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**Adaptation to post-stroke homonymous hemianopia - a prospective longitudinal cohort study to identify predictive factors of the adaptation process**

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**Abstract**

***Purpose:*** to determine any factors that predict how an individual will adapt to post-stroke hemianopic visual field loss, with close monitoring of the adaptation process from an early stage.

***Materials and Methods:*** the Hemianopia Adaptation Study (HAST) is a prospective observational longitudinal cohort clinical study. Adult stroke survivors (n=144) with new onset homonymous hemianopia were monitored using standardised mobility assessment course (MAC) as the primary outcome measure of adaptation.

***Results:*** Several baseline variables were found to be good predictors of adaptation. Three variables were associated with adaptation status at 12-weeks post-stroke: inferior % visual field, % total MAC omissions and MAC completion time (seconds). Baseline measurements of these variables can predict the adaptation at 12 weeks with moderate to high accuracy (Area under ROC curve, 0.82, 95% CI 0.74 – 0.90). A cut-off score of ≤25% target omissions is suggested to predict which individuals are likely to adapt by 12-weeks post-stroke following gold standard care.

***Conclusions:*** Adaptation to hemianopia is a personal journey with several factors being important for prediction of its presence, including MAC outcomes and extent of inferior visual field loss. A clinical recommendation is made for inclusion of the MAC as part of a functional assessment for hemianopia.

**Keywords:** Hemianopia; Stroke; Adaptation; Visual impairment; Mobility Assessment Course; Prediction

## Background

Visual impairment is a common finding after stroke with a recently reported point prevalence at 73% and incidence of new onset post-stroke visual impairment at 60% [1]. Visual impairment may include impaired central or peripheral vision (visual field), eye movement defects, reading difficulties and / or visual perception disorders including agnosias and visual inattention. There is currently no standardised comprehensive screening for visual impairment following stroke and as such, many deficits go unidentified and untreated.

Recent development of a screening tool (VISA) does however provide a standardised and validated method for detection of visual impairment in this cohort, using non-specialist screeners [2]. This tool, available in paper or app format, is yet to be fully utilised in the UK NHS clinical setting but shows real potential for early identification of impairments. Following identification, appropriate and timely treatment and referral to vision services is vital, as detailed in a stroke-vision care pathway developed using consensus methodology [3].

One type of post-stroke visual impairment is homonymous hemianopia, a loss of visual field to one side. Its existence has wide-reaching impact including loss of independence, increased risk of falls and difficulty reading [4]. People with hemianopic field defects cannot process the visual world in the same way as those with a full visual field [5]. They have difficulty in detecting and locating objects in the visual space to the affected side. People with hemianopic

visual field defects report difficulty with navigating their environment; specifically, they report bumping into objects on their blind side [6].

It is important to note that visual inattention can co-exist with visual field loss, particularly in stroke events in the right side of the brain [7]. Visual inattention is different to visual field loss. While visual field loss is an actual loss of vision, inattention is a perceptual impairment. Visual inattention prevents people from being able to attend to one side of the world, with a lack of awareness of any deficit in function. If field loss is combined with visual inattention an individual does not automatically scan or track to the affected side, making adaptation more problematic and less likely to occur.

In current eye care practice, whilst it is routine procedure to assess the extent of visual field loss in homonymous hemianopia, it is not commonplace for eye care clinicians to assess an individual's ability to navigate the environment, or to assess the change in this ability over time [8]. From a clinical perspective, it would be advantageous to assess navigation in relation to visual impairment, and to capture information on the impact of hemianopia on everyday demands of independent living. One tool that has the potential to allow such an assessment is the mobility assessment course (MAC), which was first described by Verlander *et al.* [9]. The course was originally designed to measure the extent to which people with visual spatial disorders visually scan and identify hazards when walking [9]. The MAC design can be replicated in any ward setting and adapted for navigation using a wheelchair if required. The MAC is not a test routinely used in clinical practice, however studies have reported it is a potentially useful tool to provide a dynamic assessment of visual inattention [9-11]. There are currently no reported studies involving the use of such a course to assess how an individual adapts to homonymous hemianopia.

Adaptation to hemianopia is the process by which individuals change their behaviours to become better suited to a new visual world. To adapt to their loss of vision, stroke survivors

with hemianopia are required to make adaptations and adjustments to their everyday life [12]. How successfully they make these adaptations and the time course of this process will depend on many factors. The factors may concern the extent of visual field loss itself, other stroke-related sequelae, as well as other social and personal factors [13]. Factors that are important for the adaptation process to hemianopia remain unknown. A systematic review of the literature exploring the factors that influence how a person adapts to post-stroke visual field loss highlighted a lack of evidence in this area [13].

The overall aim of this research was to investigate the factors important for adaptation to post-stroke homonymous hemianopia. Our objectives were to determine any factors that predict how an individual will adapt to their visual impairment, with close monitoring of the adaptation process and response to treatment from an early stage.

## Methods

This study is reported in accordance with the STROBE statement [14]. The clinical study was undertaken in accordance with the Tenets of Helsinki with NHS research ethical approval (16/NW/0542).

### *Design*

A prospective observational longitudinal cohort design was used for the clinical study, undertaken between 11th November 2016 and 13th June 2019 [15]. Individuals were eligible for inclusion if they were 18 years of age or older, had clinical diagnosis of stroke as defined by World Health Organisation and had the presence of a new onset homonymous hemianopia (diagnosed within four weeks of stroke onset). People without the cognitive ability to consent were excluded. Those with significant disorders of eye movement were also excluded as this would have a potential impact on their ability to adapt to their loss of visual field using

scanning techniques. Recruited participants included those with a diagnosis of complete or partial homonymous hemianopia, with or without the additional presence of visual inattention to the same side.

Prior to recruitment, a list of factors considered as potentially important for the adaptation process (as well as potential confounders) was devised through consultation with a group of stroke survivors with visual impairment and with experts in the area of stroke and visual impairment (table 1) **(table 1 near here).**

***Patient and public involvement***

A core group of individuals with experience of adapting to post-stroke visual field loss were directly involved throughout the design, planning, conception and conduct of this study. These individuals are members of a vision and stroke patient and public group (VISable), of which at least five members were regularly involved in this research.

***Recruitment and Assessment***

Recruitment and follow-up took place at one main hospital site following routine screening carried out by acute research nurses. Additional ad-hoc identification of eligible participants took place at participating hospital sites and community stroke teams across two further Greater Manchester NHS Trusts. Each recruited participant underwent comprehensive vision assessment performed by the same orthoptist. All factors identified in table 1 were assessed and recorded where possible.

***Variables and data sources***

A full routine medical and general history was recorded for all participants including general stroke signs and symptoms, date of stroke onset, stroke scan information, thrombolysis status, ocular signs and symptoms reported by the participant / carers, previous ophthalmic history, spectacle wear and driving status. A modified Barthel score was recorded for all participants at the baseline visit as a measure of stroke severity [16, 17]. The modified scale gives a score from 0 (totally dependent) to 20 (completely independent). Where possible a cognitive assessment score in the form of a Montreal Cognitive Assessment (MoCA) was documented at baseline to record the level of cognitive impairment [18]. Both the Barthel and MoCA scores were taken from the participants usual clinical care stroke specialist assessment on admission to ensure completion by trained stroke clinicians. Participant demographics including age, gender, ethnicity and postcode were collected. Using the participants' postcode, an income deprivation decile score was calculated using the Ministry of Housing, Communities and local government calculator [19].

Routine specialist vision assessment comprised detailed assessments of case history, visual acuity, reading speed and accuracy, ocular alignment / movement, binocular vision, visual fields, visual attention and visual perception.

A formal quantitative measure of visual field was undertaken where possible with an automated perimeter using a binocular Esterman programme. Where formal perimetry was not possible, a standardised confrontation method was employed using both static and kinetic target presentation, using a 1cm diameter red target. Grading of visual fields was undertaken by means of calculating a percentage of visual field loss to the hemianopic and unaffected sides. For the hemianopic side, the percentage of loss in the inferior and superior visual field areas was also calculated.

Visual attention was assessed using a combination of three paper-based tests: line bisection, clock drawing and cancellation tests. The combined results were used to make a clinical

decision on the presence and extent of any visual inattention, coupled with clinical observations by the multidisciplinary team.

Following informed consent, further variables were collected including handedness, self-reported adaptation status, compliance with scanning exercises at follow-up, living arrangements, occupation and MAC outcomes.

A standardised MAC was located at the main hospital site, in ward and out-patient corridor settings. Staff, patients and visitors were free to enter the corridors. Along the corridor, 24 visual markers (yellow 10x10cm) were attached to the walls with 12 on each side (figure 1). **(figure 1 near here)** Constant scanning was required throughout the course as targets were occasionally obscured from view and only visible when the participant had reached the target and not before. If the participant was unable to walk the course, they were pushed in a wheelchair by a member of staff or relative. Targets were positioned in equal standardised distribution at four different heights (30cm, 80cm, 130cm and 180cm). Participants were instructed to walk through the course at a leisurely pace. Participants were scored on the time taken to complete the course, number of target omissions to each side, total number of omissions and number of collisions to the standard obstacles. The percentage of total targets missed as well as the asymmetry score was recorded for each participant. The asymmetry score was calculated as the absolute difference between the number of omissions to the hemianopic and the unaffected / less affected side. Collection of patient-reported outcome measures included the following validated questionnaires combined into a single booklet form for participants to complete in one sitting: EQ-5D-3L, NEI VFQ-25 and Connor Davidson resilience scale [20-22]. Fatigue severity was measured using the Fatigue Severity Scale (FSS) to explore the impact of fatigue on an individual's ability to adapt to visual loss [23].

***Division of cohort into groups: recovered, adapters, non-adapters***

When a participant demonstrated recovery of hemianopia by week 12, they no longer met the criteria of adaptation, hence they were not included in the week 12 analyses. To calculate a cut-off in visual field loss for recovery status, exploration of those participants who had enough visual field recovery to return to driving at the 12-week assessment was made. There were 12 of the 129 participants who attended the 12-week assessment, who were advised they could return to driving at that time in view of visual field recovery. All participants returning to driving at 12-weeks had a total percentage visual field loss on the hemianopic side of ≤10%. Therefore, anyone with ≤10% visual field loss at 12-weeks was removed from the analysis as having a recovered visual field. This research focusses on adaptation to visual field and this cannot be explored if the visual field has recovered sufficiently.

Further analysis of the data found that 14 participants had a ≤10% visual field loss at 12-week assessment, as there were a further two participants who were not car drivers. These 14 were removed from analysis of adaptation status, to ensure only those with a residual visual field defect were considered.

We used self-reported adaptation at 12 weeks to divide the not-recovered patients into two groups: adapters and non-adapters. Participants were asked at each visit to report if they felt they had fully adapted to their visual loss, answering yes or no. Those who reported no problem with their vision and therefore showing a total lack of insight into their visual loss were unable to answer this question and therefore considered as not adapted as they were not aware of the problem and therefore deemed unable to adapt to it.

Exploration of visual field recovery was made at the 12-week assessment. To calculate a cut-off in visual field loss for recovery status, exploration of those participants who had enough

visual field recovery to return to driving at the 12-week assessment was made. All participants returning to driving at 12-weeks had a total percentage visual field loss on the hemianopic side of ≤10%. Therefore, anyone with ≤10% visual field loss at 12-weeks was deemed recovered and removed from analysis (whether a car driver or not).

***Treatments offered***

All participants were offered a mixture of standardised and targeted treatments and advice. Standardised treatment included condition-specific information leaflets, paper-based scanning exercises and referral for registration of visual impairment [24]. Scanning exercises comprised an A4 landscape card with a combination of horizontal and diagonal numbered circles radiating from a central fixation target [25]. Other relevant management options were offered to participants on an individual needs-assessed basis including verbal advice, activity book / additional scanning exercises, reading aids such as typoscopes or line guides, yellow overlay for glare, web-based therapies (read-right or eye-search), driving advice or referral to other services [26-29].

***Review and follow-up***

Review appointments were made dependent on individual clinical need. Typically, this followed minimum national guidelines with review at 4, 12 and 26-weeks post-stroke onset. The primary outcome time point was 12-weeks post-stroke and is reported in this paper.

***Study size***

Due to the requirement for a logistic regression analysis using a number of variable factors, the sample size was considered prior to recruitment commencing. To determine the sample size for this study, an estimate of 10-15 events per variable to be included in the final model was used [15]. Hospital records show that there were approximately 500 stroke admissions per year at the main hospital site. Using experience of previous acute stroke studies, 60% of these were expected to be able to undergo vision screening assessment and 80% of people expected to agree to the assessment [1, 30]. From clinical and research experience, homonymous hemianopia is prevalent in approximately 30% of stroke survivors [30]. This elicits an expected 72 participants per year recruited at the main site. With a two-year recruitment period it was expected that 144 would be recruited. A recruitment target of 144 participants was therefore used.

***Statistical methodology***

Analysis of self-reported adaptation was performed in relation to all of the variables that had potential to affect or confound the adaptation process (table 1) and in relation to MAC scores. Data analysis was performed in a systematic manner with initial univariate analysis (5% significance level) to compare baseline outcomes with 12-week self-reported adaptation status. For categorical variables with a sufficient number of expected items (at least five) the Pearson's chi-squared test for association was used, otherwise the Fisher exact test was selected. For continuous variables, the two-sample t-test was used for data that was normally distributed or could be transformed to be normally distributed; otherwise using the Mann-Whitney U test. Significant variables were entered into a multi-variable analysis. Furthermore, a backward selection procedure was used to construct the multivariable model. Variables were entered and retained in the model with a $p<0.05$. An area under ROC curve (AUC) was constructed for the model as a quantitative measure of the ability of specific factors to discriminate between those

who would report adaptation at 12-weeks and those who would not [31]. In addition, sensitivity analyses were performed. When a participant demonstrated recovery of hemianopia by week 12, they no longer met the criteria of adaptation. For this reason, when groups of adapted and non-adapted were compared, those who recovered were excluded. Data were managed in Excel and all analyses were done in SPSS.

## Results

### *Participants*

We recruited 144 participants during the period of November 2016 to December 2018, with baseline assessment at a mean 16.8 days (SD 11.9) after stroke diagnosis (median 16).

Of the 144 participants, 129 (89.6%) attended for 12-week post-stroke review when they were assessed for recovery, adaptation or non-adaptation (figure 2). **(figure 2 near here)**

Overview between recovered, adapted and non-adapted at 12-weeks

Notably, the there was a trend between the three groups: recovered, adapted and non-adapted. The most drivers were among recovered (85.7%), then adapted (73.2) and the lowest among non-adapted (51.4%) which was significant (p=0.01069, 3-sample test of equality of proportions). This difference was however due to a difference between recovered and non-adapted (p=0.0181) while the others two comparisons were not significant. An analogical trend was observed in the Barthel score, with the highest value in recovered (mean 19.5), then adapted (mean 18.1) and then non-adapted (mean=15.1), which was significant (*p*=0.002, one-way ANOVA) (figure 2). This difference is due a difference between recovered and non-

adapted ($p$=0.013, t-test) and adapted and non-adapted ($p$<0.001), while the recovered and adapted did not differ ($p$=0.225).

Self-reported adaptation at 12 weeks

Of the 129 who attended at 12-weeks, there were 14 participants who had recovered, leaving 115 participants for main analyses. Of the 115 remaining participants, 41 (35.7%) reported they had adapted to their hemianopia. The remaining 74 (64.3%) reported that they had not adapted. Differences between the two groups of participants (adapted versus not adapted) were explored for baseline variables with the aim of using these measures to predict the 12-week adaptation outcome. Associations were explored between baseline general demographics and characteristics (table 2), stroke-specific information (table 3) and vision-specific information (table 4) for the two groups. **(tables 2,3 and 4 near here)**

***General demographics and characteristic vs self-reported adaptation at 12-weeks***

None of the collected demographic variables showed a significant difference between adapted and non-adapted groups (table 2).

***Baseline stroke-specific information vs self-reported adaptation at 12-weeks***

There were some differences in baseline stroke-specific variables observed between adapted and non-adapted groups (table 3). Those who reported adaptation at 12-weeks had a higher mean Barthel score at baseline (mean 18.1) in comparison to non-adapters (mean 15.1). This higher Barthel score indicates better performance in activities of daily living tasks and was a statistically significant difference ($p$<0.001). In addition, there was a significantly higher

percentage of self-reported adapters reporting no problems with general health using EQ-5D-3L scoring (14.6%) than non-adapters (0.0%), $p$=0.002.

***Baseline vision-specific information vs self-reported adaptation at 12-weeks***

In terms of vision-specific information, there were several baseline factors showing a statistically significant difference between the group of participants who reported adaptation and those who did not at the 12-week point (table 4).

Firstly, extent of baseline visual field loss was found to be significantly different between the two groups. Mean total percentage visual field loss was lower in those reporting adaptation (63.1) than non-adapters (81.6), $p$=0.014.

Visual field loss was divided into superior and inferior loss. Superior visual field loss was not found to be significantly different between the two groups. Inferior visual field loss however was found to be significantly different between groups ($p$=0.001). Mean inferior visual field loss was lower in participants who reported adaptation (58.4%) than non-adapters (81.7%).

A further factor found to have a statistically significant difference between the two groups concerns the presence of binocular vision ($p$=0.001). Those who reported adaptation were more likely to have binocular vision (92.7%) than those who did not report adaptation (75.7%).

Some other vision-specific characteristics were found to be significantly different between groups. One of these concerns the presence of visual inattention at baseline assessment ($p$<0.001). A smaller proportion of those who reported adaptation to visual field loss had the presence of inattention (14.6%) than non-adapters (33.8%). In addition, a higher percentage of those reporting visual symptoms at baseline were non-adapters than adapters. Those who reported adaptation were less likely to report visual symptoms ($p$=0.009).

### *Associations between self-reported adaptation and baseline MAC outcomes*

Baseline MAC outcomes were compared to self-reported adaptation at 12-weeks, to explore whether the initial baseline MAC scores were able to provide information about the 12-week adaptation status (table 5). **(table 5 near here)** Participants reporting adaptation completed the MAC in a shorter amount of time (median 58 seconds) compared to the non-adapted group (median 77 seconds), $p<0.001$. In addition, the mean total percentage omission score was lower for adapters (17.9) when compared to non-adapters (36.8), $p=0.002$.

### *Cut off score for MAC omissions*

The baseline MAC results were used to develop a proposed cut-off score for adaptation. To develop a cut-off score, the total percentage omissions for self-reported adapters and non-adapters at 12-weeks were compared to develop the scoring (table 5). Those participants who reported adaptation at 12-weeks post-stroke had a mean total percentage omission score of 17.9%; SD 16.5; 95%CI 12.8 – 22.9%. In contrast, those who reported non-adaptation had a mean score of 36.8%; SD 21.5; 95% CI 31.9 – 41.7%. The confidence intervals for the two groups did not contain any overlap, supporting their statistically significant difference ($p=0.002$). Using the upper limit of those who reported adaptation, a proposed, rounded cut-off MAC omission score for adaptation of ≤25% is suggested. Using this baseline score to predict 12-week adaptation status means that, based on this sample, there can a 95% confidence that the MAC omissions percentage score will be ≤25% for adapters and >25% for non-adapters.

***Baseline factors found to be important for the prediction of self-reported adaptation at 12-weeks***

The analysis reported in previous sections discovered several baseline factors that were potentially important for the prediction of self-reported adaptation at 12-weeks. These factors were found to be significantly different at the 5% significance level between the group of self-reported adapters and non-adapters. The baseline factors included: Barthel score, EQ-5D-3L score, total % visual field loss, inferior % visual field loss, presence of binocular vision, presence of visual inattention, presence of visual symptoms, MAC completion time, MAC omissions to most affected side and MAC total % omissions. These factors were taken forward into a multi-variable regression model with the aim of developing a prediction tool for adaptation status.

***Prediction model***

Ten baseline factors were evaluated for their ability to predict self-reported adaptation status at 12-weeks. Statistical analysis, using a backward selection multi-variable logistic regression, showed that three of these factors were associated with adaptation status at 12-weeks post-stroke, baseline inferior % visual field, baseline % total MAC omissions and baseline MAC completion time (seconds).

A ROC curve was produced, with the area under the curve (AUC) for baseline factors (inferior % visual field, % total MAC omissions and MAC completion time) calculated as 0.82 (95% CI 0.74 – 0.90). This means that the prognostic strength of the selected variables is between 74 and 90%. Therefore, if two new patients are diagnosed with hemianopia and one of them adapts and one does not at 12 weeks, it is possible to accurately discriminate between them at baseline, in approximately 74 to 90% of cases (figure 3). **(figure 3 near here)** We also

calculated an optimal threshold giving the highest probability of correct classification and this corresponds to sensitivity 0.76 and specificity 0.73 (blue lines, figure 3). So, 76% of those who will not adapt will be correctly identified as not adapters; and 73% of those who do adapt will be correctly identified as adapters.

**Discussion**

The aim of this research was to determine any factors that predict how a person will adapt to post-stroke homonymous hemianopia over time. This clinical study explored the factors considered important for the adaptation process. An individual was found to be more likely to adapt if they had the following characteristics at baseline assessment:

- a better performance in activities of daily living (higher Barthel score),
- no reported problems with general health (EQ-5D-3L score),
- a lower total percentage of visual field loss,
- less inferior visual field loss,
- evidence of binocular vision,
- no evidence of visual inattention and less visual symptoms.

In addition, the MAC at baseline was a useful predictor of 12-week adaptation status. When all baseline factors were analysed collectively, the most effective predictors of adaptation status at 12-weeks were MAC completion time, MAC total percentage target omissions and percentage of inferior visual field loss. As an important prediction tool for adaptation status, a cut-off score for the MAC was developed. Using this cut-off score, adaptation is considered more likely if there are ≤25% total omissions at baseline. It is important to note that all

participants in this study received early assessment and diagnosis of their visual loss as well as early provision of scanning advice and treatment.

This paper presents prediction of adaptation status, based on assessments carried out at 12-weeks post-stroke. All assessments including the MAC were repeated at 26-weeks post-stroke and will be reported separately.

The factors found to be important for the adaptation process are partially supported by evidence already reported in the literature. Firstly, individuals with less disability in daily living, in terms of a higher Barthel score and less reported problems with general health (EQ-5D-3L) were more likely to report adaptation in this study. Although a connection between these factors and adaptation was not found specifically in the literature, there is a strong evidence base for the development of compensatory strategies in order to adapt. A study by Taylor *et al.* provides information regarding the development of head and shoulder movement strategies as a potentially important compensatory mechanism [32]. It seems likely that individuals with more limitations in everyday tasks, reduced general health and higher levels of disability are less able to utilise such compensatory strategies due to physical and cognitive restrictions imposed. On a similar note, individuals with binocular vision were more likely to report adaptation in this study. Although there were no reports discovered in the literature relating to binocular vision and adaptation specifically, it seems plausible that individuals are more likely to adapt if they have this skill. Those with binocular vision are potentially better able to utilise the scanning techniques and compensatory mechanisms as described in the literature [33-37].

Adaptation was found to be more likely in those individuals who had a lower total percentage of visual field loss, and more specifically those who had less inferior visual field loss. This was a factor found to require further exploration in the literature [13]. Studies that detailed the extent

of visual field loss did not explore any relationship with the adaptation process [37-39]. Our clinical study used a graded visual field scoring system and therefore allowed exploration of extent of visual field loss in comparison to self-reported adaptation and other relevant factors. These findings support a recommendation for clinicians to consider individuals with more significant loss of the inferior visual field as potentially requiring more support to adapt. It also supports the directing of further intervention development to consider specifically targeting the inferior visual field area, for example, with reading therapy tasks.

Visual inattention is an important area identified within the literature review as a potential factor and confirmed as important in this study. Those with visual inattention at baseline were found to be less likely to report adaptation at 12-weeks post-stroke. Although no studies reported specifically on the presence of inattention and its association to adaptation, Cassidy *et al*. reported on a reduced prognosis in general with its presence [40].

Furthermore, the presence of visual symptoms was reported as significant for adaptation in this study. Individuals who reported less symptoms were more likely to report adaptation. It could however be argued that those who have already adapted are less likely to report symptoms. There is also a potential that those who are keen to prove adaptation, such as those desiring a return to driving are less likely to report their true visual symptoms, hence this finding should be viewed with caution. In addition, the presence of visual inattention should be taken into consideration as this condition can result in a lack of awareness of symptoms in connection with the lack of attention to the hemianopic side. Three studies have reported on the lack of awareness / symptoms in hemianopia [30, 41, 42]. These studies report on a lack of awareness to hemianopia but no specific link to adaptation was reported.

The MAC outcomes at baseline were found to be an effective prediction tool for adaptation status. Although the published literature describing the MAC have focused on visual inattention and not hemianopia, research has suggested it may be a useful tool in the dynamic assessment of hemianopia [9-11]. Both outcomes of MAC completion time and target omissions were found to be important as predictors.

The mobility assessment course was instrumental to this research study. However, the course itself has limitations as already recognised by other researchers [10, 11]. Firstly, it is not possible to completely standardise use of the MAC across a variety of settings, despite careful monitoring of methods employed. Use of the MAC in this research was standardised across settings where possible but it is inevitable that there were differences in the background of corridors and obstacles present within those corridors including static items such as radiators and passing traffic / distractions. This variation is likely to have affected overall performance to some degree. Nevertheless, significant differences were discovered in MAC outcomes between those who reported adaptation and those who did not, despite all assessments being subject to the same degree of variation. In summary, we propose the MAC as an appropriate clinical tool for the assessment of functional outcomes in hemianopia. It requires minimal set up and completion time and is generally accepted by stroke survivors as a suitable clinical test. It is feasible to carry out on a ward setting in the acute post-stroke stage, as well as in an out-patient environment.

**Conclusions**

In conclusion, adaptation is a personal journey that continually evolves to meet the needs of a specific environment and task. Several factors have been found to be important for the adaptation process to occur, including having a hemianopia associated with less severe stroke, lower percentage of inferior visual field loss, no co-existing visual inattention and time.

A further conclusion is that the MAC is an effective way to predict adaptation status in the immediate post-stroke stage; using a cut-off score of ≤25% target omissions for those who are likely to adapt by 12-weeks post-stroke.

A recommendation is made for clinicians to include the MAC as part of their functional assessment for hemianopia. It is straight forward to set up with little time or equipment needed and can be replicated in most clinical settings. A further recommendation is to support adaptation with early diagnosis and provision of scanning advice / training from an early stage post-stroke.

Further research is now required to further validate the prediction of the adaptation on further datasets, and to develop interventions to support individuals in their adaptation journey. This research should take into consideration the important factors (MAC outcomes and extent of inferior visual field loss) and their relationship to the adaptation process.

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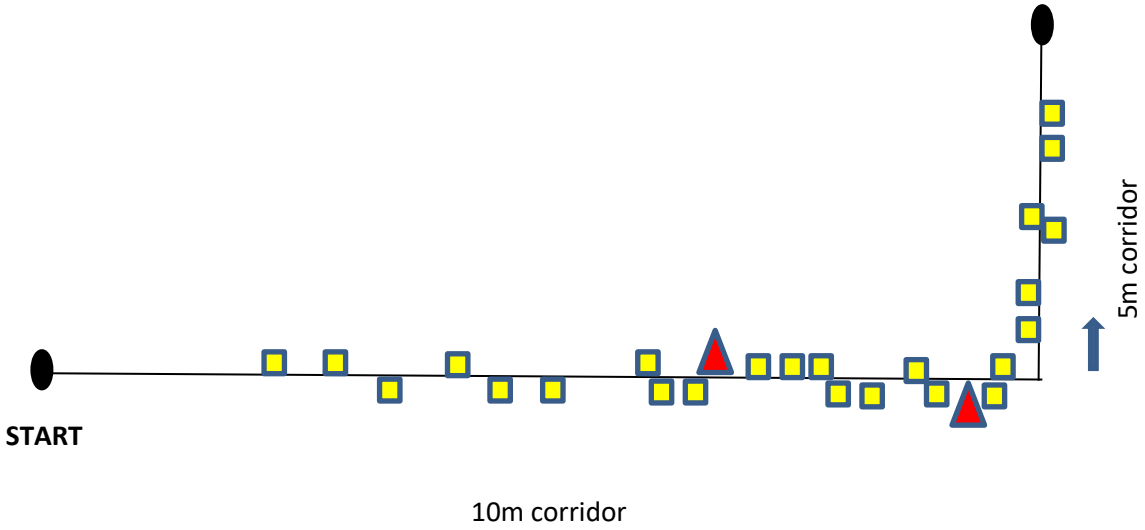
Table 1: List of factors considered as having potential to be important for the adaptation process

| | Potential factors |
|---|---|
| Demographic | Age |
| | Gender |
| | Ethnicity |
| | Deprivation score (postcode) |
| | Handedness |
| | Car driver status |
| | Living arrangements |
| | Resilience score |
| | Occupation |
| Stroke specific information | Stroke type |
| | Stroke laterality |
| | Thrombolysis status |
| | Timing since stroke |
| | Stroke severity (Barthel score) |
| | Cognition (MoCA score) |
| | Side of hemianopia |
| | Fatigue severity score |
| | Health status (EQ-5D-3L Index score) |
| Vision specific information | Total visual field loss (%) |
| | Superior visual field loss (%) |
| | Inferior visual field loss (%) |
| | Impaired central visual acuity |
| | Presence of binocular vision |
| | Presence of visual inattention |
| | Presence of hallucinations |
| | Presence of symptoms |
| | Reading speed |
| | Self-reported visual function (NEI VFQ-25 score) |
| | Compliance with scanning exercises |

Figure 1: Mobility assessment course (MAC) layout plan




- marker to be identified by participant.

- Obstacles (wet floor signs) placed directly onto hospital corridor at set distances of 6m and 9m, one on the right side and one on left.

- Directional arrow (2cm black arrow against a yellow background).

Figure 2: Participant overview

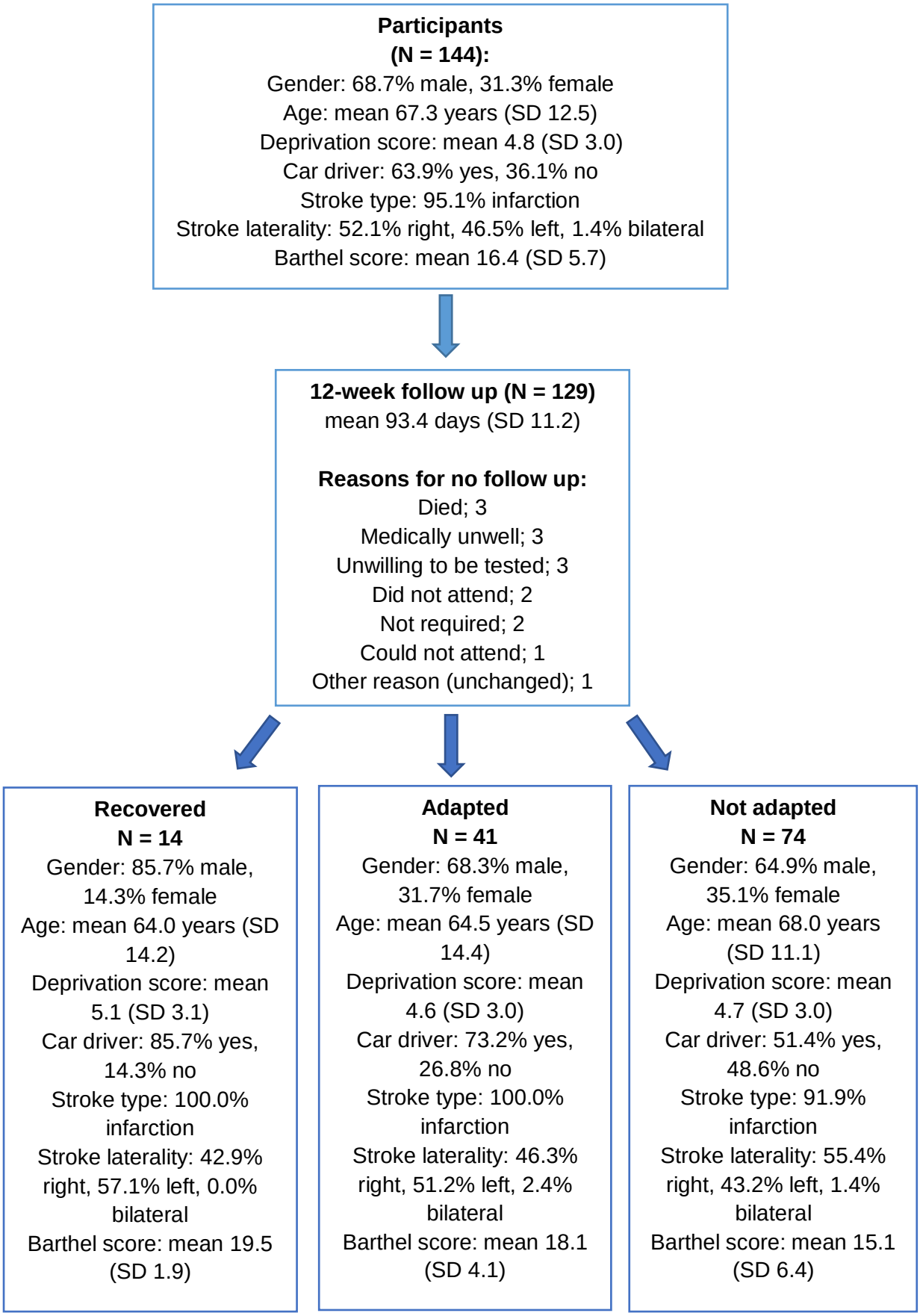


Table 2: General demographics and characteristics: self-reported adapted vs non-adapted at 12-weeks (* significant result)

| | | **Adapted n=41** | **Non-adapted n=74** | ***p* value** |
|---|---|---|---|---|
| Age (years) | Mean (SD) | 64.5 (14.4) | 67.95 (11.1) | 0.060 |
| Gender | Male (%) | 28 (68.3) | 48 (64.9) | 0.376 |
| | Female (%) | 13 (31.7) | 26 (35.1) | |
| Ethnicity | White British (%) | 37 (90.3) | 71 (95.9) | 0.412 |
| | Indian (%) | 1 (2.4) | 2 (2.7) | |
| | Pakistani (%) | 2 (4.9) | 0 (0.0) | |
| | Chinese (%) | 1 (2.4) | 0 (0.0) | |
| | Other (%) | 0 (0.0) | 1 (1.4) | |
| Deprivation score | Mean (SD) | 4.6 (3.0) | 4.72 (3.0) | 0.994 |
| Handedness | Right (%) | 39 (95.1) | 71 (95.9) | 0.826 |
| | Left (%) | 2 (4.9) | 3 (4.1) | |
| Car Driver (time of stroke) | Yes (%) | 30 (73.2) | 38 (51.4) | 0.057 |
| | No (%) | 11 (26.8) | 36 (48.6) | |
| Living arrangements | Lives alone (%) | 10 (24.4) | 21 (28.4) | 0.875 |
| | Lives with someone (%) | 31 (75.6) | 53 (71.6) | |
| Resilience score (/40) | Mean (SD) | 29.0 (10.1) | 19.3 (11.0) | 0.499 |
| Occupation vision related | Yes (%) | 33 (80.5) | 52 (70.3) | 0.168 |
| | No (%) | 8 (19.5) | 22 (29.7) | |

Table 3: Baseline stroke-specific information: self-reported adapted vs non-adapted at 12-weeks

| | | **Adapted**<br>**n=41** | **Non-adapted**<br>**n=74** | ***p* value** |
|---|---|---|---|---|
| Stroke type | Ischaemic (%) | 41 (100.0) | 68 (91.9) | 0.145 |
| | Haemorrhagic (%) | 0 (0.0) | 6 (8.1) | |
| Stroke laterality | Right (%) | 19 (46.3) | 41 (55.4) | 0.786 |
| | Left (%) | 21 (51.2) | 32 (43.2) | |
| | Bilateral (%) | 1 (2.4) | 1 (1.4) | |
| Thrombolysed | Yes (%) | 2 (4.9) | 6 (8.1) | 0.648 |
| | No (%) | 39 (95.1) | 68 (91.9) | |
| Baseline Barthel score (/20) | Mean (SD) | 18.1 (4.1) | 15.1 (6.4) | <0.001* |
| Baseline MoCA score (/30) (n=48) | Mean (SD) | 23.5 (3.8)<br>n=18 | 22.5 (3.5)<br>n=22 | 0.403 |
| Side of hemianopia | Right (%) | 21 (51.2) | 34 (45.9) | 0.858 |
| | Left (%) | 20 (48.8) | 40 (54.1) | |
| Baseline Fatigue severity score (/63) | Mean (SD) | 36.1 (19.4) | 45.3 (19.0) | 0.732 |
| Baseline EQ-5D-3L score | No problem (score ≤5) (%) | 6 (14.6) | 0 (0.0) | 0.002* |
| | Problem reported (score >5) | 35 (85.4) | 74 (100.0) | |

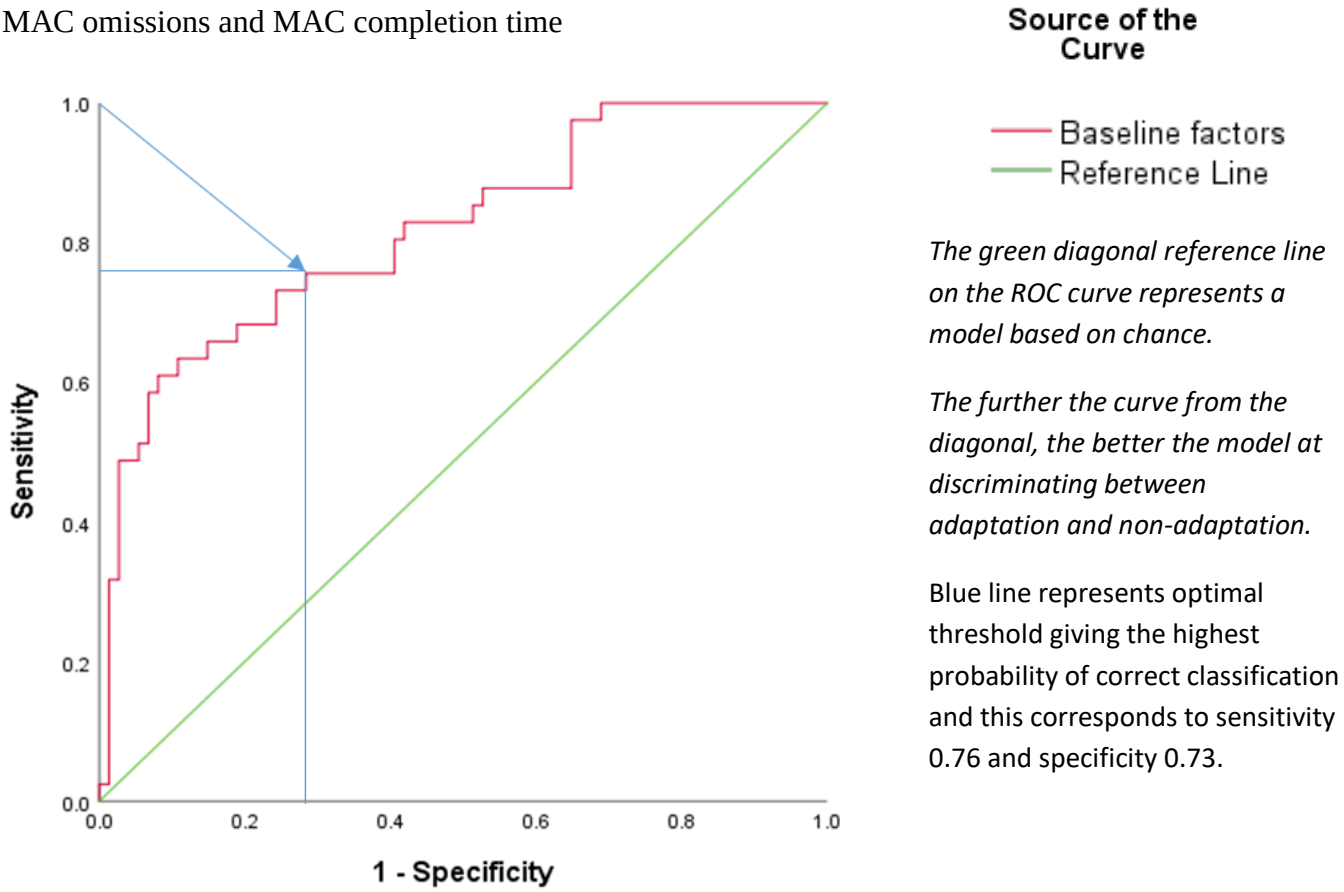
Table 4: Baseline vision-specific information: self-reported adapted vs non-adapted at 12-weeks (* significant result)

| | | **Adapted n=41** | **Non-adapted n=74** | ***p* value** |
|---|---|---|---|---|
| Total % baseline visual field loss | Mean (SD) | 63.1 (25.0) | 81.6 (19.3) | 0.014* |
| Superior % visual field loss at baseline | Mean (SD) | 73.4 (22.7) | 81.5 (19.0) | 0.663 |
| Inferior % visual field loss at baseline | Mean (SD) | 58.4 (30.9) | 81.7 (20.5) | 0.001* |
| Impaired central visual acuity | Yes (%) | 2 (4.9) | 14 (18.9) | 0.060 |
| | No (%) | 39 (95.1) | 60 (81.1) | |
| Presence of binocular function | Yes (%) | 38 (92.7) | 56 (75.7) | 0.001* |
| | No / Unclear (%) | 3 (7.3) | 18 (24.3) | |
| Presence of hallucinations | Yes (%) | 2 (4.9) | 11 (14.9) | 0.091 |
| | No (%) | 39 (95.1) | 63 (85.1) | |
| Baseline reading speed (seconds) | Mean (SD) | 6.8 (3.3) | 7.9 (1.9) | 0.459 |
| Baseline NEI VFQ-25 score | Mean (SD) | 62.5 (13.4) | 46.2 (15.4) | 0.214 |
| Presence of visual inattention at baseline | Yes Mild (%) | 6 (14.6) | 17 (23.0) | <0.001* |
| | Yes Severe (%) | 0 (0.0) | 8 (10.8) | |
| | No (%) | 35 (85.4) | 49 (66.2) | |
| Presence of baseline visual symptoms | Yes (%) | 32 (78.0) | 71 (96.0) | 0.009* |
| | No (%) | 9 (22.0) | 3 (4.0) | |

Table 5: Overview of baseline mobility assessment course outcomes against self-reported adaptation at 12-weeks (* significant result)

| | | **Adapted**<br>**n=41** | **Non-adapted**<br>**n=74** | ***p* value** |
|---|---|---|---|---|
| Completion time (seconds) | Median (IQR) | 58 (28) | 77 (34.75) | <0.001* |
| Omissions to most affected side (/12) | Mean (SD) | 3.2 (2.9) | 6.9 (3.6) | 0.004* |
| | 95% CI | 2.3 – 4.1 | 6.1 – 7.7 | |
| Omissions to least affected side (/12) | Mean (SD) | 1.1 (1.8) | 1.9 (2.0) | 0.112 |
| | 95% CI | 0.5 – 1.7 | 1.4 – 2.4 | |
| Total % omissions | Mean (SD) | 17.9 (16.5) | 36.8 (21.5) | 0.002* |
| | 95% CI | 12.8 – 22.9 | 31.9 – 41.7 | |
| Asymmetry score | Mean (SD) | 2.5 (2.5) | 5.0 (2.6) | 0.339 |
| | 95% CI | 1.7 – 3.3 | 4.4 – 5.6 | |

Figure 3: ROC curve for baseline factors prediction model: inferior % visual field, % total MAC omissions and MAC completion time




*The green diagonal reference line on the ROC curve represents a model based on chance.*

*The further the curve from the diagonal, the better the model at discriminating between adaptation and non-adaptation.*

Blue line represents optimal threshold giving the highest probability of correct classification and this corresponds to sensitivity 0.76 and specificity 0.73.