**Eye gaze and stroke rehabilitation**

Action observation (AO) and movement imagery (MI) have been suggested as adjuncts to physical therapies in the rehabilitation of motor dysfunction (Ertlet, 2007; Hewett, Ford, Levine, & Page, 2007). The simulation theory of Jeannerod (2001) has been proposed as a possible mechanism to explain the effects of these interventions in clinical settings. The theory suggests AO, MI and intended action (leading to action execution) 'share' aspects of a common motor representation for a given behaviour or task. Consequently, repeated activation of the neural correlates of the representation through any of the simulation states may change the nature of the representation through neural plasticity such that change can be seen in the markers of the other two states. The representational 'sharedness' (Decety & Grèzes, 1999) has been demonstrated through relatively general central and peripheral markers assumed to reflect an equivalence across the three states. What is less clear, however, is whether the specific eye movement and eye gaze parameters in the three conditions are consistent. Arguably, the visual characteristics reflect, in part, the attention of the individual. If attentional focus in important in the learning process (Bandura, 1977), then for AO and MI to be used optimally, the eye movement and gaze metrics should be assessed and controlled across conditions to ensure greater consistency in representation behaviour. To date, this has been assumed in all the AO and MI literature. Further, if one or more of the simulation states is compromised following CVA, then how this is reflected in the eye metrics is important for the rehabilitation team if they are to use AO and MI techniques. To date, these important issues remain untested and so form the main focus of this programme of research.

Slowness of movement is commonly experienced in individuals affected by stroke (IAS). Adjusting imagery speed and priming a movement with AO have been reported to alter subsequent movement speed in a healthy population (Brass, Bekkering, & Prinz, 2001; Collet, Doyon, Guillo, Magali, & Maton, 2008). This research will also determine whether these findings generalise to the stroke population.

The aims and study outlines of this PhD are shown below (projected delivery is attached).

**Study 1:** To examine the motor representation of a goal directed task during AE, AO and MI through extensive eye gaze metrics.

**Study 2:** To compare the motor presentation of goal directed task AE, AO and MI in healthy older adults and older individuals affected by stroke through eye gaze metrics.

**Study 3:** To compare eye gaze metrics in AO, AE and MI during the learning of a novel task.

**Study 4:** To investigate the effect of the observed stimulus speed on subsequent MI and AE through eye gaze metrics

**STUDY 1** (March 2012 – July 2012)

**Aim:** See aim 1 above. **Participants:** 15 healthy, right handed individuals, aged between 18 and 45 years. All participants will have normal or corrected to normal vision and above average imagery ability (assessed using the Movement Imagery Questionnaire-Revised, MIQ-R, Hall & Martin, 1997). **Method:** Participants will be seated and asked to perform a computerized visually guided pointing task (VGPT). A chin rest will be used to restrict head movement and an upright body position will be maintained to restrict movement to that of the upper limb only. The task will involve a single motor pattern consisting of (1) touching a starting target with a mouse; and (2) extending the elbow joint in order to reposition the mouse to the finishing target located either at 10, 15 or 20 cm away from starting point. Participants will be requested to physically perform the task and informed that subsequent tasks (pseudo-randomized) will involve AO and MI of the executed task from a first person perspective. To obtain appropriately matched conditions, a recording of the participant’s physical performance will be presented during AO. Tasks will be completed using both the dominant and non dominant hand. In this design, participants will act as their own controls as well as providing control for other participants. **Measures:** Gaze metrics will be recorded using a high frequency infra-red eye tracking system. Movement kinematics (peak and mean velocity) of the arm will be obtained via differentiation of positional data of the mouse. Surface electromyography (EMG) will be measured in the upper arm to control for muscle movement during MI and AO. A chronometric measure (task duration) will also be included as a control for MI. **Analysis:** The data will be separated into two phases: target selection and inter-target movement. Individual 3 (simulation states) x 2 (handedness) x 3 (inter-target distance) repeated measures ANOVAs will be used to compare the dependent variables in each phase. The variables in the inter-target movement phase will include number of saccades, peak saccade velocity and initial saccade amplitude. The target selection phase with comprise number of fixations, fixation location and total dwell time. A 2 (handedness) x 3 (inter-target distance) repeated measures ANOVA will be used to compare the hand kinematics. The variability within and between participants will be identified by calculating the inter-individual coefficient, with a lower value of coefficient representing greater consistency across metrics. **Hypothesis:** Congruency in eye metrics will be demonstrated between AE, AO and MI. Gaze will be less efficient and effective (more fixations of a shorter duration, hypo/hypermetric saccades) during task execution with the non dominant hand and movement kinematics will show an altered profile in this condition.

**STUDY 2** (March 2012 – November 2012)

**Aim:** See aim 2 above. **Participants:** Fifteen AIS and fifteen controls (matched for age and handedness). **Method:** The same method and measures will be employed as study one, however the MIQ-R will be replaced with the Kineasthetic and Visual

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*Note 1:* If high speed mobile eye tracking equipment becomes available the VGPT will be performed using an electronic tablet.
Imagery Questionnaire (KVIQ, Malouin et al. 2007). This questionnaire is designed to assess imagery ability in healthy, motor impaired and stroke individuals. Participants with a score of more than two standard deviations from the mean will be excluded. This study will run concurrently with study one to allow sufficient time for the recruitment of appropriate participants. Stroke units in Central and Greater Manchester have been identified as possible sources for recruitment. **Hypothesis:** The congruency in eye metrics between AE, MI and AO will be similar between IAS and healthy older adults (non paretic hand). There will be a difference in the eye gaze metrics between IAS and healthy older adults during all tasks related to the paretic hand. There will be a difference in hand movement kinematics between IAS and healthy older adults (paretic hand only).

**STUDY 3** (October 2012 – April 2012)

**Aim:** See aim 3 above. **Participants:** Forty-five, healthy individuals (55-75 years) will form 3 groups, matched for age, gender and handedness. **Method:** All participants will learn the same novel task through a different modality, dictated by group; group 1 through AO, group 2 through MI and group 3 through AE. Prior to the learning phase all groups will physically perform, observe and imagine the task. The task will involve moving a ‘joystick’ to guide a stimulus (round disk) through a maze. Conventional joystick movements will be reversed, ensuring task novelty. To obtain appropriately matched conditions the speed of AO will be self determined throughout the learning phase. All participants will be given 400 attempts to practice the task. Incentives will be offered periodically to ensure motivation and commitment to learning. **Measures:** At the beginning, middle and end of the task all groups will be asked to physically perform, observe and imagine the task. Eye metrics (dwell time, number of fixations, saccade velocity, saccade amplitude), performance accuracy and task duration will be measured. EMG will act as control for muscle activity and task duration as a control for MI. **Hypothesis:** Changes in eye gaze metrics and performance measures, influenced by skill learning through a single simulation state, will be observed in the other two states. Improvements in performance time and accuracy will be greatest in the AE group. The self selected speed of the AO stimulus will increase with skill learning.

**STUDY 4** (May 2013 – February 2014)

**Aim:** See aim 3 above. **Participants:** Thirty IAS and 30 controls (matched for age and handedness), similarly assessed for imagery ability as in study 2. **Method:** Participants will initially physically perform, observe and imagine two tasks using the paretic hand (or matched control). The tasks will be the VGPT (described earlier) and a modified component from the Chessington Occupational Therapy Neurological Assessment Battery (COTNAB). The COTNAB task will require participants to grasp and relocate small dowels at inter-target distances similar to that of the VGPT. IAS and controls will be split into two groups; fixed motion and fast motion. The fixed motion group will observe their own performance and the fast motion group will observe their performance at a speed that is 20% faster than their own performance time (participants will not be informed of this). Repeated AO will be performed as a block, immediately followed by MI and AE. Each block will be repeated three times for two inter-target distances. The task order (VGPT or COTNAB) will be randomized. **Measures:** Eye metrics and movement kinematics will be collected pre and post training period. Control for EMG and MI as per study 3. (Note: A goniometer and accelerometer will be used to collect kinematic data during the COTNAB task.) **Hypothesis:** Performance times for MI, and possibly AE, will be reduced in the fast motion groups (both AIS and controls). The velocity of the hand movements may increase in the fast motion group. There will be no significant difference between the relative findings for the experimentally controlled VGPT and the ecologically valid COTNAB task.

**Participant criteria for individuals affected by stroke**

Recruitment of IAS will be supervised by the clinical PhD team, name of the leader. Participants will: be aged between 55 and 75 years; have experienced a stroke either no earlier than 3 months before participation; have a Brunnstrom score of four for upper extremities (some movement patterns mastered); have normal eye movements (assessed by the international Cooperative Ataxia Rating Scale (ICARS, items 17-19; Trouillas et al., 1997); be able to understand and follow simple verbal instruction since the stroke; have their stroke caused by a haemorrhage in the middle cerebral artery; no joint complaints (e.g., arthritis).

**References**


