Human Movement Science 59 (2018) 244–257

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Changes to online control and eye-hand coordination with healthy ageing

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A R T I C L E I N F O

Keywords:
Ageing
Online control
Double-step task
Saccade
Eye movement
Reaching

A B S T R A C T

Goal directed movements are typically accompanied by a saccade to the target location. Online control plays an important part in correction of a reach, especially if the target or goal of the reach moves during the reach. While there are notable changes to visual processing and motor control with healthy ageing, there is limited evidence about how eye-hand coordination during online updating changes with healthy ageing. We sought to quantify differences between older and younger people for eye-hand coordination during online updating. Participants completed a double step reaching task implemented under time pressure. The target perturbation could occur 200, 400 and 600 ms into a reach. We measured eye position and hand position throughout the trials to investigate changes to saccade latency, movement latency, movement time, reach characteristics and eye-hand latency and accuracy. Both groups were able to update their reach in response to a target perturbation that occurred at 200 or 400 ms into the reach. All participants demonstrated incomplete online updating for the 600 ms perturbation time. Saccade latencies, measured from the first target presentation, were generally longer for older participants. Older participants had significantly increased movement times but there was no significant difference between groups for touch accuracy. We speculate that the longer movement times enable the use of new visual information about the target location for online updating towards the end of the movement. Interestingly, older participants also produced a greater proportion of secondary saccades within the target perturbation condition and had generally shorter eye-hand latencies. This is perhaps a compensatory mechanism as there was no significant group effect on final saccade accuracy. Overall, the pattern of results suggests that online control of movements may be qualitatively different in older participants.

1. Introduction

Goal directed movements like reaching play a critical role in activities of daily living. For rapid tasks like reaching to a peripheral target, a saccade is typically made to the target location ahead of the hand (Land, 2009). For slower, more naturalistic tasks like making a cup of tea or a sandwich, people tend to make saccades to the goal of the hand movement (Hayhoe & Ballard, 2005). These results suggest that eye-hand coordination plays a key role in performing goal directed movements. As people age, there is evidence that motor performance as well as visual performance declines (Haegerstrom-Portnoy, Schneck, & Brabyn, 1999; Owsley, 2011; Seidler et al., 2010). For instance, older people typically make slower hand movements and have longer saccade latencies. Since eye position (e.g. Prablanc, Echallier, Komilis, & Jeannerod, 1979) and target eccentricity (e.g. Gegenfurtner & Franz, 2007; Ma-Wyatt & McKee, 2007) have been shown to significantly influence reaching and pointing performance, longer saccade latencies may also

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https://doi.org/10.1016/j.humov.2018.04.013
Received 14 April 2017; Received in revised form 23 April 2018; Accepted 24 April 2018

impact eye-hand coordination during goal directed movements. With longer saccade latencies, the eye position may not be at the goal of the movement during the final online correction phase of the movement and this may compromise endpoint accuracy. Online control is an important aspect of goal directed movements and provides a valuable insight into the efficacy of sensorimotor control (Elliot et al., 2010). We used an online updating task to quantify how ageing affects pointing performance and eye-hand coordination.

The double step paradigm has been used to investigate online updating in younger people. In this paradigm, a target is displaced while the hand is in flight. The participant must update their hand movement to the final target location, and the measure of performance is how quickly and accurately the participant can make this online correction (e.g. Paulignan, Mackenzie, Marteniuk, & Jeannerod, 1991). It is a useful task for quantifying the effect of changes to the integration of visual and proprioceptive information with task demands or changes in stimuli (Sarlegna & Mutha, 2010). This paradigm has been used to test models of sensorimotor control by varying parameters including the speed of the movement, the visual properties of the target and the time of the target displacement. Using this method several groups have demonstrated that the updating of the reach is often completed in the range of 110–150 ms (Ma-Wyatt & McKee, 2007; Paulignan et al., 1991) and in some cases, even without conscious awareness of a target shift (Goodale, Pelisson, & Prablanc, 1986).

The ability to update a goal directed movement at any time during the planning or execution process is essential to fluid and flexible control of action and like many other aspects of sensorimotor control, there is evidence it can be adversely affected by age. There have been only a few studies that have used the double-step paradigm to investigate how sensorimotor integration might change with healthy ageing. Sarlegna (2006) had six younger (mean age = 28) and six older healthy participants (mean age = 56) complete a double step reaching task in which they were required to make rapid reaching movements to a visually defined target. He demonstrated that older participants took significantly longer to initiate a corrective movement towards a displaced target by examining their reach trajectories using a method adapted from Pisella et al. (2000). Based on this, Sarlegna concluded that ageing significantly affected online correction of the trajectory. However, endpoint accuracy was not explicitly assessed in this study. This would have been beneficial as previous research has indicated that older subjects actively slow their responses to preserve accuracy in an attempt to compensate for slower processing speed (Goggin & Meeuwsen, 1992).

Rossit and Harvey (2008) used a double step paradigm to compare online control for younger and older participants, and also measured reach accuracy. Although older subjects took significantly longer to initiate, execute and correct a goal directed reach, they performed with a level of accuracy comparable to that of the younger participants. Furthermore, a profound slowing was also observed on non-perturbed trials. This led them to conclude that ageing does not specifically affect an individual's ability to perform corrections to goal directed reaches *per se* but rather produces a general slowing and increased variability of movement planning, initiation and execution. However, Rossit and Harvey also noted that it may be argued their classification of a successful correction did not strictly fit the criteria of an automatic, fast correction, because the duration of the correction was significantly longer than that previously reported in other studies (e.g. Ma-Wyatt & McKee, 2007; Prablanc & Martin, 1992; Sarlegna, 2006). A longer duration would also provide more time for integration of visual and proprioceptive feedback that could be used to improve endpoint accuracy and precision (e.g. Sober & Sabes, 2005). It is therefore unclear if the observed slowing is due to an active strategy to preserve accuracy or a limitation of sensorimotor integration with ageing.

Some aspects of saccade dynamics, for example saccade latency (the time taken to initiate an eye movement), accuracy and velocity, also show age related degradation (Irving, Steinbach, Lillakas, Babu, & Hutchings, 2006; Rand & Stelmach, 2012). Peltsch, Hemraj, Garcia, and Munoz (2011), in a large sample of elderly subjects aged 60–85 years, found older participants were slower to initiate a saccade and made more directional errors. Similarly, Munoz, Broughton, Goldring, and Armstrong (1998) reported an increase in saccade latency of 100–150 ms for older (65–79 years) compared to younger (20 years) participants. Older people have also been shown to spend more time fixating in a sequential aiming task when a reach accompanies a saccade. In a two segment aiming task where accuracy constraints and hand movement requirements were manipulated, Rand and Stelmach (2011) found that compared to younger people, older people made less modifications to eye movements in response to task requirements and maintained gaze fixation on the initial target for longer. The intersegment interval was also longer in the older group when the termination requirements of the eye and hand differed, suggesting older people may have difficulty modifying eye and hand movements differentially to meet task demands.

The late portion of a trajectory is often associated with explicit feedback based reach regulation to improve accuracy (Chua & Elliott, 1993). Older participants may perhaps rely more heavily on visual feedback regarding target and finger location to maintain or improve endpoint accuracy and compensate for any negative age related effects of online control in movement planning and execution stages of the reach (Welsh, Higgings, & Elliot, 2007). If older participants do rely more heavily on explicit visual feedback throughout completion of the reach and have difficulties dynamically modifying eye movements to meet task demands, then these age related changes to visual function may provide a negative flow on effect to the other aspects of sensorimotor control and should be evident in changes to eye-hand coordination and endpoint accuracy. Specifically, the delayed acquisition of visual information stemming from an increase in saccade latencies may adversely affect updating of internal sensorimotor information regarding aspects of perceived target location, actual target location and hand location (Henriques, Medendorp, Khan, & Crawford, 2002). This may negatively influence endpoint accuracy in a highly time dependent task and as suggested by Kimura, Kadota, and Kinoshita (2015) may be the source of endpoint variability in older people.

In the current study, participants completed a perturbation task in which perturbations were presented early in the reach (200 ms), at an intermediate time in the reach (400 ms) and late in the reach (600 ms) with an overall time pressure of 800 ms. These times were selected to allow investigation of how sensorimotor integration affects performance at different times during the reach. The overarching aim of our study was to quantify how ageing affects specific aspects of performance during online control, and this generated specific hypotheses for each of these questions. Older participants have been known to actively slow their reach to preserve