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Effect of ageing on the ability to adapt to a visual distortion during walking

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Abstract

Degradation of major sensory systems such as proprioception, the vestibular system and vision may be a factor that contributes to the decline in walking stability in older people. In the present study this was examined by introducing a visual distortion by means of prism glasses shifting subject's view 10 degrees to the right while subjects walked towards a target (exposure condition). Shifting the view while walking towards a target will cause subjects to alter their heading in such a way that their walking trajectory describes a curvilinear path. It was expected that older people, when compared to young people, would have greater difficulty adjusting their heading and would show a greater decrease in heading stability, quantified by means of the standard deviation of the lateral position (SDLP). This was indeed the case. When performance in a pre- and post-exposure condition, in which subjects walked without prism glasses, were compared to each other, older people (O group) showed a greater decrease in heading stability than young people (Y group) and middle aged people (M group). Furthermore, it appeared that during the exposure condition adaptation effects were present in the Y and M group, which were absent in the O group. It is discussed that this adaptation is a form of realignment of the proprioceptive and visual system. The absence of realignment in the O group is argued to be caused by degradation of the proprioceptive system, which results in a lowering of the proprioceptive bias of vision.

Keywords: Ageing; Prism paradigm; Realignment; Heading stability; Proprioception

1. Introduction

Falls in older people during walking often result in serious injuries. Reported numbers vary but approximately one third of community living people over 65 years of age report one or more falls each year [1–3]. Approximately 20% of these falls require medical attention and almost 10% result in a fracture [2,4]. Although much is still unknown about factors associated with falls and gait stability in older people, age related changes in sensory input may play an important role.

Three major sensory systems can be distinguished, which provide feedback about the position of our body relative to the environment: proprioception, the vestibular system and vision. It has been well documented that these systems degenerate with age. Older people show a decreased sensitivity of joint receptors in both ankle and knee [5] and the perception-threshold for vibratory stimuli increases with age [6]. Age-related changes have been reported also for the vestibular system and include a decline in primary vestibular neurons and up to 40% reduction of hair cells [7,8]. Regarding the visual system, reduction of the ability to deduce heading from optical flow, reduction in contrast sensitivity, decreased depth perception, restriction of the visual field and reduced acuity are specific age-related changes [9–12]. Although vision declines substantially with age, older people still rely heavily on the visual sense and some experiments report that older people are even more dependent on visual information for maintaining balance during gait than younger people [13,14].

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To assess the effects of visual distortions on motor performance and the ability to adapt to these distortions, the prism adaptation paradigm is a frequently employed experimental procedure. Although experiments have been performed in which walking subjects wore prism glasses [15,16], no experiments have investigated the ability to adapt to these distortions during walking and, until now, the prism adaptation paradigm has not been applied to a gait related experiment. In a typical prism adaptation experiment subjects perform a motor task, usually throwing or pointing to a target, while wearing prism goggles [17,18]. During the task, named the exposure condition, motor performance and visual input have to be adapted and realigned. By adding a pre-exposure and post-exposure condition, in which the task is performed without prism goggles, the after-effect of the prism adaptation can be assessed. In these throwing or pointing experiments two specific adaptation mechanisms can be distinguished: strategic perceptual-motor control and adaptive spatial (re)alignment [19,20].

Strategic perceptual-motor control refers to a relatively fast working type of adaptation. It can be viewed as a feed forward system, based on knowledge of results, in which the difference between task-goal and perceived performance is used to adjust the (motor) output. For example, when a subject has just started the exposure condition in a target-pointing task with prism goggles shifting the visual field to the right and he intends to point at a target perceived straight ahead, he will point towards a position to the right of the target. During the pointing movement he might adjust his movement to the left, properly pointing at the target, but in subsequent trials he will already initiate a movement more to the left. This adjustment, probably initially based on a cognitive-verbal strategy (“I know I deviate to the right, therefore I point more to the left”), is referred to as strategic perceptual-motor control.

Adaptive spatial alignment is a much slower process and refers to the changes taking place within a sensory system to make its represented space realign with the represented space of another sensory system. In the previously mentioned example proprioceptive limb space does, at first, not align with visual limb space. During the pointing task, if performed under the proper circumstances, the proprioceptive representation of space will gradually align towards the visual representation of space. However, when a subject is able to fully optimise task performance using constant visual feedback, realignment will hardly take place [19]. In the previous example this would be the case when the complete pointing trajectory is visible to the subject. Concealing a part of the pointing trajectory would prevent constant visual feedback, facilitating realignment. Realignment will cause an after-effect typical for a prism adaptation task: in the mentioned pointing experiment, using prism goggles shifting the visual field to the right, subjects will point left of the target after removal of the goggles.

In the current experiment the prism adaptation paradigm is used for distorting the visual input while subjects walk. Although the paradigm does not directly apply to walking, it is possible that similar effects occur in a walking experiment. When walking towards a target while prism goggles shift the view to the right, subjects will reach the target but their walking trajectory will show a curve right of the midline [15,16]. If realignment were to take place during the exposure condition, in time the curve would decrease and subjects would start walking straighter. In the post-exposure condition an after-effect would then be present resulting in a walking curve left of the midline. However, since there is a constant visual feedback during this exposure condition, it is expected that realignment will hardly take place. Hence, a typical prism adaptation after-effect will most likely be absent.

Instantly after the prism goggles are removed, subjects will have to readjust their heading. Since this readjustment is driven by visual, proprioceptive and vestibular input, a decrease in the latter two may have a negative effect on it. Welford describes in a model, derived from the signal detection theory, that signals from sensory organs and signals within the central nervous system have to be distinguished against a background of random activity. A decrease in signal amplitude leads to a decrease in signal-to-noise ratio, which causes a slowing of performance in older people [21,22]. Based on this theory, it is expected that the decrease in proprioceptive and vestibular output will cause the heading readjustment to take longer in older people, which may have a negative effect on the heading stability. This expectation is verified by recording subject’s walking trajectories before, during and directly after wearing prism goggles. Heading stability will be defined in terms of subject’s deviation from the optimum walking trajectory. It is expected that older people will show a larger decrease in heading stability than younger people when they have to adjust to large changes in visual input.

2. Methods and materials

2.1. Subjects

Thirty-six healthy subjects, divided into three age-groups, participated in the study: 12 young people (Y group), 12 middle aged people (M group) and 12 older people (O group). The age and sex distributions of these groups are presented in Table 1. During intake an anamnesis was taken by means of a standard questionnaire concerning medical history and current use of medication. Furthermore, a short physical examination was performed in which motor ability and possible vestibular disorders were assessed. No subject had a history of motor, vestibular or neurological disorders and all subjects had normal or corrected to normal vision. Subjects in the Y group were recruited from hospital staff and students. Subjects in both the M and O group were recruited through local newspaper advertisements. They all were physically active and lived independently. The study was approved by the hospital’s ethics committee and an informed consent was obtained from each subject.