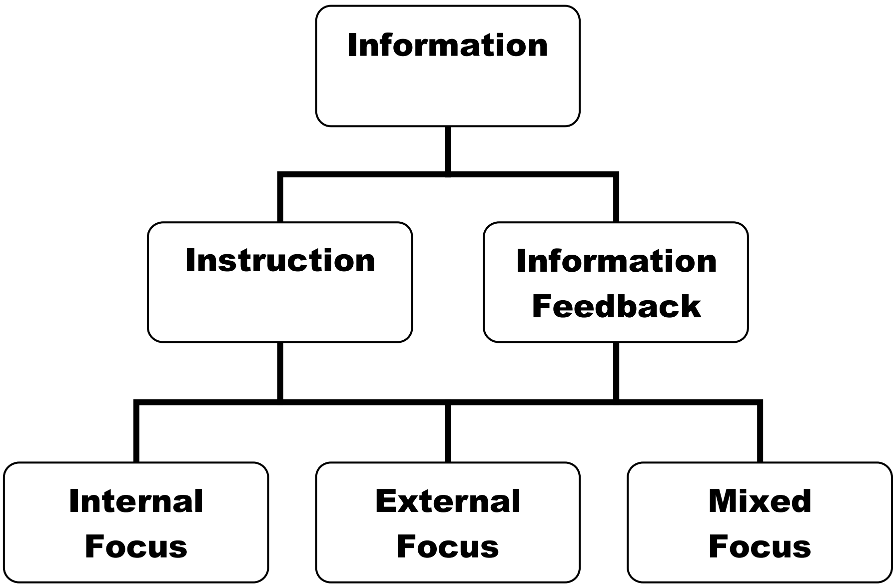


Figure 2.2 Framework to identify attentional focus

Credibility, rigour and dependability of the study

Efforts were made to increase the credibility, rigour and dependability of the study. Data triangulation and member checking of the assignments of codes to the video transcripts increased the credibility of the study (Maggs-Rapport 2000). Rigour or the trustworthiness of the data was increased through the use of multiple methods (Robson 2002). The purpose of the project was also presented to the therapists and patients in terms which did not highlight the researcher's pre-exitsting beliefs towards the study. The researcher did not want to bias the participants, so data collected reflected 'usual treatments' and true responses during the interviews, instead of the possibility of responses which reflected the interviewees' perception of what the interviewer wanted to hear. Measures were also taken to maximise the dependability of the study and included interviewing the patients immediately after the video recordings and allowing therapists to view the video record to aid their recollection of the treatment recorded. Both patients and therapists were also provided the opportunity to express their views freely by using opens questions both within the interviews and therapist questionnaire.

2.4.5 Summary of ethical issues

As with any research ethical issues that arise need to be considered and accommodated. Researchers need to protect their participants, develop a trust with them, promote integrity and encompass issues such as the authenticity of the research (interpretation) and issues of personal privacy (Isreal & Hay 2006). In this study it was carefully explained to the participants that they were able to withdraw from the study at any time. Confidentiality of information was ensured by keeping all data secured under lock and key and dissociating participants names during the data analysis. Only members of the research team directly involved in the research had access to the data.

The next chapter presents the results of study 1 in the form of the published paper connected to the study. The insertion of this paper provides a useful summary of the issues when examining the results.

CHAPTER 3 - PUBLISHED PAPER 'USE OF INFORMATION FEEDBACK AND ATTENTIONAL FOCUS OF FEEDBACK IN TREATING THE PERSON WITH A HEMIPLEGIC ARM.'

Katherine Durham, Paulette M. van Vliet, Frances Badger, Catherine Sackley

Physiotherapy Research International 14(2): 77-90 (2009)

3.1 Abstract

Purpose: Feedback about motor performance can induce either an internal focus of attention (about body movement) or an external focus of attention (about the effects on the environment) in the learner. The main aim of this pilot study was to examine the attentional focus of feedback given by physiotherapists during treatment of the hemiplegic arm. A second aim was to examine the frequency of feedback about motor performance during treatment.

Method: A multi methods design was used (quantitative and qualitative). Eight physiotherapists and eight patients with stroke were recruited from two hospitals. Data was collected by video recordings of treatment, interviews (both therapists and patients) and questionnaire (therapists). Information feedback, instructions and motivational statements were identified from the video recordings. Feedback and instructions were further grouped into internal focus, external focus or mixed focus of attention. Themes were drawn from the interview transcripts. Triangulation was used to provide corroborating information from the different data sets.

Results: Two hundred and forty-seven of the total 1,914 statements identified in the videos were feedback, the rest comprising instructions and statements of motivation. Of the feedback statements, 236 of the total 247 identified had an internal focus. Therapist interviews and questionnaires revealed more external focus communication than actual treatment.

Conclusions: Physiotherapists used instructions and statements of motivation more than feedback, and directed the patient's attention more to body movement than movement effects. The outcome of this study may prompt clinicians to examine the amount and the attentional focus of the feedback they use in their clinical practice, and to consider whether it is most effective approach in the light of current evidence.

Keywords: Stroke, Feedback, Attentional focus

3.2 Introduction

In healthy subjects, motor learning can be facilitated by the delivery of information feedback (Magill 2007;Schmidt & Wrisberg 2000). Information feedback provides information about a movement error and/ or information to correct a movement error. For example, 'you need to lift your arm higher next time'. Feedback differs from instructions because it gives information based upon the previous observed movement attempt. The delivery of feedback has been recommended to therapists facilitating the relearning of movement following stroke as it has the potential to increase the effectiveness of the rehabilitation programme (Carr & Shepherd 2003;van Vliet & Wulf 2006). Feedback may be even more necessary for people with stroke because implicit motor-sequence learning can be impaired (Boyd & Winstein 2001).

Despite these recommendations to use feedback, two studies have found that the amount of information feedback used by therapists in stroke rehabilitation is limited (Parry 2005;Talvitie 2000). Talvitie et al. (2000) found that for a mixed group of patients, including those with stroke, feedback was mainly motivational and reinforcing. Parry (2005) observed that movement errors were often communicated in an indirect or ambiguous way (e.g. by a further instruction). There is also limited information about the frequency of feedback use in treatment.

When information feedback is given, it can be directed to focus either on the body movement (internal focus) or on the effects of the movement on the environment (external focus) (Magill, 2007). For example, to encourage greater extension of the elbow in a reach-to-grasp movement, one could say ‘next time, straighten your elbow more’ (internal focus) or ‘next time, move closer to the cup’ (external focus).

In healthy subjects, numerous studies have shown that inducing an external focus of attention is more effective for motor performance and learning than inducing an internal focus of attention (McNevin, Shea, & Wulf 2003;Wulf, Lauterbach, & Toole 1999b;Wulf et al. 2002;Wulf & Prinz 2001). One suggested reason for this has been that when subjects are asked to focus on their movements, they ‘tend to actively intervene in the motor control processes, thereby disrupting automatic control processes’ (‘constrained action hypothesis’) (van Vliet & Wulf, 2006, p.833). It is unclear if results from healthy subjects apply to the neurologically impaired. Existing evidence in stroke suggests that instructions that induce an external focus are more effective for improving the performance of reaching tasks (Fasoli et al. 2002). External focus instructions have also been found to be more effective than either internal focus instructions or a control condition in maintaining standing balance during perturbation of the support surface in patients with Parkinson’s disease (Landers et al. 2005). Conversely, another study has shown that internal focus of attention instructions were more beneficial than external focus for a group of stroke subjects, in reducing the amount of postural sway in a balance task (McNevin & Wulf 2003). No studies have yet examined the attentional focus of <u>feedback</u> used by therapists during stroke rehabilitation treatment.

This pilot study therefore has two aims: 1) to identify the relative frequency of feedback, and instructions in the therapist-patient interaction and 2) to explore the attentional focus of feedback given by physiotherapists during treatment. Physiotherapy treatments of the hemiplegic arm were chosen as a treatment example, as this is an area requiring more research evidence to guide treatments and improve outcome of arm function (Nakayama et al. 1994).

3.3 Methods

3.3.1 Study Design

A mixed-methodology design was adopted to explore the complex interactions between the patient and therapist, with a focus on the use of attentional focus feedback (Sale, Lohfeld, & Brazil 2002) . The methods used were video recordings of physiotherapy treatments, separate face-to-face semi-structured individual interviews of patients and therapists, and a therapist questionnaire. The design adopted was classified as a concurrent mixed methods design and allowed comparison of the methods (Maggs-Rapport 2001;Miller & Fredericks 2006). The primary paradigm adopted was logical positivism and the secondary paradigm was that of the naturalistic paradigm (Johnstone 2004).

Quantitative research questions were identified from the literature: What was the frequency of information feedback? Was the attentional focus primarily external or internal? The qualitative methods of video and interviews were applied to explore emerging themes associated with delivery of feedback and attentional focus from both therapist and patient perspectives. The integration of qualitative and quantitative methods provided a comprehensive picture of the use of feedback for training the hemiplegic arm.

3.3.2 Participants

Between March and August 2006 eight physiotherapists and eight of their patients were recruited from two hospital trusts. Physiotherapists were recruited purposively to include a) more than 1 hospital site to avoid a possible cluster effect due to influence of local practices; b) a range of clinical experience; and c) therapists working in both inpatient and outpatient departments. This was considered important to provide an indication of the use of feedback at all stages of stroke rehabilitation. Inclusion criteria for patients were a medical diagnosis of stroke, receiving treatment for the upper limb, and a score ranging from 3 to 13 on the upper limb section of the Rivermead Motor Assessment (RMA) (Lincoln & Leadbitter 1979). Exclusion criteria were an upper limb deficit due to non stroke pathology, severe sensorimotor deficit (< 1 one for touch and proprioception on the dorsum of the hand, on the Rivermead Assessment of Somatosensory Performance (RASP) (Winward, Halligan, & Wade 2002), more than 24 months post-stroke and a score of five or less on the receptive skill section of the Sheffield Screening test for Acquired Learning Disorders (SSTALD) (Syder et al. 1993). All patients were treated in their usual inpatient or outpatient setting by their usual physiotherapist. Ethical approval was obtained from the local Research Ethics Committee.

3.3.3 Data Collection

Patient characteristics were measured by the researcher to describe the group. Measurements included cognitive impairment, including language, memory, praxis, and attention (Birmingham University Cognitive Screen) (Humphreys et al. 2009); mood (Hospital Anxiety and Depression Scale - HADS) (Zigmond & Snaith 1983); arm motor impairment (10 hole peg test) (Turton & Fraser 1986); pain (McGill short form pain questionnaire (Melzack 1987); sensation - surface pressure, surface localisation, proprioception and 2 point discrimination (RASP - deficit was classified as 'mild' if there were two or less errors in either the surface pressure or proprioception subtests). Demographic data included age, date of birth, present condition, history of present condition, past medical history, and social and drug history. Computerised tomography results were recorded where available.

Video Recordings

The video captured 30 minutes of upper limb training for each patient. This provided a means of recording the patient- therapist interaction within a naturalistic paradigm. The aim was to record the use of feedback and instructions during rehabilitation of the hemiplegic arm, to add a qualitative reality to answer the research questions. The researcher was present throughout all video recordings but remained removed from the patient/therapist interaction. To allow habituation to the presence of the researcher and the camera, the researcher developed a rapport with both the patient and therapist to help diminish potential anxiety and reduced her eye contact with them while filming (Caldwell & Atwal 2005;Robson 2002). Therapists and patients were told that the study was to examine the use of internal and external focus feedback and were given definitions of these terms.

Therapist Interviews

Semi-structured interviews were conducted separately with the therapists and the patients. The aims of the interviews with the therapists were: (1) to find out which focus the therapist perceived they were using in the treatment (2) to explore reasons behind their use of attentional focus in the feedback delivered in the recorded treatment, and (3) to corroborate their answers with the communication captured by the video.

A semi structured interview guide was devised and the topics covered in the interview with the therapist included: the goals for the session(s), the therapist's description of feedback used, the therapist's opinions about the feedback and instructions, the attentional focus of the information given and the effect of the presence of the camera. An example of a question to the therapists was '*Can you tell me about the feedback you used to improve X's movement performance?'* The interview focused specifically on the information used within the treatments that were video recorded. All interviews were conducted by the researcher. The therapists were interviewed within a week of the recorded treatment session and the video recording was available to review to aid recall during the interview. Therapists were given the option to watch the video recording in its entirety or to be shown excerpts of communication with an internal, external or mixed focus of attention. Interviews were audio recorded and then transcribed verbatim.

<u>Patient interviews</u>

The emphasis of the patient interviews was to explore their perception of the therapist's use of attentional focus because of a lack of previous research in this area. Topics in the patient interview included: goal(s) for the session, understanding of information from the therapist, effect of information on movement performance, preference regarding attentional focus of information and the effect of the presence of the video. An example of a patient question which aimed to elicit the perception of the attentional focus of feedback was '*The information X (name of therapist) gave you was about how to move your arm. What effects did you notice this information having on the way you did the movement?'* and '*The information X gave was* *about what to do with the object in the task. What effects did you notice this information having on the way you did the movement?'* This direct approach to patient questions helped to focus the interview and prompt patients' recall of the therapy. Patients were interviewed immediately after the treatment session. This allowed patients to reflect immediately on the information given during the training and minimised the impact of possible memory difficulties.

Therapist Questionnaire

The aim of the questionnaire was to explore the attentional focus of feedback that the therapists perceived they used in their routine practice (outside of the recorded treatment session). The questionnaire comprised an open question '*Can you list 3 verbal feedback statements that you commonly use when retraining reach-to-grasp?'* followed by eight multiple choice questions which asked therapists to choose feedback statements that were most similar to those they would use in their routine clinical practice. The eight questions each related to an aspect of upper limb kinematics: shoulder forward flexion, protraction and lateral rotation of the scapula, external rotation of the shoulder, elbow extension, supination, wrist extension, finger extension and thumb abduction and opposition. For each aspect, three choices of statement were provided: internal focus, external focus or mixed attentional focus, which made reference to both the body part and the environment. An example of an external focus feedback statement about elbow extension from the questionnaire was '*Next time I would like you to reach closer towards the cup'* An example of an internal focus feedback statement is '*next time I would like you to stretch your arm further forwards*'. An option was also given to provide alternative feedback statements and to make comments. The questionnaire was piloted with two physiotherapists unrelated to the study and minor changes were made.

3.4 Data Analysis

<u>Video transcripts</u>

An initial thematic coding framework was devised for the analysis of the video transcripts. Clear definitions for feedback, instruction and for each attentional focus were formulated beforehand, derived from the literature (Magill, 2007). This framework was derived from the research questions and was used to analyze the verbal communication in the patient-therapist interactions (Robson, 2002). In order to identify frequency of feedback compared to other statements, communication by the therapist was coded as either feedback or instruction. Transcripts were examined line by line, searching for occurrences of these codes. This process revealed interactions which did not fit the a priori codes and a new code of 'motivational statement' was identified. Motivational statements were defined as those which encouraged, without providing specific movement information e.g. '*well-done*', '*good*'. Within the themes of 'feedback' and 'instruction', three sub themes were identified: internal focus, external focus or mixed focus of attention.

Initial coding of the entire first video transcript was undertaken independently by three members of the research team in order to reach consistency in assigning the codes (Pope et al. 2000). Results of independent coding were discussed by the researchers and concordance was reached regarding the assignment of categories to the framework. Samples of all the remaining transcripts were also independently coded by a researcher naïve to the study to ensure the guidelines were clear. This process aimed to ensure a rigorous approach to coding and analysis (Bowling 1997). The researcher then coded all the transcripts using this robust framework.

Frequencies of feedback, instructions and motivational statements were recorded and expressed as a percentage of the total number of these categories. Similarly, frequencies of internal, external and mixed focus of attention feedback were recorded and expressed as a percentage of the total number of these categories. The quantitative aspects of the study allowed the use of frequencies for data reduction. This helped to contain the qualitative video data to allow a pragmatic approach to manage the rich data collected (Miller and Fredericks 2006).

Interview transcripts

Owing to the exploratory nature of the qualitative data, content analysis was an appropriate analytical approach (Robson, 2002). Four of the six themes identified in the analysis of both therapist and patient interviews reflected the interview topics. These were: methods of communication, attentional focus, goals, and impact of presence of the camera. In addition, two other themes emerged (Robson, 2002) from both therapist and patient interviews: the amount of communication and statements of motivation. All of the interview transcripts were analyzed by one researcher.

Questionnaire analysis

For the questionnaire data, the frequency of each statement concerning attentional focus, for each of the upper limb kinematics, was recorded.

Using triangulation, findings from the three data sources were considered as a whole to identify consistent or discrepant findings. This increased the interpretability by providing depth and completeness to the phenomenon under study (Sale et al. 2002). The data were analysed within the context of each methodology*: quantitative, qualitative and mixed methods*. Consequently both commonalities and divergence within the data were sought, both within the body of qualitative data, as well as between the qualitative and quantitative data sets (Murphy et al. 1998)**.**

3.5 Results

The therapists were all female with between 18 months to 10 years (mean 6.7 years, SD = 3) post qualification experience. The group included one junior physiotherapist, six senior physiotherapists and a stroke clinical specialist. All therapists had been treating their patient for a mean of two months (SD = 1 month).

Table 3.1 shows the patient demographic data. The mean patient age was 56 years (SD = 9). The mean time since stroke was 7.1 months (SD = 8). Seven patients were male and one female. Four were treated as an inpatient in a stroke or rehabilitation ward and four as an outpatient in a day hospital or outpatient department.

Table 3.1 Patient demographic data

Patient	Age	Sex	Rivermead UL score	Site of stroke	Time since stroke (months)	Place of Treatment
1	41	M	7	R frontotemporal	2	In-patient
2	51	M	13	L Subarachnoid	21	Out-patient
3	67	F	3	L hemisphere (PACI)*	18	Out-patient
4	59	M	13	L Posterior fossa	4	In-patient
5	49	M	9	L hemisphere (PACI)	2	In-patient
6	68	M	11	R Parietal lobe	0.5	In-patient
7	55	M	3	L hemisphere (PACI)	2	Out-patient
8	60	M	8	L hemisphere (PACI)	11	Out-patient

* PACI – partial anterior circulation infarct (Bamford classification)

The results of clinical assessments showed that three patients had mild arm impairment (RMA score of 11 – 13; patients 2, 4 and 6), three patients were moderately impaired (RMA 7-9; patients 1, 5 and 8) and two were more severely impaired (RMA 0 – 3; patients 3 and 7). Six patients had mild sensory problems. Three patients had pain in their hemiplegic arm (patients 5, 7 and 8). Four had problems with praxis and four had memory problems. Only patient 2 had no cognitive/ perceptual problems. Only patient 7 had anxiety and no patients were depressed according to scores on the HAD. Appendix F pp 237 lists the full results of the clinical assessments.

All eight patients reported no adverse effects from the video and felt that the treatment content was similar to usual treatments. The only effect noted was therapists tended to be 'less chatty'. Although all eight therapists stated that there was no change in the content of their treatments, six said they were more conscious of their actions due to the presence of the video.

Three therapists set out clear goals for the treatments whereas the other five set out to increase activity more globally.

3.5.1 Information Feedback, Instruction and Motivational Statements

Instruction and statements of motivation were used more frequently than information feedback in all of the recorded treatment sessions as seen in table 3.2. Feedback comprised 247 (13%) of the total 1,914 of identified statements, compared to 1,027 (54 %) for instruction and 641 (33%) for statements of motivation. Examples of motivational statements were '*keep going*', and '*well done*', to encourage or act as reinforcement to facilitate the motor performance.

Table 3.2 Number of feedback, instruction, and motivation statements recorded in each treatment session (and percentage of total number of statements to patient)

Patient/therapist interaction	1	2	3	4	5	6	7	8
Feedback	22	14	36	46	32	22	51	23
%	(15)	(8)	(16)	(16)	(12)	(12)	(19)	(7)
Instruction	79	111	110	145	138	90	142	212
%	(53)	(62)	(49)	(52)	(50)	(48)	(52)	(62)
Motivation	49	54	78	89	107	77	80	107
%	(32)	(30)	(35)	(32)	(38)	(40)	(29)	(31)

In the interviews, all therapists felt they had provided sufficient feedback to their patients and all of the patients agreed, although some therapists reported some difficulty with the differentiation between the use of instructions, information feedback and statements of motivation. Five of the eight therapists stated in their interviews that they were not conscious of the choice of words used in the treatment sessions. For example, one therapist stated *'I suppose I'm not always conscious of every word I'm saying, a lot of it is just spontaneous and comes out'*.

All eight therapists emphasised the importance of motivating statements with one stating *'Generally I just motivate and encourage patients rather than telling them that they have not done that very well.'* From the patient interviews, five appreciated receiving statements of motivation with patient 5 saying *'[She] always says very well, very good, great. I appreciate* *when they say that. It gives you more enthusiasm to do it you know'.* Two patients stressed the importance of providing feedback to the therapist.

3.5.2 Attentional focus of feedback and instructions

Of the total 247 feedback statements identified, 236 (96%) had an internal focus (table 3.3). In four of the treatments only internal focus feedback was used whereas in the other four, two had a small proportion of external focus feedback, (patients 1 and 2: 3 statements each). A smaller proportion of statements used mixed attentional focus feedback, (patients 1, 3 and 5: 3, 1 and 1 statements respectively).

The attentional focus of the instructions was also examined due to the relatively small proportion of information feedback. Table 3.3 shows that the instructions were also predominantly internal (816 of 1027 instruction identified (79%)).The use of external focus and mixed attentional focus instructions was greatest with patient 1.

Table 3.3 Number of internal focus, external focus, and mixed attentional focus statements recorded in each treatment session: feedback and instructions

Patient/therapist interaction		1	2	3	4	5	6	7	8
Feedback	**IF** [a]	16	11	36	46	31	22	51	23
	% [b]	(72)	(79)	(97)	(100)	(97)	(100)	(100)	(100)
	EF [c]	3	3	-	-	-	-	-	-
	%	(14)	(21)						
	Mixed	3	-	1	-	1	-	-	-
	%	(14)		(3)		(3)			
Instruction	**IF**	29	92	90	107	113	61	139	185
	% [d]	(37)	(83)	(82)	(74)	(82)	(68)	(98)	(87)
	EF	28	2	8	8	6	9	0	3
	%	(35)	(2)	(7)	(5)	(4)	(10)		(1)
	Mixed	22	17	12	30	19	20	3	24
	%	(28)	(15)	(11)	(21)	(14)	(22)	(2)	(12)

[a] Internal Focus

[b] Percentage of total feedback statements given to the patient

[c] External Focus

[d] Percentage of total instructions given to the patient

In the interviews, the reasons given by therapists for using an internal focus of attention were (a) wanting patients to perform the movement correctly first time e.g. ‘*to think about their body and where their body is and bits they are moving so they are moving it correctly rather* *than learn the wrong way to do it .'* (b) To tune the patient into the movement so they can later focus on the functional task without being conscious of the movement, and (c) it reflected their learning experiences e.g. '*this is what you are taught when you go on the Bobath courses'*. Therapists stated a common reason for choosing external focus was to emphasize function e.g. *'To be functional I guess, he's not going to be thinking about his arm, where it is and how it feels, he is going to be thinking about what he is achieving'*. Some therapists however said they used both types of attentional focus for example: '*Normally I would probably focus on the task, and probably then break it down to the body part in order to achieve that task.*

Therapist questionnaire responses reflected the theoretical use of attentional focus in the feedback they used in their routine clinical practice, rather than the feedback used within the video recordings. Therapists' most frequent responses to the multiple choice questions (on use of internal focus, external focus, or mixed focus) can be seen in table 3.4. All therapists chose a mixture of internal and external focus statements with no therapists consistently choosing one type of attentional focus. However, three therapists most frequently chose a mixed focus and three most frequently chose an internal focus. Therapist 2 and 7 had an equal frequency of two of the categories.

Table 3.4 Comparison of attentional focus of feedback from the video recordings, therapist interviews, patient interviews and therapist questionnaires

Patient	Video	Therapist Interview	Patient Interview	Therapist Questionnaire
1	IF, 14% EF 14% mixed	EF	No preference	IF
2	IF, 21% EF	Mixed	EF	EF & Mixed
3	IF 3% mixed	IF	IF	IF
4	IF	IF then EF	No Preference	Mixed
5	IF 3% mixed	EF then IF	Mixed	Mixed
6	IF	Mixed	Mixed	Mixed
7	IF	IF	EF	IF & EF
8	IF	IF	No preference	IF

IF – internal focus EF – external focus

There was disparity between therapists' recollections of their use of attentional focus feedback in the interview and the video recorded data (table 3.4). The dominant attentional focus observed in the videos was internal focus for all treatment sessions. However, the therapists for patients 1, 2, and 6 perceived that their feedback mainly had either an external or mixed focus. The therapists for patients 4 and 5 perceived that both internal and external focus feedback were used, whereas there was no external focus feedback for patient 4, and only a small amount for patient 5.

For five of the eight therapists there was also disparity between the choice of attentional focus statements in the questionnaire and the recorded treatments (table 3.4). For example, for the therapist treating patient 6, the therapist interview and questionnaire data described mixed attentional focus feedback, i.e. each statement included components about the body and the effect of movement on the environment. However, the video recording showed 100% use of internal focus feedback for this patient. There were no clear trends with respect to seniority or experience.

In the patient interviews, five of the eight patients expressed a preference for either internal or external focus feedback. Of these five, two preferred external focus, two preferred mixed and one preferred internal focus. One patient with a preference for external focus information stated*: 'there is no good saying 'reach' 'cos I will only do that (patient demonstrated a small movement) but with (reaching to) the ceiling you are going to get an extra three inches out of me.'* Of the two that preferred external focus, one received some external focus feedback. Of the two that preferred mixed, one received a small amount of mixed focus feedback.

3.6 Discussion

3.6.1 Instructions and Feedback

Instruction was the predominant choice of communication by the therapists. This finding is similar to that found by Talvitie (2000). All therapists however, felt they had provided sufficient feedback to their patients. This may be because information about movements completed was often communicated by a new instruction, such as '*and further forwards*'. Although this is not information feedback, an example of which was: '*that time the elbow straightened more'* (descriptive information) or '*you need to straighten the elbow more'* (corrective information), the therapists' perceptions may be that they have delivered the information necessary and so considered that the feedback was sufficient. Another reason for this indirect way of communicating information to patients was also noted by Parry (2005) who found that therapists felt that giving direct feedback about the problem might distress and de-motivate the patient. If the therapist can gain the patient's confidence, it can have a positive effect on the interaction (Gyllensten et al. 1999;Sluijs et al. 1993), so it is understandable why therapists may be tentative in using information feedback. Another study also found that feedback that is too specific, although it improves performance, 'discourages exploration and undermines the learning needed for later, more independent performance' in healthy subjects (Goodman et al. 2004, p.248). However, a lack of information feedback may be to the detriment of motor learning. Evidence from the healthy population (Magil, 2007; Schmidt & Wrisberg, 2000) and the stroke population (van Vliet & Wulf 2006), has shown that feedback can be beneficial to improve motor performance and learning. Information feedback can promote the correction of errors which may not be so clear with more indirect methods of providing feedback and may be particularly important when implicit motor-sequence learning is impaired (Boyd and Winstein 2001).

3.6.2 Motivational Statements

These statements were used more frequently than information feedback. The main properties of the feedback in the study by Talvitie (2000) were also motivational and reinforcing. All the patients were positive about such motivation and the frequency of these statements may have contributed to the high patient satisfaction regarding the amount of feedback.

3.6.3 Attentional Focus

When information feedback was used in the treatments, it predominantly had an internal focus of attention. Instructions also primarily induced an internal focus of attention. This finding is at odds with the studies demonstrating that external focus instructions result in better performance of motor tasks in stroke patients (Fasoli et al. 2002; Landers et al. 2005). Although research in this area is scarce and another study has demonstrated an advantage for internal focus instructions for stroke patients (McNevin and Wulf 2003), taken together with the literature from healthy subjects, the majority of evidence to date suggests an advantage for an external focus of attention. Therefore, it is hypothesized that therapists may be providing less than optimal feedback by not making more use of information with an external focus. The discrepancy between video and interview results could be explained by the fact that therapists used more external/mixed focus in instructions than in feedback and when describing their treatment, they may have combined them rather than distinguishing clearly between the two. Therapists did report some difficulty with the differentiation between the use of instructions, information feedback and statements of motivation.

The finding that five therapists reported not being aware of the choice of words used within the sessions, implies an intuitive use of communication, rather than a conscious consideration of the words used, a suggestion that also arose from the observational study by Talvitie (2000). It could also be hypothesized that some therapists perceive that they deliver external focus information in their treatments, but in actual fact they do not. There may be a benefit in therapists having their treatment video recorded for their own development, to increase self-awareness of their style of communication. An additional reason for disparity between the treatment recorded and the questionnaire could be that although a therapist may predominantly choose one type of focus to reflect their practice generally, with an individual patient, they may decide that a different focus may be more effective (Cirstea et al. 2006). The degree of cognitive deficit for instance has been found to correlate with performance level when internal focus information was given in a reaching task, but there was no such correlation when information was given about movement endpoint precision (Cirstea et al., 2006). So patients' individual cognitive characteristics may affect how useful internal focus or external focus information can be.

Also, in healthy subjects, people with a higher level of skill can benefit more from external focus and people with less skill from internal focus learning conditions (Perkins-Ceccato, Passmore, & Lee 2003). So it may be that the level of arm impairment influences the choice of focus used by the therapist.

There was more similarity between the therapists reported use of attentional focus feedback from the interviews and the questionnaire than between either of these two methods with the video recordings. The use of attentional focus feedback reported in the interviews may have therefore reflected the therapist's theoretical use of attentional focus feedback rather than the actual use, even though they were asked to focus on the actual treatment.

The prevalence of internal focus feedback in this study suggests that the therapists may have concentrated more on quality of movement rather than functional ability. It is not known whether improving quality of movement directly improves function. This is something which future research could address.

3.6.4 Patients and Attentional Focus

The patient group as a whole expressed no consistent preference for feedback with an internal or an external focus. Some expressed no preference. Some patients had difficulty understanding the subtle difference between internal and external focused feedback, although this was discussed with them in broad terms i.e. body movements or objects and the environment. Despite the prevalent use of internal focus information, few patients perceived the use of attentional focus feedback to be internal.

The type of focus used by the therapists was often not the patient's expressed preference. As this could adversely affect interaction between therapist and patient, and success of treatment, further investigation is warranted.

Importantly, the adoption of a mixed methodology for this study was critical in revealing the dissonance between therapists' perceptions of their approaches to rehabilitation and how they were actually practicing.

3.6.5 Limitations

The therapist questionnaire was not able to explore whether different statements may be used at different times depending upon degree of motor or cognitive impairment, or other characteristics such as pain, which could in particular direct attention towards the area of discomfort for both the patient and therapist and thus encourage internal focus information. Also, a shorter time between the therapist interview and the video recording was desirable, but was limited by the availability of the therapist, so to mitigate faulty recollection of events, the video was available for the therapist to view. The findings cannot be generalised to all patients receiving treatment for their hemiplegic arm but does serve as an indication of the use of attentional focus information in a cross section of physiotherapists with different levels of experience, in two hospitals. There is some variance in the study population with respect to time since stroke and level of arm impairment. However, the fact that the bias towards internal focus information was present across all participants suggests that internal focus information is used predominantly despite factors such as time since stroke and the level of arm impairment. In future studies the effect of these factors could be elucidated by purposively recruiting more homogenous groups with larger sample sizes.

It would be worthwhile for future studies to explore in more detail the reasons why therapists prefer a particular attentional focus, and how they may change their choice according to individual patient circumstances. It would also be useful to investigate whether the internal focus bias is widespread amongst therapists. Additional studies are needed to assess the effectiveness of feedback with the different attentional foci. Although literature from healthy subjects at present indicates external is more effective, it is not yet known whether this applies to stroke patients.

3.6.6 Conclusions

This study explored the use of attentional focus feedback in the retraining of the hemiplegic arm. Information feedback was used little compared to instructions and motivational statements. The focus of attention in both feedback and instructions was predominantly internal in all treatments. This information may prompt clinicians to examine the amount, and the attentional focus of the feedback they use in their clinical practice, and to consider whether it is most effective in the light of current evidence.

CHAPTER 4 –EXPERIMENTAL METHODS – STUDY 2

4.1 Introduction

A purpose of Study 1 was to assist with the idenfication of feedback statements used in clinical practice while retraining reach to grasp after stroke. These statements informed Study 2 which examined whether feedback inducing an internal compared with an external focus of attention was more effective during the motor performance of reach to grasp after stroke. Study 2 used three-dimensional motion analysis which provided a sensitive system of measurement allowing subtle performance differences to be detected (Coluccini et al. 2007). This chapter details the motion analysis system used for the forthcoming study, the set up of the equipment, rationale for marker placement, the processing and extraction of data and the kinematic outcome measures. The clinical outcome measures used in addition to those used within the first study (detailed in section 2.43) are also described.

4.2 Equipment set up

4.2.1 Motion analysis equipment

Motion analysis enables the collection of kinematic measures which provides a window on the motor control of the movements captured. It therefore forms an important method in motor control research allowing sensitive quantitative evaluation of movement deficits such as those found in reaching after stroke (Wagner et al. 2007). The motion analysis system used was Qualisys TM (Qualisys Medical AB, Gothenburg, Sweden). It consisted of four infrared cameras, passive markers and a laptop connected to the cameras, to process the information obtained. The system operated through tracking movement of passive markers in three-dimensional space. A two-dimensional image of the markers were processed by each of the four cameras, the coordinates of which were sent as a data stream output to the Qualisys tracking manager programme onto the laptop. Two-dimensional data captured by the cameras were then combined with data from another camera to calculate the three-dimensional position coordinate of each marker, using an algorithm from the Qualysis track manager located on the laptop. The system used passive markers. An alternative would have been to use active markers which required wires which would have potentially restricted movement. The drawback of using passive markers was that occasionally markers could be obscured during measurement. The four Proreflex cameras were arranged to cover the measurement volume required for the reaching tasks (Chapter 5: section 5.4.5). The cameras were placed in an arc around a table measuring 60cm x 80cm x 75cm (figure 4.1) such that the reflective markers were visible by at least two cameras at all times as shown in figure 4.2.

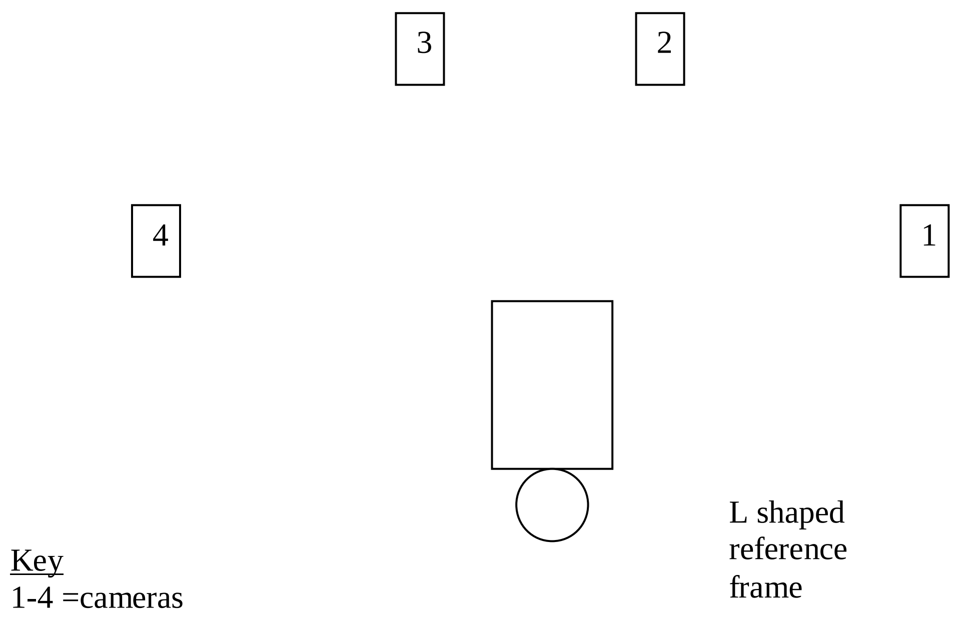


Figure 4.1 Schematic Motion unit camera setup

Figure 4.2 Actual camera and subject setup

4.2.2 Accuracy of motion analysis system

The optical tracking system used was considered more accurate than video based methods (Haggard & Wing 1989;Weller et al. 2006), and is itself very accurate (Johanson et al. 2006;Qualisy Motion Capture Systems 2006). Measurement errors may however occur through marker movement and during the integration of the data from 2D to 3D coordinates. The assessment of accuracy was therefore carried out so it was understood what was attributed to software errors and what was due to the dependent variable, an important consideration for the internal validity of the experimental findings. The following method was therefore employed.

4.2.3 Procedure for testing the accuracy of the motion analysis system

Linearization and Calibration of the system

First updated linearization files for the cameras were installed to maintain high levels of accuracy of the system. The purpose of these linearization files were to account for any distortions associated with the camera lens which can affect the conversion of 2D data into 3D data. Next the system was calibrated. The calibration process gave the Qualisys software system information about the orientation and position of each camera. This enabled markers to be accurately tracked and allowed the 2D coordinates to be converted into 3D data. The method of calibration adopted was wand calibration. The wand measured 300 mm. An L-shaped reference structure, with five reflective markers attached, was placed on the table within the workplace measurement volume. The L-shaped reference frame was placed as shown in figure 4.1 and the short side was labeled as the x-axis, the long side the y-axis. The wand was then moved around inside the measurement volume, contained by the L-shaped reference structure, in the frontal, sagittal and tranverse plane. Movement in all three directions was important to allow scaling in the x,y and z axes. The position and orientation of each camera was calculated by evaluating the camera's view of the wand using automatic calibration algorithms in the Qualisys tracking manager software. The resulting output detailed the calibration error scores, presented below, and through consultation with Qualisys were considered acceptable and was in keeping to that found by other authors (Johanson et al. 2006).

Calibration Results (error of each individual camera)

Camera 1	0.17122 mm
Camera 2	0.14470 mm
Camera 3	0.15178 mm
Camera 4	0.21117 mm

Identifying the work space volume

Following calibration the work space volume was measured using one reflective marker to identify the magnitude of the Cartesian coordinates. This was achieved by identifying the boundaries where the marker could be seen by at least two motion unit cameras. This distance was measured in each plane, the measurements of which are given below. The table where subjects were to perform the experiment was then placed within the workplace volume, and the position of the table was recorded so it could be replaced in the same position at each measurement occasion.

Workspace Volume

X	=	970 mm
Y	=	1230 mm
Z	=	1050 mm

Calculation of system accuracy

Next a wand with two markers placed exactly 500 mm apart was placed in a central position in the workspace, on the table. The static position of the wand was recorded for four seconds using a data collection frequency of 200Hz, which was equivalent to collecting 200 frames per second, each frame equal to 0.005s. Using the functions in the Qualisys software, the data was filtered, with a cut off frequency of 35Hz and then exported into Excel. The distance between the two markers at each frame was then calculated by calculating the length of the vectors between the markers. This was done using the equation below.

$$\sqrt{(x_2-x_1)^2 + (y_2-y_1)^2 + (z_2-z_1)^2}$$

The mean distance over the four seconds was calculated, which represented the distance Qualisys calculated the markers to be apart. This was followed by calculation of the standard deviation (s.d) which represented the variance either side of the calculated mean distance (see table 4.1).

Table 4.1 Results of accuracy

	Mean distance between the 2 markers	**s.d**
Static spatial error	501.203 mm	0.0058 mm
Dynamic spatial error	500.751 mm	0.3606 mm

s.d. – Standard Deviation

The dynamic position of the wand was then recorded while moving the 500 mm wand forward and backwards in the y plane (which corresponded to the direction of reaching during the experimental tasks), for four seconds. This allowed the calculation of dynamic spatial error using the same procedure as above.

Static spatial error of the mean distance represented the difference between the actual length of the 500 mm wand and the length measured using Qualisys. This error was found to be very small indicating that the conversion of 2D data into 3D data was very accurate. Dynamic spatial error was however much larger. This was considered more representative of the experimental error as the experimental tasks used within the study involved motion. The dynamic spatial error could have related to noise, for example hand tremor whilst moving the wand. Additionally noise may have occurred through the erroneous determination of a 3D point and could have been affected by a different camera being used to measure the marker during the movement of the wand. This would have happened when a marker was obscured from one camera and so information from a different pair of cameras would be used to calculate the position of the marker. It was anticipated that the magnitude of the noise during the experiment would also depend upon the experimental conditions, such as presence of reflective materials, the equipment and calibration accuracy. Although dynamic spatial error was larger than the static spatial error it was more accurate than that found by Pfau et al. (2005) who reported a dynamic spatial error of 0.58 mm (Pfau et al. 2005). The accuracy measurements found in this study was comparable to another study, (Hill 2006), and were deemed acceptable (Josefsson et al. 1996). Overall the result indicated the motion analysis system used (Qualisys) exhibited high accuracy and precision.

Other factors affecting accuracy

Calibration, camera linearization and environmental aspects were all factors considered to affect data accuracy as discussed above. Additionally reflective marker integrity was also considered to affect accuracy and steps were taken to reduce this source of error. The interaction between cameras and marker is such that each marker was exposed to infra-red light which was reflected back to the camera. Dents, dulling and scratches of the markers could affect the reflected image. Regular checks of the integrity of the markers were therefore performed and markers were replaced as required. Where possible the same markers were used for each participant and maximum efforts were made to ensure the markers, attached to the skin, using toupee tape, stayed in place throughout data collection.

4.3 Recording markers

4.3.1 Placement of reflective markers

Eleven reflective markers were used in total. Each was hemispheric and measured 5 mm in diameter. The position of each marker was identified anatomically to ensure standardization. Marker placement is described in Chapter 6: Methods (p 149).

Figure 4.3 provides a visual representation for the placements of the trunk and arm markers.

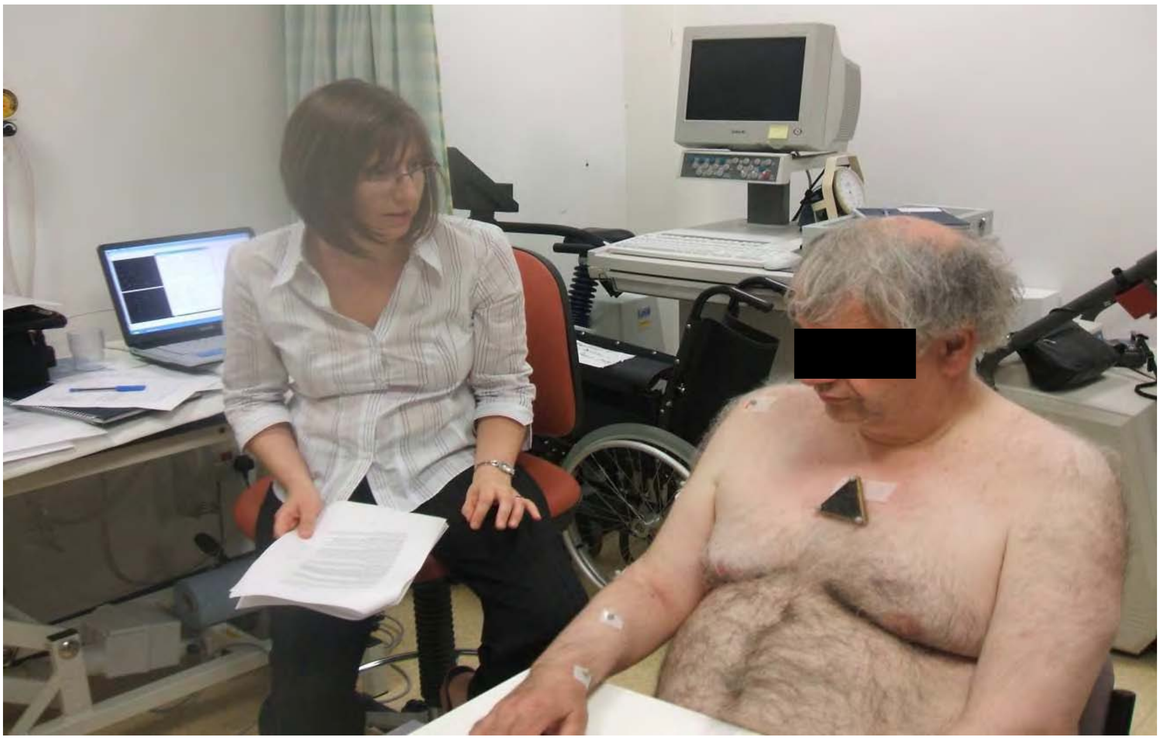


Figure 4.3 Placement of arm and trunk markers

4.3.2 Rationale of marker placement

Markers were placed directly upon the skin. This is considered acceptable practice although using skin mounted markers can cause displacements due to soft tissue motion (Fuller et al. 1997) which can cause an over prediction of the actual skeletal motion (Reinschmidt et al. 1995). All subjects however were subject to the same conditions so any error was considered constant. The placement of the reflective markers on the skin, were chosen based upon the kinematic outcomes measures used, which were selected to match those commonly used in other studies measuring performance of reach-to-grasp (Cirstea et al. 2003a; Michaelsen et al. 2004). A marker was placed on the thumb and index finger and enabled the calculation of grasp aperture. Markers were placed just below the bed of the nail as opposed to the actual nail as often used, to increase the distance between the markers. This reduced the possibility of cameras identifying each marker as one common marker, as occurred on some pilot trials. A marker on the wrist was chosen to measure displacement and derivatives of displacement e.g velocity, as it is less affected by movement of the hand, so was considered to be the most distal point to measure hand transport, which would provide consistent data between subjects. The wrist marker and other remaining markers were used to enable the calculation of Euler joint angles. This required a minimum of three markers for each of the three segments: the trunk, upper arm and forearm and enabled measurement of all degrees of freedom (Schmidt et al. 1999). Placement was chosen to maximize the distance between the markers to reduce the risk of the system identifying each marker as one common marker, and to maximize the visibility of the markers during the reaching tasks. The trunk markers were placed upon a rigid body, one centimetre below the sternal notch as placement was easily repeatable between participants and was considered representative of trunk movements which can occur during reaching.

4.4 Data processing

4.4.1 Qualisys settings

The same system settings were used at the start of each data collection. These were decided upon after pilot trials where optimal settings were found. This included settings which identified the reflective markers clearly. For example, it was found that the optimal cameras position, shown in figure 4.1, maximised the identification of all the markers and in particular those on the finger and thumb throughout the reaching movement. The workspace options used were:

Camera system – 200Hz per seconds

Timings – Use external trigger (start)

Marker – Passive markers, default discrimination

Flashes – use all

Lineariszation for each camera – visible in 'workspace options'

Connection – Buffer mode – immediate

Calibration – Wand kit 300 mm Z positive axis, Y long Axis. (Y was in the sagital plane, away from where the participant sat. X was in the frontal plane along the table edge)

Analogue acquisition and video devices unselected

Processing – track the measurement in 3D was selected with do not fill the gaps

Tracking – prediction error 10, maximum residual 10; acceleration.factor 50000; noise factor 10, autojoin enable, maximum frame gap 10.

4.4.2 Rationale for Qualisys system settings

Data was collected at a frequency of 200Hz, the equivalent to 200 frames per second which provided high resolution, increasing accuracy of data. An external trigger was used which enabled data collection to be started remotely. This was set up for practical reasons so the therapist was able to remain next to the participants throughout data collection, a necessity to enable optimal delivery of a feedback statement after each movement attempt (chapter 5, section 5.4.3 and chapter 6 table 6.4). Passive markers were used to allow unconstrained reaching as described above (section 4.2.1). Flashes were used to light up the passive reflective markers. All the different intensity and strobe volumes were chosen to ensure good marker detection. It was important to ensure the linearization for each camera were visible otherwise data calculations were not made. The connection was set to immediate buffer mode so that when the external trigger was pressed data was collected without a delay. Calibration of the system, as described in section 4.2.2, was carried out before each data measurement session. The calibration settings were therefore standardized using the 300 mm length frame as it formed the best fit within the workspace being used. The x,y,z axes were defined by convention to allow comparison with the definitions commonly used in other studies. A video was not used during data collection and was therefore unselected. The processing was set for 3D data collection. Where there were gaps in the identification of markers during a trial, which occurred where two cameras were not able to visualize a marker for one or more frames during data collection. It was chosen not to fill these gaps automatically. This was so the algorithm could be manually applied later, in the tracking process, to ensure only small gaps, less then 10 frames, were filled, instead of all gaps (represented by selecting autojoin enable, maximum frame gap 10). A ‘plus’ sign by each labelled marker indicated where the trajectories had been automatically joined. Gaps of more than 10 frames were processed manually at the data labelling stage to ensure a full trajectory as possible for each participant. In the tracking process, the automatic tracking software used the marker’s position in previous frames to predict the new position. A prediction error of 10 mm was set which equated to the maximum distance a marker could be away from its location in the previous frame and still be assigned to the same trajectory. This setting allowed for some unpredictability of marker movement, which occurred with movements of the hemiplegic arm, yet was set low enough to reduce the chance markers being inaccurately tracked (e.g. confused with another marker). A maximum residual of 10 mm was selected, and represented the maximum distance a marker was still considered part of the same trajectory from the intersection of the 2D marker rays. This was chosen to reduce high segmentation. Where a marker was obscured during measurement it resulted in an additional trajectory being formed for that marker, so that a marker tracked throughout the movement may comprise of several segmented trajectories. Careful camera positioning, marker placement and the maximum residual setting kept segmentation to a minimum.

The acceleration factor and the noise factor were set at 5000 and 10 respectively. These both assisted to determine the start of each trajectory. Neither factors were considered sensitive, so the settings used were those recommended by the manufacturer.

4.4.3 Data processing procedure

Following data collection markers were assigned labels. Two labelled files, which represented data collected from the left or right arms were created. The labels used were sternum top, sternum left (L), sternum right (R), shoulder L/R, humerus L/R, Elbow L/R, Wrist L/R, finger L/R, Thumb L/R. The labels were assigned to each folder for each subject. Next automatic identity models relating to the left and right arm were created. This enabled trajectories to be automatically assigned to the labels which were then manually checked. Where there were remaining trajectories which had not been assigned, these were examined manually to establish whether they represented a marker and were assigned to the correct marker label where appropriate. Where a trajectory could not be confirmed as representing a particular marker, the trajectory was discarded. Other trajectories unrelated to the markers were discarded. In some severely impaired subjects, some of the trajectories were incomplete, due to the marker not being visible by two cameras through some of the movement and reflected the abnormal movement pattern used by these subjects. For example, pronation of the forearm or the thumb crossed over the finger.

Data was then exported as a C3D file. This provided the correct format for Visual 3D (C-Motion, Inc) which was used to digitally filter the data and then used to extract the desired outcome variables.

4.4.4 Filtering motion analysis data

Prior to the calculation of the kinematic outcome measures all data was digitally filtered to reduce the noise introduced by the measurement system. The noise was the motion analysis signal which was not due to the reaching movement (Winter 1990). Sources of noise have been previously described in this chapter (section 4.2.2). Digital filtering algorithms were used to allow the low frequency movement component to be passed and the higher frequencies usually associated with noise to be removed (Winter et al. 1990). The type of digital filter used was a second order Butterworth filter as it is a common digital filter used in motion analysis as it is designed to pass low frequencies and attenuate high frequencies. It does not however work well at the signal onset and endpoint where it causes a signal distortion, represented as a 90˚ phase lag. A dual pass also known as a fourth order Butterworth filter was therefore used. This filtered the data in both directions which cancelled the phase lag.

The decision regarding the filter cut-off point was considered important as it determined how reliable the kinematics measures were within the study (Fioretti 1996). In gait studies, it has been found that 99.7% of the signal power was contained in the frequency band below 6Hz (Winter 1990). A low cut off frequency, below 6Hz, would have smoothed out the data too much and would not have accurately represented all the movement units commonly seen following stroke. A high frequency cut off point would have allowed too much noise to pass through which would have made differentiation between the noise and the movement difficult. The effect of different cut-off frequencies were examined so an informed decision regarding the cut frequency used within this study could be made. Data from a healthy subject was filtered at 2Hz, 6Hz and 10Hz and the resultant velocity/ time graphs were compared.

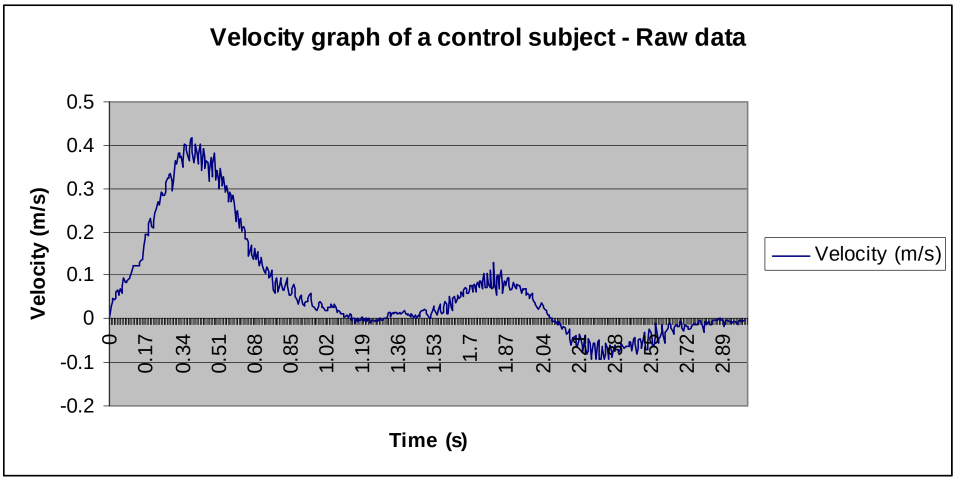


Figure 4.4 Raw data for the movement task of reaching and lifting a jar

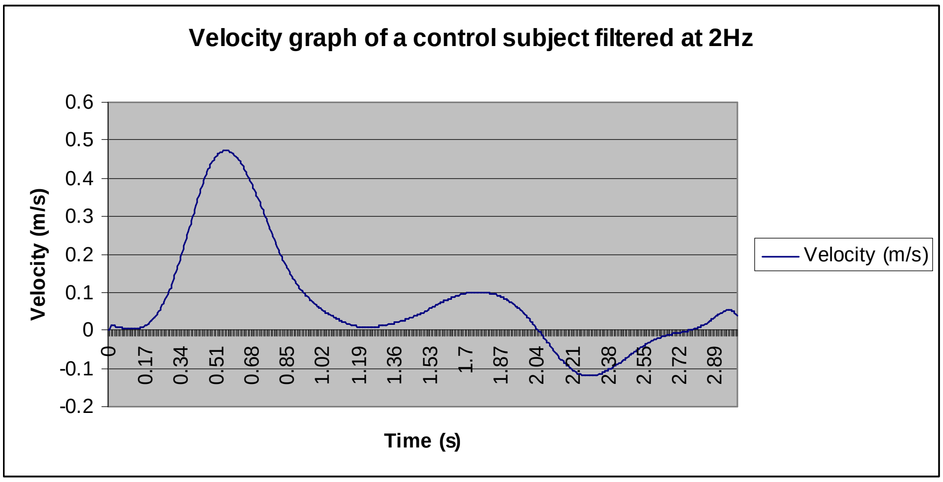


Figure 4.5 Data filtered at 2Hz

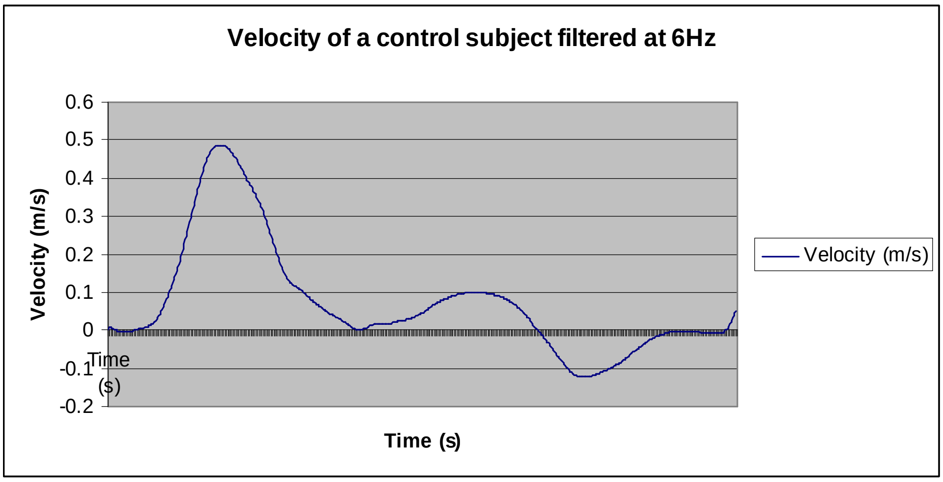


Figure 4.6 Data filtered at 6Hz

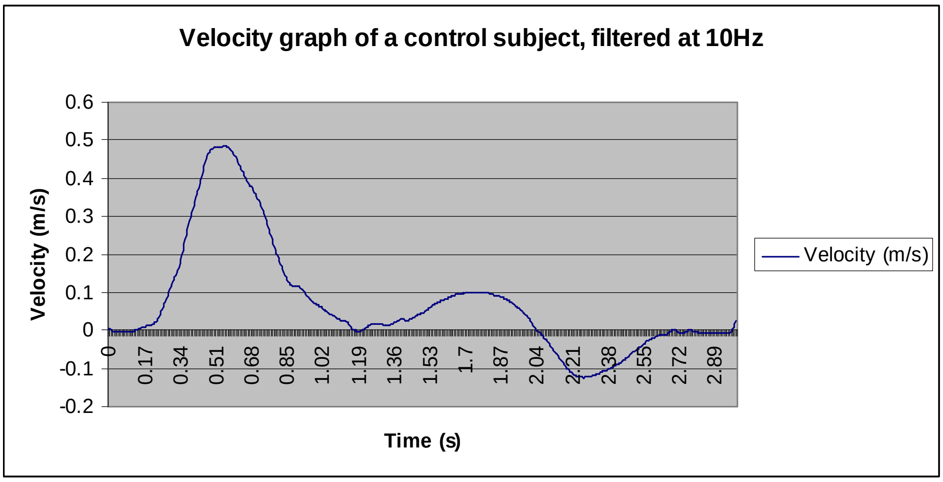


Figure 4.7 Data filtered at 10Hz

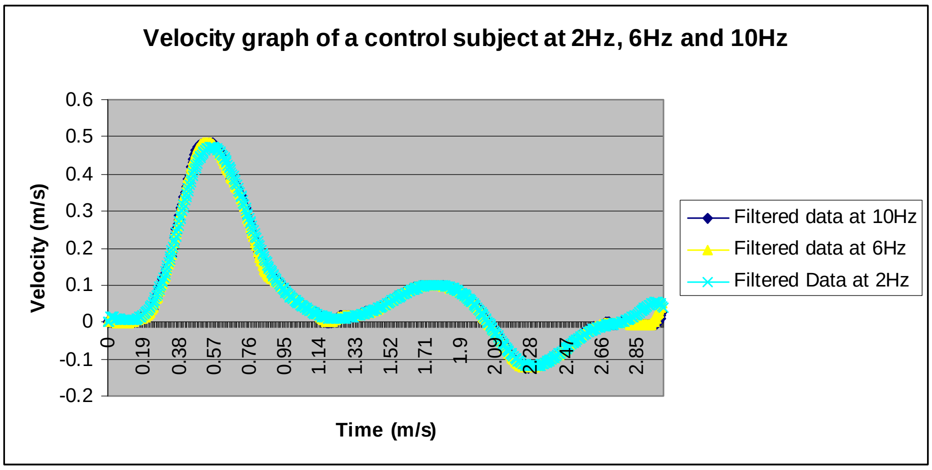


Figure 4.8 Superimposed filtered data at 2Hz, 6Hz, 10Hz

Figure 4.5 shows a very smooth velocity time curve compared with the unfiltered data shown in figure 4.4. Filtering at the other two frequencies produced less smooth curves (Figures 4.6 & 4.7). From observation it was considered that filtering at 2Hz produced too smooth a curve which may have reflected the removal of the complexities of a reaching movement. The decision was therefore between a cut off frequency of 6Hz and 10Hz. Multiple differentiation of the data has been found to magnify noise (Fioretti 1996) which would introduce inaccuracies that would be magnified in the derived velocity and acceleration calculations. Additionally finger movements have been associated with frequencies between 8-10Hz (Eakin et al. 2001). With respect to this and the commonality of using a 10Hz cut-off frequency in the literature (Archambault et al 1999; McCrea & Eng 2005; Seidler et al. 2004) the decision was to use a 10Hz cut off frequency.

4.5 Data extraction

4.5.1 Kinematic outcome measures

Two types of measures were used, one that reflected motor control issues and one which examined the amplitude of joint angles. Joint angles were included to provide clinically meaniful data as they can be observed or measured by therapists in the clinical setting. Primary outcome measures were chosen from each category. These were: peak velocity, movement duration, maximum elbow extension and maximum aperture. These were chosen as they were considered to provide key measures of reach-to-grasp performance. Additional outcome measures were chosen which aimed to provide an in depth understanding of the effects of attentional focus on motor control and amplitude of joint movements. All measures are common parameters used in other studies investigating reach-to-grasp (Bennett & Castiello 1994; Kamper et al. 2002; Cirstea, Ptito, & Levin 2003b; Michaelsen et al. 2004). A full list of the kinematic measures can be found in chapter 6: section 6.3.6, and the definition of each measure in chapter 4: sections 4.6 and 4.7.

4.5.2 Identification of movement onset and endpoint

'Visual 3D' software was used to calculate the kinematic outcome variables and was based upon the following definitions. The movement onset for each trial was defined as the time when the three-dimensional resultant velocity of the wrist first exceeded 25 mm/s for five consecutive frames. This was chosen to identify movement onset above any resting oscillations due to instability or tremor (Cirstea et al. 2003a). It also ensured the actual start of the movement excluded false starts as it required that the criteria was only met if velocity of the wrist exceeded 25 mm/s. This method of defining movement onset was similar to that used in other studies of reach-to-grasp (Mihaltchev et al. 2005;Reinkensmeyer et al. 2002).

The movement endpoint was defined as the maximum two-dimensional resultant displacement of the wrist in the horizontal plane. To ensure movement endpoint represented the end of the transport phase of reaching, additional requirements were met: For Task A, endpoint must have occurred before the jar was lifted. For Task B and C, movement endpoint must have occured before aperture increased, which indicated the release of the jar (please refer to section 5.4.5 for a description of the tasks). This approach was found to be the most effective method which when incorporated into the analysis scripts provided the most accurate data.

4.6 Motor Control Measure definitions used for Visual 3D calculations

Table 4.2 Motor Control Measure Definitions

Measure	Abbreviation	Definition
Peak Velocity	PV	Peak velocity was defined as the maximum 3-D resultant velocity of the wrist between the movement onset and endpoint calculated through the first derivative of wrist position and was measured in mm/s^{-1}.
Movement Duration	MD	Movement duration was defined as the time between movement onset and endpoint and was measured in milliseconds.
Peak aperture (Task A Only)		Peak aperture was defined as the maximum displacement between the thumb and finger markers between movement onset and endpoint. This measurement was only used for task A as the task required reaching to grasp the jar. For task B and C the tasks began with grasping the jar. Peak aperture was measured in centimetres.
Time to Peak Velocity	TPV	The time in milliseconds from movement onset to peak velocity
Percentage time to Peak Velocity	%TPV	The time to peak velocity expressed as a percentage of the total movement duration.

Measure	Abbreviation	Definition
Peak Deceleration	PD	The lowest value of the 2^{nd} derivative of wrist displacement, found between movement onset and endpoint and was measured in mm/s^{-1}.
Time to Peak Deceleration	TPD	The time in milliseconds from movement onset to peak deceleration
Percentage time to Peak Deceleration	%TPD	The time to peak deceleration expressed as a percentage of the total movement duration.
Time to maximum Aperture	TMA	The time in milliseconds from movement onset to maximum aperture.
Percentage time to maximum aperture	%TMA	The time to maximum aperture expressed as a percentage of the total movement duration.
Lateral Path Deviation of the Wrist		Lateral deviation of the wrist from the straight line path was measured to provide an indication of deviation from the straight line path. A straight line path is normally expected in healthy reach-to-grasp movements (Desmurget et al. 1999). Maximum lateral deviation of the wrist marker from the straight line path was measured in the y-axis.

4.7 Joint Angle definitions used for Visual 3D calculations

4.7.1 Maximum Elbow Extension

Euler rotations (for details see section 4.7.11), sequenced x-y-z, were used to express the elbow angle of the forearm with respect to the humerus. The x axis represented the frontal plane, the y the sagittal plane and the z the transverse plane (figure 4.9). Elbow flexion-extension was measured about the x-axis and the maximum elbow angle was that found between movement onset and endpoint.

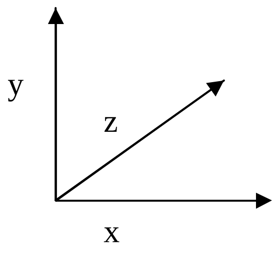


Figure 4.9 Axis orientation used for the Euler angles

4.7.2 Shoulder Flexion

Euler rotations sequenced x-y-z, were used to express the maximum shoulder flexion of the humerus with respect to the trunk. Shoulder flexion-extension was measured about the x-axis, as a straight line path is normally expected in healthy reach to grasp movements, to the front. The maximum shoulder angle was that found between movement onset and endpoint.

4.7.3 Trunk forward flexion

Maximum trunk forward flexion was determined by calculating the maximum displacement which occurred between the positional coordinates of the trunk markers, between movement onset and endpoint.

4.7.4 Euler angles

Euler angles were used to calculate the joint angles as it provided a three-dimensional angle that was considered to be more accurate than two-dimensional angles calculated through trigonometry. This was because Euler angles are calculated independent of segment size and are therefore more generalizable across individuals. Two-dimensional measures also tend to provide a measure of relative movement of one segment with another, whereas three-dimensional measure can more accurately reflect the joint movement by accommodating more degrees of freedom of the movement. However standard deviations of the derived angle have been reported to be up to 25 degrees for three-dimensional angles, although it is considered that these can be reduced with clearly defined movement onset and endpoints (Mackey et al. 2005). The problem of soft tissue movement however remained as discussed in section 4.3.2. Euler angles provide angles from three rotations around orthogonal axes. The order of these rotations in this experiment was rotations first through the x axis, followed by the y and z. The x axis was defined by the frontal plane so movement around the axis represented flexion and extension. The y axis was defined by the sagital plane so movement around the axis represented abduction and adduction. The z axis was defined by the transverse plane so movement around the axis represented internal and external rotation. This order was chosen as the first rotation is considered to be the most accurate (Mackey et al. 2005) and the angles of interest were flexion and extension. The derived calculation was that where the two segments in question were aligned. So in the case of calculating maximum elbow extension, the value calculated represented the derived value, preceded with a minus sign, whereas maximum elbow flexion represented the derived value subtracted from 180 degrees (figure 4.10). Three markers were required for each segment, the forearm, upper arm and trunk, which were used to form a rigid body in Visual 3D. These were used to define the positional vector of one segment upon another which formed a rotation matrix. Markers at the wrist, forearm and elbow formed one segment, the elbow and two humerus markers formed the upper arm segment. This allowed elbow angle to be calculated. Three markers on the trunk allowed for the calculation of the movement of the trunk. These trunk markers combined with the upper limb segment also enabled the calculation of shoulder flexion.

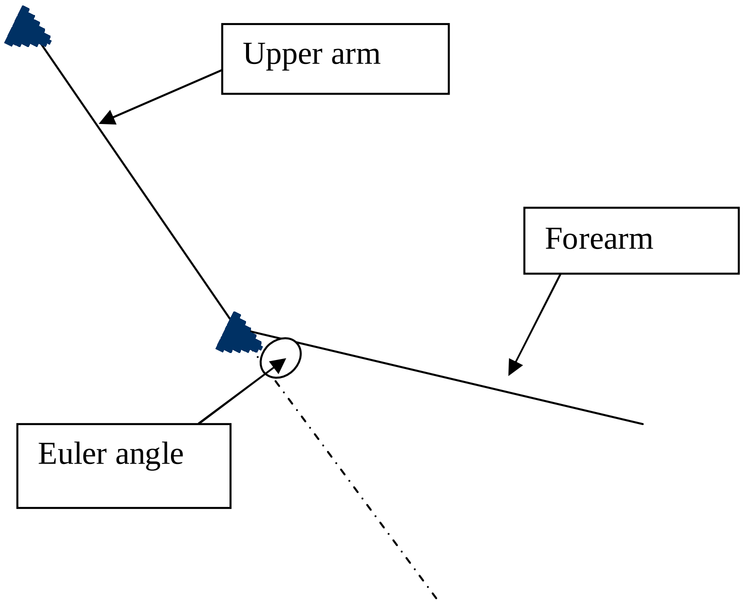


Figure 4.10 Schematic representation of the first Euler rotation about the x axis measuring elbow joint flexion/extension

Improved performance was characterised by: a shorter movement duration, higher peak velocity, larger maximum aperture, increased absolute and percentage time to peak velocity and deceleration, reduced lateral deviation from the straight line path, greater elbow extension and shoulder flexion and reduced trunk flexion.

4.8 Visual 3D Procedure

Visual 3D scripts were written using the definitions described sections 4.6 and 4.7. Please refer to appendix G for an example of a visual 3D used for the study. Visual 3D was used as it provided a visual representation of each reaching movement which enabled careful data checking to be carried out. For each participant the visual 3D files for all reaching trials recorded by the motion analysis equipment were loaded. In addition a MODEL file was created for each participant. This was a file which consisted of one motion frame, at the beginning of data collection, and was used to inform the system what each marker represented. Markers were associated to the three segments of interest, the forearm, upper arm and trunk and allowed a visual representation of the movement (see figure 4.10).

Data extractions scripts, referred by visual 3D as ‘pipeline’, were loaded. Visual 3D provided the scripts required for the calculations. These were loaded in a logical sequence and provided all the required data values.

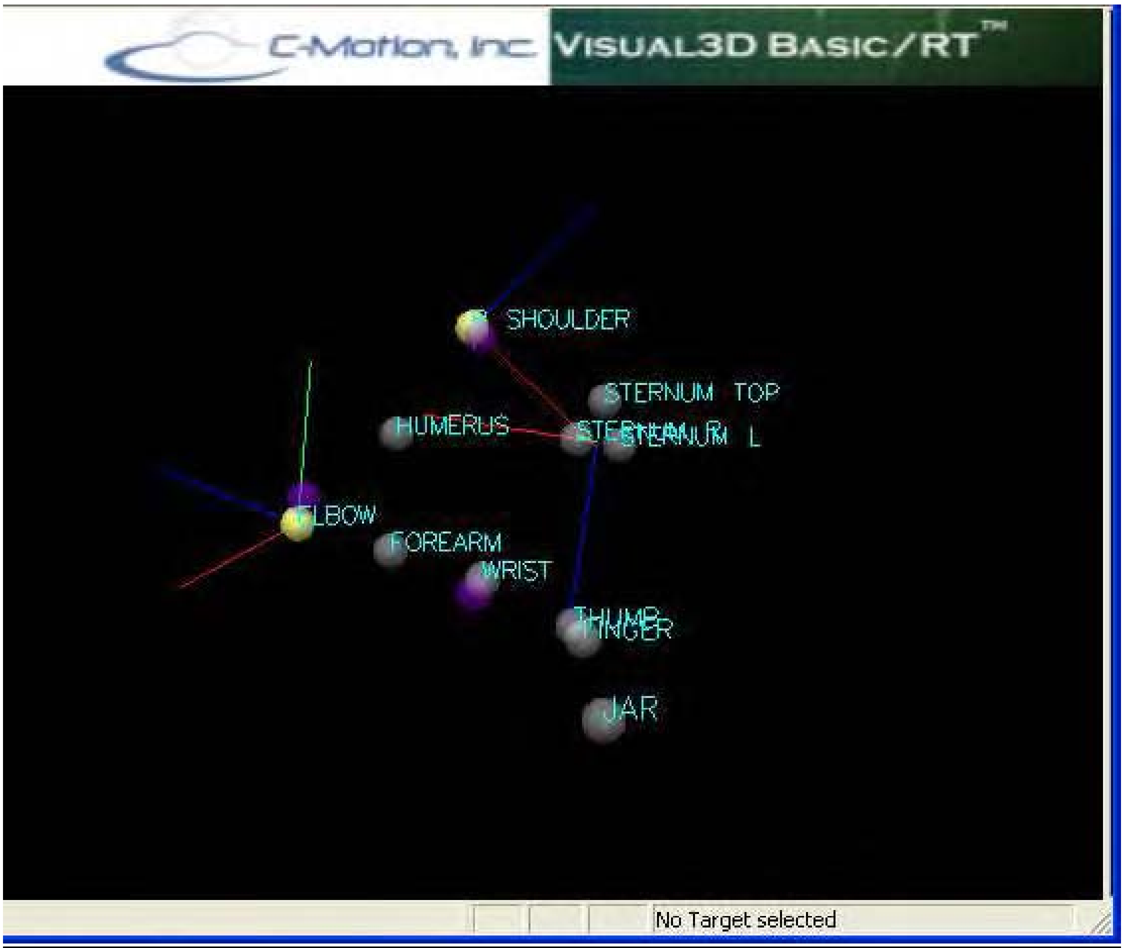


Figure 4.11 MODEL created by Visual 3D which allowed visual representation of the reaching movement

4.8.1 Data Cleaning

To ensure the data used for statistical testing was accurate, methods were employed to check the data. This was principally achieved through the manual checking of data values provided by Visual 3D. It was possible within Visual 3D to plot graphs for each outcome measure. For example a velocity time graph was plotted and the movement onset, endpoint and peak velocity, peak deceleration, maximum aperture was marked upon the graph using the ‘Event’ function within the Visual 3D script (see figure 4.12). Values which corresponded to the labels were accepted. Where there was mismatch between expected label placement, the value was either recalculated or discarded. For example, where movement onset was not labelled correctly in Visual 3D, this may have been due to the participant starting their movement before the start of data collection in the Qualysis system. This resulted in Visual 3D identifying an inaccurate peak velocity value. In such cases the value which represented the actual peak velocity was taken from the graph and used in place of the original value. This process was aided by viewing the movement using the model created to ensure that what appeared to be the correct value from the graph correlated to the point expected within the actual reach. Where it was not possible to identify the actual outcome value, for example where data was missing through some of the movement, the trial was discarded. This process was repeated for all trials used for statistical analysis for each outcome variable.

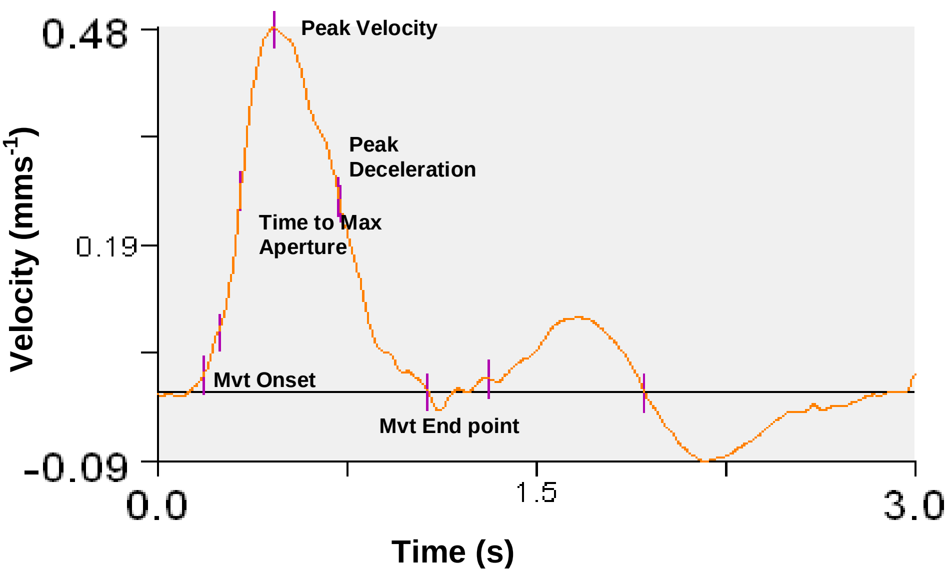


Figure 4.12 Velocity time graph with key points highlighted

4.9 Clinical Assessments

In addition to the kinematic analysis of reaching, clinical measures were also used to describe the individual characteristics of participants. Clinical tests were completed to compare participants in similar studies. It also made it possible for clinicians to compare the results from these participants with people with stroke they see in practice. Additionally it helped the interpretation of the kinematic results by allowing consideration of the functional ability/ level of impairments of participants. The scoring sheet and guidance notes used for each clinical assessment can be found in the appendix H (pp 248). The purpose, validity and reliability of the clinical assessments used, in addition to those used within the first study, will now be outlined. For the full list of measures used within study 2, please refer to chapter 6, clinical assessments.

4.9.1 Fugl-Meyer (Fugl-Meyer et al. 1975)

The motor function section of the upper limb section of the Fugl-Meyer was used to identify the level of arm impairment after stroke. The upper limb section encompasses the testing of reflexes, the assessment of joint positions required for specific movements involving flexion and extension of the arm, wrist and hand and a test for coordination. The maximum score is 66 and represents no observable arm deficits. It is considered a valid tool for assessing upper limb impairment following stroke (Deakin et al. 2003;Malouin et al. 1994;Platz et al. 2005) and intra reliability between subjects has also been found to be very good (Pearson correlation coefficient > 0.96)(Duncan et al. 1983).

4.9.2 Erasmus modifications to the revised Nottingham Sensory Assessment (Stolk-Hornveld et al. 2006)

The Erasmus modifications to the revised Nottingham Sensory Assessment, is considered a reliable somato-sensory assessment for subjects with intracranial disorders such as stroke (Stolk-Hornsveld et al. 2006). The test consists of assessing light touch, pressure, pinprick and sharp blunt sensations as well as two-point discrimination and proprioception. Please refer to appendix H for scoring guidance (pp 248). A test of sensation was included as somatosensory deficits have been associated with less favourable functional outcome, which could influence the effectiveness of the intervention within the experiment (Han et al. 2002). Participants with severe sensory deficits were excluded as they were less likely to benefit from the intervention and therefore if included would not help to test the hypotheses set (Chapter 5: section 5.3).

4.9.3 The mini mental test examination (Hodkinson 1972)

The mini mental test is comparable to the mental test score although instead of being measured out of 30, is measured out of 10. Both are used to recognize mental impairment although the larger scale is used where identification of the confusional state is required. In this study however, questions within the shortened version were sufficient and covered attention, recall and ability to follow instructions, attributes closely associated with the ability to utilize the feedback provided in study 2. A score of less than seven out of 10 represents significant mental impairment (Hodkinson 1972). The measure has been found to be both valid (Kendals coefficient >0.79) (Jitapunkul 1991) and reliable (Cronbach's α coefficient >0.78 (Jitapunkul 1991;Little et al. 1987).

4.9.4 Optic ataxia (Karnath & Perenin 2005)

Dorsal stream pathways projecting from the visual to the parietal cortex are thought to provide action relevant information during reaching (Goodale et al. 1991). This includes the position of an object. Lesions within this pathway lead to optic ataxia whereby the visual guidance of goal directed movements are impaired (Dijkerman et al. 2006). Individuals with optic ataxia have difficulty reaching in the right direction and adjusting their hand orientation when reaching to an object (Shumway-Cook & Woollacott 2001). The test used to detect the presence of this condition required each participant to maintain the focus of their eyes upon the examiner's nose whilst reaching with their impaired arm to touch the examiners fingertip, which was sequentially placed in 10 positions in each hemi-space, thus only using peripheral vision. This test was carried out on both arms and then the whole procedure repeated with the participant being allowed to use foveal vision, by looking at the target. A positive test for the presence of optic ataxia was where participant missed the examiner's fingertip and were unable to correct their position, with peripheral vision, but could accurately touch the fingertip with foveal vision.

This test was considered important because within study 2 the tasks involved reaching or placing a jar. Corrections to a movement due to optic ataxia could influence the effectiveness of the intervention within the study. The test is valid and reliable as it examines all aspects of optic ataxia and is simple to admininster (Karnath & Perenin 2005;Perenin & Vighetto 1988).

4.9.5 The Tardieu Scale (Gracies et al. 2000)

The Tardieu scale (Gracies et al. 2000) was used to measure spasticity and has an advantage over the commonly used Ashworth scale as it differentiates between the effects of spasticity and muscle length, on muscle tone. This was achieved by measuring a high velocity stretch of the muscles groups being tested, elbow, wrist and finger flexion and extension, which identified the presence of spasticity measured on a scale of 0-4. Additionally slow movements on each muscle group tested were performed which examined the presence of contractures. It is considered a valid tool (Patrick & Ada 2006). Excellent reliability has been found in children with cerebral palsy with >90% agreement for intra-rater reliability (Gracies et al. 2010). It was used in this study to identify whether participants were limited by spasticity in achieving the necessary joint ranges to perform the experimental tasks.

4.9.6 The Intrinsic Motivation Inventory (IMI) (Ryan 1982)

Intrinsic motivation refers to engagement in an activity as a result of whether an individual finds it interesting and enjoyable (Mouratidis 2008). The Intrinsic Motivation Inventory was used in this study as a test for intrinsic motivation because it provided a multidimensional measure of a participant's experience with regard to the experimental tasks. It assessed the participant's interest and enjoyment of the reaching tasks as well as perceived competence, choice with the tasks and tension experienced whilst performing the tasks. The interest and enjoyment section was considered the self report measure of intrinsic motivation. Inclusion of the other sub-sections: perceived competence, choice and tension, were added to strengthen the validity of the measure (McAuley et al. 1987). Measurement of intrinsic motivation was considered important within the study 2 as motivation has been linked to an individuals ability and willingness to attend to the task at hand (Mouratidis 2008).

CHAPTER 5- DESIGN AND ANALYSIS CONSIDERATIONS FOR STUDY 2

5.1 Introduction

This chapter discusses the design decisions made for study 2. It reiterates the aims and research questions followed by the considerations associated with using a counterbalanced design. The development of the feedback statements used within study 2 are then discussed. Next the experimental tasks are presented including the amount of practice and methods adopted to maintain treatment conditions. This chapter concludes with a detailed discussion of the statistical methods used to analyse the kinematic data. The chapter precedes the paper currently under review (Chapter 6), where the results of study 2 are reported.

5.2 Aims

The primary aim of study 2 was to examine whether feedback inducing an internal focus of attention compared with an external focus of attention was more effective at improving motor performance of reach to grasp after stroke. Two different feedback schedules were used to induce either an internal or external focus of attention in people with stroke whilst they practised reach-to-grasp tasks (section 5.4.5). The study was an exploratory trial and corresponds to a Phase II trial within the framework for the design and evaluation of complex interventions (Campbell et al. 2000). Secondary aims were to explore the influence of the level of arm impairment and working memory on the delivery of feedback and attentional focus type such that: (a) whether people with greater arm impairment during the performance of reach to grasp benefited more from feedback which induced an external or internal focus of attention and (b) whether people with reduced working memory capacity would benefit more from feedback inducing an external or internal focus of attention during the performance of reach to grasp.

These latter two aims were explored to incorporate the wide array of impairments which can present after stroke and to provide insight into the complexities of the use of attentional focus after stroke.

5.3 Research Question and Hypotheses

Primary Research Question:

Does feedback inducing an external focus of attention compared with feedback inducing an internal focus of attention improve motor performance of reach-to-grasp after stroke?

Experimental hypothesis: 1) Feedback inducing an external focus (EF) of attention differs from feedback inducing an internal focus (IF) of attention in improving motor performance of reach to grasp after stroke.

Alternate hypothesis: 2) Feedback inducing an internal focus of attention is equally effective to feedback inducing an external focus of attention during the performance of reach-to-grasp after stroke.

Secondary research questions were:

a) Does the level of arm impairment after stroke affect which attentional focus type improves the performance of reach-to-grasp?

Experimental hypothesis: 1) People with increased arm impairment after stroke will benefit more from either adopting feedback inducing an internal or external focus of attention during the performance of reach-to-grasp.

Alternate hypothesis: 2) There is no difference between level of arm impairment after stroke and feedback type on the performance of reach-to-grasp.

-b) Does the level of working memory after stroke effect which attentional focus type improves motor performance of reach-to-grasp?

Experimental hypothesis: 1).People with poor working memory after stroke will benefit more from adopting feedback inducing either an external focus or internal focus of attention during the performance of reach to grasp. Alternate hypothesis: 2) There is no difference between the level of working memory impairment after stroke and feedback type on the performance of reach-to-grasp.

5.4 Methods

5.4.1 Design

A within-subject, counterbalanced repeated measures design was adopted to contrast two feedback schedules, feedback inducing an internal focus of attention and feedback inducing an external focus of attention. All participants received both conditions. Half the subjects received internal focus feedback first (Order 1), and half the participants received external focus feedback first (Order 2). This design was chosen over other designs as each subject served as his/her own control, thus removing the confounder of between participant differences (Hills & Armitage 1979). Participants were randomized to order group 1 or order group 2, using a computer generated sequence to provide each subject an equal chance to be allocated to either group, thereby causing an expected value of any between group differences to be zero (Chatsfield 1998). The effect of counterbalancing controlled for order effects such as fatigue, practice and learning. The order groups were therefore considered comparable so that any differences found could be attributed to the intervention. Each order was additionally balanced on two key characteristics: upper limb impairment, measured by the Fugl-Meyer motor assessment (see chapter 4 section 4.9.1) and working memory measured by the sustained attention section of the Birmingham University Cognitive Screen (BUCS). Chapter 4 section 4.9.1 provides more details. For details of measurement of working memory please refer to appendix D (pp 223).

5.4.2 Control Condition

Consideration was given as to whether a control condition, where people with stroke performed reach to grasp without receiving verbal feedback, should be included in the design. It was decided not to include such a control condition for several reasons. If a control condition i.e. performing the reaching movements without verbal feedback was performed first, the performance of the control group may have been better than in other conditions as there would be no effect of fatigue, which was a possibility in the conditions performed later. Alternatively, placement of a control condition between the feedback conditions may have caused the control condition to be influenced by the previous condition. Counterbalancing order of conditions, including a control group, or randomizing with the three conditions, including a control condition, would have created six orders of condition permutations. This would have decreased statistical power as there would be only seven subjects in each order group. Therefore it was decided not to include a control condition in the counterbalanced design.

An alternative study design would have been a randomized controlled trial (RCT) where a separate control group using different stroke participants could have been included for comparison. Such a study would consist of three groups: control, external focus and internal focus. This would have required larger numbers of participants and a blinded assessor to perform the outcome assessments, both of which were outside the resources available for this doctoral thesis. An RCT would however be a logical step for the future (Chapter 7: section 7.4.2).

In addition to people with stroke, aged matched healthy control subjects performed the reaching tasks. Previous research has identified reaching kinematics for healthy subjects, but by obtaining kinematic data pertaining to the tasks used within this experiment, it allowed like for like comparisons to be made between healthy subjects and the people with stroke. The number of healthy controls used was four which was a similar number to other studies that have used healthy controls for similar reasons (e.g. Reinkensmeyer et al. 2002, Kamper et al. 2002).

The control participants practiced the same tasks performing the same repetitions after receiving the same instructions to the stroke participants.

The procedure followed can be found in Appendix J (pp 264).

5.4.3 Development of feedback statements

Feedback statements relevant to the retraining of reach-to-grasp after stroke were required so feedback schedules which induced either an internal focus or external focus of attention could be formulated. Two contrasting feedback schedules equivalent in content were developed, one which directed the learner’s attention to their body movements (IF) and an equivalent statement relating to the task or movement effects (EF).

The feedback statements were developed from three main processes: 1) identification of actual feedback statements used by therapists participating in Study 1: from the video recordings, for example: “The arm needs to stretch further forwards” and “This time can you get the cup on the mark more quickly", and from the therapist questionnaire for example: "Can you open your hand out to grasp the cup"; 2) feedback statements were developed from first principles, based on the style of those found within the literature on attentional focus. For example Wulf et al. (2002) gave feedback with either an internal or external focus of attention, with feedback of one attentional focus corresponding with the other attentional focus condition. For example "Shortly before hitting the ball, shift your weight from the back leg to the front" for internal focus and "Shortly before hitting the ball, shift your weight towards the target" for external focus; 3) Two physiotherapists known to the researcher were asked to identify common feedback statements which they used in clinical practice.

Study 1 provided valuable information regarding the principles clinical therapists consider important when they deliver information to patients. For example, therapist's reported the importance upon maintaining a positive therapeutic relationship and was supported by the commonality of statements such as 'well done' 'keep going'. This was translated into the development of feedback statements by positively phrasing the feedback, such that the feedback statements developed only focused on the change required by the participants, and not the error made. This was considered important to maintain intrinsic motivation, an important consideration as motivation has been linked to a participant's willingness to perform and attend to tasks (Mouratidis 2008). Feedback phrased positively also has been found to place less cognitive demands compared with feedback about errors (Koehn, Dickinson, & Goodman 2008) which given the population was considered useful to help maintain their focus. People with stroke can find themselves in a position where they need to change faulty movement patterns, which they have developed since their stroke. This can be a frustrating time and therefore maintaining motivation to encourage the patient to continue with practice was considered important (Magill 2007), and concurred with the opinion expressed by the steering group committee which met for a second time to discuss design considerations for study 2 (Chapter 2 section 2.1).

From these resources matching feedback statements were generated based upon the model used by Wulf et al. (2002). Feedback statements which induced an internal focus of attention used words about the movement of body parts, whereas feedback which induced an external focus used words which related to the movement effects on the environment or the target. Reference to body movements was avoided in the external focus condition.

The content of the feedback was based upon the key kinematic components of reaching (invariant features of reaching). Feedback statements were devised about different aspects of reaching with particular detail given to the wording of each statement in each condition, to offer a clear distinction between the two types of feedback. Feedback was given after each movement attempt to increase the amount of feedback given over the 16 trials. This was based upon the literature finding that performance is improved with increased frequency of feedback, particularly where the tasks involve complex movement skills (Wulf et al. 1998a). A delay of a few seconds was provided prior to the delivery of the feedback. Delaying feedback has been found to encourage the use of intrinsic feedback mechanisms which can improve performance and learning (Liu & Wrisberg 1997, Swinnen et al. 1990). More detail can be found in chapter 1, section, 1.4.9.

Prior to the beginning of data collection, the feedback statements were checked by three physiotherapists consisting of therapists from both within and outside the research team to ensure that there was sufficient distinction between the two conditions. The list of feedback statements generated can be found in Chapter 6, table 6.2 pp 148.

A video recording was also made of the delivery of feedback under IF and EF as per the research protocol. This was then observed by another member of the research team to ensure that there was sufficient distinction between the two conditions and to ensure that the feedback was delivered as per the schedule. The feedback was found to be delivered in accordance with the schedule, so no further changes or training was considered necessary.

5.4.4 Delivery of feedback statements

Feedback statements were given dependent on the observed movement during the practice trials of each task (Section 5.4.5). The movement was observed for the invariant features of reaching as well as other aspects such as speed of movement. Where the movement deviated from 'normal' movement, feedback focused upon those areas. Where a number of errors were observed the researcher chose to focus upon components that, if improved would provide maximum benefit in terms of promoting normal movement. To increase standardization of feedback selection, feedback statements were chosen in the following order: whether the main transport components were present, followed by grasp components, speed, co-ordination and accuracy. Where all the invariant kinematic features of transport and grasp were present, speed was chosen as the focus of the feedback followed by accuracy and coordination. Where the participant performed two consecutive correct movements, the content of the feedback was changed to focus upon another component. In total a maximum of three feedback statements were used for each task. This was chosen to induce realistic therapy conditions as therapists commonly focus upon more than one area during a treatment session.

Feedback given in the second condition (e.g. with external focus) was directed to the same components, for the same number of attempts, as in the first condition (e.g internal focus).

5.4.5 The three reaching tasks

Three reaching tasks were chosen:

A Reaching to a square jar placed at 90% of arms length.

B Placing a square jar, placed at 90% of arms length (ability to lift and move the weight of jar).

C Placing a square jar, placed at 90% of arms length, when measured in the sagittal plane, onto a shelf 300 mm above the table height (ability to lift arm and jar).

The dimensions of the square jar were 65 x 95 x 65 mm, and weighed 250g.

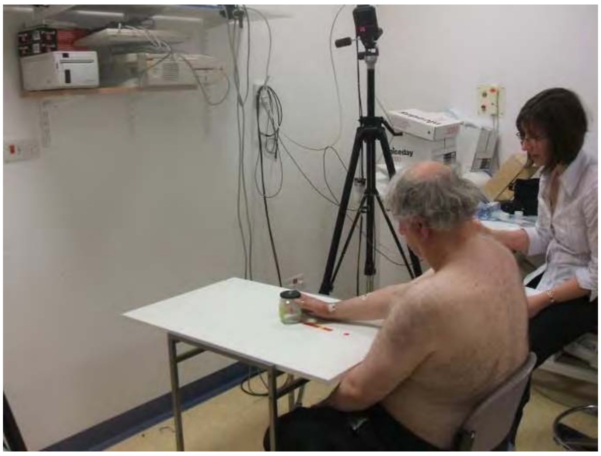


Figure 5.1 Subject reaching to the jar (task A)

The tasks increased in difficulty, similar to the progression used in clinical practice. As each task examined different components of reaching it was considered it would reduce the possibility of fatigue across the muscle groups (Gentilucci 2002;Winstein & Pohl 1995), and reduce boredom. An alternative would have been to use one task using more repetitions. Although this had merit particularly in that it did not require participants to switch between different attentional foci, minimising muscle fatigue and boredom, which possibly would have reduced individual's intention to partake in the exercises, was considered an important consideration. Adopting three tasks also allowed examination of whether the findings were transferable across different tasks (Fasoli et al. 2002, Winstein & Pohl 1995).

The index of difficulty for each task was measured using Fitts’ index of difficulty (Fitts 1954). The purpose was to allow comparisons with other studies eg Fasoli et al. (2002) and provided a suggested method of standardization for future experiments.

Index of difficulty = $\log^2(2D/W)$

D = The distance from the point of movement to the beginning of the object

W = The width of the object

The ‘index of difficulty’ was calculated as:

Reaching and placing a jar 90% of arms length, and reaching for a jar = 1.54.

Placing a jar on a shelf 300 mm above table height =1.63.

According to Fitts, task A and B were calculated as having the same index of difficulty. This was because the calculation only considers distance travelled and width of the object.

Wallace & Newell (1983) as cited by Fasoli et al. (2002) found that an index of difficulty below 4.58 can be executed through a pre-planned strategy. An index of difficulty below this number therefore increased the participant’s chance of being able to use a pre-planned strategy to accomplish the tasks. However following stroke, motor programmes can be disrupted. And participants were therefore likely to require extrinsic feedback to assist the execution of motor programmes.

5.4.6 Amount of practice

All tasks were practised within one session to increase the reliability of the measurements. A relatively large number of trials were required to maximize the effectiveness of the feedback. The amount of practice was chosen based on the number of repetitions it was considered all people with stroke recruited to the study would be able to perform (van Vliet & Sheridan 2007;van Vliet & Sheridan 2009). Ninety-six trials were considered achievable and sufficient. This number was similar to that used by other research papers which found statistically significant differences between conditions with 70 (Cirstea, Ptito & Levin 2003) and 80 repetitions respectively (Michaelsen et al. 2001). It is worth noting that significant differences between conditions have also been found in stroke populations using only three (Lang et al. 2005) and eight (Fasoli et al. 2002) trials for each condition.

The 96 trials comprised of 32 trials for each of the three tasks, with 16 trials for each condition. A five minute rest period was given between conditions to reduce the effect of one condition influencing the next condition. This washout period was in keeping with other studies which adopted a counterbalanced design. Vance et al. (2004) used five minutes' rest between conditions and Landers et al. (2005) a three minutes washout, the latter using a neurological population. Neither of these studies reported finding an interaction between attentional focus and order. This therefore suggested that using a five minute's rest between conditions was sufficient to minimize any effects from the first condition affecting the second. Ten minute's rests were given between tasks to minimize fatigue (Halder et al. 2005) and additional rests were given when requested by participants.

A blocked practice schedule was adopted to maximize motor performance (Marley et al. 2000;Wulf et al. 1999a). Each task was completed under both conditions before starting the next task. Tasks were always performed in the same order, (task A followed by B and C).

5.4.7 Instructions to participants

All participants were given the same basic instructions about each task. These instructions incorporated both elements of internal and external focus. This was deemed important so that the experimental findings related to the use of the feedback given opposed to the instructions (Appendix J)

5.4.8 Manipulation check

A common criticism of the attentional focus literature has been that it is unclear whether participants focused their attention as directed by the researcher (Bund, Weimeyer,& Angert 2007; Gray 2004). Many studies have regularly reminded participants where to direct their focus (e.g Wulf and colleagues, de Bruin 2009) although with this approach it remains unclear whether this direction was adhered to. To address this problem in the current study, the people with stroke were asked where they focused their attention after each practice movement, to gain insight into their preferred focus of attention, and then again after each condition.

After each condition participants were asked:

'During the last 16 movements – what did you find yourself focusing upon?' with the prompt given as required 'did you find yourself mainly focusing on your arm and body movements or the task, ie the jar and surrounding environment?' This approach of asking participants where they directed their attention has been used successfully by Fasoli et al. (2002) who found participants reported adhering closely to the focus of instructions given.

5.5 Statistical analysis

5.5.1 Selection of data for statistical analysis

Previous studies have found that early trials show increased variability (Fasoli et al. 2002). Therefore as a starting point the stability of trials across each task were examined to identify which data was to be used for statistical analysis. This was done through the use of control charts, an established method to examine quality of performance (Chatsfield 1998). For each group (IF first or EF first) the mean across participants for each of the 32 trials (16 under one condition and 16 under the other condition) was calculated for the variable peak velocity (a primary outcome measure). This was plotted alongside constant lines which represented the mean of the means and upper and lower limits of the kinematic variable (See figure 5.2). The 'mean of the means' represented the mean of the mean values of each trial across all participants. The upper and lower limits were two and three standard deviations above and below this mean value. The expectation was that 99% of the values would lie within the outer limits (three standard deviations) (Chatsfield 1998) representing 'stable' data. Figure 5.2 shows that all the data points fell within the outer limits. Overall the last five trials of each condition showed most stability across data points as represented in Figure 5.2 where the data was less variable around the mean at these time points (trials 11-16 and 28-32). Therefore, for each task the mean of the last five trials of each 16 practiced under each condition were selected for statistical analysis. These trials were also most likely to show the best performance of the task as the participant had more practice, so would make visible any main effect present. This was considered important due to the relatively small sample size. After each attempt during the last five trials participants received feedback comprising of all the components trained within that task. Thirty-four individuals received three different feedback statements whereas eight individuals received two different feedback statements. For example after each of the last five trials one individual was told : “This time as you reach further forwards you need to straighten your elbow more, and also get more contact with your fingers and thumb so you have a firm grasp, as well as bringing your arm forwards faster” for the internal focus condition and “This time try and reach closer to the jar, and try and encompass the jar fully to make it more secure, while also moving towards the jar faster” under the external focus condition. This was done as it was considered representative of clinical practice where towards the end of treatment sessions therapists bring together all elements of the movement that were practiced during the training session. Lastly the use of the last five trials increased the time between conditions. This was considered to reduce the possibility of an order effect. Any lasting effects from one condition upon the next, was expected to be diminished with the use of later trials.

5.5.2 Distinguishing treatment effects from confounders

In the counterbalanced design used, possible confounders considered were:

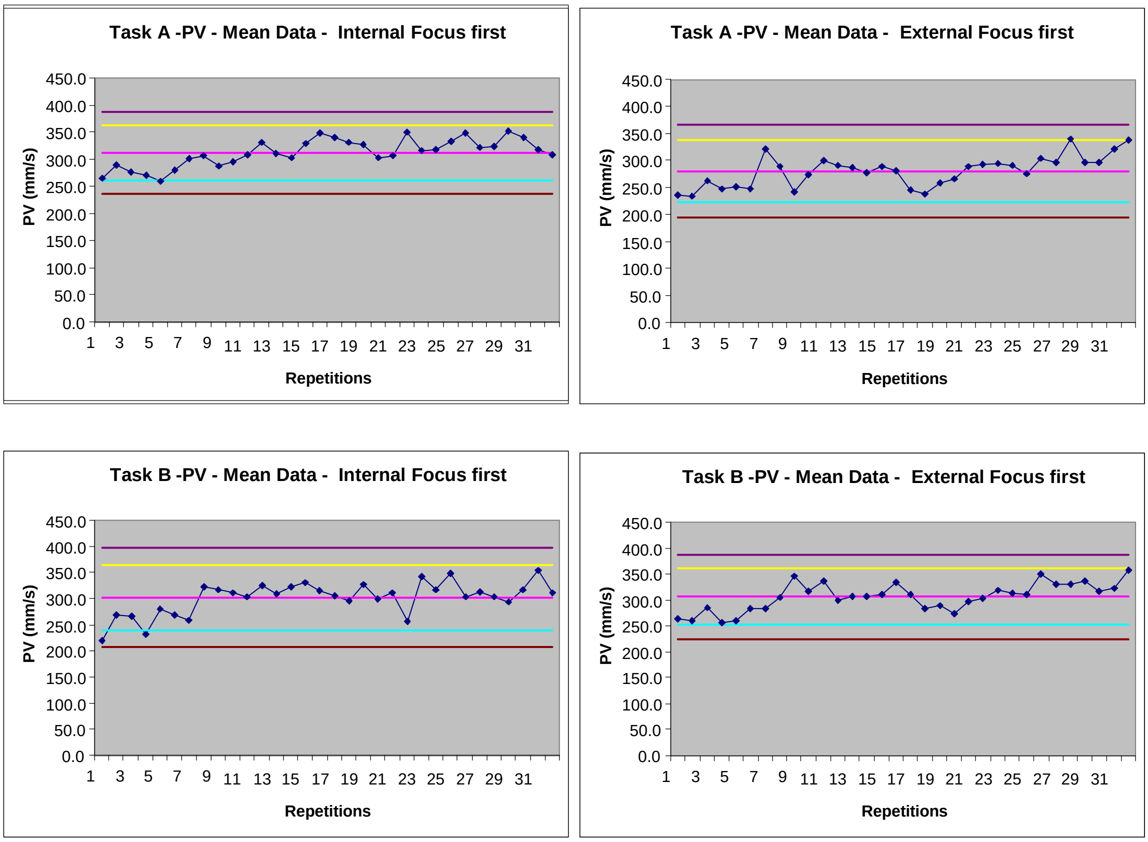
1. Group effect – Group 1 (IF/EF) vs Group 2 (EF/IF)

2. Period effect – whether the effect of condition was influenced by its placement in time (i.e. did the effect of condition A when delivered first vary from the effect of condition A when it was delivered second?)

3. Order effect – whether the first condition influenced the second condition

In this experiment the effect of group and order were the same as there were two orders and two groups. In order to assess the effect of group and order separately, the experiment would have needed an order AABB and BBAA. This would have equated to having two conditions of internal focus followed by two conditions of external focus and the reverse order. This was not done as it would have required more people with stroke and required each person to perform more trials in a session which may have exceeded the capability of some individuals.

Adopting a within-subject design warranted examination of all the possible causes of the effects found. The control charts visually represented the total effect of order, period and feedback type (see figure 5.2).



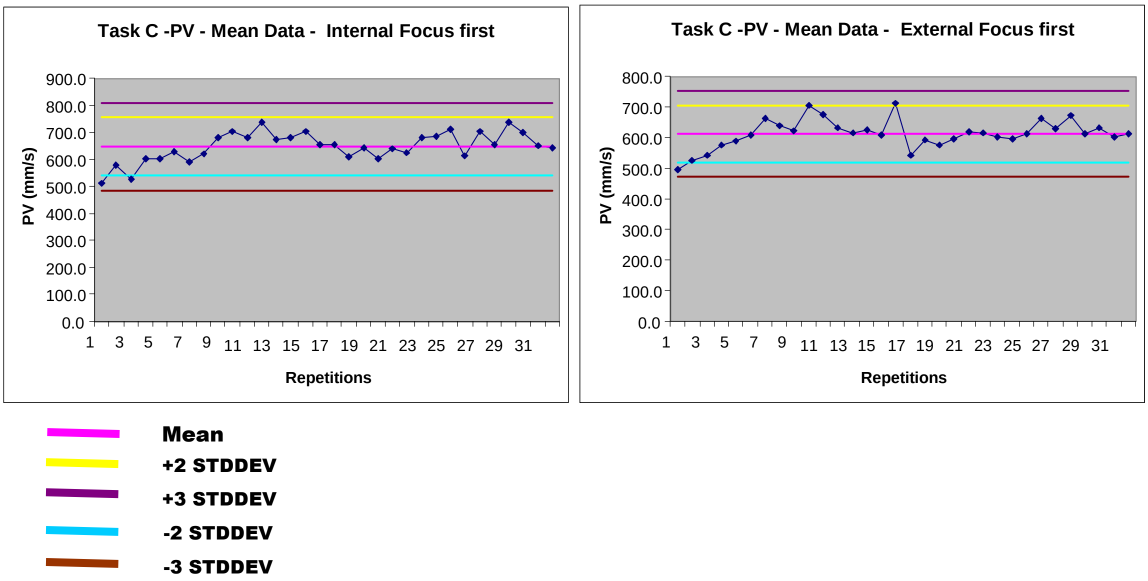


Figure 5.2 Control charts for Peak Velocity

Trends were visible within the graphs (see figure 5.2). The graphs showed progression from trial 1 to trial 32 with a small regression sometimes occurring between trials 16 and 17 where the feedback type was changed. To understand the nature of these observable trends all possible confounders were explored.

<u>Group effect</u>

An effect of group was excluded, that is practice, fatigue and learning effects were considered negligible. The assignment to group was randomized so it was feasible that between participants each had an equal chance to have a fatigue/practice or learning effect and any effect could therefore be negated from impacting on the outcome of the analysis.

<u>Period effect</u>

An interaction between period and the treatment conditions could not be completely negated, that is the effect of treatment varied dependent upon which period it occurred. The groups however were randomized so the mean response over the two groups was not expected to significantly differ. A main effect of period was also excluded theoretically. This was because the point in time when a condition was delivered was not considered to have influenced the data. Environmental conditions between the two time points was not considered to have had an effect, as period two followed period one after a rest of five minutes and the environment did not change during this period.

<u>Order effect</u>

One of the most challenging issues which can arise from within participant designs is the possibility of carryover otherwise known as an order effect (Hills & Armitage 1979). This is where the treatment applied in the first period effects the treatment given in the subsequent period. Distinguishing a carry over effect from treatment effects is considered difficult and is best dealt with through the implementation of measures at the design stage (Hills & Armitage 1979). Employing a sufficient 'washout' period, that is, the time between conditions is considered the most effective method to remove this confounder. A washout period of five minutes was introduced at the design stage of the study although it was not known whether a five minute washout period was sufficient so a main interaction of interest was that between feedback condition and order. An order effect of one type of feedback on the other was not expected a priori as there was no evidence in the literature to suggest this. However, this did not mean it was not present. Interaction line graphs were therefore plotted using the mean value of the last five trials for each of the outcome variables to examine this possible interaction further. The graphs showing an interaction can be found in appendix K (pp 273).

5.5.3 Consideration of statistical methods

The interaction graphs suggested an order effect (Appendix K), so order was factored into the statistical model. This was achieved by placing order as a between group difference in an analysis of variance. By applying order as a factor to the analysis model, it allowed for individual differences and incorporated order as a possible effect. It was therefore possible to determine whether one order was more beneficial than another. This was considered clinically important as Study 1 identified that therapists reported adopting one focus followed by another focus of attention in their clinical practice. The effects of the different feedback schedules on the outcome measures were therefore determined through a repeated measures analysis of variance, with feedback type (internal or external focus) as the repeated measure and order (internal or external focus first) as a between subject factor.

An alternative method would have been to analyse the first condition in each order which would have completely removed an effect of order as only the last five of the first 16 trials would have been used for the analysis. This alternative method would have provided a clear analysis of the first task, but this would not have been the case for the other two tasks, as both conditions had been performed before each task. Additionally analysing the first condition would have compared data between individuals which was not considered desirable considering the wide variation between the individuals which was the main reason a within subject design was adopted. Therefore this alternative method was not used.

Additionally statistical analysis was conducted to explore the influence of arm impairment and working memory. This was considered a valuable addition to the study as it had not been previously explored (please refer to chapter 6, data analysis section for more details).

The p value used for all outcome measures was set at 0.05, the same used for another pilot study (Woodbury et al. 2009).

Next the paper under review is presented detailing the findings of study 2.

CHAPTER 6 – PAPER SUBMITTED FOR REVIEW 'ATTENTIONAL FOCUS OF FEEDBACK FOR IMPROVING PERFORMANCE OF REACH-TO-GRASP AFTER STROKE – A PILOT STUDY'

Katherine Durham, Martin Edwards, Christine Wright, Catherine Sackley, Alan Wing, Paulette M van Vliet.

6.1 Abstract

Background: In healthy subjects, research has shown that feedback inducing an external focus of attention (about movement effects) produces better motor performance compared to feedback that induces an internal focus of attention (about body movements). To date, it is unclear whether this finding extends to people with stroke.

Objective: To examine whether feedback inducing an internal or external focus was more effective for performing reach-to-grasp after stroke.

Methods: Forty-two people with stroke performed three reaching tasks in an exploratory, counterbalanced, within-subject study. They were randomly assigned to two feedback order groups: Internal focus feedback (IF) first followed by external focus feedback (EF) or EF first followed by IF. Kinematic measures were collected using motion analysis. Primary outcome measures were movement duration, peak velocity of the wrist, size of maximum aperture and maximum elbow extension.

Results: Feedback inducing an external focus of attention produced faster movements (p=.008) and an increased percentage time to peak deceleration (p=.01), when performing the task 'placing a jar forwards onto a table', and an increased percentage time to peak velocity (p=.039), when performing the task 'reaching to grasp a jar', compared to feedback inducing an internal focus of attention.

Conclusions: Feedback inducing an external focus of attention has potential benefit for improving motor performance of reaching in people with stroke. Further investigation of the effects of the attentional focus of feedback is needed.

6.2 Introduction

When learning motor skills, feedback is vital to calibrate a motor response to the aims of the task (Sidaway et al. 2005) and can increase the level or the rate at which a skill is achieved. Intrinsic feedback processes can be disrupted after stroke (Hartveld & Hegarty 1996). Therefore, the use of extrinsic feedback could be important for people with stroke to learn basic components of a motor skill (Puttemans et al. 2004), improve movement efficiency (McCrea & Eng 2005) and improve consistency of performance (Mononen et al. 2003). When information feedback, that is skill relevant information about a performance attempt (Amorose & Weiss 1998), is given verbally, it can be directed to focus either on the body movement (internal focus) or on the effects of the movement on the environment (external focus) (Wulf et al 2002). For example, to encourage greater extension of the elbow in a reach-to-grasp movement, one could say ‘next time, straighten your elbow more’ (internal focus) or ‘next time, move closer to the jar’ (external focus). In healthy subjects information feedback which has induced an external focus of attention has consistently led to improved motor performance compared with adopting an internal focus (Shea & Wulf 1999; Wulf et al. 2002). In people with stroke, the effect on motor performance of using feedback with an external (EF) versus an internal focus (IF) is not known, but the effect of instructions inducing an external or internal focus has been investigated (Fasoli et al. 2002; Landers et al. 2005). For example, Fasoli et al. (2002) compared the effect of EF and IF instructions on movement kinematics in people with stroke during functional reaching tasks. The results were significantly shorter movement times and greater peak velocities during the EF condition, which they suggested indicated an improvement towards normal performance. It is not known whether this result for instructions also applies to feedback.

The findings that movement improvements occur from inducing an external focus have been explained by the ‘constrained action hypothesis’ (McNevin, Shea & Wulf 2003; Wulf, McNevin, & Shea 2001). This states that directing a person’s attention to their movements (with IF) causes conscious motor control. This is suggested to constrain the motor system and disrupt automatic control processes. In contrast, focusing on the movement effect (with EF) reduces a person’s ability to actively intervene in their control processes and consequently enables faster more efficient automatic movements. Another suggestion explaining the improved performance seen under EF conditions, is that there are smaller demands on working memory (Maxwell, Master, & Eves 2000; Maxwell & Masters 2002; Poolton et al. 2006). The ‘conscious processing hypothesis’ (Masters 1992) proposes that explicit knowledge about the movement impedes motor performance and places increased load on working memory. In relation to attentional focus it has been suggested that more working memory is required when inducing an internal focus, as information from both body movement and salient features in the environment needs to be processed, whereas with EF, only information from the environment is used (Maxwell & Masters 2002). Despite both of these hypotheses favouring EF for improving motor performance, some studies have also found a benefit from instructions inducing an internal focus in novice performers (without neurological deficit) (Beilock et al. 2002;Casteneda & Gray 2007;Ford, Hodges,& Williams 2005;Gray 2004;Perkins-Ceccato, Passmore, & Lee 2003). This was explained by novices requiring attention for each movement component of the task (Anderson 1983; Fitts & Posner

1967). It is possible that the level of motor impairment after stroke could influence the effectiveness of attentional focus on motor performance. It might be that with extensive motor impairment, the motor skills become ‘novice like’ and so benefits from feedback inducing an internal focus may be detected. It is worth acknowledging however that severe impairment after stroke may not necessarily equate to an early stage of learning associated with novices. The time since stroke and the extent of stroke need consideration. Where increased arm impairment is present, it could indicate an extensive stroke which may also affect working memory capacity. It could be that a potential benefit from focusing upon movement components maybe cancelled by the need to minimize the demand upon working memory.
In the brief review presented here, (section 1.5) the weight of evidence suggests adopting an external focus of attention produces more effective movement performance. It is not clear whether the benefit of the external focus of feedback extends to improving functional movements after stroke. It is also unknown whether the level of motor impairment and working memory capacity are influential factors. Therefore this pilot study aimed to compare the effect of feedback inducing an external focus of attention with that inducing an internal focus, on movement performance in people with stroke. The study did not aim to assess retention of changes in motor performance (motor learning). We hypothesized that feedback inducing an external focus (EF) of attention would differ from feedback inducing an internal focus (IF) of attention in improving motor performance of reach to grasp after stroke. Measures indicating motor control of reach-to-grasp (transport of the hand and opening and closing of the hand) and the amplitude of joint movements were used to describe motor performance in this study, since both of these aspects are important in the therapeutic context (Mirbagheri & Rymer 2008; Wagner et al. 2007). A secondary aim was to explore the influence of impairment level and working memory. We predicted an interaction effect where

the effectiveness of the focus used would moderate with the amount of arm impairment, so that feedback inducing either an internal or external focus would be more effective for people with stroke who have greater arm impairment. We also predicted participants with impaired working memory capacity would benefit more from either an internal or external focus of attention.

6.3 Methods

6.3.1 Participants

Forty-two stroke participants were consecutively recruited from stroke units and physiotherapy outpatient departments in five local hospitals by the primary author. Inclusion criteria for the study were an upper limb score between 19 and 61 on the upper limb section of the Fugl Meyer assessment which represented a lesser (19) or greater (61) degree of functional arm movement (Fugl-Meyer et al. 1975). Other criteria included being less than 18 months post stroke and being medically stable. Exclusion criteria were upper limb movement deficits unrelated to stroke, severe somato-sensory disturbance (less than 1 on the Erasmus MC modification to the revised Nottingham Sensory Assessment) (Stolk-Hornsveld et al. 2006) and receptive aphasia (less than 5 on the ‘receptive skills’ section of the Sheffield Screening Test for Acquired Language Disorders). Figure 6.1 details the recruitment process. Four healthy control subjects were recruited to provide comparison data. These participants were selected by their age and absence of neurological deficits or pathology related to the upper limb. Table 6.2 shows the demographic and clinical characteristics of the stroke participants.

Baseline assessments were conducted to characterise the population in terms of physical and neuropsychological impairment: Arm impairment - Upper limb section of the Fugl-Meyer scale (FM) (Fugl-Meyer et al. 1975). Participants were scored between 0-66 with 66 representing no observable arm deficits.

Sensation - The Erasmus modifications to the revised Nottingham Sensory Assessment (Stolk-Hornsveld et al. 2006) which included light touch, sharp/blunt, proproception and two-point discrimation with the first four sections being scored on a scale of zero to two.

The ‘receptive skills’ section of the Sheffield Screening Test for Acquired Language Disorders (Syder et al. 1993) was used to measure receptive impairment, an hierarchal measure with a maximum score of nine.

The Birmingham University Cognitive Screen (Humphreys et al. 2009) was used to assess attention, memory and apraxia. Each subsection was scored individually as being ‘spared’, ‘relatively spared’ or ‘impaired’.

The mini mental test (Hodkinson 1972) was used to measure mental impairment with a maximum score of 10. A score of less than seven out of 10 represented significant mental impairment (Hodkinson 1972).

A test for optic ataxia (Karnath & Perenin 2005) was used to determine if visual guidance of goal directed movements were impaired (Dijkerman et al. 2006).

Hospital anxiety and depression scale (Zigmond & Snaith 1983) used a 14-item questionnaire and measured both anxiety and depression on a scale of zero to three.

The Intrinsic Motivation Inventory (IMI) (Ryan 1982) was used to measure intrinsic motivation because it provided a multidimensional measure of a participant’s experience with regard to the experimental tasks. It required participants to mark 21 statements on a seven point likert scale with one representing ‘not at all true’, and seven ‘very true’. This was then scored to give an overall instrinsic motivation measure with a maximum score of 49, with a higher value representing increased motivation.

The Tardieu scale (Gracies et al. 2000) was used to measure spasticity and muscle contractures using a scale of zero to four with zero representing no spasticity.
The 10 hole peg test (Turton & Fraser 1986) was used to measure arm function and involved timing how long participants required to move 10 pegs forwards.
McGill short form pain questionnaire (Melzack 1987) was used to measure pain on a scale of zero to 10.

Sample size was decided based upon a power analysis using standard deviation estimates from a previous study with a similar stroke population (van Vliet et al. 1995). This analysis revealed that a study with 42 participants would have 95% power to detect a 50 mm.sec -1 difference in peak velocity of the wrist and a 1 second difference in movement duration and 80% power to detect a difference of 5% in percentage time of peak velocity %TPV ($p < 0.05$).

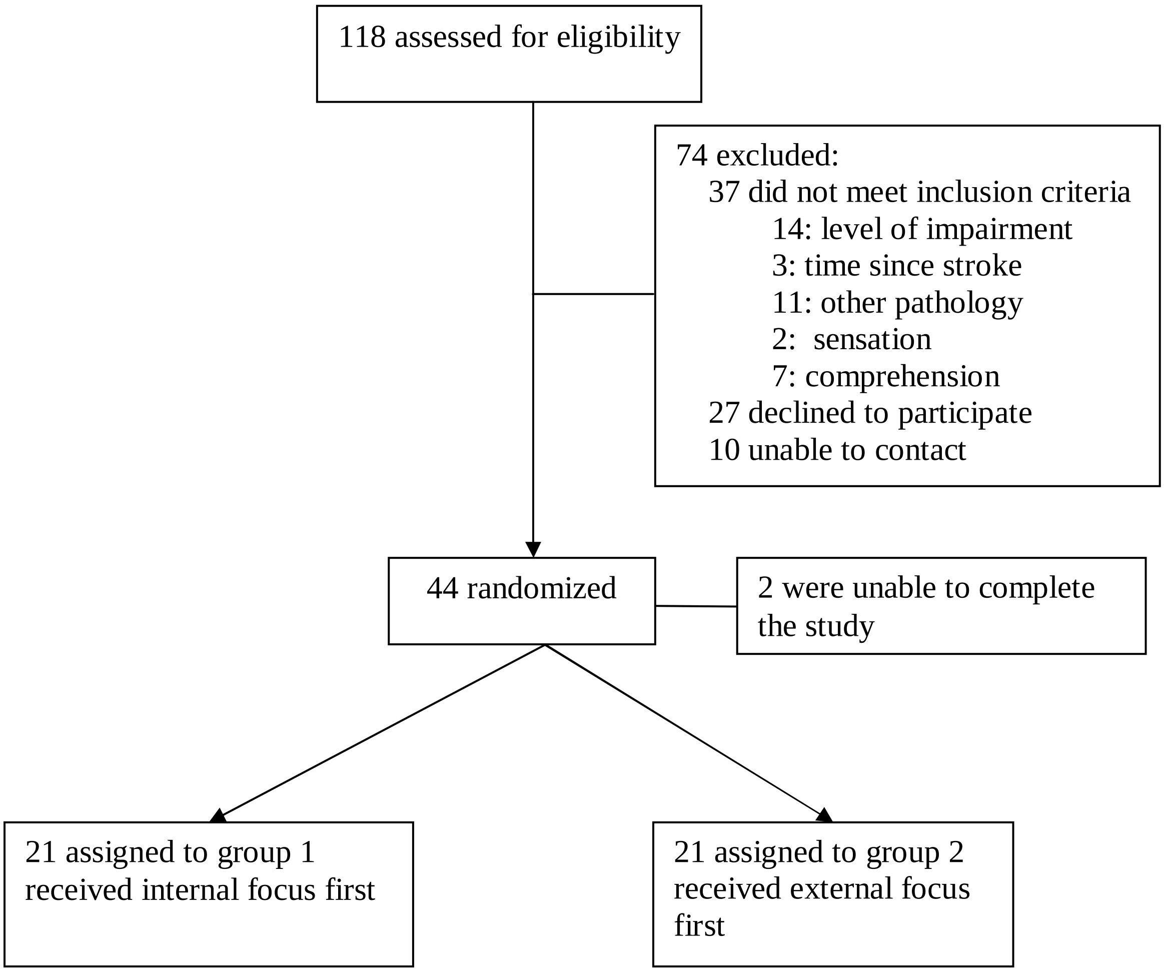


Figure 6.1 Flow of stroke participants for recruitment to the study

Table 6.1 Characteristics of stroke participants

Characteristic	Order 1 (n=21)	Order2 (n=21)
Age (years)	63 (13)	59 (14)
Time since stroke (months)	7.45 (5.58)	8.68 (5.59)
Side of lesion: Left (n=20)	11	9
Right (n=22)	10	12
Fugl Meyer (Max. score 66)	45.6 (13.3)	42.1 (16.4)
Sex: Male (n=30)	15	15
Female (n=12)	6	6
eNSA (Poor sensation =3)	1.18 (0.39)	1.05 (0.22)
SSTALD –receptive speech	7.27 (2.00)	7.86 (1.24)
Praxis (section of BUCS)	1.36 (0.66)	1.19 (0.40)
Long term memory (BUCS)	1.45 (0.74)	1.5 (0.63)
Attention (BUCS)	1.50 (0.80)	1.62 (0.86)
MMSE (Max. score 10)	8.60 (1.22)	8.54 (1.01)
Optic ataxia	1.70 (0.80)	1.56 (0.51)
Anxiety	5.95 (5.76)	4.81 (4.07)
Depression	5.95 (4.95)	5.70 (2.57)
Motivation	33.41 (9.87)	34.35 (7.53)
Tardieu (Spasitcity)	1.1 (0.30)	1.1 (0.20)
10-hole Peg test: Affected (n=11)	54 (42.00)	70 (45.00)
Unaffected (n=42)	18 (5.00)	17 (7.00)
Pain	1.5 (0.5)	1.6 (0.6)

Footnote: Order 1 = Internal focus first; Order 2 = external focus first; reported summaries are Mean (SD) except where specified otherwise

6.3.2 Design

Two feedback schedules, internal focus feedback and external focus feedback were delivered to participants using a counterbalanced repeated measures design. This design has been used successfully in other attentional focus research (McNevin & Wulf 2002;Vance et al. 2004;Zachry et al. 2005). Half the subjects received internal focus feedback first (Order 1), and half the participants received external focus feedback first (Order 2). All participants performed reaching movements under both feedback conditions. Each participant therefore served as his/her own control. Participants had a five minutes rest between conditions.

After measurement of baseline characteristics, participants were randomly allocated to an order group using a computer generated sequence (Figure 6.1). Each order group was additionally stratified on upper limb impairment and working memory to ensure the groups were balanced on these key characteristics. Arm impairment was classified according to the upper limb section of the Fugl-Meyer assessment with greater arm impairment defined as participants with a score of 44 and below, and lesser impairment defined as a score of 45 and above. This classification was determined from previous research (Cirste et al. 2003a;Cirstea & Levin 2000; Michaelsen, Dannenbaum, & Levin 2006). Working memory was classified using the auditory attention section of the Birmingham University Cognitive Scale (BUCS), with poor working memory being defined as a score of one or two and good working memory defined as a score of three (Appendix D pp 223).

Ethical approval for the study was gained from a local research committee and all participants gave written consent.

6.3.3 Tasks

In order to assess the effect of EF or IF on reach-to-grasp performance across a range of everyday tasks, three types of reaching tasks were performed: (A) reaching to grasp a jar; (B) placing a jar forwards onto a table and; (C) placing a jar on a 30cm wooden platform. Task A enabled assessment of the ability to transport the hand to an object, whilst opening and closing the hand. Task B enabled assessment of moving an object. Task C was included as a more challenging task for more able participants.

The combination of feedback order and tasks proceeded as follows: Task A: 16 trials with the first assigned feedback condition followed by a five minute rest, then 16 trials with the second feedback condition. Task B: 16 trials with the first assigned feedback condition followed by a five minute rest, then 16 trials with the second feedback condition. Task C: 16 trials with the first assigned feedback condition followed by a five minute rest, then 16 trials with the second feedback condition. A five to ten minute rest occurred between each task. Thus in total 96 reaches were completed by each subject, 16 for each type of feedback in each task.

The rationale for delivering both feedback types before changing to a new task was so that the effect of feedback type on each particular task could be assessed. Although this required the subject to switch their attention between the two feedback types, it was considered important that the participants experience both types of feedback whilst performing the one task.

6.3.4 Procedure

All movements were performed in a single data collection session. In all tasks, the jar was placed at 90% of arm's length to reduce the use of the trunk, but trunk movement was not restricted (Mark et al. 1997). Participants were seated at a table with their hips and knees at 90 degrees and elbow flexed to approximately 90 degrees. The starting position for task A was with the thumb and index placed together over a mark placed 15cm from table edge, in a midline position. For tasks B and C the participant started with the hand grasping the jar that was placed on the same 15 cm midline marker. If participants had difficulty grasping the jar in tasks B and C, assistance was given to place the hand around the jar. Participants performed up to three practice trials before each task. During this practice, the researcher observed the performance and chose a maximum of three components of reach-to-grasp to provide feedback about, selected from a predetermined list (Table 6.2). After practice, to understand attention preference, the participants were asked: 'Whilst performing that (those) movement(s) what did you find yourself focusing on (thinking about)?' with a prompt as required 'did you find yourself focusing more on your arm (body movements), or the jar (task relevant cues within the environment) or a mixture of the two?' Each task was then performed in the assigned order, so that both feedback conditions were received before moving onto the next task. A feedback statement was given after each trial. On the last five trials of each set of 16 trials, the feedback statements from that set of trials were combined. To check whether the participants followed the allocated external focus or internal focus feedback, the question used to establish attentional preference was repeated (manipulation check) at the end of each 16 repetitions. A physiotherapist experienced in training reach-to-grasp movements delivered the feedback. For each internal focus feedback statement, there was an equivalent external focus statement. All feedback statements are shown in Table 6.2.

Five external cues were placed within the environment to provide reference points for the tasks and to complement the feedback statements: tape was placed from the start position to end position of the jar to indicate hand path, stickers were placed on the jar and thumb for opposition feedback, a sticker was placed 10 cm ahead of the start marker for grasp timing feedback, and a marker was placed on the wooden platform to indicate where the jar should be placed. A straw was attached to the wrist and was present in both conditions. In the external focus condition the purpose was to improve wrist extension whereas in the internal focus condition the straw was placed just above the wrist.

Table 6.2 Feedback statements

Desired body movement	Internal focus	External focus
Trunk (E)	This time I would like you to try and stretch your arm rather than move your body forward (demo of mvt coming from arm not the body)	This time you need to keep close to the chair behind (demonstration is given) as you move the jar forwards
Shoulder (F)	This time as you reach can you think about lifting your arm up higher	This time as you reach forwards think about being higher off the table
Shoulder (ER) and adduction	Bring your arm straight ahead rather than across your body/out to the side	Do you see the tape I have just placed on the table? (tape placed vertically between start and endpoint) Try to follow it.
Elbow (E)	This time as you reach further forwards you need to straighten your elbow more.	This time try and reach closer to the jar
Wrist E	As you bring your arm forwards try and bring your wrist back as well	With this straw I have taped on, can you ensure you keep close to it as you approach the jar. (flexible straw on dorsum of hand, taped to wrist – and straw bent to required amount of wrist extension)

Desired body movement	Internal focus	External focus
Fingers (E) (amount)	This time try and open out your fingers wider as you bring you arm forwards	This time open out wider in preparation for the jar
Finger (F)	Try and grip with your thumb and ALL of your fingers (demonstrate without jar)	To grip well you need to curl around the jar more (demonstration is given with jar)
Thumb (abd) during transport	This time try to open out your thumb wider as you bring your arm forwards	This time open wider as you move to the jar
Thumb (abd) at jar	This time try and get your thumb right the way around to form a good grip	This time try to open as wide as you can to encompass the jar (Demonstration is given with the jar)
Thumb (opposition)	Next time try to get firm contact with the pad of your thumb (indicate pad of thumb)	Next time try and get the two stickers to touch (sticker on the jar and sticker on pad of thumb)
Grasp (amount)	This time try and get more contact with your fingers and thumb so you have a firm grasp	This time try and encompass the jar fully to make it more secure
Speed	This time can you bring you arm forwards faster	This time can you move faster to the jar

Desired body movement	Internal focus	External focus
Accuracy	So this time aim for the hand closing to be as precise as possible	So this time can you grasp the jar as accurately as you can?
Smoothness	This time can you try to keep your hand moving smoothly through space as you bring it forwards	This time can you try to keep the jar moving smoothly through space as you bring it forwards
Coordination at start	Next time, as you start to bring your arm forwards try and open your fingers out (demonstration is given)	Next time when you pass this marker can you be opening out more in preparation for the jar (demonstration is given and marker is indicated)

6.3.5 Data collection

A motion analysis system (Qualisys ™) was used to collect kinematic data from reaching movements using four infrared cameras. Seven reflective markers were placed on the hemiplegic arm: 10 mm distal to the bicipital groove, 40 mm lateral to the lateral epicondyle, 100 mm distal and 10 mm medial to the line connecting the shoulder and elbow markers, the radial styloid, 10 mm medial to the midpoint between the elbow and wrist markers, distal and medial to the thumbnail, distal and lateral to the nail of the index finger. Three markers were placed on the trunk on a rigid body, 50 mm apart, with the superior marker placed 10 mm distal to the sternal notch. One marker was also centralised on the jar lid.

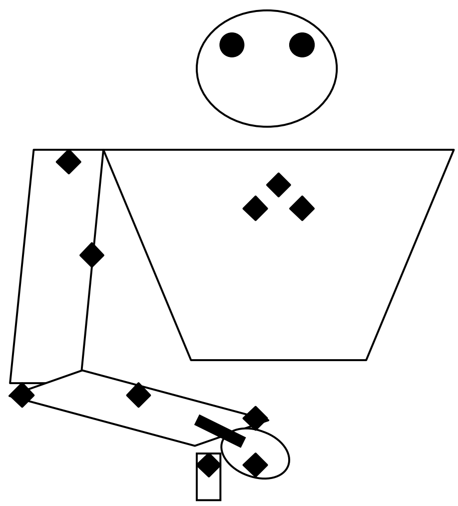


Figure 6.2: Schematic representation of the placement of the reflective markers and straw

The accuracy of the Qualisys system was measured using a previously established method (Haggard & Wing 1989). The axes were aligned such that the xy defined the horizontal plane with x aligned with the shoulders, and z defined the vertical axis. The accuracy of the system was measured as 0.0058 mm for static spatial error and 0.3606 mm dynamic spatial error.

6.3.6 Outcome Kinematic Measures

Outcome measures were chosen to describe the motor control of reach-to-grasp, and also to describe the amplitude of joint angle movements. Motor control measures included movement duration, peak velocity, time to peak velocity (TPV), time to peak deceleration (TPD), percentage time to peak velocity (%TPV) and percentage time to peak deceleration (%TPD), to describe the transport component; peak aperture size, time to peak aperture (TMA) and percentage time to peak aperture (%TMA) to describe the grasp component, temporal coupling (correlation) of TPD to TMA as an indication of coordination between transport and grasp components and the path deviation of the wrist to describe movement smoothness. The amplitude of joint movements was described by peak elbow extension, peak shoulder flexion and peak trunk flexion. Primary outcome measures were maximum movement duration, peak velocity, maximum elbow extension and peak aperture (task A only).

6.3.7 Data Analysis

Kinematic data was digitally filtered at 10Hz using a dual pass Butterworth filter. The movement onset for each trial was defined as the time when the 3-D resultant velocity of the wrist first exceeded 25 mm/s for five consecutive frames. The movement endpoint was defined as the maximum 2-D resultant displacement of the wrist in the horizontal plane and was used to avoid the potential issue of participants stopping during a reaching movement. For the primary outcome measures, movement duration was defined as the time between movement start and end, peak velocity was defined as the maximum 3-D resultant velocity of the wrist between the movement onset and endpoint calculated through the first derivative of wrist position, and peak aperture was defined as the maximum distance between the thumb and index finger markers. Maximum elbow extension was calculated using Euler angles. Using the sequence x-y-z, the angle formed between the forearm with respect to the humerus was calculated with maximum elbow extension taken as the measure about the x-axis between movement onset and endpoint. The coordinate system measurements corresponded to x axis representing the line perpendicular to the plane formed by the wrist and elbow, the y axis represented the direction of travel of the arm and was perpendicular to the x axis. The z axis was vertical and perpendicular to the x and y axes. Additionally maximum shoulder flexion was calculated from the angle formed between the humerus and trunk using the sequence x-y-z with maximum shoulder flexion taken as the measure about the x axis, between movement onset and endpoint. Trunk flexion was calculated as the maximum angle formed between the trunk and the global coordinate system around the x axis, between movement onset and endpoint, with the x axis representing the frontal plane of the body. Peak velocity, peak deceleration and maximum aperture were also expressed as percentages of total movement durations (%TPV, %TPD, %TMA). Path deviation of the wrist was measured as the maximum displacement of the wrist in the y-axis relative to the straight line path.

6.3.8 Statistical analysis

SPSS version 17 was used for all statistical analyses with the significant level set at $p < 0.05$.

Comparison of feedback conditions

A repeated measures analysis of variance was conducted, with feedback type (internal or external focus) as the repeated measure and order (internal or external focus first) as a between subject factor. Analyses were conducted on mean values for the last five trials for each condition. A 3-way ANOVA was conducted on impairment level (high or low Fugl-Meyer score), feedback type and order of feedback to explore the influence of impairment level, and a 3-way ANOVA was conducted on working memory capacity (good or poor working memory as determined by the BUCS), feedback type and order of feedback to explore the influence of working memory capacity. All analyses were conducted for each outcome variable.

<u>Manipulation check</u>

Frequencies of the predominant attentional focus used for each task and condition, as reported by participants from the manipulation check question were calculated.

<u>Order effects</u>

Order effects were not expected a priori as there was no evidence in the literature to suggest that order of feedback would have an effect on performance. However, the experimental design adopted made an order effect theoretically possible and therefore order was included as a factor in the analysis of variance comparing feedback conditions.

Control data was analyzed using a repeated measures analysis of variance with one factor as the repeated measure (first and second set of the last five trials in each task).

6.4 Results

6.4.1 Baseline characteristics

Table 6.1 show similar baseline characteristics in each order group.

6.4.2 Stroke subjects

The motor control measures indicated that external focus feedback produced faster movements than internal focus feedback in Task B ($F_{1,40}$ = 7.927, p=.008). In order 1 the mean movement duration when feedback induced an internal focus was 2.53 seconds compared with 2.12 seconds where feedback induced an external focus of feedback (table 6.3). This 0.41 seconds difference represented a 16 % improvement under the external focus condition.

External focus feedback increased percentage time to peak velocity in Task A ($F_{1,40}$ = 4.539, p=.039) and increased the percentage time of peak deceleration in Task B (F1,35 = 7.405, p=.01), more than internal focus feedback. Means responses for all motor control measures and amplitude of joint movements are presented in Tables 6.3 and 6.4.

Table 6.3 Results of Motor Control Measures (mean and standard deviation)

		MD (s)	PV mm/s-1	Aperture (cm)	TPV (s)	%TPV	TPD (s)	%TPD	TMA (s)	%TMA	Deviation of Wrist (mm)
IFA	Order 1	2.96	321	9.91	0.55	22.00	0.78	33.90	1.570	55.00	18.19
	(IF1)	(1.84)	(143)	(2.79)	(0.30)	(8.70)	(0.33)	(14.00)	(1.42)	(25.70)	(10.23)
	Order 2	3.11	317	10.1	0.82	26.60	1.13	41.60	1.75	65.50	17.85
	(IF2)	(1.95)	(177)	(2.78)	(0.63)	(8.90)	(0.76)	(16.30)	(1.61)	(19.30)	(10.00)
EFA	Order 1	2.96	333	9.81	0.62	26.40	0.86	38.10	1.38	63.90	18.10
	(EF2)	(1.88)	(181)	(2.82)	(0.42)	(10.40)	(0.47)	(13.50)	(0.90)	(21.50)	(9.81)
	Order 2	3.06	286	9.99	0.87	28.50	1.27	43.50	1.75	63.10	18.98
	(EF1)	(1.86)	(158)	(2.78)	(0.78)	(11.00)	(0.93)	(15.20)	(1.74)	(22.60)	(11.19)
Control	1st set	1.28	424	10.76	0.33	27.70	0.54	44.90	0.62	52.90	19.25
		(0.29)	(44)	(0.82)	(0.06)	(4.40)	(0.07)	(4.90)	(0.09)	(10.60)	(8.66)

		MD (s)	**PV mm/s-1**	**Aperture (cm)**	**TPV (s)**	**%TPV**	**TPD (s)**	**%TPD**	**TMA (s)**	**%TMA**	**Deviation of Wrist (mm)**
IFA	Order 1	2.96	321	9.91	0.55	22.00	0.78	33.90	1.570	55.00	18.19
	(IF1)	(1.84)	(143)	(2.79)	(0.30)	(8.70)	(0.33)	(14.00)	(1.42)	(25.70)	(10.23)
	2nd set	1.14	462	10.73	0.33	31.30	0.55	52.50	0.60	57.30	28.25
		(0.30)	(51)	(0.71)	(0.05)	(4.04)	(0.06)	(3.50)	(0.08)	(6.90)	(4.27)
IFB	Order 1	2.53	301		0.79	27.70	0.95	37.20			18.16
	(IF1)	(1.85)	(205)		(0.79)	(11.60)	(0.87)	(16.00)			(9.79)
	Order 2	2.35	322		0.58	24.50	0.85	37.00			18.00
	(IF2)	(1.18)	(139)		(0.41)	(9.50)	(0.53)	(10.5)			(10.23)
EFB	Order 1	2.12	324		0.61	28.60	0.90	44.30			15.50
	(EF2)	(1.63)	(172)		(0.45)	(11.40)	(0.60)	(15.00)			(9.00)
	Order 2	2.27	321		0.70	26.90	1.00	41.00			16.46
	(EF1)	(1.11)	(126)		(0.62)	(10.60)	(0.80)	(13.10)			(8.42)

		MD (s)	PV mm/s-1	Aperture (cm)	TPV (s)	%TPV	TPD (s)	%TPD	TMA (s)	%TMA	Deviation of Wrist (mm)
IFA	Order 1 (IF1)	2.96 (1.84)	321 (143)	9.91 (2.79)	0.55 (0.30)	22.00 (8.70)	0.78 (0.33)	33.90 (14.00)	1.570 (1.42)	55.00 (25.70)	18.19 (10.23)
Control	1st set	1.02 (0.15)	497 (83)		0.34 (0.02)	33.80 (2.90)	0.55 (0.08)	54.40 (4.50)			15.00 (4.55)
	2nd set	1.05 (0.22)	486 (76)		0.39 (0.09)	39.00 (7.90)	0.60 (0.09)	58.20 (7.70)			18.50 (6.61)
IFC	Order 1 (IF1)	1.64 (0.80)	714 (283)		0.52 (0.35)	30.40 (8.60)	0.72 (0.40)	42.70 (11.20)			18.10 (8.67)
	Order 2 (IF2)	2.13 (1.19)	620 (222)		0.71 (0.53)	43.80 (12.60)	1.13 (0.79)	43.80 (12.60)			20.57 (6.45)
EFC	Order 1 (EF2)	1.82 (1.19)	680 (259)		0.80 (0.94)	36.70 (17.3)	1.04 (0.91)	49.10 (16.4)			17.54 (5.39)

		MD (s)	PV mm/s-1	Aperture (cm)	TPV (s)	%TPV	TPD (s)	%TPD	TMA (s)	%TMA	Deviation of Wrist (mm)
IFA	Order 1	2.96	321	9.91	0.55	22.00	0.78	33.90	1.570	55.00	18.19
	(IF1)	(1.84)	(143)	(2.79)	(0.30)	(8.70)	(0.33)	(14.00)	(1.42)	(25.70)	(10.23)
	Order 2	2.35	639		0.65	41.80	0.96	41.80			20.90
	(EF1)	(2.14)	(240)		(0.38)	(12.80)	(0.58)	(12.80)			(5.81)
Control	1st set	1.13	773 (79)		0.40	35.70	0.57	51.80			19.50
		(0.24)			(0.09)	(7.20)	(0.10)	(11.80)			(2.65)
	2nd set	1.09	781 (46)		0.36	33.20	0.58	53.80			19.50
		(0.17)			(0.10)	(10.20)	(0.10)	(12.20)			(2.52)

Footnote: EFA = external focus task A; EFB = task B; EFC = task C; IFA= internal focus task A; IFB =task B; IFC = task C; EF1 =external focus presented first; EF2 =external focus presented second; IF1 =internal focus presented first ; IF 2= internal focus presented second

Table 6.4 Amplitude of Joint Movements (mean and standard deviation)

		Elbow F (degrees)	Sh F	Tr F
IFA	Order 1 (IF1)	125	31	8
		(32)	(10)	(7)
	Order 2 (IF2)	130	26	11
		(22)	(9)	(5)
EFA	Order 1 (EF2)	125	31	9
		(35)	(10)	(7)
	Order 2 (EF1)	121	26	11
		(29)	(9)	(5)
Control	1st set	138	36	2
		(7)	(7)	(1)
	2nd set	139	35	2
		(8)	(7)	(1)
IFB	Order 1 (IF1)	128	31	8
		(36)	(11)	(5)
	Order 2 (IF2)	139	29	10
		(19)	(9)	(6)
EFB	Order 1 (EF2)	125	31	10
		(36)	(11)	(5)
	Order 2 (EF1)	138	26	11
		(21)	(10)	(6)

		Elbow F (degrees)	Sh F	Tr F
Control	1st set	141	34	6
		(8)	(9)	(2)
	2nd set	138	35	6
		(7)	(10)	(3)
IFC	Order 1 (IF1)	130	48	6
		(28)	(14)	(3)
	Order 2 (IF2)	136	46	9
		(22)	(10)	(6)
EFC	Order 1 (EF2)	128	49	6
		(27)	(13)	(2)
	Order 2 (EF1)	133	46	8
		(18)	(9)	(4)
Control	1st set	133	61	4
		(9)	(2)	(1)
	2nd set	136	60	4
		(12)	(1)	(2)

Footnote: EFA = external focus task A; EFB = task B; EFC = task C; IFA= internal focus task A; IFB =task B; IFC = task C; EF1 =external focus presented first; EF2 =external focus presented second; IF1 =internal focus presented first ; IF 2= internal focus presented second

Three significant interaction effects between feedback and order were found when external focus was preceded by internal focus for: movement duration for task B ($F_{1,34} = 6.158$, $p=.018$), maximum aperture task A (%TMA) ($F_{1,33} = 4.569$ $p=.04$) and time to peak deceleration for task C ($F_{1,40} = 6.596$ $p=.017$). The interaction showed external focus was more beneficial when it was preceded by internal focus. There were no other significant main or interaction effects.

6.4.3 Control subjects

There was no difference between tasks for healthy control subjects on all outcome measures except peak velocity and %TPD in task A. In task A, peak velocity significantly increased between the mean of the last five from the first set of trials (set 1) and the mean of the last five from the second set of trials (set 2) by 38 mm/sec, and %TPD task A there was a 7.6% significant increase between set 1 and 2.

Individual feedback statements were used at different frequencies and are presented in table 6.5.

Table 6.5 Frequency of feedback statements used

Feedback statement topic	Task A	Task B	Task C
Trunk (E)	18	8	6
Shoulder (F)	11	12	5
Shoulder (ER) and adduction	10	8	12
Elbow (E)	11	15	7
Wrist (E)	1	2	0
Fingers (E) (amount)	6	1	0
Finger (F)	0	2	0
Thumb (abd) during transport	0	0	0
Thumb (abd) at jar	4	5	0
Thumb (opposition)	2	0	3
Grasp (amount)	23	9	6
Speed	23	27	21
Accuracy	0	3	3
Smoothness	4	11	3
Coordination at start	4	0	0
Total	117	103	66

Footnote: E = extension ; F = flexion; ER = external rotation ; abd = abduction

6.4.4 Manipulation check

The manipulation check revealed that 17% of participants stated that they focused their attention as directed. Thirty-one percent of participants reported using their preferred attentional focus: Fifty-four percent reported to prefer an internal focus, 23% an external focus and another 23% preferred using a combination of both types. Another 35% reported using a combination of both internal and external focus of attention and 17% reported attending to the opposite focus to the one directed.

6.4.5 Effect of Severity

No significant differences were found between the effect of inducing feedback with an internal and external focus in participants with greater or less arm impairment.

6.4.6 Effect of working memory

No significant differences were found between the effect of inducing feedback with an internal or external focus in participants with good or poor working memory.

6.5 Discussion

The main aim of the study was to examine the effect of external compared with internal focus of feedback on reaching performance in people with stroke. The results found some support for feedback inducing an external focus of attention was more effective than feedback inducing an internal focus of attention. The null hypothesis that there would be no difference between the two feedback types was therefore rejected. First, feedback inducing an external focus of attention produced shorter movement duration in task B. An increased movement duration has been negatively associated with performing activities of daily living (Archambault et al. 1999; Cirstea, Ptito, & Levin 2006b; Kamper et al. 2002) and as stroke participants moved between two and 2.5 seconds, over one second slower than healthy control subjects, who moved with a mean time of 1.03 seconds, a reduction in movement duration found by inducing an external focus is likely to be clinically significant. For example a 16% reduction in movement duration in task B in the external focus condition could in real terms influence the risks associated with carrying a cup filled with a hot drink. It is possible that lessening the time taken to carry a cup both lessens the time which a possible spill could occur as well as possibly reducing the work rate required to execute the task.

Second, feedback inducing an external focus of attention produced an increased percentage time to peak deceleration in task B and an increased percentage time to peak velocity in task A. This indicated that less time was spent in the deceleration phase. People with stroke tend to extend the deceleration phase of reach-to-grasp movements, in order to utilise on-line correction, therefore a decrease in time spent in the deceleration phase represents a change towards a more normalised mode of control with increased reliance on a pre-planned movement pattern (Wu et al. 2007).

In a related study, Cirstea et al. (2007) compared feedback about the movement outcome (Knowledge of Results-KR) with feedback about movement performance (Knowledge of Performance - KP). KR and EF feedback are similar but not identical – KR can be a measure such as movement duration, which could be interpreted as EF (e.g. time taken to reach a target in the environment), but KR could also take the form of a score such as an error value, which is not related to the actual goal or environment, and therefore could not be said to have an external focus. Similarly KP can have an internal focus, for example joint angle information, but could also have an external focus, for example feedback could be given about the amount of shoulder internal rotation and abduction occurring in reach-to-grasp by the number of times an object on the table was accidentally knocked over. Notwithstanding these differences, the findings of Cirstea et al. (2007) have relevance for this study. The KP group were given feedback about shoulder flexion and elbow extension and improvements were observed in the angular motion at these joints. The present study also contained feedback about shoulder flexion and elbow extension, but no improvements in these variables were observed. It is probable that many repetitions are needed to obtain these improvements as participants in the Cirstea et al. study practised 75 repetitions per day, five days per week, for two weeks. Also, the KP group was able to significantly reduce movement duration compared to a control group who practised a non-reaching task. In the present study, participants were able to reduce movement duration within a single practice session, so it appears possible to achieve these gains more quickly than changes in joint angles. Interestingly, in our study, movement duration was shorter in the external focus condition, in contrast to the study by Cirstea et al. (2007), where the type of KP information given could be regarded as having an internal focus, as it was related to movement of body parts.

In the current study, the benefit from external focus feedback was accentuated when it was preceded by internal focus. It is possible that people with stroke required information about how to perform the task, and also feedback that encouraged an external focus. As use of implicit information has been found to be impaired after stroke (Boyd & Winstein 2001), explicit information gained through inducing an internal focus may have therefore provided some benefit from that of adopting an external focus which is thought to elicit less explicit information (Maxwell & Masters 2002). Therefore, the internal focus might have comprised of explicit information which was first integrated and then used to promote implicit processes during the external focus condition.

Previous studies have examined whether the most beneficial attentional focus type varies with experience (Beilock et al. 2002; Casteneda & Gray 2007; Ford et al. 2005; Gray 2004; Perkins-Ceccato, Passmore & Lee 2003) with the suggestion that where automatic movement have yet to be developed focus upon the movement components may improve performance. No difference was found between internal and external focus in participants with greater arm impairment in this study.

The benefit of adopting an external focus has been reported to be due to reduced cognitive demands (Maxwell & Masters 2002, Poolton et al. 2006). Maxwell & Masters (2002) found less explicit knowledge is formed when adopting an external focus, when the focus is on the task, compared with internal focus, where the focus is both on the execution of the skill and the task, suggesting inducing an external focus requires less working memory. No difference was found between internal and external focus in participants with either good or poor working memory in this study.

Not all measures showed differences between conditions. This may be accounted for by a number of possibilities. Firstly, visual feedback was available to participants which in some circumstances may have been a sufficient source of feedback (Ford et al. 2009). Ford et al. (2009) compared inducing instructions in healthy subjects with either an internal or external focus both with and without vision. They found a benefit for EF only when vision was obscured. Another possibility was that differences were seen only in the movements most frequently trained in participants (Zentgraf & Munzert 2009). Feedback statements pertaining to speed were used most frequently which matched the most striking finding of reduced movement duration when an external focus was induced (Table 6.5). Another possibility is that some participants may not have grasped the distinction between feedback types (Durham et al. 2009) or may have reverted back to their preferred attentional foci as indicated from the manipulation check and seen elsewhere (Wulf, Shea & Park 2001, Maxwell & Masters 2002).

6.5.1 Study Limitations

The design of this study allowed the effect of different focus of attention in feedback to be seen in motor performance, but did not allow retention of any change in motor performance to be assessed. To assess retention, a future study would require random allocation of participants to the two feedback interventions, with a retention test included some time after the intervention has ceased. A transfer test could also be included, to assess whether what has been learned can be transferred to a different, but related task. Within the randomised controlled trial design, it would also be possible to double the number of movement trials in a single session, as each participant would have to perform under only one of the feedback conditions.

The presence of an order effect in the data is a limitation. The cause of this order effect was considered to be because one condition influenced the second condition. Other sources of order effects were ruled out as they were accounted for within the design. For example sufficient rests were implemented and both conditions were performed under the same circumstances. Another study examining the attentional focus of instructions in people with stroke found order interactions when using a counterbalanced design but were unable to distinguish the cause of the effect (Fasoli et al. 2002), whilst others studying healthy subjects report no order effects (McNevin & Wulf 2002), and some, examining healthy subjects and subjects with neurological deficits failed to report any effects (Canning 2005; Landers 2005; Landers et al. 2005; Wulf, Wallmann & Guadagnoli 2005; Wulf et al. 2004; Wulf 2008; Wulf & Su 2007; Zachry et al. 2005).

Future studies would benefit from a rigorous method of assessing adherence to the directed feedback. This will be a challenge as previous attempts to clarify this issue have often been disappointing, with Maxwell & Masters (2002) suggesting that subjects use attentional foci interchangeably despite clear direction.

Stroke participants were considered representative of the stroke population, with upper limb scores between 19 -61 on the upper limb section of the Fugl-Meyer. This broad inclusion, however, resulted in increased variability amongst paritipants, which could have limited the observed effects.

6.5.2 Conclusions

Feedback inducing an external focus compared with inducing an internal focus improved motor performance after stroke in some outcome variables.

The benefit of external focus was accentuated when it was preceded by internal focus.

Internal focus did not improve performance compared to external focus in participants with greater arm impairment.

The suggestion that the effects of external focus could be attributed to working memory, rather than external focus per se, was not upheld.

These findings have potential implications for therapists using feedback in training reach to grasp following stroke but further research is necessary to establish the robustness of the findings.

CHAPTER 7: IMPLICATIONS FOR PRACTICE, LIMITATIONS AND FUTURE RECOMMENDATIONS

7.1 Introduction

This thesis explored the focus of attention therapists induce when providing feedback whilst retraining arm function after stroke. It also examined whether feedback inducing an external focus was more effective compared with feedback inducing an internal focus during the performance of reach to grasp after stroke. Additionally the influence of the level of arm impairment and working memory on the delivery of feedback and attentional focus type was explored. This was achieved in two main ways. First a mixed methods study, study 1, was carried out which included observing how therapists direct their patient's focus of attention when retraining reaching after stroke. Next a quantitative study, study 2, was undertaken which examined the effects of two types of feedback conditions: feedback inducing an internal or external focus of attention, during the performance of reach to grasp after stroke. The influence of arm impairment and working memory impairment on attentional focus type was also explored. This chapter discusses the main findings of these studies, and considers possible explanations for the results found and the implications for practice. In addition the limitations of the studies are described along with recommendations for future research.

7.2 Synthesis of study 1

7.2.1 Infrequent use of feedback

The first study found that therapists used verbal feedback infrequently. Instead more emphasis was given to the use of instructions. One explanation for this finding could be that feedback may have been inherent in the task, so therapists may have felt additional feedback was unnecessary.

For example one of the video recordings collected showed a therapist asking a patient to pick up and stack cones upon each other. Verbal feedback about success was not provided to the patient, but the task provided visual feedback which may have been considered sufficient. Visual feedback however requires an individual to be able to interpret the information received, using mechanisms which may have been affected by stroke, so reliance upon visual feedback may be insufficient.

The presence of visual, cognitive and perceptual impairments may mean that information feedback is more necessary for people after stroke. It is considered important that individuals are made aware that an error has been made which needs correcting. Without this awareness individuals may appear de-motivated "to change their response on the next trial" (Hodges & Franks 2002). It is possible therefore that therapists may perceive improved motivation to participate when providing information feedback as it provides individuals with the awareness an error has been made and a change is required. The perception of therapists was that information feedback provides negative information and so was used infrequently being replaced by providing further instructions.

7.2.2 Use of instructions

Like Parry (2005), study 1 found that instructions were used frequently by therapists. Instructions usually provide information before a movement whereas information feedback provides information pertaining to the movement just completed (Mulder 1991). Instructions can be used to indirectly give feedback. For example where instructions are used to suggest changes to a subsequent movement, it can be considered feedback (Wulf et al. 2002). The important difference between instructions and feedback is whether individuals are aware that a change to the movement is required. Instructions are viewed as providing information less directly (Parry 2005). This may be useful particularly where associated impairments such as depression and anxiety exist after stroke (Rijntjes 2006). These individuals may experience low self esteem and may interpret information as criticism. This in turn would affect motivation leading to reduced performance (Kluger & DeNisi 1992). Of the people with stroke who participated in the first study, only three of the eight had any notable problems with depression (BS02, MF03, DM07) and two of these same participants with anxiety (BS02, DM07) (Appendix F). The presence of depression and anxiety therefore does not explain the preference of therapists to use instructions over feedback. This less direct approach to providing information may have meant that some individuals, particularly those with significant cognitive and perceptual problems, (MF03, RE05) may not have acquired the necessary information to improve their movement. The information may not have been sufficiently clear that a change to their movement was required.

The finding that physiotherapists use instructions more frequently than verbal feedback is not new (Niemeijer et al. 2003;Parry 2005). Niemeijer et al. (2003) found physiotherapists gave instructions frequently and feedback infrequently. However, the feedback given was generally positive and may relate to the view of therapists in study 1 which placed high importance with maintaining a positive relationship with their patients.

7.2.3 Statements of motivation

The importance placed upon maintaining a positive therapeutic relationship was evident from the video recordings, therapist interviews and questionnaire. Short statements classified as statements of motivation for example: ‘that’s it’, ‘good’, ‘well done’ comprised between 29-40% of the information provided during the video recordings (Chapter 3, table 3.2 pp 75). One therapist in her interview stated ‘with neuro-patients sometimes you might want perfection but you don’t get it, so it is important to encourage people if they are going in the right direction’ (BS02). Another commented, with reference to the feedback used, ‘That’s it, Well Done, Good, that’s exactly what we’re looking for, keep it up. That would be the sort of thing I would use’ (DM07). In total six therapists in their interviews made specific reference to the importance of motivating their patients. From the questionnaires 5 therapists, when asked to provide commonly used feedback statements gave examples such as ‘good’. This finding was not surprising. ‘Rehabilitation professionals consider motivation to engage in rehabilitation to be an important determinant of rehabilitation outcome’ (Demain et al. 2006), and therefore emphasis was placed upon developing and maintaining a positive environment within rehabilitation, with the communication style reflecting this (Maclean et al. 2000;Maclean et al. 2002).

The use of verbal encouragement does have merits. It has been found to have a positive effect on motor performance both in healthy subjects (Kilduski & Rice 2003) and in people with impaired hand grip (Desrosiers et al. 1998). Interestingly however Kilduski & Rice (2003), where study participants were learning an isometric force task, did not find the benefit of encouragement transferred to learning compared to other styles of feedback. On retention trials, when the feedback was absent, using statements such as ‘a little too hard’ ‘good,’ were found to be no more beneficial than when visual information about the force used was given. Information feedback was not however used in the study which limits the applicability of the findings to the results of the current study. Encouragement is thought to personalize and increase the learner’s motivation (Kilduski & Rice 2003). It can be associated with competence which can increase engagement with a task (Allen & Howe 1998;Amorose & Weiss 1998), all which can in turn increase the amount of practice of a task, an important variable in motor learning (Platz et al.

2001). Additionally where patients have difficulty processing detailed information, encouragement may have a place.

So there is some suggestion that there could be a place for using statements of motivation however the use of verbal encouragement has been associated with limited improvement compared with information feedback (Fredenburg Lee & Solmon 2001). Fredenburg, Lee & Solmon (2001) found that in complex tasks information feedback was more beneficial than providing encouragement and this supports other findings where no correlation has been found between effort to increase motivation and performance level (Mouratidis 2008). Others suggest maintaining positivity in the information provided to learners is important particularly in tasks considered difficult (Mouratidis 2008;Tzetzis et al. 2008). Information feedback can be phrased positively and has been found to be effective in improving performance (Amorose & Weiss 1998;Kernodle & Carlton 1992). Information feedback phrased positively has the benefit of offering individuals the perception of doing well in addition to being informative (Amorose & Weiss 1998).

7.2.4 Predominance of inducing an internal focus of attention

The main aim of study 1 was to explore the attentional focus therapists induced when providing feedback whilst retraining arm function after stroke. This was extended to include the attentional focus of instructions as only between 8-19% of the video recordings included information feedback. Instructions and feedback can induce either an internal or external focus of attention. Study 1 explored whether an internal or external focus predominated in the instructions and feedback used by therapists. The results from study 1 showed that where feedback was used it predominantly induced an internal focus of attention. This finding was similar to that found by

Niemeijer et al (2003) who found that when motor performance was less skilled in children with a developmental coordination disorder, the physiotherapists tended to comment on the movements pattern, which is akin to information with an internal focus. It is unclear which focus of attention of feedback is most effective to use in the neurologically impaired.

7.2.5 Influence of associated impairments

The range of impairments after stroke can be considerable. Taken together with individual personal factors it is possible that these factors were influential in study 1 with regard how information was presented and also how it was interpreted (Appendix F). All the therapists reported in their interviews that they adjusted their communication according to the patient's individual requirements. For example, due to one individual's recent shoulder sprain the therapist reported that she was trying to "decrease the pain from the sprain in his shoulder so that could have been why I was focusing more internally" (DM07).

People who experience high anxiety have been found to focus on both self relevant and task relevant variables (Wine 1971). Two patients were classified as anxious according to 'HAD' scores (BS02,DM07) (Bjelland et al. 2002) in the first study. In these individuals it would therefore be appropriate to minimise negative feedback, in order to minimise the risk of increased scrutiny of self movements (Kluger & DeNisi 1992). Providing the information in the form of praise, may not however offer the desired effect, as praise has also been associated to cause focus upon the self (Kluger & DeNisi 1992), which can be considered to be indirectly inducing an internal focus of attention. A therapist however reported "I tend to try and use positive reinforcement continuously so they feel good about coming down and feel that they are achieving something" (GS08). Not only may this strategy not be useful in the attentional focus it may induce, such an approach may also have been interpreted as evidence that the movement solution is working, which may reduce the likelihood of the individual attempting to change the movement (Goodman et al. 2004). A fine balance regarding information content however is required as thoughts of doing badly have also been associated with focusing more on the self (Hutchinson et al. 2008). It could be that the use of corrective feedback which focuses on the change required in a positive way could be a way forwards.

Many therapists reported being unaware of the focus of attention they used. It was possible that information was provided 'more as routine than as a result of careful consideration' (Talvitie 2000), which was supported by one therapist saying *'I suppose I'm not always conscious of every word I'm saying, a lot of it is just spontaneous and comes out'*(CB04). As a result it may be that therapists were indirectly inducing an internal focus of attention with their frequent use of praise and statements of motivation.

7.2.6 Limitations of study 1

The limitations to the study have previously been reported in Chapter 3, with the main issue surrounding the generalisability of the findings. In addition it is worth considering the influence of people willing to consent to research. These people may have acted and perceived events differently from individuals who would not partake in research. It is also worth noting that a clustering effect around Birmingham may have existed with the different therapists being trained by the same individuals which may have exaggerated the main findings. It did however provide a detailed and useful insight into how participating therapists and patients viewed their therapy interactions.

7.2.7 Summary of study 1

The main findings from study 1 were:

- Therapists preferred to use instructions and statements of motivation over information feedback.
- The instructions and information feedback used predominantly directed attention towards the body movements (internal focus).
- The focus of attention therapists reported to have used often did not match the actual focus of attention used, neither did it consistently match with patients reported preferred focus of attention.

7.3 Synthesis of Study 2

Study 2 aimed to examine whether feedback inducing an external focus of attention was more effective compared with feedback inducing an internal focus of attention during the performance of reach to grasp after stroke. The findings of study 2 provided some support for the benefit of providing feedback which induced an external focus of attention compared with feedback which induced an internal focus of attention in some aspects of motor control. This finding was in line with the work of Wulf and colleagues and other authors (Freedman et al. 2007;Lohse, Sherwood, & Healy 2010;Marchant, Clough, & Crawshaw 2007) who found inducing an external focus of attention improved performance in healthy subjects (Shea & Wulf 1999, Wulf, Hobb & Prinz 1998, Wulf, Lauterbach & Toole 1999) and in people with neurological deficits (Fasoli et al. 2002;Landers et al. 2005).

The reasons surrounding why a benefit of inducing an external focus of attention was found will be discussed. This will be followed by discussing the findings which explored the influence of the level of arm impairment and working memory on the different focus of attention used during the performance of reach to grasp. Finally suggestions about why support for adopting an external focus of attention was not found across all outcome measures used will be made as well as limitations to the study, clinical significance of the studies, recommendations for future work and final conclusions.

7.3.1 Support for adopting an external focus of attention in stroke rehabilitation

The most compelling finding from study 2 was that providing feedback which induced an external focus of attention produced faster movements, as indicated by the movement duration data from task B, compared to feedback which induced an internal focus of attention. This finding was in line with Fasoli et al. (2002) who found reaching tasks were faster under the external focus condition and Weiss et al. (2008) who found healthy subjects were able to complete a basketball throw faster, when given instructions with an external focus (Weiss et al. 2008). Both these previous studies however related to the provision of instructions opposed to feedback, thus the current study adds new information pertaining to feedback. The reasons behind this finding can be explained by research which has found that adopting an external focus of attention encourages an automatic response, as demonstrated by reduced reaction times (Wulf et al. 2001a), increased frequency of movement (McNevin et al. 2003; Wulf et al. 2001a; Wulf et al. 2004), reduced EMG activity (Marchant et al. 2008; Marchant et al. 2009; Vance et al. 2004; Wulf et al.2004; Zachry et al. 2005) and increased force production (Wulf et al. 2007; Wulf et al. 2010, Marchant et al. 2009) when adopting an external focus of attention. Higher frequency movement adjustments, when adopting an external focus of attention, has been associated with coordinating additional degrees of freedom within a movement which has been associated with more skilled, autonomous movements (McNevin et al. 2003). Adopting an external focus of attention is thought to promote more effective agonist and antagonist coupling (McNevin et al. 2003). This proposed improved sensorimotor integration is relevant to people with stroke as muscle co-contraction is a common occurrence (Carr & Shepherd 2003).

The findings related to more efficient recruitment of muscles in healthy subjects when adopting an external focus of attention (Marchant et al. 2009; Marchant et al 2008; Vance et al. 2004; Wulf et al. 2010) could be transferrable to people with stroke, and could account for the improved movement duration seen in study 2. Efficient muscle activation when an external focus of attention was induced could account for the movement to occur over a shorter timeframe.

Given the literature detailing the benefits of increased force production when adopting an external focus of attention, the expectation would have been to see an increased peak velocity under the external focus condition. This was not however observed in this experiment.

It is possible that under the external focus condition, the movements were more economical, with less energy expenditure requirements (Marchant et al. 2011). This could be clinically relevant to people with stroke as more efficient movements would cause less muscle fatigue which could positively impact upon the amount of repetitions an individual can perform, an important variable for motor learning (Enebo & Sherwood 2005). These mechanisms which underlie the benefit of adopting an external focus of attention have been supported by fMRI findings which have shown higher activation in the primary somatosensory area, primary motor cortex and insular cortex when adopting an external focus of attention (Zentgraf et al. 2009). This activation under an external focus of attention, which integrates sensory and motor signals, more strongly underpins the proposition that an external focus of attention promotes more automatic movement, in line with the constrained action hypothesis (Wulf et al. 2001a).

7.3.2 A temporal component to attentional focus

The finding that inducing an external focus of attention improves movement duration suggests a temporal factor in the reasons why using an external focus of attention is beneficial. With regard to the pair of feedback statements ‘move towards the jar faster’ for the external focus condition and ‘move your arm forwards faster’ for the internal focus condition, the jar is further away from the body than the arm. It is possible that as the jar is further away, the feedback statement inducing an external focus of attention promoted faster movements compared with the feedback statement which induced an internal focus of attention. This suggestion concurs with Wulf et al. (2000), experiment 1, which involved a tennis task. A benefit was found when focus was upon the ball leaving the tennis racquet compared with the tennis ball approaching the tennis racquet. Again it can be argued that the ball leaving the racquet occurred temporally later than the ball approaching the racquet. Both examples align with the suggestion that ‘it should make a difference if the focus of attention is directed to an aspect of the movement which is temporally closer to the effect’ (Hegele & Erlacher 2007, p.21) and therefore the focus of attention which is greater in distance from the body, an external focus, will provide improved movements.

7.3.3 Interaction between order and condition

The findings from the second study also demonstrated an order effect in four measures (please refer to Chapter 6, results, ‘order effect’). Interestingly where the order effect was found it always reflected support for the proposition that the benefit of external focus is enhanced when it was preceded by internal focus (Appendix K). This finding was interesting in that it supported the view of five therapists in study 1, who in their interviews reported that they provide internal focus information followed by external focus information. For example from the first study one therapist said they began with focusing on the ‘movement and then (go) to the goals’ (JB06). This new finding of a benefit of adopting an external focus of attention is enhanced when preceded with an internal focus of attention implies that disruption to the motor pathways after stroke, may change the most beneficial type of attentional focus of feedback, compared to that found to be beneficial to healthy subjects. Thus, although feedback inducing an external focus improved some measures of motor performance, there may be a benefit in preceding external focus feedback with that which induces an internal focus.

Another study has found order interactions when using a counterbalanced design but were unable to distinguish the cause of the effect (Fasoli et al. 2002), whilst others report no order effects (McNevin & Wulf 2002) and some failed to report about such effects (Canning 2005; Landers et al. 2005; Wulf et al. 2004; Wulf 2008; Wulf & Su 2007; Zachry et al. 2005). It is possible however that the benefit of external focus when preceded by internal focus is valid particularly in the stroke population. If for example a motor programme has not yet been established, in the early stages of learning, it could be that information pertaining to the movement components required for the task is necessary to allow the motor programme to become established (Hodges & Franks 2002). Inducing an internal focus of attention has been associated with providing information explicitly (Maxwell & Masters 2002). This may be necessary in people with stroke as implicit learning has been found to be impaired where there is no explicit knowledge available (Boyd & Winstein 2001). Initially directing focus upon the body movements, may therefore provide information in a way which individuals can use to promote automatic movements (Maxwell & Masters 2002).

7.3.4 External focus of attention and low level of skill

There is contention within the attentional focus literature regarding the effect of an individual's level of experience in performing a task and the benefits of adopting either and internal or an external focus of attention. Therefore, the influence of impairment level on the different attentional focus conditions during the motor performance of reach to grasp after stroke, study 2, was explored. The results from study 2 found no interaction between level of impairment and attentional focus. That is, the hypothesis that proposed adopting an internal focus of feedback compared with an external focus would benefit participants with greater arm impairment, was not upheld. This finding should be interpreted cautiously due to the small sample size. With a sample size of 42, it was likely to have required a large change in the outcome measures used to demonstrate a significant difference (Ottenbacher 1995). The absence of an interaction between level of arm impairment and attentional focus aligns with the findings of Wulf & colleagues. Wulf and colleagues have consistently found that adopting an external focus of attention is beneficial to skill acquisition in both subjects novice to a task (Wulf, Hobb & Prinz 1998, Wulf, Lauterbach & Toole 1999, Wulf et al. 2000,Wulf Shea & Park 2001, Shea & Wulf 1999, Wulf et al. 2004) and subjects experienced in the task being examined (Wulf et al. 2002: Wulf & Su 2007; Wulf 2008).

Findings in contrast to the body of evidence have however been found. Beilock et al. (2002), Perkins-Ceccato, Passmore & Lee (2003), Ford, Hodges & Williams (2005), Gray (2004), Castaneda & Gray (2007), all found that healthy subjects who were classified as being low skilled in a task, benefited most when they focused upon the movement itself as opposed to the movement effects. This research suggests that learning of the fundamental movement pattern along with the appropriate parameterization is first required (Shea & Wulf 2005), which is likely to require an internal focus of attention.

The long accepted view has been that less skilled individuals, likened to people with greater arm impairment after stroke, although not necessarily always the case, (see chapter 6 p.139) require step by step knowledge of the movements needed to perform a task, which often relate to the body movements, hence inducing an internal focus of attention (Anderson 1982;Fitts & Posner 1967). It is this traditional view which has established itself both in the coaching and rehabilitation setting (Wulf et al. 2002). This could explain the dominance of inducing an internal focus of attention found in study 1 as the required steps of a task are commonly related in terms of body movements (IF) instead of movement outcome (EF).

Traditional theories of learning have described a progression from dissociative information, providing knowledge of the steps required to perform a task, to a stage where movements become automatic (Anderson 1982, Fitts & Posner 1967). This view suggests novices and experts require different information to maximize learning, and has some support (Beilock et al. 2002, Perkins-Ceccato, Passmore & Lee 2003,Ford, Hodges & Williams 2005). For example, in the second experiment, a soccer dribbling task carried out by Beilock et al. (2002), it was found subjects novice to the task benefited from focusing upon the skill, which in this example was focusing upon the side of the foot which came in contact with the ball, instead of subjects who were distracted from the task by being asked to perform the dribbling task while performing a secondary auditory-word-monitoring task. In a similar experiment, Ford, Hodges, Williams (2005) found that subjects less skilled at performing a dribbling task, found focusing attention upon the foot, did not interfere with performance outcome, whereas interference was caused in the skilled subjects. Perkins-Ceccato, Passmore & Lee (2003) concluded that focusing upon the movement when performing a golf pitch shot was more beneficial in the less skilled subjects as it produced less variable results.

The suggestion that differences exist between novices and experts and how they approach a task is not new. Automatic movements have been reported to be a feature of successful performance in experts (Anderson 1982;Singer et al. 1993). On this basis Singer, Lidor & Cauraugh (1993) considered whether novices could act more like experts to improve performance. A 'Five Step Approach' for skill development was devised which incorporated both body awareness and non awareness components. The study found novices were able to successfully adopt strategies associated with experts in a ball throwing task. This finding supported the view of Gentile (1998) who acknowledged that although novices need to develop a movement structure, this can be achieved through focusing on the goal, i.e. novice performers do not require body awareness to improve performance. This research suggests adopting an external focus of attention is more beneficial to subject's novice to a task. This view is further supported by research which has examined the influence of attentional focus at a muscular activity level and reaction times. These studies have found that muscles responded more quickly (Wulf, McNevin & Shea 2001) and more selectively (Lohse, Sherwood, & Healy 2010;Marchant, Greig, & Scott 2009;Marchant, Greig, & Scott 2008;Vance, Wulf, Tollner, McNevin, & Mercer 2004;Wulf, Dufek, Lozano, & Pettigrew 2010;Zachry, Wulf, Mercer, & Bezodis 2005)(Lohse, Sherwood,& Healy 2010; Marchant et al. 2009; Marchant et al. 2008; Vance et al. 2004; Wulf et al 2010; Zachry et al. 2005) when adopting an external focus of attention. Both factors are associated with skill, which suggests adopting an external focus of attention is more beneficial regardless of skill level.

Overall greater support exists for adopting an external focus of attention irrespective of skill level based upon the weight of evidence, and the absence of an interaction found between attentional focus type and skill level in this study.

The question therefore is why is there conflict within the literature regarding the most beneficial focus of attention in individuals new to a skill? Firstly it is worth noting that the literature contradicting the benefit of adopting an external focus of attention in novices does not directly compare internal with external focus of attention. Many of these studies used a dual task paradigm where subjects were distracted from focusing upon their body movements. The addition of a secondary task to act as a distraction would have increased processing demands, which would have made the tasks more challenging, particularly for the less skilled, although this potentially may have supported the use of adopting an external focus as it is associated with requiring less processing capacity (Maxwell & Masters 2002). Providing distraction through the use of a secondary task does not mean individuals would have necessarily focused upon movement effects. This is important as Wulf et al. (2000) found it was the focus upon the movement effects which is beneficial to learning, not distraction from the body movements. Commonality between these studies can however be found when the terminology used within the studies, are examined. For example, although Wulf and colleagues support the benefit of focusing upon movement effects, one paper, Wulf et al. (2000), experiment 2, found a benefit to focus on a target nearer to the body (golf club compared with ball trajectory). This apparent discrepancy can be used to understand the small body of research which contradicts the benefit of external focus in less skilled subjects. These authors have associated focus towards the body as inducing an internal focus of attention. For example Beilock et al. (2004) instructed subjects to ‘monitor their swing and attempt to keep their club head straight as it travelled towards the target’ (Beilock et al. 2004). This can be likened to inducing an external focus of attention as focus was mainly directed upon what the golf club head was doing. The paper however reported it as focusing upon the skill. Both Wulf et al. (2000) and Beilock et al. (2004) appear to have found similar results, although have drawn different conclusions.

7.3.5 Influence of distance of focus of attention

The debate surrounding the most beneficial focus of attention in the less skilled can be resolved by the findings of Casteneda & Gray (2007). They included the influence of the distance of attentional focus which can be used to clarify the attentional focus effects in motor performance. Casteneda & Gray (2007) examined the effect the distance of attentional focus had on less skilled baseball players. Like Wulf et al. (2000), experiment 2, it was found that the less skilled subjects benefited more from focusing closer to the body compared with focusing upon movement effects. Additionally Casteneda & Gray asked participants to focus upon the body (internal focus) and focus upon baseball bat, a near external focus. Only a slight benefit to adopting an external focus (baseball bat) compared with an internal focus (body) was found. Taken together it appears that skilled players benefit more from distant effects and less skilled from more proximal effects, a view shared by others (Hegele & Erlacher 2007;Pesce et al. 2007). The distance between the different feedback styles in study 2 was small and may account for no differences being detected between attentional focus type and arm impairment level.

7.3.6 Attentional focus and working memory

In addition to impairment level, the influence of working memory impairment on the benefits of adopting either an internal or an external focus of attention on the performance of reach to grasp was explored, to provide clarification regarding why adopting an external focus of attention is beneficial. Working memory was chosen to allow comparison with Poolton et al. (2006) who suggested the level of working memory could account for attentional focus effects. Additionally it is not well understood how different impairments may require different approaches (Pomeroy & Tallis 2002). The intention was to explore the suggestion proposed by Poolton et al. (2006) that attentional load can explain the effects seen when adopting an external focus of attention. Working memory can operate 'as a temporary information store and manipulator of explicitly accessible information allowing movements to be monitored and modified 'online''(Poolton et al. 2005). It was therefore hypothesised that the level of working memory would influence performance when adopting a different focus of attention, such that inducing an external focus of attention in participants with poor working memory would be more beneficial compared to the induction of an internal focus of attention in the performance of reach to grasp after stroke. Therefore individuals were stratified according to working memory capacity to explore whether it had any influence on how they performed with the different feedback conditions. It was predicted that focusing externally would reduce the demands upon the compromised memory system. The exploratory study however found there was no interaction between the level of working memory and attentional focus type. The level of working memory did not influence the benefit of external focus so the hypothesis that inducing an external focus of attention in participants with poor working memory would be more beneficial compared to the induction of an internal focus of attention was rejected. This finding however should be interpreted with caution due to the small sample size. It did however suggest a contrary finding to that found by Poolton et al. (2006).

Poolton et al. (2006) used a golf putting task and provided healthy subjects with either internal focus instructions, swing of the hands, or external focus instructions, swing of the putter head. No difference was found between the groups, immediately after practice and during a retention test. However, an external focus of attention was found to be more beneficial on a transfer task where subjects were required to perform a secondary counting task in addition to the golf task. This was interpreted as when an internal focus of attention was used it caused attentional overload. This explanation was supported by a second experiment, where using the same task, subjects were provided with an equal number of rules pertaining to the task, which either induced an internal or external focus of attention. The results found no difference between the conditions suggesting it was not focusing externally which was beneficial but rather the amount of information which needed to be processed.

7.3.7 Complexity of the task may influence attentional focus effects

It is proposed that the tasks used in study 2, and those used in other studies, such as Wulf et al. (2002), where a benefit to adopting an external focus of attention has been found could explain the different conclusions drawn with those proprosed by Poolton et al. (2006). For example, it was possible that no differences were found between the groups of individuals with different working memory capacity and attentional focus type because the reaching tasks did not require a complex solution. This was demonstrated by the calculated index of difficulty for the tasks: 1.54 and 1.63 respectively (chapter 5, section 5.4.5). An index difficulty of below 4.58 has been associated with the tasks being executed through a pre-planned strategy and therefore would not have placed increased demands upon working memory (Wallace & Newell 1983). Working memory capacity has been found to become a factor where a complex solution is required (Beilock & DeCaro 2007). Poolton et al. (2006) used a golf task, which required a complex movement solution. Lander et al. (2005) also only found a benefit to external focus instructions in the most challenging balance task. Although it could be argued that some of the people with stroke in study 2 had a pre-planned strategy available, study 2 also used corrective feedback, that is, feedback statements which contained specific information about how to correct the movement. This may have guided the individuals about the required movement change such that it reduced the number of cognitive processes required (Jodi,Goodman & Wood 2004). Study 2 may therefore not have found a benefit to adopting an external focus of attention compared with an internal focus of attention in individuals with poor working memory in the performance of reach to grasp as the reaching tasks used may not have been sufficiently demanding for the individuals. The nature of the task may also relate to how quickly the effect of one attentional focus type over another would become evident. For example complex tasks may demonstrate a benefit towards adopting an external focus of attention more quickly, with changes seen after only five practice trials. For example, the study by Wulf, Lauterbach & Toole (1999), which used a golf task, found an immediate improvement when adopting an external focus whereas Wulf, Hob & Prinz (1998) who used a stabilometer task, which could be described as less complex, only demonstrated a benefit to adopting an external focus of attention on retention trials.

7.3.8 Theories to explain the benefit of adopting an external focus of attention

Potential mechanisms which cause the apparent benefit of inducing an external focus of attention can be suggested based upon the results of the study 2. Previously several different theories have been proposed, some directly associated with the effects of attentional focus (Wulf, McNevin & Shea 2001; Poolton et al. 2006) as well as those closely associated with the attentional focus literature (Masters 1992, Hardy, Mullen et al. 2001, Deikman 1966, Hossner & Ehrlenspiel 2007). These theories are summarised below:

The constrained action hypothesis (Wulf, McNevin & Shea 2001;McNevin, Shea & Wulf 2003) states that an internal focus of attention promotes conscious control of movements, interfering with automatic motor control processes which would normally control the movement, whereas external focus is thought to allow movements to be executed more automatically, without the interference from conscious control and so promote motor learning.

The attentional threshold hypothesis (Hardy et al. 2001), proposes attentional capacity problems causes the breakdown in performance, particularly evident when individuals are under pressure. The results of the second study align more with the constrained action hypothesis rather than the attentional threshold hypothesis as movements were faster under the external focus condition which suggested that the movements were performed more automatically. This was further supported by the findings from the exploratory studies, which found no difference between attentional focus type and working memory capacities. The constrained action theory has however come under some criticism for not providing sufficient detail to explain some of the nuances in the literature (Bund, Weimeyer, & Angert 2007).

It is therefore useful to examine other theories and propose factors which would benefit from consideration in future attentional focus theories. One proposition is that the tasks used within the experiment may not have been sufficiently challenging to test the limits of working memory. It is possible in the event of a more complex task or challenge to working memory that a different finding may have been found. Opposing views to each other have also been reported by authors regarding the influence of attentional capacity. For example Gucciardi & Dimmock (2008) did not find attentional capacity to cause performance decrements whereas it has in another study (Hodges & Lee 1999). Hodges and Lee (1999) examined the capacity of working memory by giving one group of healthy subject's specific instructions and found improved performance to another group who received general instructions. However when a secondary task was added, the specific instruction group performed worse than the general instruction group. This suggested that specific information improved performance within the capacity of working memory, but when the working memory threshold was reached, when another task was added, performance decreased.

Another group of hypotheses, including the conscious processes hypothesis (Masters 1992), deautomatization of skills hypothesis (Deikman 1966) as cited by Mullen (2007), or the explicit monitoring process (Beilock & Carr 2001) all basically propose that the cause for the breakdown of a skill under psychological stress is due to consciously controlling movements. These theories relate to the adoption of an internal focus of attention as both discuss focus upon the components of the movement.

One hypothesis could be that feedback inducing either an internal or external focus of attention can to some extent be regarded as increasing conscious movement control. Adopting an internal focus however, is considered to induce conscious control by focusing upon the step by step components required within a performance, whereas adopting an external focus is thought to present the information in more global terms, often related to movement effects (Guacciardi &

Dimmock 2008). It is possible that ‘global forms of conscious processing maybe less detrimental to performance as they place fewer demands on working memory thereby allowing implicit knowledge of the task to be processed automatically’ (Guacciardi & Dimmock 2008) so where explicit knowledge of a task is required, such as when feedback is provided, it supports inducing an external focus of attention.

Another suggested reasons for the benefit of adopting an external focus of attention is the ‘Nodal-point hypothesis’ (Hossner & Ehrlenspiel 2006). This is ‘based on assumptions that movements are controlled by the anticipation of their sensory effects’ (Ehrlenspiel 2007). This hypothesis proposes that where movement effects can be reliably predicted, individuals benefit from focusing upon the end effect. Where individuals are less skilled and require information about how to develop the movement, so movement effects can be predicted, intermediate effects are required. This hypothesis appears to advocate adopting an external focus of attention for more skilled individuals but suggests a different focus for less skilled individuals. It could be that this difference relates to whether individuals benefit more from adopting a distal external focus, upon the movement effects, or from adopting a more proximal external focus, for individuals who require information that relates to the desired movement form.

7.3.9 Lack of difference between conditions on some outcome measures

Some outcome measures did not find a benefit of adopting an external focus of attention. This warrants discussion with suggestions to why this occurred.

Was the verbal feedback used by participants?

Some of the people with stroke who participated in the second study may not have used some of the verbal feedback provided as they were able to gain the information from other sources within the environment. For example participants with less arm impairment may have been able to acknowledge and use the visual feedback available, as they may have retained many of their intrinsic feedback mechanisms, of which visual feedback is one. This was a possibility as a minority of participants were measured as having sensory (5/42) and perceptual problems (11/42) (Appendix I). It was possible that these participants may have executed the task through existing performance routines (Mullen 2007) rather than using the feedback given. This however may have been have resulted in reduced performance, as the information provided to specifically address individual impairments may not have been acted upon. It is possible that some of the feedback only offered subtle improvements, which may have reduced the participants' perceived importance of the information.

Individual factors

Movement impairments after stroke are typically caused by decreased cortical input but as some individuals were a long time since the onset of their stroke, secondary changes may have been present. This was seen in the results obtained from the Tardieu scale, (Appendix I) with 14 participants displaying significant spasticity in one or more muscle group. Indeed it has been suggested that progress after stroke may reflect which mechanisms are dominant at each time point (Mirbagheri & Rymer 2008). Some individuals within this study may have had factors such as muscle length issues which would not have changed with the type and duration of the treatment given, which could account for no change seen in some measures, for example the amplitude of joint angles.

The number of reaching movements performed

It is possible that too few repetitions of the reaching tasks may have been performed to demonstrate a difference between conditions. Study 2 required 96 reaching movements to be performed, and although other studies have found reduced movement times with up to 55 repetitions in subjects with severe hemiparesis, compared with approximately only 20 in healthy subjects, (Cirsta, Ptito & Levin 2003), this study only used 16 trials per condition for each task. This was chosen to explore the transferability of attentional focus across different tasks, although this relatively low number of trials for each condition may explain why a more uniform benefit of adopting an external focus of attention was not found. It is worth noting however that Fasoli et al. (2002) had people with stroke practise eight trials under each task condition with 48 reaches in total being performed and similarly Lang et al. (2005) required only three repetitions of each condition. Both studies however revealed significant differences in kinematic performance between conditions. This example suggests 16 reaches per condition should have been sufficient. Fasoli et al. (2002) however used more difficult reaching tasks, using less severe stroke participants, as the inclusion criteria included subjects being able to complete all the reaching tasks. Subjects included therefore were likely to possess less arm impairments to those adopted in this study.

Feedback statements

The external focus feedback statements used in this study focused upon the skill of reaching. The close proximity between the two conditions may have resulted in non-significant differences being found, similar to Casteneda et al. (2007). Casteneda et al. (2007) found that when instructions were focused upon the skill, either with regard the body movments or the movement of the baseball bat, no significant differences were found between these two conditions. The attentional focus literature suggests increasing the spatial distance between internal and external focus conditions creates more distinct differences between conditions (Casteneda et al. 2007; McNevin, Shea & Wulf 2003, Wulf et al. 2000 experiment 1). It is likely that a balance is required when considering the spatial distance between the conditions to accommodate for the different level of impairments. The less impaired, who had sufficient movement structure, may have demonstrated more benefit from an external focus of attention, if for example attention was directed towards the placement of the jar, in tasks B and C. The influence of the effect of the distance of the attentional focus feedback warrants further work.

The specific feedback statements chosen by the therapist, during data collection, may also have influenced the findings. Directing attention to one performance variable may have been at the expense of the performance of another variable (den Brinker et al. 1986). For example, individuals who received feedback statements relating to grasp would not necessarily have improved their reach extent. Both maximum aperture size, a measure of grasp, and maximum elbow extension, a measure of reach extent were used as outcome variables within study 2, with some feedback statements being used more than others (Chapter 6: table 6.5). This may have influenced the differences seen in some measures especially as the most striking finding between conditions related to movement duration. The feedback statements pertaining to speed, influencing movement duration, were used most often, with it being used 27 times in task B. It was necessary however to choose statements for each individual to reflect their clinical need, and is the process used in routine clinical practice.

7.3.10 Limitations to study 2

Order effect

The presence of an order effect complicated the interpretations of the data from the second study. This meant, only tentative conclusions about the benefit of inducing an external focus of attention could be made. For example the main finding which showed improved movement duration in the task moving a jar forwards, when an external focus of attention was induced, showed different effects depending upon the order in which the individuals received the different styles of feedback. Individuals in the second group who received external focus first, displayed similar movement times whether receiving internal or external focus feedback statements (Appendix K, Chapter 6: table 6.3). It was from the individuals in the first group, where internal focus feedback statements were provided first, that the benefit of inducing an external focus of attention was clearly demonstrated. The order in which the different styles of feedback were presented appeared to matter with the results suggesting a benefit of external focus when it was preceded by internal focus. In addition to the suggestions put forward in chapter 6 regarding why EF precede by IF may be useful, another consideration is the literature which has shown that interal focus has been associated with increased muscle activity (Vance et al. 2004; Zachry et al. 2005; Marchant, Greig & Scott; Wulf et al. 2007; Wulf et al. 2010). It is possible by adopting IF first it assists with the activation of muscles, a common problem after stroke. This activity may then be refined through the use of adopting an external focus of attention.

Future research is needed to establish whether an external focus preceded by internal focus is more beneficial, or whether the findings seen in study 2 were due to order effects such as an insufficient washout period.

Manipulation check

Manipulation checks, which aim to discover the extent to which individuals adhere to the focus of attention as directed, have been considered important in the literature (Bund, Weimeyer, & Angert 2007;Gray 2004;Marchant, Clough, & Crawshaw 2007;Mullen 2007;Oudejans et al. 2007). Many of the studies conducted by Wulf and colleagues however did not establish the focus of attention which subjects actually adopted (Mullen 2007). Instead they relied upon regular reminders of the focus style. Wulf defends the absence of such checks highlighting that 'few variables in the motor learning domain have produced effects as reliable as those seen under internal versus external focus conditions (Wulf 2007). A manipulation check provides a useful addition to understanding how individuals use the information provided, although application of such a check can be a challenge as shown in study 2, with only 17% reporting adhering to the feedback style as directed.

In study 2, clarification of the focus individuals actually adopted was achieved through directly asking each individual where their attention lay. This method had merits in terms of understanding which focus of attention participants used but there were also limitations.

Participants were asked to identify where their focus lay throughout each set of sixteen trials. This may have caused difficulty for the participants as they may have used more than one attentional focus at different time points (Hommel 2007) relating to individual factors such as fatigue (Marchant 2007)and perceived performance (Hommel 2007). For example an external focus has been related to being adopted after a perceived successful movement and an internal focus after a perceived failure (Hommel 2007). This may have accounted for some of the mismatch found between the reported focus with the intended focus. Difficulty with using manipulation checks is not new. Other studies also have found subjects did not always adhere to the intended focus of attention. For example Maxwell & Masters (2002) found subjects often switched their focus from IF to EF, because they found adopting an external focus improved performance. Marchant, Clough & Crawshaw (2007) also found that subjects did not adhere to the intended focus during all the performance trials.

Another possibility when considering the results of the manipulation check is that some participants in study 2 may have found it difficult to focus as directed. Individual factors such as cognitive and perceptual problems (Appendix I) may have affected the accuracy of their report. Less impaired participants with more automatic movements may have used more implicit processes (Maxwell & Masters 2002). In this instance information ‘may or may not be available as a conscious level’ (Guadagnoli & Lee 2004) which may have caused difficulty to verbally describe the focus of attention adopted (Magill 1998).

Individual preferences and associated factors such as the presence of pain (Kluger & DeNisis 1992), fatigue (Marchant et al. 2007), anxiety (Masters 1993) may also have made it difficult for some individuals to comply with the intended focus with such issues increasing self focus (Wine 1971). This may have been an issue for seven participants who reported pain and 15 participants who were measured as being either anxious or depressed.

It may be that it is reasonable to expect some variation of focus (Hommel 2007) and it is the predominant focus which is what is important rather than the total exclusion of one style. It is possible that participants may have predominantly used the focus as directed, but this was not reported as individual factors such anxiety prompted a different response. Future studies would benefit from a more robust manipulation check to clarify each individual's position with regard their focus of attention.

7.4 Recommendations

7.4.1 Lessons learned to benefit future research studies

1.) Future studies using a counterbalanced design would benefit from increasing the length between conditions with the inclusion of a distractor task between conditions to reduce the chance of the effect of the first condition influencing the second condition.

2.) It would be useful to consider using external feedback statements which are proximal to the body (skill focused) and compare these with external feedback statements which are more distal (environmental focus) therefore examining the effects of the distance of the focus of attention.

3.) The manipulation check used could be improved to include: Was the feedback used? Did the feedback influence the next movement? What percentage time would you attribute to focusing upon your arm/body, task/environment, or something else? This would have been more insightful and helped to understand why some participants reported to focusing on both their arm and the task. To be more thorough asking participants what aspect of the body, task/envinroment they attended to would have been useful.

4.) With reference to the use of motion analysis it would be useful to use a rigid body to attach the reflective markers to each segment, and not just the trunk segment. This would likely to further increase measurement reliability by reducing the movement of the markers upon the skin. Additional markers would also have been useful to enable joint centres to be defined (e.g inclusion of a medial and lateral epicondyle marker as suggested by Schmidt (1999).

7.4.2 Future studies

Future studies would benefit from adopting a randomised controlled trial (RCT) design in which individuals are randomly allocated to one of two attentional focus conditions. This would provide clarity regarding the effect of external focus without the complication of an order effect. Additionally, it would be useful to increase the number of movement repetitions. It may be possible to extend the number of repetitions to 300 movements in one treatment session, which was successfully completed in a recent study (Birkenmeier et al. 2010). Alternatively individuals could be tested over multiple sessions which would also allow for the examination of the effect attentional focus has on motor learning, in addition to motor performance. Increased numbers participating in future studies would also be recommended to increase power. Participant numbers in future studies would be determined using a power calculation with the results from study 2 informing the calculations.

7.5 Clinical significance of the studies

Study 1

- Many therapists who participated in the first study did not choose their words consciously when communicating with their patients.
- The attentional focus type used in the video session was not always the same to what therapists reported to have used. To increase the awareness of communication used by therapists with their patients the use of peer working is recommended. A peer could video record a treatment session which could then be discussed in terms of how the choice of words used influenced the treatment outcome.
- Therapists should give careful consideration to the focus of attention they are inducing in their patients and have clear reasons for their choice. Focusing upon more social aspects of communication, such as motivating their patients, may not produce optimal clinical outcomes. Therapists need to consider creating a therapeutic environment, which extends beyond improving their patients emotional wellbeing and focuses upon improving motor performance and learning.
- Increased use of corrective feedback, which focuses upon the change required, may remove therapists concerns about providing negative information to their patients.

Study 2

- Feedback inducing an external focus of attention may improve performance of reaching compared to feedback inducing an internal focus of attention, and so may warrant being included as part of a rehabilitation programme. Specifically feedback inducing an external focus of attention was found to reduce movement duration in placing a jar forwards by

16%. The clinical significance of this finding could relate to possibly reducing the work rate required to execute a task which in turn may enable increased repetitions to be performed. Although the main support for inducing an external focus of attention is centred upon improved movement duration, it is possible that positive changes supporting an external focus of attention may also have been found in the joint angles if measurement error was reduced. For example, the joint calculations with the markers used in the study may have been confounded by skin marker movement. Future studies would warrant from considering the International Society of Biomechanics recommendations for upper limb coordinate systems, to minimize error within the joint calculations (Wu et al. 2005). The addition of a marker on the hip may also have improved the trunk angle calculations.

- It may be beneficial to focus first upon the skill of the movement, potentially either with an internal or external focus, followed by an external focus of attention which is more distal from the body. Future studies would need to clarify how this is best achieved. It is anticipated that it may be best to initially focus attention externally, towards the skill, that is, with close proximity to the body so individuals can be assisted with finding an optimal movement pattern, followed by directing attention externally but with greater distance from the body.
- It is likely that level of arm impairment and working memory capacity does not influence the attentional focus type adopted. It is possible however, that complex tasks, with increased processing demand may influence attentional focus type adopted. This will need further investigation.
- It is useful to understand individual characteristics including cognitive, perceptual, pain, anxiety as well as arm impairment level, as these may influence where an individual's

focus of attention may be directed, and could assist identify where best to focus an individual's attention.

7.6 Conclusions

The main findings from this thesis were:

1. Therapists used feedback infrequently and where it was used predominantly induced an internal focus of attention.
2. Inducing an external focus of attention has the potential to improve performance of reach to grasp particularly in terms of movement duration.
3. This study did not find a differential effect of the type of attentional focus and level of arm impairment and working memory capacity, and as such aligns with the constrained action hypothesis which proposes that adopting an external focus of attention increases automatic control of movements.
4. Study 2 found that in some measures, feedback which induced an external focus of attention was more beneficial when preceded by feedback which induced an internal focus of attention during the performance of reach to grasp after stroke.
5. A new attentional focus theory may be required which supports the benefit of adopting an external focus of attention and includes the issue of task complexity and the processing demands of a given task.

This thesis has highlighted that therapists may not be using the most efficient modes of communication to improve motor performance in retraining reach to grasp after stroke. Additionally this study is the first to show a benefit of inducing an external focus of feedback when preceded with an internal focus of feedback in the performance of reach to grasp after stroke. This is a new finding and warrants further investigation.

Appendix B - Literature Search Strategy

Databases searched were: Medline, Embase, Cinahl, Amed, Sports Discus and Web of Science. Search terms included medical subheadings (MeSH) and free text terms. $ represented any ending in the Medline and Embase databases whereas * represented any ending in the Cinahl, Amed and Sports Discus databases. Additionally the Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library, was searched as were associated research databases. These were: National Institutes of Health and Clinical Trials Database (NIH), Physiotherapy database (PEDro) and Occupational therapy databases (OT search and Otseeker). Reference lists of key papers found were also used to ensure a comprehensive search of relevant literature was carried out.

1. stroke/ or post-stroke/ or stroke patient/ or cerebrovas$
2. hemipleg$/ or hemipar$ or exp paresis/
3. rehabilitat$
4. functional recovery/ or motor recovery
5. physical therap$/ or physiotherap$
6. arm/ or upper limb/ or upper extremity/ or reaching/ or grasping/ or reach-to-grasp/ or manipulation/ or kinematics/ or impairment
7. 1 or 2 or 3 or 4 or 5 or 6 *(combines rehabilitation of the arm after stroke)*
8. motor learning/ or motor relearning/ or motor control/ or motor performance
9. attentional focus/ or attention/ or external focus/ or internal focus
10. (attentional focus/ or attention/ or external focus/ or internal focus).tw
11. 8 or 9 or 10 *(combines motor control and attentional focus)*
12. feedback
13. knowledge of results
14. knowledge of performance
15. instructions
16. 12 or 13 or 14 or 15 *(combines feedback and instruction terms)*
17. 7 and 11 *(combines stroke rehabilitation of the arm and attentional focus)*
18. 7 and 16 *(combines stroke rehabilitation of the arm and feedback and instructions)*
19. 11 and 16 *(combines motor control, attentional focus and feedback and instructions)*
20. 7 and 19 *(combines stroke, attentional focus, feedback and instructions)*
21. 6 and 8 *(combines motor control and arm)*
22. qualitative research
23. 1 and 2 and 3 and 4 and 5 and 21 *(combines stroke rehabilitation and qualitative research)*

Appendix C – Interview scripts and therapist questionnaire

Patient's Interview

Introduction

Thank you for taking part. I would now like to ask you some questions to clarify my understanding of what I have seen within this treatment session. In particular I would like to understand how you felt about the information you were given.

Please be as open as possible, the information will be used for research only and will be kept confidential. It will not be discussed with your therapist. It will not affect your physiotherapy treatment in any way.
The interview will last about 20 minutes. You may stop the interview at any time.

Before we start is there anything you would like to say or ask?

General

Can you tell me what goals you have for your Physiotherapy? (What you want to get out of your physiotherapy?)

Focus on the UL goals where possible

Do you have goals? What are your goals?

Are these your own personal goals or those set with your therapist? Do you think you are meeting your goals?

Are you working towards improving any particular/specific task?

About the session(s)

So now if we can think about the session you have just done

Can you tell me about your treatment session today?

How did you find it?

Communication

Can you tell me in what ways X gave you information?

How easy was it to follow this information given?

*Were there any times when it was no*t so easy? If so why do you think this was?

Sometimes the information related to your arm movement and sometimes to the task itself. So if we think about those in turn.

Can you tell me about any differences you noticed in what X said to you…

If we can think back to some examples:
Can you tell me how you found ?? exercise? (IF instruction)

The information X gave was about how to move your arm. What effects did you notice this information having on the way you did the movement?
Can I ask what you were thinking about during that task?
Can you remember whether you were thinking more about your arm or the task itself?

What do you think X was trying to get you to think about when she gave you the information in this way?

The information X gave was about what to do with the object in the task. What effects did you notice this information having on the way you did the movement?

X used 2 ways to describe the same exercise, both giving information about the task and how to move the arm. What effects did you notice this having on the way you did the movement?

Feedback

What sort of information do you like to receive about how you are doing with your physiotherapy?
Can you tell me in what ways, you found out about, how you were doing with your physio session?
In what ways did X let you know how you were doing in the session?

Did you feel you were able to change how you moved as a result of the information given?
Some information was given to you before you practised a movement. What effect did this have on the next movement you peformed/did?
Some information was given to you as you practised a movement. What effect did this have on your movement?
Some information was given to you after you have practised some movements. What effect did this have on your movement?
How do you think you are doing with the movements in you arm? *Have you noticed any changes in your arm from this session? Was this treatment similar to previous treatments you have had?*

Did you find the presence of the video affected you in any way?

Just out of interest what do you consider to be the best way of picking up/learning new information/ skills?
Present visually, focussed on the outcome, the quality of the movement?
Do you have anything else to add?

Summary

So to clarify what you have been saying. Which method of communicating information from this session did you find most useful? Was it that which related to the body, the task or a combination of the two or something else?

Do you think you were given enough information/feedback about your movement performance?

Thank patient

Therapist's interview

Introduction

Thank you for your continued support with this project. I would now like to ask you some questions to help with my interpretation of the videotape. The purpose is to increase my understanding of the feedback you used in the filmed treatment session. This will be followed by a questionnaire.
The interview and questionnaire is expected to last about 40minutes.

Before we start would you like to ask anything?

General

Can I ask how long have you been qualified for?

How long have you been working in this area/ward (in what capacity?)

About the patient

I would now like to ask you some questions about Y

Can I ask how long have you been treating Y?

How much time would you say you have spent treating the upper limb? (Then break this down to number of sessions a week, for how many weeks and for how long each session)

Can you tell me about Y's goals?

What are the current goals? Were these set with the patient? Do you think the patient is meeting the goals?

How would you describe Y in terms of his global impairments eg for instance memory, and what are the management approaches you are taking to accommodate these?

About the session

So if we can think about the session. Please let me know if you would like see any parts of the video as a reminder?

Can you tell me how you found the session that was videotaped?

Communication

Can you tell me in what ways you gave Y information?
How well do you think Y followed the information you gave?

Can you tell me about what you were trying to achieve with the words used during the tasks? Sometimes the information related to the body movements or the task itself. So if we think about those in turn. Can you tell me about any differences you noticed in how Y responded depending on the words you used?

So if we can look at some examples.
SHOW EXAMPLE
Can you tell me how you thought this task went? (IF instruction)
Can I ask what you were wanting Y to focus on during the task?
What do you think Y was actually focussing on?

-***The information you gave related to how to move the arm. What effects did you notice this having on Y?***

-The information you gave was about what to do with the object in the task. What effects did you notice this information having, on the way Y performed the movement/ reacted?

-Sometimes you used 2 ways to describe the same exercise, both giving information about the task and how to move the arm. What effects did you notice this having on the way Y performed the movement/ reacted?

So that is thinking about the words X used. Can you tell me about any other ways in which Y gained information during the session? (eg nonverbal the nonverbal cues (or vice versa)

Did you find some tasks worked better than others*? What reasons could account for this?*
Do you think the way the task was presented and the feedback used affected performance?

Feedback

Can you tell me about the feedback you used to improve Y's movement performance?

What sort of information do you think Y like to receive about how they are doing with their arm movements?
Can you tell me which types of feedback had the most beneficial effect on the movements which Y was attempting to perform?

Some information you gave before Y practised a movement. What effect did this have on the next movements they did?

Some information you gave as Y practised a movement. What effect did this have on their movement?
Some information you gave after Y had practised some movements. What effect did this have on Y next movement?

What are you thoughts about providing information about the quality of the movement? (If yes) In what ways were you trying to do this with Y?

What are you thoughts about giving information about how well a task has been performed? How often did you use this with Y?
What are your thoughts about attentional focus feedback? (that is feedback that directs attention to the movement of the arm or to the effects of the movement on the environment)?
How did you use this within this session?

I noticed the use of…… , what effect do you think this had?

Do you think you gave enough feedback about Y's movement performance?

Do you think you would do anything different another time?

E.g. More feedback , a different focus etc,

Did you find the presence of the video affected you in any way?

Do you have anything else to add?

Can you just summarise what you consider to be the key methods of communication you used which Y responded the most positively to?

Thank therapist and provide the questionnaire.
To be completed with researcher present. Ask therapist not to discuss the interview or questionnaire with colleagues participating in the study.

Feedback Questionnaire
The purpose of this questionnaire is to identify what verbal feedback statements you use with stroke patients when training reach to grasp.

1. **Can you list 3 verbal feedback statements that you commonly use when retraining reach-to-grasp as a whole component.**

....
....
....

2. **Feedback statements**
This section relates to the feedback statements you use within your current physiotherapy practise.
Please circle (a-c) which is most similar to the feedback statements you use. You may choose more than one option.

2.1. Statements relating to forwards flexion of the shoulder
a) Next time I would like you to stretch your arm further forwards
b) Next time I would like you to reach towards the cup (or equivalent object).
c) A combination of the above
d) Neither of the above

If answered (c) or (d) please give an example of an alternative statement that you have used or would consider using in this patient.
....
....

Please could you give a reason for your answer?
....
....

2.2. Statements relating to protraction and lateral rotation of the scapula
a) This time I would like you to focus on bringing your shoulder blade forward as you reach with your arm
b) This time I would like you to reach towards the cup (or equivalent object) and place it beyond the tape (*table marked by tape to encourage a position of scapular protraction)*
c) A combination of the above
d) Neither of the above

If answered (c) or (d) please give an example of an alternative statement that you have used or would consider using in this patient.
....
....

Please could you give a reason for your answer?
....
....
....

2.3. Statements that relate to external rotation of the shoulder

a) *Arm positioned by asking the patient to copy the therapist's demonstration*. This time whilst keeping your arm within the tape markers please reach your arm towards the cup (or equivalent object).

b) *Arm positioned by manual guidance*. This time please reach forwards keeping your elbow and forearm still as you reach.

c) A combination of the above

d) Neither of the above

If answered (c) or (d) please give an example of an alternative statement that you have used or would consider using in this patient.

....

....

Please could you give a reason for your answer?

....

....

2.4. Statements related to training elbow extension

a) That time, you kept your elbow straight as you reached.

b) That time you touched the cup (or equivalent object), which was placed 5cm further away.

c) A combination of the above

d) Neither of the above

If answered (c) or (d) please give an alternative statement that you have used or would consider using in this patient.

....

....

Please could you give a reason for your answer?

....

....

2.5. Statements that relate to supination

a) This time I would like you to focus on keeping your forearm in this position (*therapist manually adjusts forearm to mid/neutral pronation*).

b) This time I would like you to keep the sticker pointing up to the ceiling as you reach towards the cup (or equivalent object). (*a sticker is placed on top of the forearm)*

c) A combination of the above

d) Neither of the above

If answered (c) or (d) please give an example of an alternative statement that you have used or would consider using in this patient.

....

....

Please could you give a reason for your answer?

....

....

2.6. Statements related to wrist extension

a) *A Line is drawn on the table with instructions given to keep the hand in over this line*. Did you notice that your hand came away from the line as you reached towards the cup? This time I would like you to keep your hand over the line as you grasp the cup, or equivalent object.
b) Did you notice that your wrist was bending forwards as you opened your fingers to grasp the cup? This time I would like you to focus on keeping your wrist and thumb in a straight line as you reach
c) A combination of the above
d) Neither of the above

If answered (c) or (d) please give an example of an alternative statement that you have used or would consider using in this patient .

....

....

Please could you give a reason for your answer?

....

....

2.7. Statements related to the fingers

a) I would like you to straighten your fingers more as you reach the towards the cup (or equivalent object)
b) I would now like you to reach towards the larger cup (or equivalent object)
c) A combination of the above
d) Neither of the above

If answered (c) or (d) please give an example of an alternative statement that you have used or would consider using in this patient.

....

....

Please could you give a reason for your answer?

....

....

2.8. Statements related to the thumb

a) This time I would like you to focus on getting the pad of your thumb in contact with the cup (or equivalent object)
b) Holding the cup (or equivalent object) don’t let me move it (as the therapist tries to take it out of the patient’s hand)
c) A combination of the above
d) Neither of the above

If answered (c) or (d) please give an example of an alternative statement that you have used or would consider using in this patient

....

....

Please could you give a reason for your answer?

....

....

Thank you for your time

Appendix D – Clinical Assessments, guidelines and recording sheets, Stage1

Rivermead Motor Assessment - Protocol

1. Items may be attempted in any convenient order but early items should be done before later ones where possible.

   Score 1 if the patient can perform the activity
   Score 0 if the patient cannot perform the activity

2. A maximum of three attempts are allowed on each item.

3. Instructions may be given verbally or by demonstration as many times as required

4. After 3 consecutive items on any section (in order given on the form) have been failed, stop that section and score all remaining more difficult items as 0.

5. Give no feedback of whether performance is correct or incorrect but just general encouragement.

6. If any item cannot be attempted then it is scored 0.

7. All activities are to be carried out independently unless otherwise stated.

8. All arm tests refer to affected arm unless otherwise stated.

9. All sitting positions to be done sitting on a chair without arms & feet flat on the floor.

Equipment

Goniometer
20cm football
Tennis ball
Pencil
Paper
50g Putty
Knife & fork
Plate + non slip mat
1m string
Stickers
Stopwatch

No.15 is a complex pattern and involves co-ordination, speed & memory, as well a good arm function

Rivermead Motor Assessment

No.	ARM	0/1	Comments
1	**Lying :Protract shoulder girdle with arm in elevation (arm may be supported)**		
2	**Lying: Place arm in elevation. Pt to hold extended elbow in elevation for indep for 2 seconds. The palms must face in.** (Sh at neutral or in ER. Do not allow Sh retraction. Elbow must be within 30°of E and elevation beyond 90°)		
3	**Lying: F/ E elbow with arms as in (2**) Elbow at least 20° E, no IR or sh retraction		
4	**Sitting: elbow into side of body, pronate and supinate, elbow unsupported & at right angles**. ¾ ROM acceptable, check range with unaffected side		
5	**Sitting: Reach forward, pick up 20cm ball with both hands and place down.** Ball should be placed so arms need to be extend with Sh Protraction, not trunk F, Elbows E (at least –20), Palms kept in contact with the ball.		
6	**Sitting: Reach fwd, pick up tennis ball, release at mid thigh and them pick up and release on table, affected side x5**. Place ball centrally so arm needs to extend		
7	**As (6) with a pencil x5** Need to use thumb and finger grip		
8	**Sitting: Pick up piece of paper from table in from and release at mid thigh x5** A4 office paper		
9	**Sitting: Cut up putty into bite size pieces with knife and fork and place into container (use non slip mat)**		
10	**Standing: on the spot, maintain upright position and pat 20cm ball on floor with palm of hand for 5 continuous bounces**		
11	**Sitting: Continuous opposition, thumb and alternate fingers (tap =1) >x14 in 10(s)** Do not allow thumb to slide from one finger to another		
12	**Sitting: Supinate and pronate onto palm of unaffected hand (1 mvt =1) x20 in 10 (s)** Arm must be away from the body, the palm and dorsum of hand must touch palm of unaffected hand		
13	**Stand, facing wall, hand on wall, shoulder 90F elbow E, Walk away from arm until 90 abduction** Do not allow F at elobw & wrist must be E with palm fully in contact with wall		
14	**Place string around head and tie string in bow behind head (use both hands)** Do not allow neck to flex. Affected hand must be used for more than just supporting string. Can be done in sitting or standing		
15	**'Pat a cake' x7 in 15(s)** Mark 2 crosses on wall at shoulder height. Clap both hands together, place both hands on markers, clap R hand L marker, clap, L hand R marker (1 sequence). Must be correct order. Give 3 attempts		

Instructions for using the RASP

Sensory Modalities to be tested	**Areas to be tested**	**Total score**	**Application area/ Neurometer setting**
Surface Pressure Touch (1°)	Dorsum & Palmar aspect of hand	24 + 8 Shams	Setting 1 (15.5gms) Up to 1sec, until thick filament just disappears.*
Surface Localisation (1°)	"	24 + 8 Shams	Setting 1(15.5gms) Up to 1sec, until thick filament just disappears. *
Sensory Extinction (2°)	"		Setting 2 (67.5gms) Up to 1sec *
2- point Discrimination2°	"	P or F (Pass at 3,4,5 mm)	Applied to index finger tips, depressing up to 1 sec, 1 mm
Proprioception: 1.Movement 2.Direction (1°)	Elbow, wrist, thumb Elbow, wrist, thumb	36 36	Hold the side of the joint being tested. Starting position is up 20° either side of mid joint position into F/E

* = If examiner error, re-administer within the sequence.

1. Inform the participant that you are going **to test what they are able to feel**. **Explain that sensation can be felt in different ways and that is what I will be looking at. It will take about 10 minutes**.

2. Ask participant to **close their eyes**

3. For each modality test the **unaffected side first.**
For touch, test the unaffected dorsum followed by the palmar aspect of the hand and then more onto the affected side. Do the same for localisation and discrimination.
For proprioception test the elbow first followed by the wrist and thumb on the unaffected side, followed by the same order on the affected side. Test for movement and direction simultaneously.

4. **Before each stimulus is given, ask the participant what they can feel**. Inform them do not to worry if you are unable to feel all the trials.

5. 2 shams will be provided on each area of each subtest. Where is sham is given the examiner will say ***"do you feel this"*** and move the neurometer within 150mm of the skin surfance. To

ensure the neurometer makes the same sound during the sham the examiner uses the Neurometer on themselves at the same time.

6. Surface Pressure
   'I want to see if you can feel this light touch. Before each trial I'm going to say " do you feel this?" – don't worry if you don't feel all the trials and remember it is important only to indicate when you actually feel it.'

7. Surface localisation
   'This time I would like you to tell me where on your body I have touched.'
   Responses can include: a verbal description, indication with their intact hand on their own body, or use of a body chart, where necessary. If the subject indicates they have not felt the stimulus, it can be repeated once.
   There are no sham trials in this subtest.

Sensory Extinction

First establish if the subject is able to feel setting 2. If not this section is discontinued for this region.

Both neurometers are applied simultaneously in bilateral conditions

'You may feel me touching either just your left hand, just your right hand or both hands together.'

Replies are L,R or both. If communication is problematic they can make a signal or point to a chart.

Two-point discrimination

Show the subject the discriminator and say 'this will help to identify whether you can feel one or two points on your index finger.'

It is important to ensure that other parts of the hand do not come into contact with the Neurodisc. The values 3,4,5 mm are used as most healthy subjects are able to distinguish 2 points within this range. Subjects failing this range are considered to show impairment.

Start with 3 mm**.** If the subject is unable to feel 2 point reliably (< 4trials) try 4 mm and then 5 mm**.**

If a subject is unable to distinguish between 1 & 2 points reliably at any one of the three levels then the subtest is discontinued

Proprioception

'I am going to move your elbow up and down and I want you to tell me whether you can feel me moving your elbow and in which direction, as soon as you feel the movement'.
'Before each trial I'm going to say "what's this" – don't worry if you don't feel all the trials and remember only to indicate when you actually feel.'

RASP Scoring

Surface Pressure

R hand (Palmar)	T	ς	T	T	T	T	ς	T
L hand (Palmar)	T	ς	T	T	T	T	ς	T
R hand (Dorsum)	T	ς	T	T	T	T	ς	T
L hand (Dorsum)	T	ς	T	T	T	T	ς	T

Total correct (max R = 12) ☐   Total shams (max r = 4) ☐

Total correct (max L = 12) ☐   Total shams (max r = 4) ☐

Scoring

L weakness impairment cut off at < 29
R weakness " " < 29

Surface localisation

R hand (Palmar)								
L hand (Palmar)								
R hand (Dorsum)								
L hand (Dorsum)								

Total correct (max R = 12) ☐

Total correct (max R = 12) ☐

Scoring

Score as correct if within 50 mm. Only score correct localizations.
L weakness impairment cut off at < 29
R weakness " " < 28

Sensory Extinction

R hand - Palmar & dorsum	B	S	B	B	B	B	S	B

Scoring
Any subject scoring less than 6 is judged to show sensory extinction.

6 = normal,
4-5 = mild
2-3 = moderate
0-1 = severe

Two Point Discrimination

Scoring

Proprioception

Sheffield Screening Test for Acquired Language Disorders

Diana Syder, Richard Body, Mark Parker, Margaret Boddy

Score Sheet

Name……………………….. Date of birth……….. Date of test…………..

Receptive Skills (Section 2)

1**.Verbal Comprehension of Single Words** *Score*

I'm going to ask you to point to some of the things in the room…
door __________________ light_____________________chair
ceiling__________________corner____________________.

2**.Comprehension of Sequential Command**

a) Point to the window and then to the door
b) Before pointing to the ceiling, touch the chair

3**.Comprehension of a Complex Command**

Tap the chair twice with a clenched fist, while looking at the ceiling

4**.Recognition of Differences in Meaning Between Words**

I'm going to read you a list of words and I want you to tell me which is the odd one out
a) chicken, duch, apple, turkey;

b) run, drink, walk, sprint;

c) small, large, massive, huge

5.**Comprehension of a Narrative**

a) I'm going to read you a short paragraph and then ask you a question about it.

John went to the shop to buy a pen. When he got there he found that he had forgotten his wallet, so he came home and made himself a cup of tea.

What should he have taken with him?

b) I'm going to read you another paragraph.

Mrs Smith visited several shops. She bought a newspaper, a cauliflower, a stamp and some sausages.

What was the second shop she visited?

<u>SSTALD</u>

Cut off scores

Age 59 and under	17 (7.65)
Age 60 -69	16 (7.2)
Age 70 and over	15 (6.75)

Expressive section = 11

Receptive section = 9 (cut scores for receptive section only are in brackets)

Birmingham University Cognitive Screen (BUCS) – Assessment of sustained attention

”You will hear a tape with a man saying different words. When the man says “hello”, “please” or “no” you have to tap on the table. When the man says something else, just ignore him. So the threewords you have to respond to are: hello, please and no. Can you repeat these words?” (If the patient does not recall the three words, repeat the words). “We will start with an example”.

-STOP if MORE THAN 8 ERRORS at the end of ANY BLOCK (block 1 OR block 2) but DO NOT FORGET to ASK for the 3 words at the end.

PRACTICE 1 (up to 3 practices allowed)

“Can you tell me the three words you have to respond to?”______________________________

1. Please	❑ Taps	❑ Does not tap
2. Thanks	❑ Taps	❑ Does not tap
3. Goodbye	❑ Taps	❑ Does not tap
4. Hello	❑ Taps	❑ Does not tap
5. Yes	❑ Taps	❑ Does not tap
6. No	❑ Taps	❑ Does not tap

TEST

Block 1

Hello	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Hello	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap

Hello	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap

Block 2

Hello	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
Hello	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Hello	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap

Block 3

Yes	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
Hello	❑ Taps	❑ Does not tap
Please	❑ Taps	❑ Does not tap
Thanks	❑ Taps	❑ Does not tap
No	❑ Taps	❑ Does not tap
Hello	❑ Taps	❑ Does not tap
Yes	❑ Taps	❑ Does not tap
Goodbye	❑ Taps	❑ Does not tap
Hello	❑ Taps	❑ Does not tap

Can you tell me the three words you had to respond to? ________________________________

	Block 1	Block 2	Block 3
Number correct responses:	**/18**	**/18**	**/18**
Number false positives:	**/9**	**/9**	**/9**
Number omissions:	**/9**	**/9**	**/9**

Condition of testing	__________
Total number of correct responses	__________/54
Total number of false positives	__________/27
Total number of omissions	__________/27
Sustained attention index	__________
Response mode for recalling the target words	❑ free response ❑ multiple choice
Number of practices required	__________/3
Number of words recalled at the end of the test	__________/3
How well did the participant understand the instructions:	

Birmingham University Cognitive Scores – Normalised values (N=60)

DOMAIN	TASK	Impaired	Relatively spared	Spared
LANGUAGE				
- speech	Picture naming (accuracy, max=14)	0-8	9-11	12-14
	Sentence construction (accuracy, max=8)	0-6	7	8
	Instruction comprehension	1	2	3
- reading	Sentences (accuracy, max=42)	0-39	40-41	42
	Sentences (time)			
	Nonwords (accuracy, max=6)	0-3	4-5	6
	Nonwords (time)	> 9 sec.		
- writing	Words/nonwords (accuracy, max=5)	0-2	3-4	5
NUMBER				
- reading	Total (accuracy, max=9)	0-7	8	9
- writing	Numbers/prices (accuracy, max=5)	0-3	4	5
- calculation	Arithmetical facts (accuracy, max=4)	0-2	3	4
PRAXIS				
- visuo-constructive	Figure copy (total accuracy, max=47)	0-41	42-45	46-47
	Figure copy (time)	> 180 sec.		
- ideomotor	Multi-step (score, max=12)	0-9	10	11-12
	Gesture production (score, max=12)	0-9	10	11-12
	Gesture recognition (accuracy, max=6)	0-4	5	6
	Imitation (score, max=12)	0-9	10	11-12
LTM				
- orientation	Personal information (accuracy, max=8)	0-6	7	8
	Orientation (accuracy, max=6)	0-4	5	6
	Nosognosia (accuracy, max=3)	0-1	2	3
- episodic	Free story recall 1 (accuracy, max=15)	0-2	3-6	7-15
	Story recognition 1 (accuracy, max=15)	0-10	11-13	14-15
	Free story recall 2 (accuracy, max=15)	0-3	4-8	9-15
	Story recognition 2 (accuracy, max=15)	0-12	13	14-15
	Task recognition (accuracy, max=10)	0-8	9	10
ATTENTION				
- spatial	Key cancellation (asymmetry score, max=0)	<-1 or >1	-1 or 1	0
	Right visual extinction (score, max=-4)	>-3	-3	-4 or <-4
	Left visual extinction (score, max=-4)	>-3	-3	-4 or <-4
	Right tactile extinction (score, max=-4)	>-3	-3	-4 or <-4
	Left tactile extinction (score, max=-4)	>-3	-3	-4 or <-4
- controlled	Auditory attention (total accuracy, max=54)	0-49	50-53	54
	Auditory attention (number of practice, max=1)	3	2	1
	Auditory attention (word recall, max=3)	0-2	-	3
	B'ham frontal (accuracy, max=18)	0-5	6-11	12-18

HADS:
The next set of questions is about your emotions. Please answer them honestly and in a way that describes how you have been feeling over the past week.

[A] Do you feel tense or 'wound up'?		
Most of the time	☐	3
A lot of the time	☐	2
From time to time	☐	1
Not at all	☐	0

[D] Do you still enjoy the things you used to enjoy?		
Definitely as much	☐	0
Not quite so much	☐	1
Only a little	☐	2
Hardly at all	☐	3

[A] Do you get a sort of frightened feeling as if something awful is about to happen?		
Very definitely and quite badly	☐	3
Yes, but not too badly	☐	2
A little, but it doesn't worry me	☐	1
Not at all	☐	0

[D] Do you laugh and see the funny side of things?		
As much as I always could	☐	0
Not quite so much now	☐	1
Definitely not so much now	☐	2
Not at all	☐	3

[A] Do worrying thoughts go through your mind?		
A great deal of the time	☐	3
A lot of the time	☐	2
From time to time but not too often	☐	1
Only occasionally	☐	0

[D] Do you feel cheerful?

Not at all	☐	3
Not often	☐	2
Sometimes	☐	1
Most of the time	☐	0

[A] Can you sit at ease and feel relaxed?

Definitely	☐	0
Usually	☐	1
Not often	☐	2
Not at all	☐	3

[D] Do you feel as if you are slowed down?

Nearly all the time	☐	3
Very often	☐	2
Sometimes	☐	1
Not at all	☐	0

[A] Do you get a sort of frightened feeling like 'butterflies' in the stomach?

Not at all	☐ 0
Occasionally	☐ 1
Quite often	☐ 2
Very often	☐ 3

[D] Have you lost interest in your appearance?

Definitely	☐ 3
You don't take so much care as you should	☐ 2
You may not take quite as much care	☐ 1
I take just as much care as ever	☐ 0

[A] Do you feel restless as if you have to be on the move?

Very much indeed	☐ 3
Quite a lot	☐ 2
Not very much	☐ 1
Not at all	☐ 0

[D] Do you look forward with enjoyment to things?

As much as you ever did	☐	0
Rather less than you used to	☐	1
Definitely less than you used to	☐	2
Hardly at all	☐	3

[A] Do you get sudden feelings of panic?

Very often indeed	☐	3
Quite often	☐	2
Not very often	☐	1
Not at all	☐	0

[D] Do you enjoy a good book or radio/ TV programme?

Often	☐	0
Sometimes	☐	1
Not often	☐	2
Very seldom	☐	3

<u>10-hole peg test protocol</u>

Starting position:
Table 28” Chair 18” without arms
Set up with the board placed horizontally across the midline of the subject. The side with the empty holes should be aligned with the edge of the table.
Participant’s hands placed on lap before each trial
Examiner sits on the unaffected side

Instructions:
With the unaffected hand, start at the opposite end of the row of pegs and move them one at a time into the empty holes immediately opposite on the board
‘ready go’
Repeat above instructions with the left hand.

Procedure

1. ‘I would now like to see what movement you have with your arms’

2. Provide a demonstration and instructions as above, at the start of the test. Repeat when necessary before each trail.

3. Do 3 trials with each hand. **Start with the unaffected arm**. Complete all 3 trials on the unaffected side before testing the affected side.

4. The right hand picks up pegs from the left end of the row

5. The left hand picks up pegs from the right end of the row

6. Time each trial separately. Time is measured from touching the first peg to releasing the last

7. If the participant makes a mistake eg drops a peg within the first 3 pegs, correct the error and start the trial again. If an error occurs beyond this stage, continue the timing and if required remind the participant what needs to be corrected.

8. Only discuss performance with the participant, if requested, after completing the whole test.

Equipment
Stopwatch
10 hole peg test
Tape measure
Scoring card + pen

HAD Score

Anxiety =

Depression =

Overall mood status

Comments

Arm function tests

10-hole peg test

Time (seconds)		
Trial	Unaffected (L/R)	Affected (L/R)
1		
2		
3		
Mean		

Short-Form McGill Pain Questionnaire

- Do you have any current pain?
- Do you get pain at any time?

  Please circle which word describes

0 No pain

1 Mild

2 Discomforting

3 Distressing

4 Horrible

5 Excruciating

If you have circled 0 please stop here

If you have answered 1-5

- Where is your pain?
- When do you get your pain?

Appendix E- Framework analysis

Instruction

Instructions are defined as ‘verbal information given at the start of a movement or during the practice of the movement.’ It informs how to perform an exercise, and does not include information that relates to how the exercise went.

Examples include:

- Verbal information that informs the patient what to do with an exercise e.g. ‘Ok and have a reach out there again and see if you can go a bit quicker’
- General information relating to an exercise e.g. ‘We are going to have a go at doing a bit of reaching this time’& questions that are phrased like an instruction e.g. ‘and can you put it back to where it was?’
- Positioning of a patient e.g. ‘can you get onto your hands and knees and bring you weight further forwards’

Instructions will only be highlighted where it relates directly to an exercise and/ or practice of an exercise.

Information Feedback

This is information provided during or after an exercise. Example are:

- Information that relates to a description of the previous exercise practice(s). e.g. ‘at the moment it is not quite making it across’ & ‘your wrist is staying quite straight’. It can also include the therapist asking whether the patient felt something eg ‘did you feel the shaking that time?’

- Information about the previous movement and is immediately followed by information that the patient can use to improve the next movement e.g. ‘So you are doing it at the side of your finger there, can you get it right onto the pad of your finger.’ Therefore with these statements there are two pieces of information, one which relates to an error with the previous movement and then information regarding what to do with the next movement.

- Iinformation that informs the patient how to improve the next movement but does not tell the patient what was wrong with the previous movement e.g ‘I really want you to concentrate on your shoulder position’ & ‘OK so if we have a go with the third finger, see if you can get it right on the tip’

Please refer to the organizational chart (pp 58)

Both instructions and information feedback can be further classified to extract the attentional focus, internal focus (IF), external focus (EF) or a mixed attentional focus.

External attentional focus is information which relates to the environment whereas an internal attentional focus is information which relates to the body movements. Mixed attentional focus if where there is a combination of the two.

To provide a complete picture of the use of feedback, additional classifications have been identified from initial analysis of the data.

- Motivating/ reinforcement feedback – bold type (Well done, good, lovely etc)
- Any other dominating features from the transcript e.g. checking the patient is alright

Protocol for Extracting Attentional Focus Frequencies

- From the transcript the content of information will be classified
- Sections of the information will then be attributed to an attentional focus type (IF, EF or Mixed, M)
- Information feedback statements are likely to consist of clear individual statements which can then be attributed the appropriate attentional focus based on the above definitions.
- Instructions are likely to take on a slightly different format. Instructions are likely to consist of information for the set up the exercise, and subsequent information pertaining to either variation of the task, information pertaining to practice of the task or repetition of information. Information that pertains to the set up/ first practice of the task should be classified as one statement. Subsequent information should be counted as it either relates to a variation in the task, another instruction pertaining to practice, or repetition of an instruction. E.g. ‘Place the cup to the left and to the right and again’ will equate to three external focus verbal feedback statements.
- Information statements may sometimes need to be inferred depending on the use of the English language. Eg ‘reach towards the cup’ can be expanded to ‘reach your arm towards the cup’ and is therefore a mixed attentional focus.
- For motivating/reinforcing data – The number of occurrences will be summed although it is acknowledged that such statements are often used in multiple at any given time.

Appendix F - Results for the Clinical assessments – Stage 1

	CB01	BS02	MF03	CD04	RE05	JB06	DM07	GB08
RMA	7	13	3	13	9	11	3	8
RASP	Mild	Mild	Mild	Intact	Mild	Mild	Intact	Mild
Mcgill	No pain	No pain	No pain	No pain	Discomfort in shoulder	No pain	Sharp pain on movement	Pain in shoulder on movement
SSTALD	8	9	7	7	6	8	9	8
Language	Spared	Spared	Relatively spared	Relatively spared	Picture naming is relatively spared Impaired reading	Spared Reading is relatively spared	Spared	Spared
Praxis	Visuo-constructive is impaired No apraxia	Spared	Visuo-constructive is impaired No ideomotor apraxia	Impaired gesture production otherwise spared	Visuo-constructive is relatively spared. Gesture recognition is impaired	Spared	Spared	Spared
Memory	Spared	Spared	Some problems with episodic memory	Spared	Orientation intact Immediate recall is relatively spared Delayed recall is impaired	Spared	Some problems with free delayed recall and task recognition	Orientation is intact Free recall is relatively spared
Attention	Spared	Spared	R visual extinction + Impaired auditory attention. Frontal lobe is relatively spared	Spared	L spatial extinction (Lower quadrant) ? due to attention as visual extinction is intact. L tactile extinction problems. Impaired extinction problems	Spared	Spared	Spared
HAD	A= 0 D= 1	A= 8 D= 9	A = 1 D = 8	A = 6 D = 2	A = 6 D = 4	A=2 D=4	A = 13 D = 9	A = 4 D = 3
10-hole peg (M)	L= 70.0 R= 13.7	L =17.0 R = 17.4	L= 15.5 R= 97	L= 21.9 R= 86.3	L = 53 R = 16	L = 19.5 R = 14.5	Unable to assess	L = 11.8 R = 31.5

Appendix G – Visual3D Script – Script used for participants who used their right Arm

```
Lowpass_Filter
/SIGNAL_TYPES=TARGET
! /SIGNAL_NAMES=
! /SIGNAL_FOLDER=ORIGINAL
! /RESULT_SUFFIX=
! /RESULT_FOLDER=PROCESSED
! /FILTER_CLASS=BUTTERWORTH
/FREQUENCY_CUTOFF=10
! /NUM_REFLECTED=6
! /TOTAL_BUFFER_SIZE=6
! /NUM_BIDIRECTIONAL_PASSES=1
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
Subtract_Signals
/SIGNAL_TYPES=TARGET+TARGET
/SIGNAL_NAMES=FINGER+THUMB
/SIGNAL_FOLDER=PROCESSED+PROCESSED
/RESULT_NAME=FINGER-THUMB
/RESULT_FOLDER=PROCESSED
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
Signal_Magnitude
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=FINGER-THUMB
/SIGNAL_FOLDER=PROCESSED
/RESULT_NAME=FINGER-THUMB_MAG
/RESULT_FOLDER=PROCESSED
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
Signal_Magnitude
/SIGNAL_TYPES=TARGET
/SIGNAL_NAMES=WRIST
/SIGNAL_FOLDER=PROCESSED
/RESULT_NAME=WR_MAG
/RESULT_FOLDER=PROCESSED
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
First_Derivative
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAG
/SIGNAL_FOLDER=PROCESSED
/RESULT_SUFFIX=PV
/RESULT_FOLDER=PROCESSED
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
Threshold
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGPV
/SIGNAL_FOLDER=PROCESSED
```

```
/EVENT_NAME=ONSET
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
! /SELECT_RESIDUAL=FALSE
/THRESHOLD=0.025
/FRAME_WINDOW=6
! /FRAME_OFFSET=0
/ASCENDING=TRUE
! /DESCENDING=FALSE
! /ENSURE_RANGE_FRAMES_BEFORE_THRESHOLD_CROSSING=FALSE
/ENSURE_RANGE_FRAMES_AFTER_THRESHOLD_CROSSING=TRUE
! /START_AT_EVENT=
! /END_AT_EVENT=
/EVENT_INSTANCE=1
;
        File:   G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
Using threshold = 0.025000
---------------------------------------------------------------------------
Subtract_Signals
/SIGNAL_TYPES=TARGET+TARGET
/SIGNAL_NAMES=JAR+WRIST
/SIGNAL_FOLDER=PROCESSED+PROCESSED
/RESULT_NAME=JAR-WR
/RESULT_FOLDER=PROCESSED
;
        File:   G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Signal_Magnitude
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=JAR-WR
/SIGNAL_FOLDER=PROCESSED
/RESULT_NAME=JAR-WR_MAG
/RESULT_FOLDER=PROCESSED
;
        File:   G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Global_Maximum
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAG
/SIGNAL_FOLDER=PROCESSED
/EVENT_NAME=MAX_WR_DISP
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
! /END_AT_EVENT=
;
        File:   G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled
files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Global_Minimum
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=JAR-WR_MAG
/SIGNAL_FOLDER=PROCESSED
/EVENT_NAME=WR_NEAR_JAR
/SELECT_X=TRUE
/SELECT_Y=TRUE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
```

/END_AT_EVENT=MAX_WR_DISP
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Threshold
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAG
/SIGNAL_FOLDER=PROCESSED
/EVENT_NAME=MVT_STOP
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
! /SELECT_RESIDUAL=FALSE
/THRESHOLD=0.025
/FRAME_WINDOW=5
! /FRAME_OFFSET=0
! /ASCENDING=FALSE
/DESCENDING=TRUE
! /ENSURE_RANGE_FRAMES_BEFORE_THRESHOLD_CROSSING=FALSE
/ENSURE_RANGE_FRAMES_AFTER_THRESHOLD_CROSSING=TRUE
/START_AT_EVENT=ONSET
/END_AT_EVENT=MAX_WR_DISP
/EVENT_INSTANCE=1
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
Using threshold = 0.025000

Metric_Time_Between_Events
/RESULT_METRIC_NAME=MD
! /RESULT_METRIC_FOLDER=PROCESSED
/EVENT_SEQUENCE=ONSET+MAX_WR_DISP
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Second_Derivative
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAG
/SIGNAL_FOLDER=PROCESSED
/RESULT_SUFFIX=WR_ACCEL
/RESULT_FOLDER=PROCESSED
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Lowpass_Filter
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGWR_ACCEL
/SIGNAL_FOLDER=PROCESSED
! /RESULT_SUFFIX=
! /RESULT_FOLDER=PROCESSED
! /FILTER_CLASS=BUTTERWORTH
/FREQUENCY_CUTOFF=10
! /NUM_REFLECTED=6
! /TOTAL_BUFFER_SIZE=6
! /NUM_BIDIRECTIONAL_PASSES=1
;

File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Global_Maximum
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=FINGER-THUMB_MAG
/SIGNAL_FOLDER=PROCESSED
/EVENT_NAME=APERTURE
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
/END_AT_EVENT=MAX_WR_DISP
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Global_Maximum
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGPV
/SIGNAL_FOLDER=PROCESSED
/EVENT_NAME=PV
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
/END_AT_EVENT=MAX_WR_DISP
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Global_Maximum
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGWR_ACCEL
/SIGNAL_FOLDER=PROCESSED
/EVENT_NAME=PA
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
/END_AT_EVENT=MAX_WR_DISP
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Global_Minimum
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGWR_ACCEL
/SIGNAL_FOLDER=PROCESSED
/EVENT_NAME=PD
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
/END_AT_EVENT=MAX_WR_DISP
;
File: G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----
Metric_Maximum
/RESULT_METRIC_NAME=PEAK_APERTURE
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
! /RESULT_METRIC_FOLDER=PROCESSED

```
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=FINGER-THUMB_MAG
/SIGNAL_FOLDER=PROCESSED
! /SIGNAL_COMPONENTS=ALL_COMPONENTS
/EVENT_SEQUENCE=ONSET+MAX_WR_DISP
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
! /CREATE_GLOBAL_MAXIMUM=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
Metric_Maximum
/RESULT_METRIC_NAME=PV
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
! /RESULT_METRIC_FOLDER=PROCESSED
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGPV
/SIGNAL_FOLDER=PROCESSED
! /SIGNAL_COMPONENTS=ALL_COMPONENTS
/EVENT_SEQUENCE=ONSET+MAX_WR_DISP
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
! /CREATE_GLOBAL_MAXIMUM=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
Metric_Maximum
/RESULT_METRIC_NAME=PA
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
! /RESULT_METRIC_FOLDER=PROCESSED
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGWR_ACCEL
/SIGNAL_FOLDER=PROCESSED
! /SIGNAL_COMPONENTS=ALL_COMPONENTS
/EVENT_SEQUENCE=ONSET+MAX_WR_DISP
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
! /CREATE_GLOBAL_MAXIMUM=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
--------------------------------------------------------------------------
Metric_Minimum
/RESULT_METRIC_NAME=PD
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
! /RESULT_METRIC_FOLDER=PROCESSED
/SIGNAL_TYPES=DERIVED
/SIGNAL_NAMES=WR_MAGWR_ACCEL
/SIGNAL_FOLDER=PROCESSED
! /SIGNAL_COMPONENTS=ALL_COMPONENTS
/EVENT_SEQUENCE=ONSET+MAX_WR_DISP
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
! /CREATE_GLOBAL_MINIMUM=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
```

```
---------------------------------------------------------------------------
Metric_Time_Between_Events
/RESULT_METRIC_NAME=TMA
! /RESULT_METRIC_FOLDER=PROCESSED
/EVENT_SEQUENCE=ONSET+APERTURE
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Metric_Time_Between_Events
/RESULT_METRIC_NAME=TPV
! /RESULT_METRIC_FOLDER=PROCESSED
/EVENT_SEQUENCE=ONSET+PV
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Divide_Signals
/SIGNAL_TYPES=METRIC+METRIC
/SIGNAL_NAMES=MD+TPV
/SIGNAL_FOLDER=PROCESSED+PROCESSED
/RESULT_NAME=%TPV
! /RESULT_FOLDER=PROCESSED
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Divide_Signals
/SIGNAL_TYPES=METRIC+METRIC
/SIGNAL_NAMES=MD+TMA
/SIGNAL_FOLDER=PROCESSED+PROCESSED
/RESULT_NAME=%TMA
! /RESULT_FOLDER=PROCESSED
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Metric_Time_Between_Events
/RESULT_METRIC_NAME=TPD
! /RESULT_METRIC_FOLDER=PROCESSED
/EVENT_SEQUENCE=ONSET+PD
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Divide_Signals
/SIGNAL_TYPES=METRIC+METRIC
/SIGNAL_NAMES=MD+TPD
/SIGNAL_FOLDER=PROCESSED+PROCESSED
/RESULT_NAME=%TPD
! /RESULT_FOLDER=PROCESSED
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
```

```
---------------------------------------------------------------------------
Compute_Model_Based_Data
/RESULT_NAME=ELBOW R
/FUNCTION=JOINT_ANGLE
/SEGMENT=RFA
/REFERENCE_SEGMENT=RAR
/RESOLUTION_COORDINATE_SYSTEM=
! /USE_CARDAN_SEQUENCE=FALSE
! /NORMALIZATION=FALSE
/NORMALIZATION_METHOD=TRUE
! /NORMALIZATION_METRIC=
! /NEGATEX=FALSE
! /NEGATEY=FALSE
! /NEGATEZ=FALSE
! /AXIS1=X
! /AXIS2=Y
! /AXIS3=Z
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Compute_Model_Based_Data
/RESULT_NAME=SHOULDER R
/FUNCTION=JOINT_ANGLE
/SEGMENT=RAR
/REFERENCE_SEGMENT=RTA
/RESOLUTION_COORDINATE_SYSTEM=
! /USE_CARDAN_SEQUENCE=FALSE
! /NORMALIZATION=FALSE
/NORMALIZATION_METHOD=TRUE
! /NORMALIZATION_METRIC=
! /NEGATEX=FALSE
! /NEGATEY=FALSE
! /NEGATEZ=FALSE
! /AXIS1=X
! /AXIS2=Y
! /AXIS3=Z
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Compute_Model_Based_Data
/RESULT_NAME=TRUNK
/FUNCTION=JOINT_ANGLE
/SEGMENT=RTA
! /REFERENCE_SEGMENT=LAB
/RESOLUTION_COORDINATE_SYSTEM=
! /USE_CARDAN_SEQUENCE=FALSE
! /NORMALIZATION=FALSE
/NORMALIZATION_METHOD=TRUE
! /NORMALIZATION_METRIC=
! /NEGATEX=FALSE
! /NEGATEY=FALSE
! /NEGATEZ=FALSE
! /AXIS1=X
! /AXIS2=Y
! /AXIS3=Z
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
---------------------------------------------------------------------------
Global_Minimum
/SIGNAL_TYPES=LINK_MODEL_BASED
```

```
/SIGNAL_NAMES=ELBOW R
! /SIGNAL_FOLDER=ORIGINAL
/EVENT_NAME=ELBOW_START
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
/END_AT_EVENT=MAX_WR_DISP
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----------------------------------------------------------------------------
Global_Maximum
/SIGNAL_TYPES=LINK_MODEL_BASED
/SIGNAL_NAMES=ELBOW R
! /SIGNAL_FOLDER=ORIGINAL
/EVENT_NAME=ELBOW_END
/SELECT_X=TRUE
! /SELECT_Y=FALSE
! /SELECT_Z=FALSE
/START_AT_EVENT=ONSET
/END_AT_EVENT=MAX_WR_DISP
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----------------------------------------------------------------------------
Metric_Minimum
/RESULT_METRIC_NAME=ELBOW_MIN
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
! /RESULT_METRIC_FOLDER=PROCESSED
/SIGNAL_TYPES=LINK_MODEL_BASED
/SIGNAL_NAMES=ELBOW R
! /SIGNAL_FOLDER=ORIGINAL
! /SIGNAL_COMPONENTS=ALL_COMPONENTS
/EVENT_SEQUENCE=ONSET+MAX_WR_DISP
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
! /CREATE_GLOBAL_MINIMUM=FALSE
;
	File:	G:\full Stage 2 data_C3Dfiles_07_08\Stage 2 Qualysis data\DG28IF1\DG28_Labelled files\DG28REF2taskA0101.c3d
----------------------------------------------------------------------------
Metric_Maximum
/RESULT_METRIC_NAME=ELBOW_MAX
! /APPLY_AS_SUFFIX_TO_SIGNAL_NAME=FALSE
! /RESULT_METRIC_FOLDER=PROCESSED
/SIGNAL_TYPES=LINK_MODEL_BASED
/SIGNAL_NAMES=ELBOW R
! /SIGNAL_FOLDER=ORIGINAL
! /SIGNAL_COMPONENTS=ALL_COMPONENTS
/EVENT_SEQUENCE=ONSET+MAX_WR_DISP
/EXCLUDE_EVENTS=
/GENERATE_MEAN_AND_STDDEV=FALSE
! /APPEND_TO_EXISTING_VALUES=FALSE
! /CREATE_GLOBAL_MAXIMUM=FALSE
;
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Appendix H Clinical Assessment – Stage 2

Fugl Meyer – guidance sheet

I Reflex activity can be elicited

Reflex activity is tested for the patient's biceps, triceps and finger flexor reflexes to assess if activity is present- see Deakin 2003 for testing positions. Activity in the biceps or finger flexors will be scored as 2.

II Movement in synergy

a. Flexor

In a seated position the patient is asked to perform a voluntary action of brining their affected arm to the ear on their affected side. This action is to be demonstrated to the patient using the following steps.

- Full supination of the forearm
- Full elbow flexed
- Shoulder abducted to at least 90 degrees
- Shoulder externally rotated
- Shoulder retracted
- Shoulder elevated

The patient is asked to copy the movement in full. An assessment is then made against the Fugl Meyer scale against the presence of each component whilst the patient is in the final position.

b. **Extensor**

With a starting position of full flexor synergy while in a seated position the patient is asked to extend his affected arm towards the unaffected knee using the following movements: Adduction and internal rotation of the shoulder, extension of the elbow, pronated forearm.

If the patient is unable to attain the required starting position the affected arm may be passively placed therein. Ensure the movement is through the activity of the pectorals and triceps (and not through trunk rotation or through pendulating the arm forwards. Demonstrate as required

III Volitional motion performed mixing the dynamic flexor & extensor synergy dependents (to score 2 in c check full ROM with other side

The seated patient is asked to perform 3 separate actions

a. Actively position the affected hand on the lumbar spine
b. Flex the shoulder to 90˚ in pure flexion motion, Elbow E and arm neutral
c. Pronation and supination of the forearm with elbow actively F to 90˚ and shoulder at 0˚

IV Volitional movement performed with little or no synergy dependents

The seated patient is asked to

a. Abduct the shoulder 0- 90˚ (The motion should be through pure abduction, and the elbow fully extended with the forearm pronated).
b. Flex the shoulder in a pure flexion motion 90˚ -180˚ (thumb pointing forwards, starting position from 90˚F, assistance can be given to get into starting position, if unable to gain 180, check ROM with other arm to score 2)
c. Forearm pronation and supination with Elbow E (Shoulder between 30 and 90˚ Flexion- Check ROM with other side to score 2)

V Normal Reflex Actvity

Reflex activity is tested in the patient to see if any normal reflex responses are elicited. This task should only be performed if a score of 6 points is obtained for task **(IV)**.

B Wrist

1.) Wrist stability is tested at approximately 15˚ extension. The shoulder should be at 0˚, elbow 90˚, and the forearm fully pronated. If the elbow cannot be actively brought to the required position the examiner may help the patient.
2.) Ability to produce repeated flexion and extension of the wrist with the fingers flexed. The shoulder should be at 0˚, elbow 90˚, forearm fully pronated. The Elbow can be supported as required.(to score 2 activity should be present throughout the passive range. To score 2 passive range should be within at least 75% of the range of the unaffected wrist)
3.) Wrist stability is tested at approximately 15˚ extension. The shoulder should be in some flexion &/or Abduction, elbow 0˚, and the forearm fully pronated. If needed the arm can be supported in the position.
4.) Ability to produce repeated flexion and extension of the wrist with the finger flexed. The shoulder should be somewhat flexed &/or abducted, elbow 0˚. The elbow can be supported as required (see guidance for 2.) to score 2.
5.) Circumduction of the wrist

C Hand

1.) Massed finger flexion – Patient is instructed to make bend his fingers
2.) Massed Finger Extension – From massed finger flexion the patient is required to extend all fingers
3.) Grasp A – The patient is instructed to extend the MCP joints of digits 2-5 and flex the PIP and DIP joints. The grasp is tested against resistance
4.) Grasp B – The patient should perform a pure thumb adduction.
5.) Grasp C – The patient forms a pincer grip with a pencil
6.) Grasp D – The patient grasps an 8cm plastic mug using a full hand grasp
7.) Grasp E – The patient grasps a tennis ball using a full hand grasp

D Coordination /Speed

Finger nose test – The patient is asked to put the tip of his index finger to his nose 5 times, as quickly as possible whilst his eyes are closed. Start from a position of shoulder 90F and Elbow E and this position should be gained between each touch of the nose. Both sides are tested and scoring is based upon the difference between the 2 sides.

<u>Fugl- Meyer Upper Extremity Motor Function (in sitting)</u>

A Shoulder/Elbow Forearm

Task ref	Item	Activity	Scoring Criteria	Score
I	Biceps & finger Flexors	Flexor reflex activity	0 = No reflex 2 = Reflex elicited	/2
	Triceps	Extensor reflex activity		/2
IIa	Shoulder	Retraction	0 = Unable to perform 1 = Can perform partially 2 = All details performed faultlessly. Note: Scoring for tasks follow the same criteria except where additional information is provided. NB Pt's can be assisted into position. It is then the smooth mvt towards the opp knee that is important	/2
		Elevation		/2
		Abduction		/2
		External Rotation		/2
	Elbow	Elbow F		/2
	Forearm	Supination		/2
IIb	Shoulder	Adduction & Inward Rotation		/2
	Elbow	Extension		/2
	Forearm	Pronation		/2
IIIa		Hand to Lumbar Spine	1 = Hand can get passed the ASIS	/2
IIIb	Shoulder	Flexion (0-90˚)+ Elb E	0 = Immediate Sh Abd &/or Elbow F 1 = Sh Abd &/or Elb F later in mvt	/2
IIIc	Elbow (90˚)	Pronation / supination	0 = Correct shoulder and elbow position cannot be attained &/or Pro/Sup cannot be performed 1 = Active Pro/Sup with limited ROM, correct Sh and Elb position	/2
Iva	Shoulder	Abduction (0-90˚)	0 = initial Flexion and intial pronation (i.e starting position cannot be achieved) 1 = Part ROM, or elbow F, or forearm cannot be kept pronated during motion	/2
IVb	Shoulder	F (90 - 180˚)	0 = Immediate Sh Abd &/or Elbow F 1 = Shoulder Abd &/or Elbow F later in the action	/2
IVc	Elbow (0˚)	Pronation /supination	0 = Correct shoulder and elbow position cannot be attained &/or Pro/Sup cannot be performed 1 = Active Pro/Sup with limited ROM, correct Sh and El position ElbE + some Sh F	/2

V.	Normal Reflex Activity	0 = At least 2 of the 3 reflexes are markedly hyperactive 1= 1 reflex hyperactive or at least 2 reflexes lively 2 = No more than 1 reflex lively and no reflexes markedly hyperactive Total Score for Shoulder/Elbow/Forearm section	/2 /36

B Wrist

Task Ref	Activity	Scoring Criteria	Score
1.)	Elbow 90˚ Wrist Stability at 15˚ Wrist E (Wrist unsupported)	0 = unable to DF to required position 1 = DF performed but no resistance 2 = DF with some (slight) resistance	/2
2.)	Elbow 90˚ Wrist Flexion and Extension (Wrist unsupported)	0 = No active movement 1 = aROM not present throughout range	/2
3.)	Elbow 0˚ Wrist Stability (Wrist unsupported)	0 = unable to DF to required position 1 = DF performed but no resistance 2 = DF with some (slight) resistance	/2
4.)	Elbow 0˚ Wrist Flexion and Extension (Wrist unsupported)	0 = No active movement 1 = aROM not present throughout range	/2
5.)	Circumduction (Wrist unsupported)	0 = No Circumduction 1 = Jerky or incomplete movement	/2
		Total Score for Wrist section	/10

C Hand

Task Ref	Activity	Scoring Criteria	Score
1.)	Fingers Massed Flexion (against resistance)	0 = No Flexion 1 = Some Flexion 2 = Full active flexion compared with unaffected hand	/2
2.)	Fingers Massed Extension	0 = No extension 1 = Able to release the grasp 2 = Full active extension compared with unaffected hand	/2
3.)	Grasp a- MCP E, DIP & PIP F (Palm supinated, examiners finger placed between MCP and DIP for the subject to grip) (against resistance)	0 = unable acquire position 1 = grasp is weak 2 = Grasp can be maintained against relatively great resistance	/2
4.)	Grasp b- thumb adduction to fingers, pull paper (against resistance)	0 = Unable to perform 1 = Paper can be kept in place but not against a slight tug 2 = Paper held well against a tug	/2
5.)	Grasp c - pincer grip, pull pencil (against resistance)	0 = Unable to perform 1 = Can keep pencil in place but not against a slight tug 2 = Pencil held well against a tug	/2
6.)	Grasp d – Cylinder grip (against resistance)	0 = Unable to perform 1 = Can keep cylinder in place but not against a slight tug	/2

		2 = Cylinder held well against a tug	
7.)	Grasp e – Spherical grip (against resistance)	0 = Unable to perform 1 = Can keep tennis ball in place but not against a slight tug 2 = Tennis ball held well against a tug	/2
		Total Score for Wrist section	/14

D Coordination and Speed

Task ref	Activity	Scoring Criteria	Score
1.)	Finger-to nose test - tremor	0 = marked tremor, 1=some, 2= none	/2
	Finger-to nose test - dysmetria	0 = pronounced, 1 = slight, 2 = none	/2
	Finger-to nose test – speed (Compare with other side for scoring)	0 = > 6 secs slower 1 = 2-5 secs slower 2 = < 2 s slower	/2
		Total score for coordination & speed	/6

Total Score for patient **/66**

Scoring guidelines for the Erasmus Modifications to the (revised) Nottingham Sensory Assessment:

Position:
Pt undressed so they are showing the whole arm. Lies on the bed in supine (or sits if necessary)

Tactile senation (LT(light touch), Pressure & pinprick)
The skin is stimulated x3, at each location, in a random order, using the defined points of contact

0 = Absent	Pt fails to ID on all 3 occasions
1 = Impaired	Pt ID only one or two sensations
2 = Normal	Pt ID sensations on all 3 occasions

NB If 2 is scored for LT, automatically give 2 for pressure and pinprick

- Light touch — Touch the skin, at the points, lightly with a cotton wool ball
- Pressure — Use index finger to just deform the skin contour, at the points
- Pinprick — Use a cocktail stick, prick the skin to just deform the skin contour

Sharp-blunt discrimination
NB Do not test if scored 0 or 1 on tactile sensations
Stimulate the skin 6 times at each location, in random order, 3 times with a cocktail stick and 3 times with the index finger, using the defined points of contact. (similar scoring system as above, 0 = absent, 2 = no errors, 1= some errors)

Two-point discrimination
Only test of the patient has normal scores for light touch
Set dividers at decreasing levels
Apply two points simultaneously or 1 point to the skin for approx 0.5s to
- The index finger (10 mm & 5 mm)
- The thenar eminance (20 mm & 12 mm)

Repeat each distance 6 times at each location in random order, 3 times using 2 points and 3 times using 1 point.

Scoring

0 = Absent	Pt is not able to detect two points
1 = Impaired	Pt detects 2 points, index finger 10 mm, thenar eminence 20 mm
2 = Normal	Pt detects 2 points index finger 5 mm, thenan eminence 12 mm

Proprioception
Tested at the fingers, wrist, elbow and shoulder
Move each joint 3 times, score similar to above. Hold the tested limb on the lateral aspect
Use the thumb
For the wrist position place the elbow to150˚, and for the elbow place to 90˚
Shoulder, test for abd/add with the elbow at 90˚.

EmNSA Score Sheet

		Right/ Left			
		LT	Pressure	PinPrick	Sharp/ blunt
LT, Sharp.blunt & 2 pt discrimination					
	Upper arm				
	Forearm				
	Hand				
	Fingers				
2 Point discimination	Index finger				
	Thenar eminence				
Proproception	Shoulder				
	Elbow				
	Wrist				
	Fingers				

Abbreviated Mental Test Score

1. Age …………………
2. Time (to nearest hour) …………………
3. Address for recall at the end of the test. This should be repeated by the patient to ensure it has been heard correctly:
   42 West Street
   …………………
4. Year …………………
5. Name of Hospital …………………
6. Recognition of two persons (Doctor, nurses etc) …………………
7. Date of Birth …………………
8. Year of First World War …………………
9. Name of the present Monarch …………………
10. Count backwards 20-1 …………………

N.B. Remember to ask about 42 West Street

Optic Ataxia test

Typical pattern – " gross and uncorrected misreaching in peripheral vision with undisturbed reaching under foveal vision"

- Test the unaffected arm first. Ask the patient to fixate their vision onto the tester's nose directly in front of them. The tester then presents an object (a pen) at various locations on the unaffected side followed by the affected side. At each location the patient needs to reach towards the object. Try to cover all 4 spheres of vision.

- Next ask the patient to orientate their eyes and head towards the object and repeat the placement of the object as above.

Record 10 reaches on each hemisphere. Reach with the unaffected arm first to the unaffected hemisphere
Record a tick if the patient grasps the object and a cross of they miss it or did not correct their error.

Peripheral vision (eyes on nose)				Foveal vision (Eye on object)			
Unaffected side		Affected side		Unaffected side		Affected side	
Un	Affected	Un	Affected	Un	Affected	Un	Affected

Un = Unaffected Hemisphere; Affected = Affected hemisphere

Tardieu Scale

Ensure the neck position remains constant.

Each muscle group, reaction to stretch is rated at a specified stretch velocity with 2 parameters, X and Y

Velocity Stretch

- **V1: As slow as possible (minimizing stretch reflex)**
- V2: Speed of the limb segment falling under gravity – Not done as too difficult
- **V3: As fast as possible (faster than dropping the limb under gravity**

V1 = Measurement of passive range of motion
V3 = Measurement of spasticity

Quality of the muscle reaction (X)

0 No resistance through the course of the passive movement
1 Slight resistance throughout the course of the passive movement with no clear catch as a precise angle
2 Clear catch at a precise angle, interrupting the passive movement, followed by release
3 Fatigable clonus (<10s when maintaining pressure) occurring at a precise angle)
4 Unfatigable clonus (>10s when maintaining pressure) occurring at a precise angle)

Angle of Muscle Reaction (Y)
Measured relative to the position of minimal stretch of the muscle (corresponding to angle 0) for all UL joints.

Tardieu Scoring

	L muscle reaction + angle of reaction	R muscle reaction + angle of reaction
Elbow F		
Wrist F		
Finger F		

Task Evaluation Questionnaire (Intrinsic Motivation Inventory-IMI)

For each of the following statements, please indicate how true it is for you, using the following scale:

1	2	3	4	5	6	7
not at all true			somewhat true			very true

1. While I was working on the task I was thinking about how much I enjoyed it.
2. I did not feel at all nervous about doing the task.
3. I felt that it was my choice to do the task.
4. I think I am pretty good at this task.
5. I found the task very interesting.
6. I felt tense while doing the task.
7. I think I did pretty well at this activity, compared to other people.
8. Doing the task was fun.
9. I felt relaxed while doing the task.
10. I enjoyed doing the task very much.
11. I didn't really have a choice about doing the task.
12. I am satisfied with my performance at this task.
13. I was anxious while doing the task.
14. I thought the task was very boring.
15. I felt like I was doing what I wanted to do while I was working on the task.
16. I felt pretty skilled at this task.
17. I thought the task was very interesting.
18. I felt pressured while doing the task.
19. I felt like I had to do the task.
20. I would describe the task as very enjoyable.
21. I did the task because I had not choice.
22. After working at this task for a while, I felt pretty competent.

IMI scoring

Scoring information. Begin by reverse scoring items # 2, 9, 11, 14, 19, 21. In other words, subtract the item response from 8, and use the result as the item score for that item. This way, a higher score will indicate more of the concept described in the subscale name. Thus, a higher score on pressure/tension means the person felt more pressured and tense; a higher score on perceived competence means the person felt more competent; and so on. Then calculate subscale scores by averaging the items scores for the items on each subscale. They are as follows. The (R) after an item number is just a reminder that the item score is the reverse of the participant's response on that item.

Interest/enjoyment:	1, 5, 8, 10, 14(R), 17, 20
Perceived competence:	4, 7, 12, 16, 22
Perceived choice:	3, 11(R), 15, 19(R), 21(R)
Pressure/tension:	2(R), 6, 9(R), 13, 18

The subscale scores can then be used as dependent variables, predictors, or mediators, depending on the research questions being addressed.

Appendix I – Results of Clinical Assessments, Stage 2

	FM	eNSA	SSTALD	Praxis	LTM	attention	MMSE	Optic ataxia	Anxiety	Depression	Tardieu	motivation
RdB01_IF1	52	1	7	1	1	1	10	1	1	0	0,0,0	26
WB02_IF1	56	1	6	2	1	2	6	1	2	0	1,1,1	34
SS03_EF1	60	1	5	2	2	3	7	1	1	4	0,0,0	99
AM04_IF1	37	1	9	2	1	1	9.5	1	1	4	1,1,0	17
DS05_EF1	22	1	5	1	3	3	6	99	3	7	2,2,2	34
AK06_EF1	35	1	8	2	2	1	8.5	1	4	8	0,0,0	30
KC07_EF1	41	1	8	1	1	1	10	2	11	7	0,0,0	30
GS08_EF1	60	1	9	99	99	1	9	1	8	12	0,0,0	30
ID09_EF1	60	2	7	1	3	1	5	2	5	10	0,0,0	30
JH10_IF1	58	2	8	1	1	1	10	2	1	4	1,2,2	30
LT11_IF1	44	1	8	1	1	1	10	3	12	7	1,0,0	14
MRy12_IF1	40	1	6	3	1	1	7.5	3	1	0	1,1,0	30
JW13_IF1	35	1	9	1	2	3	8	2	12	7	0,0,0	37

	FM	eNSA	SSTALD	Praxis	LTM	attention	MMSE	Optic ataxia	Anxiety	Depression	Tardieu	motivation
RS14_IF1	52	1	9	1	1	1	9.5	2	5	5	0,1,1	31
TSu15_EF1	24	1	7	2	2	1	3	2	5	7	2,3,2	40
RK16_IF1	30	1	7	1	2	3	7.5	2	2	8	2,2,1	14
RB17_IF1	57	1	6	1	1	1	10	2	5	13	0,0,0	28
DA18_IF1	48	1	8	1	1	1	9.5	2	4	7	1,2,1	43
JRe19_EF1	21	1	8	2	2	3	?	2	2	3	2,2,3	43
GraS20_E_EF1	26	1	9	1	1	3	8	2	0	3	0,0,0	36
DP21_EF1	21	1	7	1	2	3	8	1	14	8	0,0,0	39
FJ22_R h_IF	55	1	6	2	3	2	8	1	20	20	1,1,1	28
RE23_R h_IF1	42	1	4	3	3	3	5.5	2	13	13	2,1,1	46
JF24_EF1	49	1	8	1	2	2	7.5	2	4	5	0,0,0	49
BC25_EF1	57	1	7	2	2	2	7.5	1	3	5	0,0,0	40
JM26_IF1	24	1	9	2	1	1	7/9	1	19	12	0,1,2	42
TB27EF1	26	1	9	1	1	2	8	99	5	6	0,1,1	35

	FM	eNSA	SSTALD	Praxis	LTM	attention	MMSE	Optic ataxia	Anxiety	Depression	Tardieu	motivation
DG28_IF1	62	1	9	1	1	1	8	1	5	6	0,0,0	39
SB29_IF1	51	1	9	1	2	1	10	2	3	1	0,1,0	49
SE30_EF1	48	1	9	1	1	1	10	1	9	5	0,0,0	36
JW31_EF1	59	1	9	1	1	1	9	2	12	4	0,0,1	13
LP32_IF1	58	2	8	1	2	3	7	1	6	6	0,0,0	44
PB33_EF1	58	1	9	1	1	1	8.5	2	6	7	0,0,0	30
HS34_EF1	60	1	9	1	1	1	10	2	3	4	1,2,2	38
DV35_EF1	30	1	7	1	2	1	7	1	0	2	2,1,1	26
JB36_IF1	59	1	1	1	1	1	10	1	1	2	1,2,1	43
FC37_EF1	18	1	8	1	1	1	9	99	0	2	2,3,3	38
HA38_IF1	21	1	6	1	1	1	7	99	6	5	2,2,2	38
PE39_EF1	51	1	8	1	1	1	10	1	0	4	0,0,0	40
JB40_IF1	50	2	7	1	3	2	9	2	7	5	0,0,0	33
KL41_IF1	18	2	9	1	1	1	9	99	5	3	2,3,2	39

	FM	eNSA	SSTALD	Praxis	LTM	attention	MMSE	Optic ataxia	Anxiety	Depression	Tardieu	motivation
BC42_IF1	53	1	9	1	1	1	9.5	2	0	3	0,0,0	30

Appendix J - Stage 2 Procedure

BEFORE DAY OF TESTING

Fugl-Meyer, Erasmus M NSA, SSTALD, optic ataxia, BUCS, mini mental test, HAD, 10 hole Peg, Signed consent.

Demographics: Age, sex, site (CT or Bamford), time since stroke, side of stroke

Stratify and assign EF or IF – write on data collection sheet

ON DAY OF TESTING

1. Camera set up & calibration

Before subject arrives

- Set up cameras. 2 should already be attached to the shelf. Arrange the 2 tripods with the other cameras on. (use the tape markers on the floor to place the tripods). Use the tape markers on the tripod to ensure the correct height of tripod and connect the camera leads. (Camera 1 = leads into ‘next’ and ‘data’, camera 4 = leads into ‘previous’). Position the table (using the tape marked on the floor). Use 1 marker on the 15cm cross on the table, in the midline to check the camera position). ENSURE YOU LOCK THE DOOR BEHIND THE CAMERA. Connect camera to the laptop and connect the external trigger input pin on the control port of Camera 1.
- Set the workspace options first
    - Camera system – 200Hz per sec
    - Timings – Use external trigger (start)
    - Marker – Passive markers, default discrimination
    - Flashes – use all
    - Linearisation for each camera – visible in ‘workspace options’ (these are ordered by the last number as 5,3,6,4)
    - Connection – Buffer mode – immediate
    - Calibration – Wand kit 300 mm Z positive axis, Y long Axis and enter exact wand length. (Y is in the sagital plane going away from where the subject will sit. X is in the frontal plane along the table edge)
    - Analogue acquisition and video devices unselected
    - Processing – select track the measurement, 3D; do not fill the gaps
        - Tracking – prediction error 10 (CRUCIAL E.G 30 GIVES EXTRA MARKERS), max residual 10; acc.factor 50000; noise factor 10, autojoin enable, max frame gap 10

- Put a marker on the table and adjust the aperture to a noise level between 4-6 (the second adjuster).

- Put a marker on the 15cm midline mark to check the camera orientation as per diagram. Use this marker to adjust the focus if required to ensure the markers are visible but not too big (first ring).
- Put the markers on myself as per the experimental marker setup (set up for the arm which the patient attending will be treated). Ensure all markers can be seen in at least 2 cameras throughout the workspace.

Calibrate

- Place the short X axis along table edge and the long Y axis in the subject's sagittal plane. Perform calibration. Set to calibrate for 15seconds instead of the default of 10s to ensure there is enough time to cover all the workspace volume during calibration. Put a 5 second delay before calibration and use the sound option. Then wave the wand one way and then the other way, trying to cover the area within the workspace volume i.e where the markers are likely to go during active movement. Try and ensure that the markers are not too close to the edge of the camera view as this could decrease the accuracy of the measurement. RECORD THE ERROR VALUE ON THE PT RECORDS. Export the calibration file for that subject (subject number, initials of patient and the date)

2. Prepare for subject

- Get markers ready with the tape
- Set up folders for the Qualisys files. Call the files by the subject number and initial eg KH, left or Right arm, IF1, EF2, IF2, EF1 for whether IF or EF was first and task A,B,C. (task A is reaching to an object, B is placing an object, C is placing an object at a height)
  A file name example is: KHLIF1A, then KHLIFB, KHLIFC, for all 3 tasks in condition 1 and then KHLEF2A (B), (C) for condition 2 where condition 1 was IF.
- Put mark 15 cm from table edge, for jar start position
- Put tape from start to jar to indicate hand path
- Put sticker on jar for oppostion feedback
- Put sticker 10 cm ahead of the 15 cm mark for grasp timing feedback [8]
- Put marker on wooden platform to indicate where the centre of the jar should be placed
- Tape/blue tac feedback statements on to the wall near your sitting position, for easy reference.

3. After subject arrives

- Briefly explain what will happen
- Complete Magill Pain Scale
- Complete Tardieu

- **Position patient**
  Remove anything reflective from the subject e.g.watch. Put a pillow on the chair if necessary and ask the subject to sit as close as possible to the table (to reduce trunk F). Ensure hip and knees are 90 degrees and approx 75% of thigh is on the chair (for tall

people ensure they are sitting well back in the chair. Provide a V- necked vest top for the patient if necessary so that the markers can be placed on the skin.

- **Establish 90% arm's length**
  Ask the subject to pick up and place the jar as far away from them as possible, with unaffected hand, without leaning forwards.
  Instructions '<u>I would like you to pick up the jar (placed on 15cm mark) using your ? (unaffected) hand and place it as far away as possible without leaning forwards. Keep yourself to the back of the chair'.</u>
  Do 1 movement with the unaffected arm. Mark where the near corner of the jar is placed and then measure (using a tape measure) the distance between the starting point and end point of the jar. Subtract the starting point number from the end point number and work out 90% of this (x0.9). Measure this distance out which is the point where the jar should be placed in Task A, and the position of the jar in task B and task C. In task C the jar will be the same horizontal distance from the start but will be on a wooden platform 30 cm high.

- **Put Markers on patient (use 0.5 markers throughout)**
  Place markers as below: 7 on arm, 3 on chest, 1 on jar – check 11 altogether
  Trunk (use fixed triangle with one marker at the top, 1 cm (finger breadth) below the sternal notch)
  Humerus (anterior border of the head of humerus, in line with the bicipital groove)
  Mid humerus (with subject in starting position, 10cm from the other humerus marker down the line of the shaft of the upper arm, which will be the anterior lateral aspect of the arm), and 1 cm medial to this line
  Elbow - Palpate Lateral Epicondyle then place marker 4 cm medial to this along elbow crease
  Wrist - Radial Styloid
  Forearm – halfway between elbow and wrist marker, and 1 cm medial to this line
  Thumb – between nail and DIP (medial aspect when in anatomical position)
  Index finger - between nail and DIP (lateral aspect when in anatomical position)
  Jar – Centre of jar lid
  Put sticker on subject's thumb for opposition feedback
  Tape straw on to wrist for wrist extension feedback

- **Get ready to capture the movement**
  New, Capture – (3-8 seconds duration dependent on the patient. Some for instance may have large reaction times). Label files as above. Sit besides the patient to analyse their movements. Use the external trigger button to start captures.
  Determine how long their movement is likely to take then set the collection time no. of seconds.

- **The tasks**
  Starting position for task A: Reaching to a jar, thumb and index over a mark placed 15cm from table edge, in a midline position. Task B: Placing a jar & C Placing a jar to a height, with the near jar edge on the 15cm mark.

- **General instructions to subject**
  'You will be practicing 3 different tasks. After each movement, I will give you feedback to improve the next movement. It is very important that you listen to the feedback given at that time, and try to follow that feedback on the next attempt.'

Task A Instructions
Set up the capture first for the practice
(Set the position of the jar) 'The goal of this task is to grasp the jar, lift it up & put it down. **So if I demonstrate first**. So sit close to the table, start with your finger and thumb lightly touching with the tip of your index finger over the mark (placed 15cm from the table edge in the midline) keep your body still and reach your arm to grasp the jar like that, lift it up and put it down'. (Demonstrate a full hand grasp movement). So from the starting position please begin when I say 'start' (Press capture using the trigger button)
Task A Practice trials
The subject then practices x2 trials without feedback (to check understanding of the task) followed by x16 trials with feedback. **While the subject does the practice, analyse their movement and decide on a maximum of 3 components to focus feedback on. Write these down on data collection sheet.** After the practice trails ask the subject
When you were doing those movements, what were you thinking most about: the jar/table/chair or your arm/hand? Record answer on data collection sheet.

Task A experimental trials
In the next 16 movements I would like you to think about
a) Your arm and hand (IF Condition)
b) The jar and the table (EF Condition)

There are 16 trials. Feedback begins after trial 1. Feedback on 1 component is given after each trial. The same feedback is usually given for several trials and then changes to a new component. Feedback is given on maximum of 3 components during the whole 16 trials. If necessary, revert to feedback about a former component. For the last 3 trials, give the subject all three (or less if there were less than 3 components) feedback statements used in the set of 12 trials so far. Precede by saying "Now, can you try doing all those things together (then say each of the feedback statements". The 3 feedback statements are repeated at the beginning of each of the last 3 trials.
When repeating a feedback statement directly after the statement has been given for the trial before, say 'Again,…'and then the feedback statement. When a statement is repeated, it should be stated exactly and not shortened. Indicate on the data collection sheet, which feedback statements were used and when.
Allow time for rest periods as required to minimize fatigue and 5 minutes between conditions.

Allow 10 minutes rest between tasks.

Ask Manipulation check question: When you were doing those movements, what were you thinking about most: the jar/table/chair or your arm/hand? Record answer on data collection sheet.

In the second set of 16 trials (using the other focus), the same pattern of feedback statements are used – same statements on same trials.

Ask Manipulation check question: When you were doing those movements, what were you thinking most about: the jar/table/chair or your arm/hand? Record answer on data collection sheet.

Task B Instructions
'The goal of this task is to place the jar, on the mark.' (Show the mark). **So if I demonstrate first** So sit close to the table, start with grasping the jar. (jar edge on the 15cm midline cross) Keep your body still and place the jar on the mark like that'. (Demonstrate a full hand grasp and place the jar in one movement, no adjustments allowed). So from the starting position please begin when I say 'start'.

Task B Practice trials
Proceed as for Task A including the manipulation check
Task B Experimental trials
Proceed as for Task A including directing the focus of attention
Manipulation check question is repeated after each 16 trials as in task A

Task C Instructions (change)
'The goal of this task is to place the jar, on the box.' (Show the mark) **So if I demonstrate first** So sit close to the table, start with grasping the jar. (jar edge on the 15cm midline cross) Keep your body still and place the centre of the jar onto the mark on the box like that'. So from the starting position begin when I say 'start'. The movement is taken as the first movement attempt, not adjustments are allowed.

Task C Practice trials
Proceed as for Task A
Task C Experimental trials
Proceed as for Task A
Manipulation check question is repeated after each 16 trials as in task A

Patient completes a shortened version of the Intrinsic Motivation Inventory.

Data collection sheet
EXTERNAL FOCUS STUDY

Name: ________________________________

Date of testing	
Tester	
Hand used	
Subluxation (Y or N)	
Subject ID (initials)	
90% arm's length	
EF or IF first	
Stratification	

Proreflex error score

1.

2.

3.

4.

Components identified from analysis:

Comments on trials & insert feedback statements used

	TASK A
	Attentional focus of feedback (EF or IF):
Practise	Attentional preference:
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

	Manipulation check question (jar/table/chair or arm/hand)
	TASK A
	Attentional focus :
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
	Manipulation check question
	TASK B
	Attentional focus :
Practise	Attentional preference:
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

	Manipulation check question
	TASK B
	Attentional focus :
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
	Manipulation check question
	TASK C
	Attentional focus :
Practise	Attentional preference:
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

	Manipulation check question
	TASK C
	Attentional focus :
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
	Manipulation check question

Appendix K - Interaction plots, Stage 2

Peak Velocity – task A

There was a trend towards a statistically significant feedback type by order interaction, where the order which had internal focus feedback first (order1), achieved higher peak velocity in the external focus condition than in the group which received external focus feedback first (order2) ($F_{1,40}$ = 3.781, p=.059).This suggests that the benefit of external focus is enhanced when it is preceded by feedback which induced an internal focus feedback.

For all graphs presented parallel lines represent no interaction. Lines that cross or have opposite gradients represent an interaction.

Figure 1: PV Vs order for the two conditions

Movement Duration – Task B

There was a statistical significant interaction effect for feedback type by order, demonstrating a shorter movement duration for EF feedback when IF was received first ($F_{1,40}$ = 6.158, p=.018). In order 2, where external focus was received first, it produced similar movement duration to the internal focus condition which was received second.

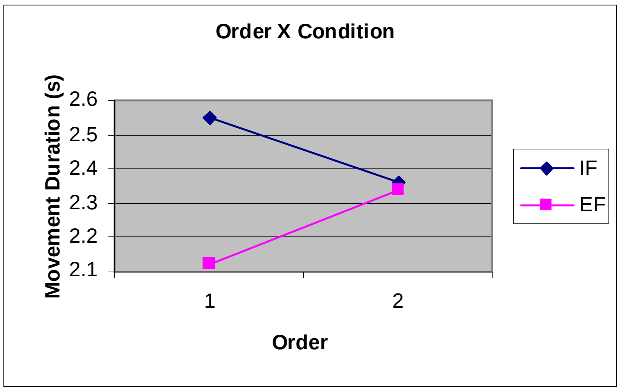

Figure 2: Movement duration Vs order

<u>Aperture – Task A</u>

There was a difference between feedback type and order for percentage time to maximum aperture ($F_{1,33} = 4.569$, p=.04). This indicated internal focus followed by external focus (order 1), was more beneficial than the reverse order (Figure 2). There was a large change between internal focus and external focus in order 1, where internal focus was received first, whereas in order 2 where external focus was received first, there was little change between the 2 conditions.

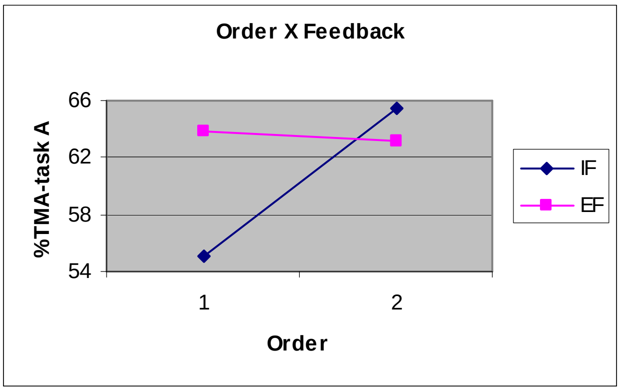

Figure 3: %TMA Vs order for the two conditions

Task C:

There was a significant interaction of feedback type by order ($F_{1,40}$ = 6.596, p=.017) for time to peak deceleration in task C. This indicated that order 1 where internal focus followed by external focus, was more beneficial than the reverse order (Figure 4).

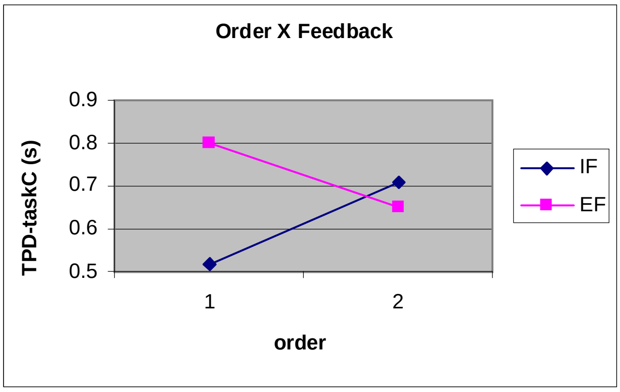

Figure 4: Time to Peak Decceleration Vs order for the two conditions

There was a trend for an interaction of feedback type by order for shoulder flexion (task C) ($F_{1,40}$ = 3.446, p=.072). Shoulder flexion under external focus was larger when it followed internal focus feedback. This supports internal followed by external focus feedback (order 1) was more beneficial than the reverse order (order 2).

There were also trends towards this finding for percentage time to peak deceleration ($F_{1,26}$ = 3.981, p=.058) and %TPV ($F_{1,26}$ = 3.317, p=.058) in task C.

As the interaction graphs suggested an effect of order this therefore formed part of the statistical analysis model.

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