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Journal of Mental Imagery, 2010, *34*(3 & 4) 3-14

Disruption to Aspects of Imagery Vividness following Stroke

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The purpose of this study was to assess imagery characteristics in individuals affected by stroke. In particular it examined differences in imagery vividness from two different visual perspectives and the experience of kinesthesis. Participants completed the Vividness of Movement Imagery Questionnaire-2 (VMIQ-2), which assesses an individual's imagery vividness in three conditions (internal visual imagery, external visual imagery, and kinesthetic imagery). A MANOVA revealed between-group differences. A significant multivariate main effect emerged for the grouping variable. Post-hoc tests revealed that individuals affected by stroke had significantly less vividness for internal perspective imagery and for movement kinesthetic imagery compared to a healthy age-matched group. However, the former group showed significantly better external perspective vividness than the latter group. These findings suggest that aspects of imagery vividness may be compromised as a result of stroke. We suggest this may be a consequence of lesion damage and functional motor inactivity. Vividness of generated images, visual perspective, and kinesthetic imagery should be considered in imagery-based stroke rehabilitation interventions.

Keywords: Imagery; Stroke; Visual Perspective; Kinesthesis

Motor imagery (MI) has been defined as a covert cognitive process whereby memory representations similar to those used during action are activated without overt movement (Mulder, de Vries, & Zijlstra, 2005). Within clinical and therapeutic environments, MI is increasingly being proposed as a technique that may support and promote post-stroke motor recovery by exploiting the plasticity of the brain, offering a potential route to the re-modeling of cortical and subcortical structures (Butler & Page, 2006). This neural reorganization

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may result from MI directly engaging similar motor cortical areas to those recruited during actual physical performance (e.g., Grèzes & Decety, 2001; Kimberley, Skraba, Spencer, van Gorp, & Walker, 2006).

There is a wealth of research now supporting the use of imagery as a rehabilitation tool for individuals who have experienced a stroke (e.g., Dunsky, Dickstein, Ariav, Deutsch, & Marcovitz, 2006; Hewett, Ford, Levine, & Page, 2007; Page, 2001; Zimmerman-Schlatter, Schuster, Puhan, Siekierka, & Steuer, 2008). However, the first randomized controlled trial of a motor imagery intervention for stroke patients was conducted by Page, Levine, Sisto, and Johnston (2001). They demonstrated that patients' functional status improved after receiving an hour of imagery "therapy," administered by physical and occupational therapists three times a week for six weeks. The authors concluded that imagery was a "feasible, cost-effective adjunct to regular therapy" (p. 233). Such positive results have led to the suggestion that imagery interventions may improve therapeutic outcomes more than physical therapy alone.

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While these and similar findings are encouraging, more recent research suggests that damage to the brain as a consequence of stroke may compromise characteristics of imagery ability, including image vividness. For example, Battaglia et al. (2006) found that individuals who had experienced unilateral cerebellar stroke in the posterior inferior cerebral artery showed deficits in motor imagery ability compared to healthy controls. In particular, such lesions seemed to disrupt kinesthetic imagery of complex motor tasks involving the hemiparetic arm, a finding supported by Gonzalez, Rodriguez, Ramirez, and Sabate (2005). Such results are also consistent with those reported by Hochstenbach and Mulder (1999), whose data suggest that approximately 18% of all stroke patients experience impaired motor imagery ability. This issue is of further concern since the research literature also suggests that stroke may cause disruption to those specific brain areas considered important for justifying imagery as a valid rehabilitation technique.

Imagery vividness has rarely been considered as a mediating or moderating variable in stroke research (de Vries & Mulder, 2007). Consequently, judgments regarding the clinical efficacy and effectiveness of imagery-based interventions in post-stroke rehabilitation should be made with caution. Therefore, assessment of an individual's imagery vividness would appear to be important prior to commencing "imagery-based" interventions, in order to provide optimal support.

The ability to generate and control imagery has been shown to decline with age, regardless of health status, according to Mulder, Hochstenbach, van Heuvelen, and den Otter, 2007. These researchers found a weak but significant shift from a first person visual perspective (1PP) (similar to internal visual imagery; as if looking through one's own eyes) to a third person perspective (3PP) (similar to external visual imagery; as if watching oneself or another from an allocentric position) with increasing age. It has been hypothesized that this may be due to the general decrease in physical activity that often accompanies aging. In addition, the inactivity affects both the physical ability to perform a movement and the ability to imagine the movement. The shift in visual perspective with aging is an important consideration when using imagery as a rehabilitation tool for stroke, as the first person perspective has been shown to be more effective for learning and re-learning skills (Jackson, Lafleur, Malouin, Richards, & Doyon, 2001). In addition, a high proportion of those individuals experiencing stroke come from the older adult population.

Denis, Engelkamp, and Mohr (1991) contend that imaging oneself performing a behavior from a first person perspective involves visual representations that are "enriched by the evocation of motor programs and elicitation of kinesthetic sensations" (p.246). The potential elicitation of kinesthesis may be key to post-stroke improvement of motor function through imagery. Experiencing kinesthesis during imagery conditions may allow individuals with hemiparesis to become aware of the position of the affected limb, allowing them to perceive the active or passive movement of a limb and its direction. Further, the effects of the kinesthetic experience include improvement of coordination patterns through strengthening of neural networks and the priming of motor neurons (Mulder, 2007).

Although current research has shown that motor imagery may increase access to motor networks and thus benefit individuals who have had a stroke,much of it has neglected to assess and report the imagery vividness of those included in the research study. Additionally, little is known about the visual perspective (internal or external) of stroke-affected individuals when they image, a factor that could significantly attenuate any functional gains resulting from imagery interventions. As well, there is little information about the ability of post-stroke individuals to experience movement kinesthesis during the imagery process. If kinesthesis is important in strengthening neural networks and priming muscle motor neurons, then the kinesthetic imagery experience in this population should be examined further. Resolving these issues could be central in the future development of imagery-based rehabilitation programs.

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The aim of the current research was to assess the imagery vividness of individuals affected by stroke through markers of their visual perspective and to see whether variations in perspective were accompanied by different kinesthetic experiences.

Method

Participants

The study employed a between-participant design involving two groups. Individuals affected by stroke comprised one group and a healthy age-matched group were included as a comparison group.

Fourteen individuals who had experienced a cerebrovascular accident (CVA) were recruited from three stroke support groups (8 males, 6 females; mean age 56.2; mean time since stroke, 47months; range, 8-93 months; side of stroke, 9 right, 5 left; type of stroke, 9 hemorrhagic, 5 ischemic). All participants scored higher than 70 on the modified Mini-Mental State Examination (Teng & Chui, 1987), suggesting that the individuals affected by stroke possessed the cognitive ability to understand the instructions provided for the study and to complete the questionnaire. The healthy age-matched group included 17 participants with matched demographics to the stroke group (8 males and 6 females; mean age 59.0). An independent-samples t-test was conducted to compare the ages of the two groups. There was no significant difference in the ages of individuals affected by stroke ($M = 56.2$ yr, $SD = 12.0$) and the healthy age-matched group ($M = 59.0$, $SD = 6.7$). All participants volunteered to take part in the study, and no incentives were provided. In the initial screening, all participants reported that they had no previous experience of, or prior exposure to, mental imagery. All healthy participants reported no known medical or ambulatory problems. The Edinburgh Handedness Inventory (Oldfield, 1971) confirmed that all participants were right-handed. No participants were involved in any athletic activities.

Written informed consent was obtained from all participants following a written and verbal explanation of the study. The study was approved by both the National Health Service (NHS) Regional Ethics Committee and the Local Institutional Ethics Committee.

Instrumentation

The Vividness of Movement Imagery Questionnaire-2 (VMIQ-2)

The VMIQ-2 (Roberts, Callow, Hardy, Markland, & Bringer, 2008) assesses the vividness of visual imagery (internal and external) and kinesthetic imagery. It defines internal visual imagery (IVI) as "first person visual imagery," external visual imagery (EVI) as "third person visual imagery of the self," and kinesthetic imagery (KIN) as "the feel of the movement." For internal imagery, participants are asked to "imagine the movement as if you are looking through your own eyes." For external imagery, participants are asked

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to "imagine the actions as if you are watching yourself performing the action." For kinesthetic imagery, participants are asked to "imagine yourself doing the movement." Participants rate the vividness of the image on a 5-point Likert scale (1 = perfectly clear and as vivid as normal vision; 2 = clear and reasonably vivid; 3 = moderately clear and vivid; 4 = vague and dim; and 5 = no image at all, you only "know" that you are thinking of the skill).

The questionnaire's authors conducted a correlated traits correlated uniqueness (CTCU) analysis to provide support for the factorial validity of the VMIQ-2. Specifically, the fit statistics demonstrated a good model fit. The VMIQ-2 was also shown to correlate with existing measures of imagery ability (Movement Imagery Questionnaire-Revised; Hall & Martin, 1997) (concurrent validity), and discriminated between high and low level imagery ability (construct validity) in athletes. The VMIQ-2 has also been shown to be reliable (IVI = α .95, EVI = α .95, KIN = α .93) (Roberts et al., 2008). The imaged activities when completing the VMIQ-2 are: walking; running; kicking a stone; bending to pick up a coin; running up stairs; jumping sideways; throwing a stone into water; kicking a ball in the air; running downhill; riding a bike; swinging on a rope; and jumping off a wall.

In the current study, some of these items were changed slightly to make the movements more relevant to the stroke population being studied, for example jumping sideways became stepping sideways. Discussion with the lead author of the VMIQ-2 confirmed these changes to be appropriate for the stroke population group and unlikely to significantly affect the validity or reliability of the questionnaire.

Procedure

All participants completed the VMIQ-2 individually in a quiet environment with only one of the researchers present. Participants typically completed the questionnaire in their own home or in a separate room at the venue of the stroke support group they attended. Stroke-affected participants took an average of 20 min and the healthy age-matched group an average of 16 min to complete the VMIQ-2. All participants were provided with written and verbal instructions prior to commencing each phase of their imagery protocol to control for potential ambiguity and any conflation of perspective, modality, and agency, factors that have presented methodological concerns in previous imagery studies (Holmes, 2007).

Participants were asked to close their eyes and imagine that they were executing the VMIQ-2 activities in each imagery condition (i.e., internal, external, and kinesthetic). For each item, they were asked to image the activity through their own eyes (IVI), as if they were watching themselves perform the action (EVI), and to "attempt to feel the action or any sensations related to the action" (KIN). Following each instruction, participants were asked to open their eyes and rate the vividness of the image. The order of the imagery conditions was counterbalanced across participants to control for potential learning or order effects. Prior to their imagery session, participants in the stroke group were made aware that "they were taking part in a study which was considering the imagery processes of individuals affected by stroke." They were not made aware, however, of any research hypotheses or the existence of the other group, thus limiting demand characteristics. The control group was provided with similar instructions without mention of stroke or the stroke group.

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Following the imagery phase, detailed post-experimental debriefings were conducted. These included a manipulation check to ensure that all participants were able to adhere to the imagery instructions and that they were not experiencing any switching of perspectives during the imagery. Three participants reported experiencing some switching of perspectives and/or agency during imagery for some trials. Two participants were from the older adult group and one was from the stroke-affected group. This data was removed prior to analysis.

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Statistical Analysis

A one-way, between-groups multivariate analysis of variance (MANOVA) (2 × 3, Group × VMIQ-2 subscale score) was performed to investigate between-group differences during imagery in the three conditions. The statistical analysis was performed by the second author, who was independent of the primary data collection, to reduce experimenter expectancy effects .

Results

Figure 1 presents the data for the two groups for the three components of the VMIQ-2. A significant multivariate main effect emerged for the grouping variable, Pillai's Trace = 0.663, $F(3,27) = 17.72$, $p < .001$, $\eta^2 = .663$, showing that the stroke group and the healthy age-matched group differ in their imagery vividness.

However, as there are three distinct subscales within the VMIQ-2 (internal, external, and kinesthetic), it was deemed necessary to conduct a follow-up analysis to see where the differences lay; that is, Did the two groups differ on one, two, or all of the subscales? Post-hoc analysis (using the Scheffé method) revealed significant differences between the stroke group and the healthy age-matched group on the internal visual imagery subscale of the VMIQ-2, $F = 11.52$, $p < .002$, $\eta^2 = .28$. Individuals affected by stroke showed significantly lower vividness compared to the healthy age-matched group. A similar profile was found for the kinesthetic imagery subscale, where individuals affected by stroke showed significantly lower vividness than the healthy age-matched group, $F = 11.53$, $p < .002$, $\eta^2 = .28$). For the external visual imagery subscale of the VMIQ-2, there was a significant difference between the stroke-affected group and the healthy age- matched group, $F = 11.46$, $p < .002$, $\eta^2 = .28$. In contrast to the other two factors, the stroke group reported significantly greater vividness in the external visual perspective compared to the healthy age-matched group.

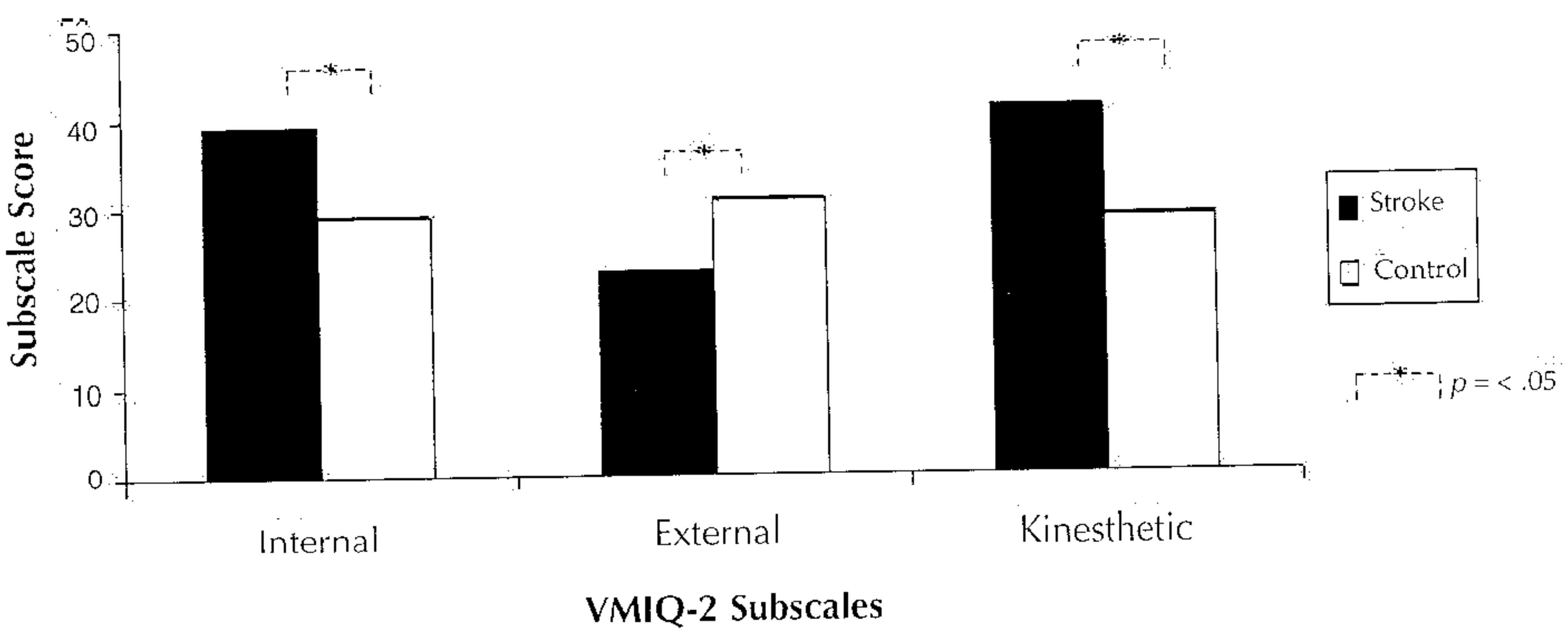

Figure 1. Mean VMIQ-2 subscale scores for individuals affected by stroke and healthy age-matched adults.

Discussion

The results indicate that the individuals affected by stroke demonstrate a different profile of imagery vividness compared to the healthy age-matched group. Specifically, they were unable to image movements as "clear and reasonably vivid" using a first person visual perspective. Individuals affected by stroke scored significantly higher (lower vividness) on the VMIQ-2 than the healthy age-matched adults; their mean score of 39.4 was greater than the 36.0 generally accepted as the cut-off point for the inclusion of individuals in imagery studies (Roberts et al., 2008). Their responses to the kinesthetic subscale also revealed that they were unable to "feel" the movements being imaged as "clear and reasonably vivid." Their mean score of 41.2 was again above the cut-off score of 36 and significantly higher than the healthy age-matched group. Based on the same cut-off point, the data revealed that individuals affected by stroke were able to image movements as "clear and rea-

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see edited MS on rating scale ok or change sonably vivid" from the external visual imagery perspective. For this factor on this subscale, the scores were significantly lower than those of the healthy group. Although the healthy group scores differed from those of the stroke group, there were also differences for the three subscales within this group. However, all mean subscale scores were below the cut-off score of 36, and the differences were revealed to be nonsignificant.

Together, these results provide additional support for the findings from previous research that has shown imagery ability disruption post-stroke. The results of the current research suggest that individuals who have had a stroke may experience disruption to visual perspective and kinesthetic imagery processes. These data support Jeannerod's (2006) proposal that individuals who receive damage to frontal and parietal lobes of the brain experience image generation problems. Additionally, data reported by deVries and Mulder (2007) show that approximately 18% of stroke patients are impaired in motor imagery ability, and as many as 40% show simultaneous impairment in visual and motor imagery.

The studies reporting positive findings from imagery interventions may have chosen their stroke population carefully in order to avoid including individuals with damage to these specific sites; unfortunately, however, in many cases this detail is not reported. In combination, these findings suggest that including an assessment of imagery vividness and/or imagery ability and screening of visual imagery perspective and kinesthesis prior to initiating any imagery-based rehabilitation program should routinely take place for individuals affected by stroke.

The findings from this study indicate that although stroke-affected participants show deficits in their internal visual imagery and kinesthetic imagery vividness abilities, their ability to image vividly from an external visual perspective appears enhanced compared to that of healthy age-matched individuals. It could be argued that the shift from internal to external visual imagery occurs as a function of aging. Although increased age may account, in part, for the results, it does not account for the nine stroke-affected participants who showed more ability for external imagery but who did not meet Mulder et al's. (2007) criteria for older adults. Further, in contrast to the healthy age-matched group, the stroke group showed significantly greater vividness for external visual imagery, suggesting a greater use of this perspective. Although individuals in this study were not classified as older adults, it is possible that the same mechanisms proposed to explain the shift in healthy elderly individuals may also explain the shift in stroke-affected individuals. Such a shift may result from the extreme decrease in physical activity that often follows stroke; many

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patients spend their time in isolated disengagement from all aspects of everyday life activities (Lincoln, Willis, Phillips, Juby, & Berman, 1996).

The proposition that movements which cannot be performed actively cannot be imaged appears plausible, based on Jeannerod's (2001). Simulation Theory. This theory suggests that similar parts of the brain are activated during actual movement and imagery of such actions. Thus, if motor imagery is primarily about motor planning and action preparation (Jeannerod, 1994), then it is likely to follow the same control rules as physical performance. Mulder et al. (2007) suggest that decreased proprioceptive input following stroke will compromise both physical ability and imagery vividness. This claim is supported by research showing that decreased sensory input, resulting from the lack of physical activity, produces reorganization in cortical areas specifically involved in movement control (Classen, Liepert, Wise, Hallett, & Cohen, 1998). If this is the case, then it would be predicted from Simulation Theory that internal imagery would also be compromised.

The lack of kinesthesis reported by the stroke group may be linked to this group's reduced ability to image vividly from an internal visual imagery or first person perspective. Consistent with this interpretation is the view that the internal visual perspective is associated with increased functional kinesthetic and peripheral efferent activity (e.g., Collins, Smith, & Hale, 1998). Furthermore, it has been demonstrated that, for some tasks, internal imagery induces a greater physiological response in terms of muscle EMG and corticospinal activity than external imagery (e.g., Stinear, Byblow, Steyvers, Levin, & Swinnen, 2006). These findings add to the evidence, albeit indirectly, that different patterns of cortical and subcortical activity are apparent when employing different imagery perspectives (Marks & Isaac, 1995) and that these factors may be further compromised in post-stroke individuals.

The potential for internal visual imagery to elicit a greater kinesthetic response, however, cannot completely explain the lack of kinesthesis in the individuals affected by stroke. Recent research (e.g., Callow & Hardy, 2004; Fourkas, Avenenti, Uregesi, & Aglioti, 2006) has suggested that an individual may experience kinesthesis during external visual imagery. For example, Fourkas et al. (2006) found evidence of corticospinal activation during external visual imagery, which was attributed to the imaged actions being matched with a visuomotor template. Therefore, it could be suggested that in order for a kinesthetic response to occur during external visual imagery, mental representations of the imaged actions need to be elaborate enough to induce the activation. While this route to kinesthesis remains a possibility for individuals affected by stroke, it is unlikely — based on the movements required on the modified VMIQ-2 — due to the stroke participants' relative inactivity.

There are two further possibilities for why individuals affected by stroke experienced significantly lower kinesthetic visual imagery vividness. First, as a result of their disability, participants' mental representations of the movements being imaged may have weakened. Although the instructions were adapted to reflect movements that the participants would be able to undertake physically and are familiar with, their functional ability to perform them with the correct temporospatial characteristics may still be compromised due to their residual disability. If participants were offered instructions to image actions that they can still physically perform, their ability to use the internal visual perspective and kinesthetic imagery may increase. Second, the lack of kinesthesis may, potentially, be due to damage from the stroke lesion to the visuomotor networks that are required not only to understand motor activities but also to "feel" the movement (e.g., centroparietal regions). In order to determine the validity of this claim, the participants' stroke aetiology would need to be controlled as a variable.

The modified VMIQ-2 was used as a measure of the vividness of the generated image. However, despite its demonstrated psychometric properties, the VMIQ-2 lacks validation in stroke populations, so caution is required when generalizing the findings from this study. At the time of data collection, no valid or reliable measure of imagery vividness was available for use with stroke-affected populations. However, the Kinesthetic and Visual Imagery Questionnaire (Malouin et al., 2007) has been developed recently for use with individuals with physical disabilities, and it is suggested that future studies may wish to use this measure with individuals affected by stroke. In addition, generalizing the findings may be further compromised by the small sample size and lack of homogeneity of the sample in the study. In particular, location of stroke, which may have influenced the imagery vividness data, was not controlled. However, since the majority of individuals affected by stroke in this study showed deficits in imaging using an internal visual perspective, this suggests that the result is valid and a consequence of the cortical disruption and inactivity caused by stroke rather than due to specific lesion locations.

The current research is the first to compare the imagery vividness profiles of individuals affected by stroke (36-77 years) and to contrast their scores with those of healthy age-matched adults (37-79 years). In particular, it is the first to attempt to assess disruption of imagery vividness in individuals affected by stroke. We have reported that imagery vividness, and in particular vividness when using an internal visual imagery perspective, may be compromised as a result of damage caused by stroke lesions (Hochstenbach & Mulder, 1999). Imagery interventions in the stroke-affected population are frequently prescribed but often fail to assess imagery vividness prior to the intervention (de Vries & Mulder, 2007). Our findings should not be interpreted to suggest that motor imagery is an ineffective rehabilitation method for the post-stroke population. Rather, they suggest that individuals should be screened for imagery vividness and, in particular, their ability to generate a vivid internal visual image prior to commencing imagery interventions. Future research should concentrate on optimizing the kinesthetic experience in post-stroke imagery interventions. For example, the use of patient-selected actions that individuals can still perform rather than generic tasks may help to increase the kinesthetic response. In addition, variables such as gender and site of stroke should be examined in relation to post-stroke imagery abilities in order to further define post-stroke individuals who will potentially benefit most from imagery interventions.

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