The effect of attentional focus on a supra postural task in hemiplegic gait

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THE EFFECTS OF ATTENTIONAL FOCUS ON A SUPRAPOSTURAL TASK IN HEMIPLEGIC GAIT

By

Jecy Kunju Kunju

A Thesis
Submitted to the Faculty of Graduate Studies through Human Kinetics
in Partial Fulfillment of the Requirements for the Degree of Master of Human Kinetics
at the University of Windsor

Windsor, Ontario, Canada

2013

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DECLARATION OF ORIGINALITY

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ABSTRACT

Dynamic stability during walking is important to prevent falls and to integrate patients into community ambulation. This study tries to examine the effect of attentional focus, mainly external focus of attention on a supra postural task while walking, in hemiplegic patients. Three cases were examined in detail. The participants were made to walk on a GAITRite™ walkway under three experimental conditions: 1) Baseline walking 2) Walking with a supra postural task with no instructional cues and performing a verbal task 3) Walking with a supra postural task with specific attentional focus instructions and the spatial and temporal parameters are recorded. The supra postural task was to hold a mug assumed to contain water. The asymmetry ratios and variability are computed to examine the changes in the symmetry of the gait pattern in each experimental condition. The results show that attentional focus does not improve temporal and spatial symmetry in hemiplegic patients where spasticity and balance issues are persistent.
Dedicated

to

Bala & Bhavani

for

your unconditional love and encouragement

and

making me believe that this was possible.
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LIST OF ABBREVIATIONS

SP – Supra Postural
COM – Centre of Mass
CPG – Central Pattern Generators
WRH - Windsor Regional Hospital
TSR – Temporal Symmetry Ratio
SSTAR – Single Support Time Asymmetry Ratio
STAR – Step Length Asymmetry Ratio
NOMENCLATURE

Spasticity: A motor disorder characterized by abnormal increase in muscle tone as a result of lesion in the upper motor neurons.

Synergy: Stereotyped mass movements associated with neurological disorders

Paretic: The affected side in hemiplegia

Non-paretic: The unaffected side in hemiplegia

Ipsilateral: same side

Contralateral: opposite side
INTRODUCTION

Bipedal locomotion is one of the characteristic features that differentiate humans from other primates. There has been extensive research on behaviours associated with human locomotion, especially on gait. This has led to a better understanding of the neurological and biomechanical intricacies involved in gait, both normal and impaired. Any impairment in the locomotory abilities of an individual has a huge impact on the quality of life and hence the continuing emphasis on research in developing new strategies for rehabilitation of impaired gait.

Rehabilitation of gait involves re-learning of well-coordinated movement patterns. Instructions are very important in learning new motor skills and attentional focus forms the basis of these instructions. The two types of attentional focus are internal and external focus of attention. Internal focus directs an individual’s attention to his own movements, emphasising on the performer’s body parts, order, time and form of movements. External focus directs attention to the effect of a particular movement on the environment which can include an object or an instrument (Wulf, 2007). External focus of attention in motor skill learning has shown better results in rehabilitation of motor skills (McNevin, Wulf & Carlson, 2000; Wulf, 2007). Previous studies have shown that external attentional focus on a concurrent task does have an effect on normal as well as impaired gait pattern (Cherng, Liang, Hwang & Chen, 2006; Canning, 2004). However, there is not much information about the specific effects of attentional focus on a supra postural task in a hemiplegic gait.

Gait is affected in more than 80 % of stroke patients (Duncan et al., 2005). Almost 60 % of the patients are limited in their community ambulation post-discharge (Jorgensen, Nakayama, Raaschou & Olsen, 1995). Community ambulation can be defined as “the ability to move and negotiate independently outside the home”
Verma, Sharma & Garg, 2012; Lord et al., 2005). A skill-specific definition of community ambulation would be the ability to integrate walking with other tasks in a complex environment (Verma et al., 2012). This would require a fair amount of dynamic stability.

Walking is often performed with a concurrent task, either cognitive or motor (deLima, Nato & Texeira, 2010). The lack of dynamic stability during walking can cause falls and the incidence of falls in stroke patients post-discharge is quite high. The risk of hip fractures and a resultant morbidity is ten times higher in this population when compared to their healthy peers (Verma et al., 2012).

The performance of dual tasks has been used in various studies as a parameter to predict falls in elderly as well as neurologically impaired patients. These studies have examined the effect of the dual task paradigm on postural stability in upright stance (Mcnevin & Wulf, 2002; Wulf et al., 2003; Cluff, Gharib & Balasubramaniam, 2010; deLima et al., 2010; Marigold et al., 2006). But instability and balance issues are more prevalent during locomotion than in standing (Winter, 1995). Hence stability measures need to be examined during walking and the performance of a concurrent supra postural task will provide more information on the factors that influence the dynamic stability of gait.

There are very few studies examining the effects of a supra postural task on walking (in terms of dynamic stability and symmetry of gait pattern) especially in a neurologically impaired gait like hemiplegia. This information can be a valuable input in designing gait rehabilitation strategies for the neurologically impaired patient population.

This study aims to examine the effects of attentional focus on supra postural motor task in hemiplegic gait. Variability of gait parameters on the unaffected and
affected lower limbs of hemiplegics will be examined. The principles of ‘constraint-induced-self-organisation or constrained-action-hypothesis’ (Wulf, McNevin & Shea, 2001) and ‘entrainment’ have been incorporated in a functionally relevant task to examine these effects. This study hypothesises that focusing on the mug (external focus) while performing a secondary task like holding a mug of water steady during walking, will promote the automatic control processes of the primary task of walking. The unaffected lower limb will self-organise into an automatic intrinsic stepping rhythm and will entrain the affected limb, which will result in a more symmetric pattern of gait. The expected outcome is an improvement in the symmetry of the gait pattern in the lower limbs.
PURPOSE OF THE STUDY

The main purpose of this study is to examine the effects of attentional focus on a supra postural task in the gait pattern of community ambulant stroke patients. It aims to determine whether attentional focus on a supra postural task can be used to enhance the symmetry of gait pattern in post stroke patients.

HYPOTHESES

Attentional focus (internal and external) on a supra postural motor task will decrease the variability and asymmetry of gait parameters on the non-paretic side, in turn entraining the same in the paretic side, thus improving the overall symmetry of a hemiplegic gait pattern.

$H_1 =$ It is hypothesized that there would be a lower stride length variability and stride time variability in comparison to the baseline measures, on both paretic and non-paretic lower limbs while adopting an attentional focus (internal and external) on a supra postural task during walking.

$H_2 =$ It is hypothesized that there will be a more normalised temporal symmetry ratio as well as a lower step length asymmetry ratio and single support time asymmetry ratio in comparison with the baseline measures, on both paretic and non-paretic lower limbs while adopting an attentional focus (internal and external) on a supra postural task during walking.

$H_3 =$ The gait pattern in external focus condition would show more symmetry and automaticity than the internal focus condition.
LITERATURE REVIEW

MECHANICS OF GAIT

Ambulation is a complex interactive phenomenon between the central nervous system and the musculoskeletal system. The dynamic aspect of ambulation makes it highly susceptible to instability. The two important components that contribute to efficient ambulation are the equilibrium and mobility components. It is the efficient integration of these two components that produce a stable gait.

Gait can be defined as the repetition of a recurring pattern of events, aptly termed gait cycles. A gait cycle comprises of a stance and a swing phase. The stance phase starts from heel strike to ipsilateral toe-off. The swing phase starts after toe-off and ends before the next heel strike. The stance phase is divided into initial double support, single support and second double support periods. The swing phase can be divided into initial swing, mid swing and terminal swing periods. During a gait cycle the body’s centre of mass (COM) passes from one limb to the other (Rose & Gamble, 2006)

The main challenge of the equilibrium or postural component is to maintain balance while keeping the centre of mass outside the base of support. These continuous changes to the centre of mass are controlled by constant anticipatory postural adjustments (Bobath, 1990). Mechanically, the hip and trunk musculature play an important role in maintaining balance. The hip abductors and extensors are the major muscle group that maintain postural stability during walking (Winter, 1995).

There is also a mobility / acceleration component involved in ambulation. There is a cyclic perturbation-stabilisation mechanism occurring with each gait cycle. During the swing phase there is a forward acceleration of the COM which almost simulates the initiation of a controlled forward fall ahead of the base of support. This
perturbation is then stabilised during the double support phase of gait (Winter 1995). The double support time is an important phase in the gait cycle as it contributes to the stability component of this dynamic activity.

**GAIT CONTROL MECHANISMS**

Recent research has shown that voluntary and automatic control of movements are no longer mutually exclusive entities but rather function in a continuum. It is the context of a movement that determines the volitional (cortical) and automatic (spinal) involvement in a movement (MacKay-Lyons, 2002). Human gait has both supra-spinal and spinal control mechanisms although the cortical control seem to dominate voluntary locomotion.

Walking has a basic motor pattern of stepping which is rhythmic and automatic. This rhythmic stepping pattern is attributed to the intrinsic pattern generated by central pattern generators (CPG) in the spinal cord (MacKay-Lyons, 2002). The CPGs are “a network of nerve cells producing specific rhythmic movement such as walking without conscious effort and without the aid of peripheral afferents”. They also have independent control over each leg (Verma et al., 2012). This rhythmic pattern influences the reflex inter limb coordination of lower limbs. The infant stepping reflex seen even before walking (8 weeks) substantiates this theory (Zelazo et al., 1972).

The fine control of walking, especially while interacting with the external environment is controlled by the higher centres like the cortex, cerebellum and brainstem. The neural pathways that descend from the higher centres help in steering, stopping and reacting to the challenges or constraints posed by the environment (Belda-Lois et al., 2011; Verma et al., 2012).
**Figure 1**: Role of brain and spinal cord in walking. Reprinted from “Understanding gait control in post-stroke: Implications for management” by R. Verma et al., 2012, Journal of Body Work and Movement Therapies, 16, p-16. Copyright (2010) by Elsevier Ltd.

**TEMPORO- SPATIAL VARIABLES OF NORMAL GAIT**

The variables that are used to quantify gait (Verma et al., 2012) are:

*Step length*: “Linear distance between two successive points of contact of the right and left lower extremity”.
**Stride length**: “Linear distance between two successive points of contact of the same foot”

**Stride time**: It is the duration between the heel strikes of two consecutive foot falls.

**Stance time**: “Amount of time during the gait cycle that the foot is in contact with the ground”.

**Swing time**: “The amount of time during the gait cycle that the foot is off the ground”.

**Single support time**: The single support time of one limb is equal to the swing time of the other limb.

**Double support time**: The amount of time that both the feet were in contact with the ground. It can be expressed as percentage of stride time of each leg. (Reisman, Wityk, Silver & Bastian, 2007).

**PATHOMECHANICS OF A HEMIPLEGIC GAIT**

The impairment in the cortical control of voluntary movements and the resulting spasticity on one side of the body contributes to the gait abnormalities in hemiplegics. The cortical lesion leads to a lack of inhibitory control resulting in impairment of the postural tone (spasticity) and postural reflex mechanisms (Bobath, 1990). The hemiparetic gait is characterised by synergistic patterns of movement on the affected (paretic) side. There is a mass extension synergy during stance phase and a flexion synergy during the swing phase. There is also an evident disturbance of the postural control mechanism leading to balance problems (Verma et al., 2012). The hemiplegic gait is best described as an asymmetric gait pattern with increased variability of temporal-spatial parameters of the lower limbs. This is attributed to the decreased motor capabilities and motor control of the paretic leg and the compensatory mechanisms adopted by the non-paretic leg (Meijer et al., 2011). The
asymmetry results in more energy expenditure, abnormal joint mechanics and instability, leading to falls (Verma et al., 2012, Forster and Young, 1995).

The temporal-spatial asymmetry which is marked by decreased single limb support duration and the uncontrolled forward movement of the affected limb can be attributed to the inability to transfer of body weight across the affected limb (von Schroeder et al., 1995). This is evident in the gait parameters as the stance phase time is decreased and the swing time is prolonged with a longer step length on the paretic side. There is also a shorter stride length and an overall shorter gait cycle time on the paretic side.

There is an increase in the stance time and decrease in the swing time on the non-paretic side and slower walking speed when compared to normal adults. This asymmetry in the non-paretic side is a compensatory mechanism for the lack of voluntary control and equilibrium on the paretic side (Verma et al., 2012).

**RELATIONSHIP BETWEEN GAIT VARIABILITY AND STABILITY**

Gait in normal individuals is characterised by some amount of asymmetry. The asymmetry is characterised by a certain amount of variability in the spatial and temporal variables of the lower limbs (Meijer et al., 2011). But this variability is exaggerated in neurologically impaired patients. The study by Meijer et al., (2011) on stroke patients has shown a four time increase in the asymmetry percentage when compared to normal adults. Stride length variability has been used as a reliable indicator to ascertain dynamic stability and predict falls (Beauchet, Berrut & Dubost, 2007).

Low stride to stride variability is an indicator for a stable gait and higher stride time variability indicates instability. According to ‘Motor Control Theory’, lower
variability indicates involvement of an automatic process which requires lesser attentional resources and higher variability indicates that greater attentional resources are required to maintain the stability of movement which means it is a less stable pattern (Beauchet et al., 2009). Therefore it can be deduced that stride time variability reflects the rhythmic stepping mechanism which is largely an automatic process (Dubost et al., 2006). An automatic process means that there is a pattern of movement that can be reproduced from stride to stride indicating less variability, more predictability and stability (Beauchet et al., 2007).

GAIT SYMMETRY AS A MEASURE OF FUNCTIONAL RECOVERY

Gait symmetry is reflective of the functional recovery of the hemiplegic patient (von Schroeder et al., 1995). There is a continuous emphasis on regaining the gait speed and gait pattern in all rehabilitation strategies involving stroke patients (Hsu et al., 2003). Gait asymmetry improves with voluntary control and thus serves as an indicator of falls in hemiplegic patients (Balasubramaniam, Neptune & Kautz, 2007). Studies have shown that this asymmetric pattern can be altered with practice, which indicates that the impaired neurological system reorganises to produce a symmetric pattern provided an appropriate stimulus is provided to it. In the study by Reisman et al., 2007, a split–belt treadmill with varying speeds was used as a stimulus to bring about changes in inter limb coordination. This supports the theory that gait asymmetry is a reversible phenomenon in hemiplegics and there has been continuous research into developing strategies to bring about more symmetry in hemiplegic gait and in turn more stability and reduced risk of falls and morbidity.

Research shows that practice can lead to the reorganisation of cortical function and improved locomotion in hemiplegics (Verma et al., 2012). This
encourages research in identifying whether attentional focus on a supra postural task can influence enhancement of symmetry in hemiplegic gait.

The standardized measures that have been used to quantify hemiplegic gait performance and the symmetry of gait pattern are temporal asymmetry and spatial (step length) asymmetry (Balasubramaniam et al., 2007; Hsu, Tang & Jan, 2003).

a) Temporal Symmetry Ratio (Patterson et al., 2010; Balasubramaniam et al., 2007):

\[
\text{paretic swing time/ stance time (seconds)} = \frac{\text{paretic swing time/ stance time (seconds)}}{\text{Non-paretic swing time/ stance time (seconds)}}
\]

b) Single support time asymmetry ratio (Hsu et al., 2003):

\[
= 1 - \frac{\text{paretic single support time (seconds)}}{\text{Non-paretic single support time (seconds)}}
\]

c) Step length asymmetry ratio (Hsu et al., 2003):

\[
= 1 - \frac{\text{paretic step length (centimetres)}}{\text{Non-paretic step length (centimetres)}}
\]

Temporal symmetry ratio should be closer to the normative range and asymmetry ratios should be low to indicate an improvement in the overall stability of the gait pattern.

SUPRA POSTURAL TASK AND POSTURAL MECHANISMS

Supra postural task has been defined as “behavioural goal that is superordinate to the control of posture” (Riley, Stoffregen, Grocki & Turvey, 1999). Supra postural and postural tasks (walking) have two independent behavioural goals but while being performed concurrently there is integration between the two, especially when performed in a functional context. The performance of the supra postural task is
not directly linked to posture but is certainly influenced by the posture control mechanism (Riley et al., 1999; Stins, Roedernik & Beek, 2011). This can be a reciprocating influence and the supra postural task can also influence the posture and movement control mechanisms.

Previous studies with supra-postural tasks have shown that walking is an attentionally demanding task and a concurrent task will have detrimental effects on ambulation (Ju-Cherng et al., 2009). But most of these dual tasks were cognitive. When the supra postural tasks involves a difficult motor task, the results have been contradictory. It has been established that difficult motor supra postural tasks require more stability and so constrain the degrees of freedom of movement (de Lima et al., 2010) which can improve balance during walking.

The stability requirements of a fine motor supra postural task are greater. This requires a stable postural framework or more efficient anticipatory control mechanisms to accurately carry out a task. The constrained trunk movements will help control the forward acceleration of the COM and the perturbations that occurs in a gait cycle. Hence the stability-constraints of this demanding motor task integrates the postural mechanism (trunk and hips) to follow suit, thus enabling more stability during walking.

Most of the concurrent task in previous studies have been done in upright stance and it has been established that there is a “functional integration between postural and supra-postural tasks on the basis of task constraints and contextual cues” (de Lima et al., 2010). However, it needs to be seen what the effect of motor supra postural task is on ambulation especially in the patient population with cortical lesions.
EXTERNAL ATTENTIONAL FOCUS ON SUPRA POSTURAL TASKS AND ITS EFFECT ON POSTURAL MECHANISM

The purpose of incorporating the external focus of attention in performing the supra postural task is because of its established influence on motor skill learning. It has been shown in studies by Wulf et al. (2001), that external focus of attention enhances the motor performance whereas internal focus of attention does not produce any remarkable difference in performance. The probe reaction time while balancing on a stabilometer showed faster times with external focus on markers in comparison with the internal focus on the participants’ feet movements. In a study by McNevin and Wulf (2003), it has been found that external focus of attention facilitates the automatic control process underlying posture. Instructions or cues that have an internal focus of attention (movement patterns & body parts) require a conscious control of movement whereas external focus of attention (movement object and external cues) focuses on the context of the task and enhances the automatic or self-organising control processes to take over (McNevin & Wulf, 2002).

CONSTRAINED ACTION HYPOTHESIS

The constrained action hypothesis was proposed by Wulf et al., (2001) to account for the efficiency of movement performance when an external in comparison to an internal focus of attention was used to learn a task. According to this view, an external focus of attention facilitates the automatic control processes to perform movements and inhibits their conscious control (Wulf, 2003). Automatic control helps achieve movement goals without conscious awareness of the performance of the movement. The movement occurs almost as a by-product rather than an explicit conscious attempt to control movement. External focus of attention will constrain the
conscious control and allow the automatic processes to take over (Wulf, 2007). The use of an external focus of attention on a supra postural (SP) task lays emphasis on the SP task and reduces the cortical control on the gait mechanisms (Wulf et al., 2003). The automatic control processes are expected to decrease variability in the gait pattern. Supra postural tasks also induce 'constraint' in the postural mechanism resulting in a stable posture. This constraint is manifested as a decrease in degrees of freedom of the trunk and proximal joints of the lower limb. This constraint is necessary for the efficient performance of a difficult motor supra postural task (de Lima et al., 2010). All these effects contribute to an overall stable ambulation.

ENTRAINMENT

Entrainment is defined as the tendency of one oscillator to match the frequency of another stable oscillator. A stable phase relationship should exist between oscillator and stimulus to produce entrainment. When adequate postural stability is present there is entrainment of the lower limbs (Whittall & Clark., 1994). The horizontal position of the arm in front of the subject will create a compensatory backward/ extensor hip control strategy in the non-paretic side. The hip abductors and extensors largely contribute to the dynamic stability during walking (Winter, 1995). The decrease in the degrees of freedom of the trunk and proximal joints of the lower limb to produce a stable posture for the performance of the supra postural task will enhance postural stability. This stability will serve as a background for a possible entrainment.

Inter limb coordination is possible even without supraspinal / cortical control, as seen in infants and in studies on spinal cord injured patients (Dietz & Harkema, 2004). Therefore the non-paretic limb, facilitated by the attentional focus, will get into
the automatic rhythmic stepping pattern and will entrain the paretic limb into a similar pattern. This can lead to an overall stable and improved symmetric gait pattern which can contribute to dynamic stability.
DESIGN AND METHODOLOGY

PARTICIPANTS

The participants who fit the inclusion criteria were recruited from the Windsor Regional Hospital’s (WRH) outpatient and inpatient rehabilitation departments.

*Inclusion criteria:* Patients diagnosed and treated for a cerebrovascular accident. The patients are to present with unilateral effects of the CVA. All participants need to be independently ambulant [Barthel’s Index (Appendix H) walking score =15].

*Exclusion criteria:* Pre-existing musculoskeletal conditions or comorbidities that can interfere with gait. There should also be no aphasia / neglect or marked attention deficits.

LOCATION

The study was conducted in the premises of the Windsor Regional Hospital.

RECRUITMENT PROCESS

The research and ethics board of the Windsor Regional Hospital as well as that of the University of Windsor had approved the recruitment of patients from the rehabilitation department of the hospital as participants for this study. The therapists at the WRH were given a criteria checklist (Appendix A) of the participants. Once the potential subjects were identified, they were informed about the study. They were given an information sheet (Appendix B) explaining the purpose of the study and what was required of them. Once the participant voluntarily agreed to participate in the study, an informal consent (Appendix C) was obtained. The researcher was then notified and the potential subject contacted. On agreeing to participate, a date for assessment and experiment was set up with the participant. A formal written consent (Appendix D) was obtained on the day of the experiment.
EXPERIMENTAL EQUIPMENT

The GAITRite™ system was used to measure the various gait parameters. This equipment has been used in previous studies to assess gait symmetry (Patterson et al., 2010). It has an electronic walkway that is 6m long. The GAITRite™ electronic walkway contains six pressure activated sensor pads encapsulated in a roll up carpet to produce an active area 24 inches (61cm) wide and 168 inches (427cm) long. These record the footfalls during the gait cycle which is analysed by software and immediate spatial and temporal parameters are obtained.

EXPERIMENTAL PROTOCOL

Each participant underwent three experimental conditions with three trials in each condition.

1. Walking on the mat without any supra postural task.

2. Walking on the mat holding a mug assumed to contain water and asked to recite numbers in the ascending order from 1 or the alphabet.

3. Walking on the mat with an external / internal focus of attention on the supra postural task.

The subject information about the participants were obtained in the form of a questionnaire (Appendix E) and details about their medical history was obtained from Windsor Regional Hospital records with due consent from the patient. The protocol of the experiment was explained to each participant. They were asked to walk on the GAITRite™ mat and no particular instructions were given other than to walk. They were asked to perform three trials of the same with a rest of 3 minutes in between each trial and more rest time was given on request. The minimum duration of 3 minutes was based on the assumption that it would take 15 seconds to complete each trial and be back in their seat. A rest period of 10 times the duration of a trial was
considered sufficient to offset the effects of fatigue. The next experimental condition was to walk on the GAITRite system while holding a mug assumed to contain water, with no specific instructions with regard to the SP task. However, they were asked to recite the alphabet or numbers in an ascending order. In the third experimental condition, the subjects were advised to assume that the mug contained water and were given specific contextual cues with regard to the task. The participants were allotted their attentional focus condition according to the order of enrolment in the study. Accordingly, the instructions were to either hold the mug as steady as possible (external focus) or to hold the wrist as steady as possible (internal focus). They were informed that the mug contains an inclinometer to assess how they perform the task.

A minimum rest period of 6 minutes or more, if requested or deemed necessary, was provided between each condition in order to allow the effects of the previous condition’s instructions to dissipate. The participants started walking ahead of the walk-way and continued walking beyond the walk-way, such that they had two gait cycles before and after the GAITRite™ mat.

The instructions to the participants were uniform (Appendix F). They were monitored in close proximity by the researcher / associate for safety precautions. A safety belt was tied around their waist and the researcher stood postero-laterally on the affected side with a hand guarding the affected shoulder. No physical contact was made during the walk unless deemed necessary to prevent falls. After each trial with the mug, the participant was asked how focused they were on the task of holding the mug steady by scoring on a visual analog scale of 1-10 (Appendix G).
DATA ANALYSIS

The measures to ascertain any changes in the symmetry of the gait pattern were *Temporal symmetry ratio, Single support time asymmetry ratio, Step length asymmetry ratio*. The measures to determine the automaticity of the gait pattern were *Stride time variability* and *Stride length variability*.

The supra-postural performance was assessed using the resultant vertical and horizontal displacement measures obtained from the inclinometer attached to the mug. The variability of lateral displacement was taken into consideration (by calculating standard deviation of the median measures of the respective trials) in order to quantify the performance of the SP task during each SP condition.

A non-parametric statistical analysis (Wilcoxon signed-rank test) was used to determine the general influence of attentional focus on a hemiplegic gait and whether the intervention changed any characteristic parameters of a hemiplegic gait. The parameters taken into consideration were indicative of the asymmetric spatial measures (step length & stride length) and reduced speed of walking (velocity and cadence). The parameters were aligned such that the difference between baseline and SP performance reflected a positive change for the Wilcoxon. An increase in stride length, step length, velocity and cadence (baseline scores – SP task scores) are assumed to reflect an improvement in the gait pattern.
## PARTICIPANT PROFILE

Table 1

<table>
<thead>
<tr>
<th>*P</th>
<th>Age</th>
<th>Sex</th>
<th>Location Of lesion</th>
<th>Side of motor impairment</th>
<th>Number Of strokes</th>
<th>Interval From Onset</th>
<th>Approximate Walking Distance/day</th>
<th>Walking aid</th>
<th>*MC</th>
<th>Berg’s Balance scores</th>
<th>Functional status</th>
<th>Falls</th>
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<td></td>
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<tr>
<td>1</td>
<td>44</td>
<td>M</td>
<td>Left Basal ganglia</td>
<td>Right</td>
<td>1</td>
<td>16 months</td>
<td>200 metres</td>
<td>none</td>
<td>none</td>
<td>52/56</td>
<td>Independent in all ADL</td>
<td>Community ambulant</td>
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<td></td>
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<td></td>
<td></td>
<td>none</td>
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<tr>
<td>2</td>
<td>68</td>
<td>M</td>
<td>Right Thalamic lacunae Left posterior internal capsule lacunae Left cerebellar</td>
<td>Right</td>
<td>3</td>
<td>3 years from the last stroke</td>
<td>100 metres</td>
<td>Standard walker for outdoors only</td>
<td>47/56</td>
<td>Independent in all ADL</td>
<td>Not much of an outdoor person</td>
<td>none</td>
</tr>
<tr>
<td>*P</td>
<td>Age</td>
<td>Sex</td>
<td>Location of lesion</td>
<td>Side of motor impairment</td>
<td>Number of strokes</td>
<td>Interval From Onset</td>
<td>Approximate Walking Distance/day</td>
<td>Walking aid</td>
<td>*MC</td>
<td>Berg’s Balance scores</td>
<td>Functional status</td>
<td>Falls</td>
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<tr>
<td></td>
<td>3</td>
<td>61</td>
<td>F</td>
<td>Left temp-parietal infarct</td>
<td>Left Middle cerebral artery</td>
<td>Right</td>
<td>8 months from last stroke</td>
<td>140 metres</td>
<td>none</td>
<td>none</td>
<td>Independent in all ADL Community ambulant</td>
<td>One before the last stroke.</td>
</tr>
</tbody>
</table>

*P denotes participants

*MC denotes musculoskeletal co-morbidities
RESULTS

Decrease in the asymmetry of gait pattern is an indicator of the return of voluntary control after stroke. Temporal symmetry ratio, step length asymmetry ratio and single support time asymmetry ratio are all indicators of dynamic stability. The normative range of temporal symmetry ratio is considered to be between 0.9 to 1.1 (Patterson et al., 2008). The step length asymmetry ratio is an indicator of the propulsive force generated by the paretic leg (Patterson et al., 2010; Balasubramaniam et al., 2007) and the single support time asymmetry ratio indicates balance control in the gait pattern. A lower value of these ratios is suggestive of improved symmetry (Patterson et al., 2010) and dynamic stability of the gait pattern.

The Wilcoxon rank test suggests whether attentional focus (external and internal) had a significant effect on the gait parameters. The significance level was set at alpha = 0.05. Reduced variability in the medial-lateral displacement of the mug was assumed to reflect better performance in the SP task.

PARTICIPANT 1

This participant is a 44 year old male who had a left basal ganglia stroke, sixteen months prior to participating in this study. He was functionally independent and community ambulant. He used a standard walker for all outdoor walking and did not require any aid for indoor ambulation. He had medical treatment for persistent spasticity in his affected side. He has also had balance issues and hence used the walker for outdoor ambulation.

Temporal, spatial and weight bearing symmetry ratios: The symmetry ratios as seen in figure 2, showed better results in the supra postural and verbal task.
condition for this participant. The focus of attention condition was performed with cues for external focus of attention.

The Temporal Symmetry Ratios were higher than the normative range in the baseline condition suggesting that this participant had a highly asymmetric pattern, where the non-paretic leg was compensated heavily for the paretic leg. The attentional focus condition made the asymmetry worse whereas there was a marginal decrease in the verbal task condition. Single Support Time Asymmetry Ratio (SSTAR) is the lowest in the verbal task condition (0.166) and highest in the external focus condition. Along with a low variability there was also a marginal increase in the velocity (0.3m/sec) in comparison with the baseline measures. This indicates that the verbal task condition produced more symmetry than the focus of attention condition.

Figure 2: The symmetry ratios (temporal symmetry ratio, single support time asymmetry ratio and step length asymmetry ratio) of participant 1 across the three conditions- Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and external focus of attention.

Step Length Asymmetry Ratio (SLAR) remained the same as the baseline SLAR in the verbal task condition, with a marginal increase in asymmetry in the
external focus condition. However, there was a marked reduction in the average step length of the paretic and non-paretic leg in the external focus condition suggesting that shorter steps were taken. The step length differential (4.76cm), which is the difference between the average step lengths of both feet, was the highest in the external focus condition indicating an increased variability in the step length measure between the two lower limbs. It is suggestive of increased compensatory movement patterns in the non-paretic limb and decreased propulsive force in the paretic leg. These changes could be adaptations to the complexity of the task in the attentional focus condition. The velocity also drops considerably (64.83cm/sec from 78.1cm/sec) in the attentional focus condition. This is suggestive of the ‘constraint-induced’ phenomenon which reduces the degrees of freedom of joints and hence the velocity of gait reduces.

Although it was only the verbal task condition that showed an improvement in the overall gait symmetry, there was an improvement in the weight-bearing time of the affected leg in both the supra postural conditions. This is a positive sign especially in stroke patients as a lot of emphasis is placed on improving the weight-bearing on the affected leg as this leads to reduction in spasticity and improved motor control.

**Stride time and stride length variability:** Stride time variability was low in the verbal task condition for the both lower limbs, with the external focus condition showing a better reduction in variability in the non-paretic leg, as shown in figure 3. The supra postural task brought about a better temporal symmetry in this condition. Stride time variability in both the supra postural tasks was lower than the baseline measures, suggesting that the addition of a supra postural task led to improved consistency in the temporal parameters of gait.
Figure 3: The stride time variability of participant 1 across the three experimental conditions - Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and external focus of attention.

However there were differences in the stride length variability (Figure 4) between the two limbs. The supra postural task seemed to have brought about a reduction in the stride length variability of the non–paretic limb, the paretic limb does not appear to entrain to the non-involved limb as its stride length variability is markedly increased under both supra postural conditions in comparison with the baseline measures. Stride length variability of the paretic leg in the external focus condition is reduced compared to the verbal task condition, suggesting that it was due to the constraint induced by the external focus of attention.
Figure 4: The stride length variability of participant 1 across the three experimental conditions- Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and external focus of attention.

Inclinometer results: The verbal task diverted his attention from the SP task and thereby reduced the overall complexity of the task. This could have resulted in a more automatic control of the primary task of walking as shown by improved symmetry in the verbal task condition. The inclinometer displacement graphs (Figure 5 & 6) show increased displacement of the mug in this condition in comparison with the external focus condition. This indicates that the performance of the SP task was better in the attentional focus condition but at the cost of gait symmetry. External focus on the SP task influenced the postural mechanism to constrain itself and led to a decrease in the spatial parameters. Thus focusing the attention onto a SP task increased the complexity of the task and reduced the symmetry of the gait pattern in this participant. Drawing his attention away from the task affected the performance of the SP task but improved his gait symmetry.
**Figure 5:** Inclinometer data. Average horizontal and lateral displacement of the mug in the verbal task condition of participant 1.

![Mug Displacement-Verbal SP task Participant 1](image)

**Figure 6:** Inclinometer data. Average horizontal and lateral displacement of the mug in the external focus condition of participant 1.

![Mug Displacement-External focus SP task Participant 1](image)

**Wilcoxon rank test results:** Analysis of the baseline vs external focus condition \(z = -2.201, p = 0.014\), revealed that the external focus led to a decrement in gait performance, which was contrary to expected results. The verbal task did not lead to any appreciable difference in gait performance, \(z = -.734, p = .231\), despite adding a cognitive load during gait.
**Effect of lesion:** This participant had a lesion in the left basal ganglia. One of the functions of the basal ganglia is to influence the initiation and control of movements. Previous studies have shown that a stroke involving the basal ganglia affects the performance of tasks where there is an involvement of the working memory (Boyd & Winstein, 2004). This means that any conscious strategies that have to be learned and adopted to perform a new task will affect the performance of that task. So when explicit information is given to perform an implicit task, the lesion in the basal ganglia affects the patient’s capacity to process this information. This affects the performance of that motor task (Boyd & Winstein, 2004). The location of the lesion might have had an influence in processing of information in the external focus condition. This could have added to the complexity of the task and resulted in the participant taking a cautious approach and thus slowing down his pace. It could also mean that the complexity of the task added to the constraint of the postural mechanisms and as a result of the constrained degrees of motion there was a reduction in the spatial parameters and a resultant drop in velocity.

**Other factors:** The increased spasticity and stiffness of the right foot as well as the ankle foot orthosis (AFO) had affected his stepping reaction and reduced the stance phase on his affected leg in his last gait assessment, dated a year ago. He might still be carrying the same problems in his right foot or developed compensatory mechanism in his non-paretic limb to counter it. He has also been using a walker for all outdoor walking as he had issues with balance. He volunteered to walk on the GAITRite™ walkway without a walker and did so successfully. However the lack of a support that he had been used to, could have further engaged his attentional resources and conscious control of gait.
PARTICIPANT 2

This participant is a 68 year old stroke patient with a history of multiple strokes. He has had lesions in the right thalamic lacunae, left posterior internal capsule lacunae and the left cerebellum. He was functionally independent and community ambulant. He did not require walking aid for indoor ambulation and uses a cane for outdoor ambulation. He has had issues with balance with his most recent Berg’s balance score (Appendix I) being 47/56.

**Temporal, spatial and weight bearing symmetry ratios:** This participant too showed better symmetry in the verbal task condition. The focus of attention condition was performed with cues for internal focus of attention.

The asymmetry ratios showed that the verbal task produced a better symmetrical gait in comparison with focus of attention. The temporal symmetry ratio showed better results than the baseline ratio which indicates that the temporal symmetry improved with the supra postural (SP) and verbal task. But it showed reduced symmetry in the internal focus condition. This could mean that the SP task produced a more symmetrical gait when the attention was not focused on the task.

The SSTAR indicates that there was more asymmetry in the internal focus condition. The symmetry improves in the supra postural condition which involved a verbal task in comparison to the internal focus of attention. Step length asymmetry ratio follows the same trend with better spatial symmetry in the verbal task condition in comparison with the internal focus condition. This suggests that the supra postural task was able to bring about better symmetry when the focus of attention was not on the task.
**Figure 7:** The symmetry ratios (Temporal symmetry ratio, Single support time asymmetry ratio and Step length asymmetry ratio) of participant 2 across the three conditions—Baseline walking, Walking with supra postural task and verbal recitation, Walking with supra postural task and internal focus of attention.

**Stride time and stride length variability:** The stride time variability is the lowest in the verbal task condition (Figure 8) for both the paretic and non-paretic lower limbs. The stride length variability was the least in the internal focus condition, suggesting that the constraint induced by the focus of attention could have reduced the average stride length (difference = 10.6 cm) and the overall variability in the paretic leg. But this is off-set by the increased variability in the non-paretic leg indicating that this limb had to compensate for the reduced stride length of the paretic limb.
**Figure 8:** The stride time variability of participant 2 across the three experimental conditions- Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and internal focus of attention.

**Figure 9:** The stride length variability of participant 2 across the three experimental conditions- Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and internal focus of attention.

**Inclinometer results:** The inclinometer data (Figure 10 & 11) showed that the internal focus of attention had improved the performance of the supra postural task.
Figure 10: Inclinometer data. Average horizontal and lateral displacement of the mug in the verbal task condition of participant 2.

Figure 11: Inclinometer data. Average horizontal and lateral displacement of the mug in the internal focus condition of participant 2.

The horizontal and lateral displacement of the mug was reduced considerably in the internal focus condition. This further supports the theory that in order to efficiently perform the supra postural task, the postural mechanism is constrained and this is reflected in the decreased spatial and temporal parameters. But in this case, the
theory that automatic patterns take over when there is focus on a supra postural task is not supported as the symmetry ratios and variability measures do not support it.

**Wilcoxon signed-rank test results:** The test results suggest there was no positive influence of the internal focus of attention on the overall performance of gait \[ z = -.943, p = 0.172 \]. The verbal task condition had a statistically significant influence on the parameters tested \[ z = -.1.782, p = .0.037 \], such that the added cognitive load led to improved performance.

**Effect of lesion:** This participant had a lacunar stroke of the right thalamus and left internal capsule as well as left cerebellum. This is a case of sensorimotor impairment of contralateral sides. The sensory status of the left lower limb has recovered since his first stroke which was about 6 years before the day of testing. Cerebellar lesions add incoordination to existing motor impairments. It also leads to an ataxic gait pattern which is typically described as a ‘drunken’ gait. Ataxia is incoordination in movement patterns and the gait is characterized by increased temporal and spatial variability (Ilg, Golla, Thier & Giese, 2007). This participant has had balance issues and his last recorded Berg’s balance score (Appendix I) was a 47/56 which is interpreted as having a low risk of falling. The increased stride length variability of both the limbs in comparison to the baseline parameters could be attributed to the effect of the cerebellar lesion as well as to the history of balance problems. A concurrent task especially in a new environment would have added to the fear of imbalance and increased the variability in the spatial parameters. However the reduced variability in stride time indicates that the body tries to self-organize into a temporal symmetry at the cost of spatial symmetry and the supra postural task influences this adaptation.
Other factors: This participant’s gait pattern with its asymmetries, as seen in the baseline measures is a set pattern, since his first stroke was 6 years prior to his participation in this study. This established pattern has become his automatic pattern of gait. Changing an established abnormal pattern of gait is difficult but the changes to the temporal and spatial parameters in the experimental conditions indicate that short term adaptations are still possible in such gait patterns.

PARTICIPANT 3

This participant is a 61 year old female with a left cerebral infarct. She had a previous history of a left temporo-parietal infarct with no motor impairments. She presented with a left cerebral infarct two years after the first episode of stroke. The motor impairment was more in the upper extremities than the lower extremities. She had near normal muscle power at time of her discharge from the rehabilitation unit. She had no issues with balance but had a pre morbid endurance problem with long distance ambulation.

Temporal, spatial and weight bearing symmetry ratios: The temporal parameters of this participant were consistently similar across the three conditions. The temporal symmetry ratios in the three experimental conditions were nearly similar and closer to the normative value of 1.1.
Figure 12: The symmetry ratios (temporal symmetry ratio, single support time asymmetry ratio and step length asymmetry ratio) of participant 3 across the three conditions - Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and external focus of attention.

The SSTAR was the lowest in the external focus condition as seen in Figure 12. This indicates that there was more inter limb coordination and symmetry in the external focus condition. The single support time of the affected limb increased indicating that there was more weight bearing on the affected limb. The SLAR was higher in the external focus condition in comparison with the verbal task condition. This could be attributed to the compensatory adaptations made by the non-paretic limb due to the increased single support time of the affected leg. The increased stance time in the external focus condition shows that there was more weight bearing in both the limbs.

There was an 11.5% increase in the stance time of paretic limb and a 12.58% increase in the non-paretic limb from verbal condition to the attentional focus condition. This increased weight bearing can be attributed to the slowing down of the
velocity and the reduced degrees of freedom. There is a drop in the velocity (15.8%), along with the stride length (10%) and cadence (7.5%). This is suggestive of a cautious approach to the task and can be attributed to the fear of imbalance.

**Inclinometer results:** The displacement measures from the inclinometer (Figure 13 & 14) show that the mug was held steadier in the external focus condition. This suggests that the SP task was performed more efficiently in the external focus condition. The reduced velocity and the increased weight-bearing in the extremities suggest that the external focus induced constraint reduced the spatial parameters to provide a stable postural mechanism to efficiently carry out the SP task.

![Figure 13](image.png)

*Figure 13:* Inclinometer data. Average horizontal and lateral displacement of the mug in the verbal task condition of participant 3.
Figure 14: Inclinometer data. Average horizontal and lateral displacement of the mug in the external focus condition of participant 3.

This participant has the most symmetrical hemiplegic gait pattern among the three cases examined. The improved temporal symmetry in the external focus condition can contribute to strategies to improve temporal symmetry during the early rehabilitation phases. The reduced velocity and stride length will not be of significance in this phase as the emphasis will be more on overcoming the synergistic pattern and improving temporal symmetry.

Stride time and stride length variability: These variability measures were found to be lowest in the external focus condition in comparison to the verbal task condition (Figure 16 & 17). This participant has the least severe motor impairment when compared to the other two participants. The non-paretic limb has lower variability measures in the two supra postural (SP) tasks in comparison with the baseline measures. The external focus condition has lower strids time variability than the verbal task condition in both the lower limbs suggesting that the external focus on the SP task had a positive effect on the temporal variability. The stride length
variability shows the lowest value in the external focus than the verbal task condition. But this is considerably higher than the baseline measures. In this participant external focus of attention has brought about a less variable pattern of gait when compared to condition without any attentional focus instructions.

*Figure 15:* The stride time variability of participant 3 across the three experimental conditions- Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and external focus of attention.
Figure 16: The stride length variability of participant 3 across the three experimental conditions- Baseline walking, walking with supra postural task and verbal recitation, walking with supra postural task and external focus of attention.

Although the SP task brings about some amount of temporal symmetry in comparison with the baseline measures, the higher variability of the stride length suggests that the lower limbs are undertaking adaptations to improve the temporal symmetry. This leads us to the understanding that in hemiplegics the movement patterns automatically adapt and alter to maintain the temporal symmetry when faced with perturbations. This is done by altering the spatial parameters and hence the increased spatial variability in the primary task of walking while performing a concurrent supra postural task.

*Wilcoxon signed-rank test results:* In contrast to the previous two participants, verbal instructions did not lead to improved gait performance \( z = -0.314, p = 0.376 \). However, external focus instructions did have a positive effect \( z = -2.201, p = 0.01 \).
**Effect of lesion:** This participant had a left infarct of the brain with a history of a previous temporo–parietal infarct. The first stroke had no physical manifestations and had only affected speech and memory. The second stroke resulted in weakness of the upper limb more than the lower limb. The second stroke was about 8 months before the date of testing. This participant had the most symmetrical gait pattern considering her lower extremity was not affected as much as the upper extremity. There is not much of an abnormal tone and the motor control of the lower extremities was near normal.

**CROSS ANALYSIS**

**Velocity, cadence and stride length measures:** The velocity, cadence and stride length measures in all the three cases reduced during the attentional focus task. The decreased cadence along with the drop in velocity suggests that the participant had slowed down. Increase in walking speed is used as an indicator of motor recovery and as a parameter to determine community ambulation (Verma et al., 2010). But in these cases, attentional focus (external and internal) brought about a reduction in the gait velocity along with a decrease in cadence and average stride length. This suggests that the participant adopted a cautious approach and this type of gait pattern is often associated with imbalance. The decreased stride length can be attributed to the reduced degrees of freedom due to the constrained postural mechanism which is required to perform the supra postural task efficiently. But the associated reduction in the velocity and cadence indicates that the overall pace of locomotion had dropped. It needs to be evaluated further whether this drop in gait velocity contributes to dynamic stability or not.
Figure 17: The average stride length of the paretic and non-paretic limbs of all the participants across the three conditions- Baseline walking with no supra postural task, walking with supra postural task and verbal recitation, walking with supra postural task and focus of attention instructions.

Figure 18: The average cadence of all the participants across the three conditions- Baseline walking with no supra postural task, walking with supra postural task and verbal recitation, walking with supra postural task and focus of attention instructions.
Figure 19: The average gait velocity of all the participants across the three conditions—Baseline walking with no supra postural task, walking with supra postural task and verbal recitation, walking with supra postural task and focus of attention instructions.

The external focus was meant to divert attention from the primary task of walking. But for an individual who has an impaired gait and has a history of balance issues, performing a new task in a new environment compounds these balance issues and increases his/her fear of falling. To counter this, the body slows movements in order to create a sense of control and stability. When the focus is on performing the SP efficiently, the adaptive response of the primary task is to slow down in order to create a sense of control. This contradicts the paradigm that an increase in gait velocity is indicative of improved motor control.

The velocity, cadence and stride length have uniformly increased in the verbal task condition (Figure 17). This suggests that in these three cases that were examined, the supra postural task when not focused on the task increased the speed of the gait. This could be attributed to the lack of a conscious awareness or fear of falling when the focus is not on the SP task.
Medial-lateral variability of mug displacement: The standard deviation values of the medial-lateral (horizontal) displacement of the mug (Figure 20) across the three trials in each of the SP task condition clearly shows that the movements in the medial-lateral direction markedly reduced in the attentional focus condition in comparison with the verbal task condition. This suggests that attentional focus had a positive influence on the performance of the supra postural task.

![Bar chart showing variability of mug displacement](image)

Figure 20: Inclinometer data. Variability of the medial-lateral displacement of the mug across the two supra postural conditions.
DISCUSSION

The purpose of this study was to determine how external focus of attention on a supra postural task will affect the gait in hemiplegic patients. The study was based on the theory of ‘constrained-action-hypothesis’ induced by external focus of attention and ‘entrainment’. This study has tried to determine whether the improvement in postural stability brought about by attentional focus on a supra postural task will influence dynamic stability of a hemiplegic gait.

The hypothesis was that external focus of attention on a supra postural task would lead to a decrease in the variability of gait parameters and improved symmetry ratios which is indicative of improved dynamic stability. The basis of this hypothesis was that external focus on the SP task would enhance the diversion of attention from the primary task of walking and influence the automatic processes to take over the cortical control of walking. It was assumed that the automatic stepping pattern will improve the symmetry of gait and reduce the variability, thereby increasing the dynamic stability of a hemiplegic gait. The results of the three cases that have been discussed here show that this cannot be applied to a hemiplegic gait. The results indicate that there are various factors that can influence the symmetry of gait while attentional focus is being employed on a supra postural task. The spatial and temporal asymmetry of a hemiplegic gait is not only influenced by the conscious control mechanisms or the lack of it (automatic control mechanism). The level of spasticity, extent of cortical damage, involvement of subcortical areas, associated neurological impairments (sensory, coordination, cognitive and vestibular), phase of recovery and interval from onset of the episode have an influence on the exaggerated asymmetry of a hemiplegic gait. Unless many of these factors are controlled, it is difficult to isolate
the direct effects (either positive or negative) that an external focus of attention on a supra postural task, will have on the gait pattern of hemiplegics.

All the participants showed a reduction in the average stride length during the attentional focus condition in comparison with baseline measures. These changes suggest that when a supra postural task is associated with attentional focus, there is constraint in the degrees of freedom (Wulf et al., 2003; McNevin & Wulf, 2002; deLima et al., 2010) of the proximal joints of both lower extremities resulting in the decreased spatial parameter (stride length). There is also a uniform drop in gait velocity and cadence in the attentional focus condition across all three participants.

De Lima et al., 2010, suggest that a decrease in the degrees of freedom can contribute to dynamic balance. However, previous studies suggest that a reduction in the velocity and stride length is an indication of imbalance and an indicator of falls especially in the elderly (Verma et al., 2010). The validity of having velocity and stride length as indicators of fall / imbalance in hemiplegics requires further examination.

The study also tried to determine the effect of external focus on the exaggerated asymmetry in hemiplegics by assessing the established measures of symmetry such as temporal symmetry ratio, step length asymmetry ratio and single support time asymmetry ratio. Contrary to previous assumptions that a concurrent task will be detrimental to the symmetry of gait and that the effect might be compounded in neurologically impaired gait, the results show that there is only a marginal increase in the asymmetry ratios between the baseline and supra postural task conditions.

The inclinometer data shows that the supra postural tasks were done more efficiently in the attentional focus conditions indicating that a stable postural
mechanism was achieved during this experimental condition. All these changes support the theory that a supra postural task constrains the postural mechanism leading to postural stability and the results also suggest that it influences the dynamics of a hemiplegic gait. But what is not established is whether these changes translate into dynamic stability, as the measures of dynamic stability (asymmetry ratios and variability measures) used in this study do not support it.

The results show that the duration of stroke and the level of impairment of the participants influence the effect of the interventions on gait. Participant three showed better stride length and time variability (Figure 15 & 16) in the external focus of attention condition. Her medical notes indicate that the lower limb functional level was near normal. This participant had very few functional limitations in the lower extremity and external focus of attention showed an improved symmetrical pattern in this participant. Hence the constraint-induced theory appears to work better in this participant whose spasticity was minimal and motor control was near normal. The single support time of both lower limbs was more symmetrical in this condition and it suggests that the constraint due to the external focus on a SP task enhanced inter-limb coordination. But this is subjective to the interference from increased muscle tone and muscle weakness. The improved symmetry and variability of the gait parameters of participant 3 due to the effect of external focus of attention can be attributed to the decreased interference from spasticity and increased motor control in the lower extremities.

The increased asymmetry in temporal, step length and weight bearing ratios in attentional focus conditions in the two chronic hemiplegic cases does not support the hypothesis of this study. External focus of attention did not serve as a diversion from conscious control of walking and did not induce automatic control. It appears that the
attention drawn to the supra postural task added to the attentional resources required to complete the entire task and compounded the fear of losing balance, which is a major contributor to the asymmetry in hemiplegic gait. The altered step length symmetry and swing to stance ratios are all compensatory adaptations towards maintaining the dynamic balance of a hemiplegic gait. The assumption that external focus of attention on a supra postural task will decrease the compensatory mechanisms and thereby contribute to a better symmetry does not hold in chronic stroke patients who have achieved a high level of functional independence but have persisting balance issues. The complexity of a secondary motor task has a direct influence on the gait pattern (Ju Cherng et al., 2007). In cases where the interval between the first episode of stroke and the intervention is more than one year and where spasticity and balance issues persists, attention drawn to a supra-postural task adds to the complexity of the secondary task and increases the asymmetry in the gait pattern.

Implications: The results obtained from the study could have implications in the understanding of the effect of attentional focus on hemiplegic gait. According to the results form one of the cases in this study, external focus of attention on a supra postural task appears to be effective in conditions where the spasticity and motor impairment are not severe. This could serve as an appropriate stimulus to increase weight bearing in the paretic limb and bring about temporal symmetry during the phase of recovery, when the spasticity is waning and the voluntary control over the synergistic pattern is returning. External focus of attention might be effective in stages 4 and 5 of the Chedoke McMaster motor recovery stages (Appendix J). If the supra postural task is modified according to the functional abilities of the patient, such that the motor task is not too complex, external focus of attention might serve to be a
stimulus to enhance automaticity in the gait pattern. But external focus of attention and the supra postural task should be selected and administered according to the functional level of the patient, with due consideration of balance and other neurological impairments that may affect its efficacy.

The constraint induced by the external focus of attention seems to reduce the degrees of freedom (as seen in the cases studied) and could possibly create a scope for improved voluntary control. The reduced velocity and range of movements could be used to encourage more weight-bearing which might help reduce spasticity and improve voluntary motor control. This could perhaps be employed in the early phase of rehabilitation when weight-bearing on the affected leg and improved temporal symmetry is more relevant than velocity of gait.

The consistency in the improved temporal symmetry in comparison with the spatial symmetry is suggestive of the self-organization capability of a neurologically impaired system into temporal symmetry. This also suggests that such a system inclines towards achieving a temporal symmetry in order to maintain dynamic balance. This temporal symmetry is achieved through the increased variations in the spatial parameters. In a study by Balasubramaniam, Riley & Turvey (2000), on the demands of a precision task on postural sway, there was an increase in the antero-lateral sway when the task required medio-lateral precision and vice versa. The increased variability in one dimension apparently contributed to the improvement of the stability in the other dimension. The results of the study (Balasubramaniam et al., 2000) suggested that some amount of variability is necessary to maintain postural stability. This supports the results of this study that spatial variability can be indicative of the ability of the body to adapt to perturbations and might be necessary to obtain a temporal symmetry which contributes towards dynamic stability.
The changes in the temporal and spatial parameters of the hemiplegic gait are manifestations of the short term adaptations to the supra postural task. Hence established movement patterns can be altered in a stroke patient provided the appropriate stimuli are provided. This encourages the attempts to improve the gait pattern of hemiplegic patients across the continuum of rehabilitation.

**Limitations:** One of the major limitations of this study as well as all studies involving stroke patients is the diversity in the presentation of motor, sensory and cognitive impairments. There needs to be an extensive control of various variables in order to arrive at a definite conclusion. The different levels of spasticity and the underlying variations of synergistic patterns as well as the uncharacteristic nature of the compensatory movement patterns add up to the complexity of a hemiplegic gait.

This study examined three cases of hemiplegia with three distinct etiologies of stroke and distinctly different presentations of motor impairments. Therefore the influence of any particular intervention on such diverse participants will produce results that have very few similarities. Two participants were tested in the external focus condition and one in the internal focus condition, making it more difficult to draw definitive comparisons between the two focuses of attention conditions.

The instructions given to the participants (Appendix F) emphasized on holding the mug or the hand as steady as possible might have added to the difficulty of the task and could have contributed to the cautious approach adopted by all the participants in the attentional focus conditions. Modifications in the instructions, with little emphasis on the efficiency of the task-performance and simple attentional focus cues could have shown an improvement in the gait velocity.
Apart from the design of the study that had between subjects attentional focus conditions, there was no definitive control factor to ascertain whether the participants actually used the specific focus of attention (internal vs. external). The results of the study were analysed based on the assumption that the participants followed the instructions given to them regarding the focus of attention.

**Recommendations:** In order to ascertain the direct effects of external focus of attention on hemiplegic gait, it is necessary to have a sample that have the same location of lesion, belong to the same phase of recovery and show similar grade of spasticity and a comparable level of motor impairment.

The results of the study do not adequately support the hypotheses that attentional focus on a supra postural task will improve symmetry, lower variability of gait parameters and contribute to improved dynamic stability. There is also not enough evidence to support the hypothesis that external focus of attention is more effective than internal focus of attention to bring about an improvement in the gait symmetry in hemiplegics.

The examination of these cases have contributed to certain insights into the gait symmetry of hemiplegics when there is attentional focus on a supra postural task. It has thrown light on the possible scope of adopting the constraint–induced theory into rehabilitation strategies. However further research with a larger sample size is required to further validate the results of this study.


APPENDIX A

CRITERIA FOR PARTICIPANT RECRUITMENT

- Unilateral hemiplegia
- Community ambulant
- Age should be within 70 years
- Gender does not matter.
- No pre-existing musculoskeletal conditions that can affect gait.
- No aphasia, agnosia, neglect or marked attention impairments.
- Barthels Index walking score = 15
- Should be capable of walking for 6 meters at a stretch without a walking aid.
APPENDIX B

INFORMATION ABOUT THE STUDY

This is a research study conducted by Dr. McNevin and Ms. Jecy Kunju Kunju from the University of Windsor with due consent and approval from Dr. Liam, the Windsor Regional Hospital Research and Ethics board and The University of Windsor Research and Ethics Board.

Walking is an integral part of recovery from stroke. The purpose of this study is to find out the how holding an object (mug of water) in your hands can affect the walking pattern in hemiplegic gait. The study aims to contribute information in the sphere of attentional focus in rehabilitation of hemiplegic gait.

You might need to set apart an hour of your time if you consent to be a part of this study. All that you would be required to do is to walk holding a mug/cup across a mat that will record your walking parameters. We would give you a report of your walking parameters on request, at the end of the study. All safety measures will be complied with and qualified personnel would be with you to monitor and assist you during the study. It will be conducted at the rehabilitation department of the hospital.

If you are interested to participate in the study and want to know further details, please fill in a consent form and we will contact you.

Thank you
APPENDIX C

INFORMAL CONSENT

NAME:

GENDER:

CONTACT ADDRESS:

PHONE NUMBER:

EMAIL ID:

CONVENIENT TIME TO CONTACT:

I AM INTERESTED IN THIS STUDY AND WOULD LIKE TO KNOW MORE ABOUT IT AND PARTICIPATE IN IT.

SIGNATURE:

DATE:
APPENDIX D

CONSENT FORMS

University of Windsor

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Attentional focus on supra-postural tasks effects during ambulation: Applications to rehabilitation

You are asked to participate in a research study conducted by Dr. Nancy McNevin, Jecy Kunju-Kunju, and Dr. Nathania Liem, from the Department of Kinesiology and at the University of Windsor and Windsor General Hospital (Dr. Liem). If you have any questions or concerns about the research, please feel to contact Dr. Nancy McNevin at (519) 253-3000 Ext. 4876.

PURPOSE OF THE STUDY

This study will assess how you walk while carrying a glass of water with and without instructions on where to focus your attention.

PROCEDURES

If you volunteer to participate in this study, you will be asked to:

Phase 1: Background information and initial assessment (Duration – 30 minutes)
1. Meet with the researcher so that information about your general health status can be obtained. Some of this information is only available from your medical records, which we will require your permission to review. The information from your medical records will ONLY be used to ascertain and confirm the date of your stroke, document your score on the Chedoke-McMaster assessment, and record any medications you have been prescribed which might impact your ability to walk.
2. If you agree to provide this information and it is felt that you will be able to complete the task requirements safely, we will schedule a date/time for you to return to complete the second phase of the study.

Phase 2: Walking trials (Duration – 45 minutes)
3. To obtain accurate measurements of your walking performance, it will be necessary to measure the lengths of each leg and your height, and weight to enter into the computer. The walkway is connected to the computer and records how fast you walked and how long your steps were.
4. When your information has been entered into the computer, you will be asked to hold a glass of water in your preferred hand and walk down the short walkway at a comfortable pace. The glass of water will have a lid on it to prevent spillage. During these trials, please try not to spill any water. You will be given a short break between each trial.
5. After you have completed two trials, you will be asked to walk down the walkway four more times while carrying the glass of water. During these trials, you will be given a set of instructions by the researcher and provided a reminder prior to each trial. These instructions will direct you to focus your attention on the glass of water or your hand while you walk. Try to follow the instructions as best as possible, and as in the previous trials, please try not to spill any water. You will be given a short break between each trial.

POTENTIAL RISKS AND DISCOMFORTS

There is always some risk associated with walking, and because you will be asked to carry an object which may interfere with your ability to walk, there is a slight increase in the risk of falling. To minimize this risk, standby assistance will be provided while you walk, and short rest breaks will be provided between trials. To prevent accidents due to slipping in spilled water, a plastic cover will be placed on the glass of water. There are no other known risks or discomforts associated with participating in this study.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

At the conclusion of testing, you will be provided with a report documenting your walking profile, which includes a measure of how your walking compared to population norms. This information may be helpful in identifying ways that you and your therapist can improve your walking; such as exercise programs and/or orthotic devices.

11/5/2010
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The results of this study will help researchers identify how different types of instructions impact certain motor skills, such as walking. If benefits are found, researchers may use this information to enhance recovery of individuals who have been affected by stroke.

COMPENSATION FOR PARTICIPATION

Participants who complete this study will be offered a "Get involved in Kinesiology research – I did" t-shirt.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. All personal/medical information will be stored on the GAITRite computer, which is protected by a password known only by the researcher and graduate student. Even though your name is stored in this dataset, only the unique identifier (a randomly assigned number) will be used to identify your data and you will never be identified by name in any publication of the results. Your signed informed consent form will be locked in a file cabinet housed in the principal investigator's office, which is locked when not in use. Data stored in electronic format will be deleted after 5 years, and your signed consent form will be destroyed at the end of 3 years.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. Please understand that once the data from this research study have been published, you will not be able to withdraw your data. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. Changes in medication or a recent fall which may increase your risk of injury are circumstances which might lead to withdrawing you from this study.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS

You may also request a copy of the results from the principal investigator via email or phone (see below)

email address: rmcnevin@uwindsor.ca

Date when results are available: July 1, 2010

SUBSEQUENT USE OF DATA

This data will not be used in subsequent studies.

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty, keeping in mind that once data have been published, it will not be possible to remove your data from the article. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study Attentional focus on supra-postural tasks effects during ambulation: Applications to rehabilitation as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Subject

Date: 4/12/2013

Signature of Research

Date: 11/1/2010

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Version Date: 2/13/2013
CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Attentional focus on supra-postural tasks effects during ambulation: Applications to rehabilitation

You are asked to participate in a research study conducted by Dr. Nancy McNevin, Jecy Kunju-Kunju, and Dr. Nathania Liem, from the Department of Kinesiology and at the University of Windsor and Windsor General Hospital (Dr. Liem)

If you have any questions or concerns about the research, please feel free to contact Dr. Nancy McNevin at (519) 253-3000 Ext. 4576.

PURPOSE OF THE STUDY

This study will assess how you walk while carrying a glass of water with and without instructions on where to focus your attention.

PROCEDURES

If you volunteer to participate in this study, you will be asked to:

Phase 1: Background information and initial assessment (Duration – 30 minutes)

1. Meet with the researcher so that information about your general health status can be obtained. Some of this information is only available from your medical records, which we will require your permission to review. The information from your medical records will ONLY be used to ascertain and confirm the date of your stroke, document your score on the Chedoke-McMaster assessment, and record any medications you have been prescribed which might impact your ability to walk.

2. If you agree to provide this information and it is felt that you will be able to complete the task requirements safely, we will schedule a date/time for you to return to complete the second phase of the study.

Phase 2: Walking trials (Duration – 45 minutes)

3. To obtain accurate measurements of your walking performance, it will be necessary to measure the lengths of each leg and your height, and weight to enter into the computer. The walkway is connected to the computer and records how fast you walked and how long your steps were.

4. When your information has been entered into the computer, you will be asked to hold a glass of water in your preferred hand and walk down the short walkway at a comfortable pace. The glass of water will have a lid on it to prevent spillage. During these trials, please try not to spill any water. You will be given a short break between each trial.

5. After you have completed two trials, you will be asked to walk down the walkway five more times while carrying the glass of water. During these trials, you will be given a set of instructions by the researcher and provided a reminder prior to each trial. These instructions will direct you to focus your attention on the glass of water or your hand while you walk. Try to follow the instructions as best as possible, and as in the previous trials, please try not to spill any water. You will be given a short break between each trial.

POTENTIAL RISKS AND DISCOMFORTS

There is always some risk associated with walking, and because you will be asked to carry an object which may interfere with your ability to walk, there is a slight increase in the risk of falling. To minimize this risk, standby assistance will be provided while you walk, and short rest breaks will be provided between trials. To prevent accidents due to slipping in spilled water, a plastic cover will be placed on the glass of water. There are no other known risks or discomforts associated with participating in this study.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

At the conclusion of testing, you will be provided with a report documenting your walking profile, which includes a measure of how your walking compared to population norms. This information may be helpful in identifying ways that you and your therapist can improve your walking; such as exercise programs and/or orthotic devices.
The results of this study will help researchers identify how different types of instructions impact certain motor skills, such as walking. If benefits are found, researchers may use this information to enhance recovery of individuals who have been affected by stroke.

COMPENSATION FOR PARTICIPATION

Participants who complete this study will be offered a "Get involved in Kinesiology research – I did" t-shirt.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. All personal/medical information will be stored on the GAITRite computer, which is protected by a password known only by the researcher and graduate student. Even though your name is stored in this dataset, only the unique identifier (a randomly assigned number) will be used to identify your data and you will never be identified by name in any publication of the results. Your signed informed consent form will be locked in a file cabinet housed in the principal investigator's office, which is locked when not in use. Data stored in electronic format will be deleted after 5 years, and your signed consent form will be destroyed at the end of 3 years.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. Please understand that non-the data from this research study have been published, you will not be able to withdraw your data. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. Changes in medication or a recent fall which may increase your risk of injury are circumstances which might lead to withdrawing you from this study.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS

You may also request a copy of the results from the principal investigator via email or phone (see below)

email address: rnmconover@uwindsor.ca
Date when results are available: July 1, 2013

SUBSEQUENT USE OF DATA

This data will not be used in subsequent studies.

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty, keeping in mind that once data have been published, it will not be possible to remove your data from the article. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study Attentional focus on supra-postural tasks effects during ambulation: Applications to rehabilitation as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Date

Feb 14, 2013

1/1/2010

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Version Date: 2/13/2013

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CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: Attentional focus on supra-postural tasks effects during ambulation: Applications to rehabilitation

You are asked to participate in a research study conducted by Dr. Nancy McNevin, Jecy Kunju-Kunju, and Dr. Nathania Liem, from the Department of Kinesiology and at the University of Windsor and Windsor General Hospital (Dr. Liem)

If you have any questions or concerns about the research, please feel to contact Dr. Nancy McNevin at (519) 253-3000 Ext. 4276.

PURPOSE OF THE STUDY

This study will assess how you walk while carrying a glass of water with and without instructions on where to focus your attention.

PROCEDURES

If you volunteer to participate in this study, you will be asked to:

Phase 1: Background information and initial assessment (Duration ~ 30 minutes)
1. Meet with the researcher so that information about your general health status can be obtained. Some of this information is only available from your medical records, which we will require your permission to review. The information from your medical records will ONLY be used to ascertain and confirm the date of your stroke, document your score on the Chedoke-McMaster assessment, and record any medications you have been prescribed which might impact your ability to walk.
2. If you agree to provide this information and it is felt that you will be able to complete the task requirements safely, we will schedule a date/time for you to return to complete the second phase of the study.

Phase 2: Walking trials (Duration ~ 45 minutes)
3. To obtain accurate measurements of your walking performance, it will be necessary to measure the lengths of each leg and your height, and weight to enter into the computer. The walkway is connected to the computer and records how fast you walked and how long your steps were.
4. When your information has been entered into the computer, you will be asked to hold a glass of water in your preferred hand and walk down the short walkway at a comfortable pace. The glass of water will have a lid on it to prevent spillage. During these trials, please try not to spill any water. You will be given a short break between each trial.
5. After you have completed two trials, you will be asked to walk down the walkway four more times while carrying the glass of water. During these trials, you will be given a set of instructions by the researcher and provided a reminder prior to each trial. These instructions will direct you to focus your attention on the glass of water or your hand while you walk. Try to follow the instructions as best as possible, and as in the previous trials, please try not to spill any water. You will be given a short break between each trial.

POTENTIAL RISKS AND DISCOMFORTS

There is always some risk associated with walking, and because you will be asked to carry an object which may interfere with your ability to walk, there is a slight increase in the risk of falling. To minimize this risk, standby assistance will be provided while you walk, and short rest breaks will be provided between trials. To prevent accidents due to slipping in spilled water, a plastic cover will be placed on the glass of water. There are no other known risks or discomforts associated with participating in this study.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

At the conclusion of testing, you will be provided with a report documenting your walking profile, which includes a measure of how your walking compared to population norms. This information may be helpful in identifying ways that you and your therapist can improve your walking; such as exercise programs and/or orthotic devices.
The results of this study will help researcher identify how different types of instructions impact certain motor skills, such as walking. If benefits are found, researchers may use this information to enhance recovery of individuals who have been affected by stroke.

COMPENSATION FOR PARTICIPATION

Participants who complete this study will be offered a "Get Involved in Kinesiology research – I did" t-shirt.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. All personal/medical information will be stored on the GAITRite computer, which is protected by a password known only by the researcher and graduate student. Even though your name is stored in this dataset, only the unique identifier (a randomly assigned number) will be used to identify your data and you will never be identified by name in any publication of the results. Your signed informed consent form will be locked in a file cabinet housed in the principal investigator's office, which is locked when not in use. Data stored in electronic format will be deleted after 5 years, and your signed consent form will be destroyed at the end of 3 years.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. Please understand that once the data from this research study have been published, you will not be able to withdraw your data. You may also refuse to answer any questions you don’t want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. Changes in medication or a recent fall which may increase your risk of injury are circumstances which might lead to withdrawing you from this study.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS

You may also request a copy of the results from the principal investigator via email or phone (see below)
email address: nmcmevin@uwindsor.ca
Date when results are available: July 1, 2013

SUBSEQUENT USE OF DATA

This data will not be used in subsequent studies.

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty, keeping in mind that once data have been published, it will not be possible to remove your data from the article. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study Attentional focus on supra-postural tasks effects during ambulation: Applications to rehabilitation as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

[Signature]

Date: 15th Feb, 2013

[Signature]

Date: 15th Feb, 2013
APPENDIX E

SUBJECT INFORMATION

Participant 1

Name: ***************
Age: 44                              Gender: MALE
Height: 5 FOOT 6 INCHES             Weight: 200 POUNDS
Diagnosis/ lesion: LEFT BASAL GANGLIA
Affected side: RIGHT HEMIPLEGIA
Date of stroke episode: NOVEMBER 26TH, 2011
Functional Status: AMBULANT WITH STANDARD WALKER AND RIGHT AFO,
FUNCTIONALLY INDEPENDENT IN ALL ADL.
Community ambulation: YES
Daily walking distance (approximate): 200 METERS
Musculo skeletal Disorders: NONE IN LOWER LIMBS, RIGHT SHOULDER PAIN
Co-morbidities: HYPERCHOLESTEREMIA AND HYPERTENSION
Medication that might affect gait: NONE
Sensory impairment: NONE       Falls : NONE
MEDICAL NOTES:
H/o increase in spasticity in 2012, underwent medical treatment for it. No longer on Baclofen. Upper extremity improved but lower extremity still had spasticity issues. Last physiotherapy report shows chedokee stage 4/7 in leg and stage 2/7 in foot. Currently using an AFO. Stepping reaction on the right foot difficult, decreased unilateral stance, weak flexion movement of the right leg, Rotator cuff tendinopathy (right). Berg’s balance 52/56
Participant 2

Name: **************
Age: 68                                      Gender: MALE
Height: 6 FOOT                                Weight: 230 POUNDS
Diagnosis/ lesion: MULTIPLE STROKE- Right thalamic lacunae, left post internal capsule lacunae, left cerebellar stroke
Affected side: LEFT HEMIPLEGIA
Date of stroke episode: FIRST STROKE- 2006; RECENT STROKE -2009
Functional Status: AMBULANT, OUTDOOR WITH CANE, INDOORS NO AID, FUNCTIONALLY INDEPENDENT IN ALL ADL.
Community ambulation: YES
Daily walking distance (approximate): 100 METERS
Musculo skeletal Disorders: NONE
Co-morbidities: HYPERCHOLESTEREMIA AND HYPERTENSION, DIABETES
Medication that might affect gait: NONE
Sensory impairment: NONE                                Falls : NONE
MEDICAL NOTES:
Participant 3

Name: **************
Age:  61  Gender: FEMALE
Height: 5 FOOT 5 ½ INCHES  Weight: 220 POUNDS

Diagnosis/ lesion: LEFT CEREBRAL INFART, MCA

Affected side: RIGHT HEMIPLEGIA

Date of stroke episode: JUNE 23, 2012

Functional Status: AMBULANT WITHOUT AID, FUNCTIONALLY INDEPENDENT IN ALL ADL.

Community ambulation: YES

Daily walking distance (approximate): 140 METERS

Musculo skeletal Disorders: NONE, ENDURANCE ISSUES PRIOR TO STROKE, CANT WALK LONG DISTANCES.

Co-morbidities: DIABETES

Medication that might affect gait: NONE

Sensory impairment: NONE  Falls: 1 before stroke

MEDICAL NOTES:
H/o old temporo parietal stroke with no motor deficit, only speech and memory affected. Recent stroke after two years – right sided weakness. Upper limb more affected than lower limb. UL= 3/5 . LL= 5/5

Lower limb coordination normal. Berg balance score= 53/56
APPENDIX F
INSTRUCTIONS

Condition 1
Baseline walking

“Start walking when I say go. Walk on the mat that is laid across and you can stop at the mark on the other end of the mat. Walk at your comfortable speed.”

Condition 2

“Walk across the walkway with this mug, at your comfortable pace. Start when I say go and stop at the mark shown. You can either count out loud from 1 onwards in an ascending order or recite the alphabet while you are walking.”

Condition 3

External Focus of Attention:

“Hold the cup as steady as possible till you reach the mark. You can start walking when I say go.”

Internal Focus of Attention:

“Hold your wrist as steady as possible till you reach the mark. You can start walking when I say go.”
APPENDIX G

VISUAL ANALOG SCALE

PARTICIPANT 1

On a score of 1 to 10, how successful do you think you were in holding the MUG steady?

Trial 1

10------9------8------7------6------5------4------3------2------1------0

Trial 2

10------9------8------7------6------5------4------3------2------1------0

Trial 3

10------9------8------7------6------5------4------3------2------1------0
VISUAL ANALOG SCALE

PARTICIPANT 2

On a score of 1 to 10, how successful do you think you were in holding the WRIST steady?

Trial 1

10--------9--------8--------7--------6--------5--------4--------3--------2--------1--------0

Trial 2

10--------9--------8--------7--------6--------5--------4--------3--------2--------1--------0

Trial 3

10--------9--------8--------7--------6--------5--------4--------3--------2--------1--------0
VISUAL ANALOG SCALE

PARTICIPANT 3

On a score of 1 to 10, how successful do you think you were in holding the MUG steady?

Trial 1

10------9--------8--------7--------6--------5--------4--------3--------2--------1--------0

Trial 2

10------9--------8--------7--------6--------5--------4--------3--------2--------1--------0

Trial 3

10------9--------8--------7--------6--------5--------4--------3--------2--------1--------0
# APPENDIX H

## Barthel Index of Activities of Daily Living

*Instructions:* Choose the scoring point for the statement that most closely corresponds to the patient’s current level of ability for each of the following 10 items. Record actual, not potential, functioning. Information can be obtained from the patient’s self-report, from a separate party who is familiar with the patient’s abilities (such as a relative), or from observation. Refer to the Guidelines section on the following page for detailed information on scoring and interpretation.

### The Barthel Index

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<thead>
<tr>
<th>Item</th>
<th>Scoring Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bowel</strong></td>
<td>0 = incontinent (or needs to be given enema)</td>
</tr>
<tr>
<td></td>
<td>1 = occasional accident (once/week)</td>
</tr>
<tr>
<td></td>
<td>2 = continent</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Bladder</strong></td>
<td>0 = incontinent, or catheterized and unable to manage</td>
</tr>
<tr>
<td></td>
<td>1 = occasional accident (max. once per 24 hours)</td>
</tr>
<tr>
<td></td>
<td>2 = continent (for over 7 days)</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Grooming</strong></td>
<td>0 = needs help with personal care</td>
</tr>
<tr>
<td></td>
<td>1 = independent face/hair/teeth/shaving (implements provided)</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Toilet use</strong></td>
<td>0 = dependent</td>
</tr>
<tr>
<td></td>
<td>1 = needs some help, but can do something alone</td>
</tr>
<tr>
<td></td>
<td>2 = independent (on and off, dressing, wiping)</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Feeding</strong></td>
<td>0 = unable</td>
</tr>
<tr>
<td></td>
<td>1 = needs help cutting, spreading butter, etc.</td>
</tr>
<tr>
<td></td>
<td>2 = independent (food provided within reach)</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Transfer</strong></td>
<td>0 = unable – no sitting balance</td>
</tr>
<tr>
<td></td>
<td>1 = major help (one or two people, physical), can sit</td>
</tr>
<tr>
<td></td>
<td>2 = minor help (verbal or physical)</td>
</tr>
<tr>
<td></td>
<td>3 = independent</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Mobility</strong></td>
<td>0 = immobile</td>
</tr>
<tr>
<td></td>
<td>1 = wheelchair independent, including corners, etc.</td>
</tr>
<tr>
<td></td>
<td>2 = walks with help of one person (verbal or physical)</td>
</tr>
<tr>
<td></td>
<td>3 = independent (but may use any aid, e.g., stick)</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Dressing</strong></td>
<td>0 = dependent</td>
</tr>
<tr>
<td></td>
<td>1 = needs help, but can do about half unaided</td>
</tr>
<tr>
<td></td>
<td>2 = independent (including buttons, zips, laces, etc.)</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Stairs</strong></td>
<td>0 = unable</td>
</tr>
<tr>
<td></td>
<td>1 = needs help (verbal, physical, carrying aid)</td>
</tr>
<tr>
<td></td>
<td>2 = independent up and down</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Bathing</strong></td>
<td>0 = dependent</td>
</tr>
<tr>
<td></td>
<td>1 = independent (or in shower)</td>
</tr>
<tr>
<td><strong>Patient’s Score:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total Score:</strong></td>
<td></td>
</tr>
</tbody>
</table>

(Collin et al., 1988)

### Scoring:

Sum the patient’s scores for each item. Total possible scores range from 0 – 20, with lower scores indicating increased disability. If used to measure improvement after rehabilitation, changes of more than two points in the total score reflect a probable genuine change, and change on one item from fully dependent to independent is also likely to be reliable.

### Sources:

APPENDIX I

Berg Balance Scale

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cueing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds
Berg Balance Scale continued...

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. ( Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid stretching of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. (Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.)
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to complete 4 steps without aid with supervision
( ) 2 able to complete > 2 steps needs minimal assist
( ) 1 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. ( To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject’s normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold > 3 seconds
( ) 1 tries to lift leg unable to hold but remains standing independently.
( ) 0 unable to try or needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)
APPENDIX J

CHEDOKE MCMASTERS STAGES OF MOTOR RECOVERY

IMPAIRMENT INVENTORY - STAGING MOTOR RECOVERY
Score Form Page 1

Table 7.1 Definitions of the Stages of Motor Recovery

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flaccid paralysis is present. Phasic stretch reflexes are absent or hypoactive. Active movement cannot be elicited reflexly with a facititory stimulus, or volitionally.</td>
</tr>
<tr>
<td>2</td>
<td>Spasticity is present and is felt as a resistance to passive movement. No voluntary movement is present but a facititory stimulus will elicit the limb synergies reflexly. These limb synergies consist of stereotypical flexor and extensor movements.</td>
</tr>
<tr>
<td>3</td>
<td>Spasticity is marked. The synergistic movements can be elicited voluntarily, but are obligatory. In most cases, the flexion synergy dominates the arm, the extension synergy the leg. There are strong and weak components within each synergy.</td>
</tr>
<tr>
<td>4</td>
<td>Spasticity decreases. Synergy patterns can be reversed if movement takes place in the weaker synergy first. Movements combining antagonistic synergies can be performed when the prime movers are the strong components of the synergy.</td>
</tr>
<tr>
<td>5</td>
<td>Spasticity wanes, but is evident with rapid movement and at the extremes of range. Synergy patterns can be reversed even if the movement takes place in the strongest synergy fast. Movements utilizing the weak components of both synergies acting as prime movers can be performed. Most movements become environmentally specific.</td>
</tr>
<tr>
<td>6</td>
<td>Coordination and patterns of movement are near normal. Spasticity as demonstrated by resistance to passive movement is no longer present. A large variety of environmentally specific patterns of movement are now possible. Abnormal patterns of movement with faulty timing emerge when rapid or complex actions are requested.</td>
</tr>
<tr>
<td>7</td>
<td>Normal. A &quot;normal&quot; variety of rapid, age appropriate complex movement patterns are possible with normal timing, co-ordination, strength and endurance. There is no evidence of functional impairment compared to the normal side. There is a &quot;normal&quot; sensory-perceptual-motor system.</td>
</tr>
</tbody>
</table>

In Stage 3 active voluntary movement occurs without facilitation, but is only in the stereotyped synergistic patterns. We observed that complete range of all synergy components returns at a later stage, and therefore revised the Brunnstrom staging so that full synergy range is not required until Stage 4 or in some cases Stage 5.
<table>
<thead>
<tr>
<th>NAME:</th>
<th>Jecy Kunju Kunju</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLACE OF BIRTH:</td>
<td>Kerala, India</td>
</tr>
<tr>
<td>YEAR OF BIRTH:</td>
<td>1979</td>
</tr>
<tr>
<td>EDUCATION:</td>
<td>University of Windsor, M.H.K., Windsor, ON, 2013</td>
</tr>
<tr>
<td></td>
<td>Saveetha University, Bachelor of Physiotherapy., Chennai, India, 2000</td>
</tr>
</tbody>
</table>