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Gaze strategies for avoiding obstacles: differences between young and elderly subjects

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Abstract

Visual input is highly relevant for safely stepping over obstacles. In this study, gaze-behaviour was investigated in elderly, middle-aged and young subjects as they walked on a treadmill repeatedly stepping over obstacles, which approached either on the right or left side. In between obstacle-steps, subjects visually fixated a target N or F located two or four steps ahead on the floor, respectively. An acoustic warning signal announced the obstacles, after which subjects were free to look wherever they wanted. Gaze-movements were measured by video-oculography. Four conditions with 20 obstacles were conducted (two with target N, two with target F). In two conditions, high-precision stepping was investigated by asking subjects to step with minimal foot-clearance over the obstacles, while receiving acoustic feedback about their performance. In the high-precision conditions, more subjects (target N: 70%, target F: 81%) turned their gaze on the obstacles and for a longer time than in unrestricted conditions. When fixating on the near target N and unrestricted stepping over the obstacles, significantly more elderly subjects (85%) turned their gaze on the obstacle compared to middle-aged (17%) and young subjects (29%).The elderly turned their gaze earlier and longer on the obstacle than middle-aged or young subjects. Our results reveal a different gaze-behaviour strategy of elderly subjects suggesting a greater dependency on visual inputs.

1. Introduction

Safe locomotion allows independent mobility in daily life, but requires a complex interaction of somatosensory, vestibular, and visual inputs. The latter seems to play a dominant role [1, 2]. Diminished afferent functions increase the risk of falling. Moreover, people who have experienced a fall may develop a fear of falling, jeopardizing their independence. The elderly in particular are prone to falling, with an incidence between 28% and 35% [3-7]. Falls are frequently caused by stumbling over obstacles [5, 7] such as uneven ground, curb stones or door steps [8, 9].

Several studies have shown different gait behaviours between young and elderly subjects during walking over challenging pathways. The elderly walked slower and with shorter steps over multi-surface terrain, such as slippery or uneven grounds [10]. Furthermore, they crossed an obstacle with a step more elongated than necessary for a safe landing position [11]. Their success rate for safe obstacle-avoidance was lower, the reaction time longer, the horizontal toe and heel distances to the obstacle were smaller, and the vertical foot-clearance was larger than in young subjects [12]. Elderly people adjusted their stepping pattern one step earlier than young subjects during walking over virtual obstacles [13].

Besides adjustments in gait parameters, gaze-behaviour appears also to be altered in aged people during challenging walking tasks. When instructed to step precisely on given targets, elderly subjects visually fixated these targets earlier and longer compared to young subjects [14]. During walking on a multi-surface terrain, elderly subjects needed more and prolonged visual inputs from the lower field than younger subjects [15]. In an obstacle-avoidance task with an additional cognitive challenge for selecting which limb crosses first over the obstacle, the elderly visually fixated the place where the leading foot should land for a longer time compared to young subjects [16]. Moreover, elderly fallers turned their gaze away from the obstacle earlier than elderly non-fallers in a dual-task condition [17].

The present study evaluates changes in gaze-behaviour during repetitive stepping over obstacles during normal and high-precision conditions in healthy young, middle-aged and elderly subjects. This investigation adds information to the existing literature, as several methodological approaches previously applied are now combined into one study. We evaluated changes in gaze-behaviour during repetitive obstacle steps (i) without restricting vision by using video-oculography, (ii) under equal conditions for each step to improve measurement accuracy, (iii) under some time pressure, and (iv) in three age groups. We hypothesized that (i) elderly subjects focus more on the obstacle and (ii) focussing on the obstacle is increased during high-precision conditions compared to unrestricted obstacle avoiding.

2. Methods

2.1. Participants

The experiment was approved by the Cantonal Ethic Commission Zurich. Participants gave informed and written agreement prior to data collection. Forty-four healthy subjects without orthopaedic or neurological disease participated and were classified in three groups: 17 subjects older than 60 years (average ±SD: 68.4 ±5.5; range 63-81 years), all living independently and recruited at the Senior University Zurich; 12 middle-aged subjects (45.2 ±5.5; range 35-53 years), recruited by advertisement via the internet, and

15 young subjects (24.0 ±3.7; range 19-30 years), recruited via a student job platform. Only subjects who could see a 2x3 cm target on the floor 2.5 m in front of them were included. Contact lenses, but not glasses, could be worn under the video-oculograph.

2.2. Data collection

Treadmill with obstacle machines

Subjects walked on a split-belt treadmill (Woodway, Weil am Rhein, Germany) with two obstacle-machines (ALEA Solutions, Zurich, Switzerland) to study repetitive stepping over a right and a left foam stick, 18 cm above the floor [18]. Force sensors (Kistler, Winterthur, Switzerland) under the treadmill detected the right and left heel strike, which randomly triggered the start of the right or left obstacle, respectively. Simultaneous to this heel strike, the obstacle started to move with the same speed as the treadmill (2.5km/h) and subjects had to cross it in the step after the next (about 1s after the obstacle-trigger). The time between two obstacle steps was varied randomly between 13 to 30 seconds. The obstacle folded up at the end of the treadmill and moved back into the starting position about 70 cm in front of the subject (Fig 1). Stumbling was prevented because the foam sticks folded back or were released when touched. At the time of obstacle-release, the subjects received a short acoustic warning signal. In the high-precision conditions (see 2.3.Protocol), the vertical distance between the crossing leading foot and the obstacle (i.e. foot-clearance) was measured by infrared sensors attached to the obstacle machines. Corresponding acoustic feedback tones of different frequencies were given to the subjects defining six levels in 2cm intervals between 0cm and 12cm.

Eye tracking system

A video-oculograph (VOG; EyeSeeCam, Munich, Germany) with an gaze-driven head-camera and infrared-sensitive scene-camera was used for measuring gaze-movements [19]. Eye-movements were recorded by two eye-cameras (recording-frequency 76Hz) laterally attached to the frame of the goggles without restricting the subject's view (Fig 1). These cameras recorded movements of the pupils via two transparent mirrors. The gaze-driven head-camera (recording-frequency 30.4Hz) was aligned parallel to the eyes by servo drivers continually updated based on the eye-movement data. The infrared-sensitive scene-camera (recording-frequency 76Hz) was used to measure head-movements (see below).

Setup

A floor plate in front of the treadmill was equipped with five infrared LEDs lying in a plane (Fig 1). The LEDs were invisible for human eyes but could be detected by the infrared-sensitive scene-camera. By knowing the position of the plane in relation to the environment, the head position (head-on-plane), i.e. where the infrared-sensitive scene-camera pointed on the floor, could be detected. By combining the eye- and head-movements data, the gaze fixation points (= gaze-on-plane) on the floor could be determined.

Variables

Recorded and analysed were the vertical forces on the treadmill for detecting heel-strike and toe-off, the obstacle trigger signals, foot-clearance, gaze-on-plane, head-on-plane and the video of the gaze-driven head-camera.

2.3. Protocol

First, subjects were familiarized with treadmill-walking and stepping over the obstacles. The walking position and/or the obstacle machines were positioned in such a way that subjects were able to step over the obstacle without changing their step-rhythm. The walking speed was 2.5km/h.

After the VOG was calibrated, the subjects performed four conditions with 20 obstacles each. In-between two triggered obstacles, subjects were instructed to gaze at a 2x3cm target fixation point located on the floor plate. As soon as the obstacle was triggered and the acoustic warning signal sounded, subjects were free to look wherever they wanted. In condition N (near), subjects had to look at the near target about two steps ahead during the time in-between two triggered obstacles. We assumed that peripheral vision could be used in this condition. In condition N+P (precision), subjects looked at the same target N, while they performed a high-precision stepping task, i.e. they had to step over the obstacles with minimal foot-clearance, receiving acoustic feedback about their performance. In condition F (far), subjects had to look at target F, located about four steps ahead. In this condition, we assumed that it was difficult to use solely the peripheral vision. Condition F+P was the same as N+P but with target F. The order of the conditions was randomized.

2.4. Data analysis

In the raw gaze data, artefacts and blinks were eliminated by a 5 Hz median filter. Data from steps in which the obstacle was touched were not analysed. For each subject and condition, the median gaze-on-plane and head-on-plane was calculated between 1.3s before and 3.9s after the obstacle-trigger for all 20 obstacle steps for the right and left sides separately. Then, the right and left median gaze-on-plane and the right and left median head-on-plane were averaged, respectively. Several gaze-characteristics were derived from the sagittal data (Fig 2): (i) the amplitude of gaze- and head-movement downwards, (ii) the latency between the obstacle-trigger and the onset of gaze- and head-movement downwards, and (iii) the duration between the onset of gaze- and head-movement downwards and redirection upwards. To minimise the subjectivity in determining these events, the analyses were performed by two investigators. If small differences between the events were found, the average was taken into the analysis. Large differences were analysed a third time.

Three gaze-patterns were identified (Fig 2): Pattern 1 – gaze-direction on the obstacle (amplitude ≥40cm for the near target N or ≥155cm for the far target F); Pattern 2 – gaze-direction towards the obstacle, but not completely (amplitude between the defined limits of gaze-pattern 1 and 3); Pattern 3 - gaze was not turned away from the given target (amplitude ≤10cm for the near target N or ≤15cm for the far target F). These borders were determined on the basis of 66 control measurements. Gaze-pattern 2 was additionally verified by studying the gaze-driven video images and the examination of the gaze-on-plane data for each individual obstacle step, before calculating the median. If head or gaze was not turned downwards (i.e. gaze-pattern 3), amplitude and duration were set to 0cm and 0s, respectively, latency was defined as a missing value.

Most data were not normally distributed and the group sizes were small, therefore, nonparametric statistical tests were used. The three gaze-patterns were considered as ordinal data. For the pair-wise comparison between the three age groups, the Mann-Whitney-U Test was used. For the pair-wise comparisons between the conditions (N vs F, N+P vs F+P, N vs N+P, F vs F+P) the Wilcoxon Test was applied. To adjust for multiple comparisons, the significance-level was set at 0.025 and 0.05 was interpreted as a tendency.

3. Results

One-hundred-sixty out of 176 datasets (4 conditions x 44 subjects) could be analysed. The rest were of insufficient quality due to recording problems (e.g. no pupil detection because of closed eyelids). Results are presented in Tables 1 and 2.

3.1. Gaze patterns

More subjects turned their gaze on or into the direction of the obstacles in the high-precision conditions N+P and F+P than in condition N and F, respectively. In the subgroups, more young and middle-aged subjects turned their gaze on or into the direction of the obstacle in condition N+P compared to N. More elderly subjects tended to turn the gaze downwards in condition F+P compared to F. The group-comparison in condition N showed that more elderly subjects turned their gaze on or into the direction of the obstacles compared to the number of middle-aged and young subjects.

3.2 Gaze- and head-amplitudes

In the high-precision conditions, subjects showed increased gaze- and head-amplitudes downwards. In condition N vs N+P, this was also observed for the subgroups (except for head-amplitude in the elderly), while in F+P vs F the difference was only significant in the young group. In condition N, larger gaze- and head-amplitudes were found in elderly compared to middle-aged subjects and a larger gaze-amplitude compared to young subjects. In condition F, elderly showed a larger head-amplitude compared to middle-aged subjects.

When analysing gaze pattern 3 including all subjects and conditions, 31% of the subjects showed no significant gaze- and head-amplitude, 10% showed a small (still in the defined range for gaze-pattern 3), but still larger gaze-amplitude than head-amplitude, and 59% showed a larger head-amplitude than gaze-amplitude.

3.3 Gaze- and head-latencies

Except for condition F, the gaze-latencies were shorter in the elderly compared to the middle-aged and young subjects (only a tendency in condition N compared to young subjects) (Fig 3). Head-latencies were shorter in conditions N+P and F in the elderly compared to the middle-aged subjects.

3.4 Gaze- and head-movement-durations

Over all subjects, prolonged gaze- and head-movements to the obstacle were observed in the high-precision conditions. Prolonged gaze- and head-movements were found in condition N+P compared to N in young subjects. In other groups, some tendencies could be found for prolonged gaze- and head-movements in the high-precision conditions. In all conditions, elderly subjects gazed longer at the obstacle than middle-aged subjects (tendencies in conditions N+P and F+P). In condition N, elderly gazed longer compared to young subjects (Fig 3). The head pointed longer to the obstacle in elderly than in middle-aged subjects in conditions N and F.

3.5 Foot-clearance

In the high-precision tasks, all subjects together showed a significantly smaller clearance than in the low precision tasks. This result was confirmed in the three subgroups (N vs N+P: tendency in the middle-aged group). The foot-clearance was smaller in condition N than in F over all subjects. In the subgroups, tendencies for the young and middle-aged groups were found. The young subjects showed a smaller foot-clearance than the elderly in the high-precision conditions.

4. Discussion

The present study investigated differences in gaze-behaviour between healthy elderly, middle-aged and young subjects during stepping over obstacles. We found that (i) compared to the younger subjects, more elderly turned their gaze on or into the direction of the obstacles in the near target condition, (ii) the elderly turned their gaze earlier and prolonged on or into the direction of the obstacles (except for condition F), (iii) in the high-precision conditions, more subjects turned their gaze on or towards the obstacles with a larger gaze-amplitude and for a longer time compared to the unrestricted conditions. This result was only partly confirmed in the subgroups. (iv) The middle-aged group behaved more like the young subjects. We assume that in the present task, gaze-behaviour was changed in subjects aged around 60 and above.

4.1. Modified gaze-behaviour

Compared to middle-aged and young subjects, more elderly turned their gaze downwards to the obstacles in condition N with the visual-fixation point two steps ahead. Indeed, peripheral vision proved to be sufficient for safely avoiding a suddenly occurring obstacle in young subjects who looked at a target about two steps ahead [20]. In the similar condition in the present study, we assume that the young and middle-aged subjects were able to get the necessary visual inputs from the peripheral vision, unlike the elderly. This might be explained by the fact that peripheral visual acuity deteriorates with age [21, 22]. Apart from condition F with the target four steps ahead, the elderly turned their gaze earlier and for a longer time to the obstacles. Apparently, the elderly required prolonged visual sampling to obtain the necessary information, which is in line with literature [14, 23] and is also observed during walking over more difficult terrains [24]. Elderly people rely more on visual information probably due to a reduced proprioceptive or a vestibular control [25, 26].

4.2. Modified locomotor performance

The elderly did not reduce the foot-clearance in the high-precision conditions as much as young subjects. Perhaps the elderly could use the visual information less than young subjects, as the elderly might have more difficulty in visually following the moving obstacle due to impaired visual tracking ability [27] or due to limited response-time for optimizing the walking trajectory [12].

Another interesting observation was that over all subjects, the clearance in condition N was smaller than in condition F, even when no low obstacle-crossing was requested. Apparently, a better availability of peripheral vision might allow a more economic stepping over the obstacles by decreasing the vertical foot-clearance, which is in line with a previous study [23]. Again, the deterioration of the peripheral acuity in age might explain why this was not found in the elderly subjects.

4.3. Head-movements

Head-movements showed more or less similar characteristics as gaze-movements, indicating that the eye- and head-movements changed congruently. However, in gaze pattern 3 with no gaze-turn to the obstacle, more than half of the subjects showed a head-movement downwards without a gaze-turn downwards, as previously reported [20].

4.4. Limitations

In our study, we analysed gaze-behaviour during repetitively stepping over a randomly released obstacle under equal temporal conditions. This enabled a relative accurate assessment of gaze-behaviour and stepping performance for this specific movement. However, this approach limits information about the gaze-behaviour at (slightly) earlier or later released obstacles, as for example investigated by Marigold et al. [20]. Furthermore, the relevance for daily life of an obstacle avoidance task on a treadmill can be questioned compared to over-ground walking. However, this approach enabled us to study gaze-behaviour in a repeatable, yet unexpected, way. Indeed, unexpected trips over suddenly approaching obstacles occur frequently, as the annual estimate of tripping over a cat or dog approximates 24'000 cases in the USA [28].

5. Summary and conclusions

The results have highlighted different gaze-behaviour strategies during walking over obstacles in healthy well-performing elderly subjects, who did not report any falls. Our hypothesis was confirmed, as the elderly subjects looked earlier and prolonged at the obstacles than younger subjects. Additionally, in high-precision conditions, more elderly subjects used their visual input and turned the gaze downward to the obstacles compared to the younger ones, who might have better used peripheral vision, acoustic feedback and somatosensory inputs. Differences were found not only between elderly and young subjects but also between elderly and middle-aged subjects.

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Figure captions

Figure 1: Experimental setup and eye-tracking system. (a) treadmill, (b) obstacle machines and (c) floor plate. 1-5 = LEDs spanning a coordinate system with the origin at LED 1, N and F are the targets for gaze fixation during the interval between two triggered obstacles in the different conditions. Video-Oculograph (EyeSeeCam, Munich, Germany) with two eye-cameras (A), a gaze-driven head-camera (B) and an infrared-sensitive scene-camera (C)

Figure 2: Three examples of head-on-plane and gaze-on-plane in relation to the obstacle trigger. The plots are averaged left and right medians of all 20 obstacle steps in one subject in a single condition. The upper trajectory shows the anterior-posterior head-on-plane [cm], the lower trajectory anterior-posterior gaze-on-plane [cm]. Example A illustrates a gaze-pattern 1 (gaze-turn to the obstacle), B illustrates a gaze-pattern 2 (gaze-turn into the direction of the obstacle), and C a gaze-pattern 3 (no gaze-turn to the obstacle). About one second after the obstacle-trigger, subject crossed the obstacle. One sample is about 13 ms.

Figure 3: Box plots of gaze-latency (A) and gaze-duration (B). Box-plots represent the median value (dark stripe within the box). The lower whisker represents the lower 25% of the observations; the box represents the intermediate 50% of the observations and is divided by the median, which divides the observations in the upper and lower 50%; the upper whisker represents the upper 25% of the observations. The values indicate the p-values for significant comparisons ($p<0.025$) or for tendencies ($0.025<p< 0.05$). Abbreviations: N = condition with visual fixation point two steps ahead, F = condition with visual fixation point four steps ahead, N+P = condition with visual fixation point two steps ahead and high–precision obstacle-avoidance, F+P = condition with visual fixation point four steps ahead and high-precision obstacle-avoidance.

6. Table(s)

Table 1: Head movement and gaze behaviour parameters for each condition

Condition	Parameter	All subjects	Elderly	Middle-aged	Young
N	Pattern type	Number of subjects	Number of subjects	Number of subjects	Number of subjects
	1	8	5	1	2
	2	9	6	1	2
	3	22	2	10	10
	Amplitude [cm]				
	head	17 [0-29]	27 [11-36]	10 [0-16]	26 [0-36]
	gaze	6 [0-38]	36 [12–72]	4 [0–6]	6 [0–25]
	Latency [s]				
	head	0.81 [0.38-1.03]	0.39 [0.37-0.83]	1.03 [0.70-2.07]	0.86 [0.53-1.01]
	gaze	0.69 [0.33-1.04]	0.31 [0.25–0.65]	0.71 [0.70–1.20]	0.93 [0.42–1.12
	Duration [s]				
	head	0.44 [0.00-0.81]	0.75 [0.54-0.88]	0.28 [0.00-0.57]	0.44 [0.00-0.84]
	gaze	0.38 [0.00-0.82]	0.78 [0.54–1.02]	0.11 [0.00–0.45]	0.35 [0.00–0.65]
	Clearance [cm]	7 [5-9]	8 [6–9]	7 [4–8]	8 [4–9]
N+P	Pattern type	Number of subjects	Number of subjects	Number of subjects	Number of subjects
	1	22	9	5	8
	2	6	2	2	2
	3	12	3	5	4
	Amplitude [cm]				
	head	41 [21-67]	46 [28-55]	24 [14-45]	48 [26-116]
	gaze	61 [7-99]	73 [25–104]	28 [2–86]	64 [13–100]
	Latency [s]				
	head	0.54 [0.36-1.05]	0.44 [0.35-0.52]	1.24 [0.58-2.08]	0.56 [0.23-1.22]
	gaze	0.45 [0.33-0.99]	0.33 [0.27–0.44]	0.75 [0.50–1.83]	0.49 [0.37–1.27]
	Duration [s]				
	head	0.93 [0.48-1.11]	1.02 [0.78-1.13]	0.68 [0.38-1.03]	0.93 [0.44-1.08]
	gaze	0.89 [0.33-1.03]	1.00 [0.78–1.17]	0.48 [0.06–0.91]	0.97 [0.35–1.04]
	Clearance [cm]	4 [3-5]	5 [4–7]	4 [3–6]	3 [2–4]
F	Pattern type	Number of subjects	Number of subjects	Number of subjects	Number of subjects
	1	10	4	2	4
	2	13	6	4	3
	3	16	4	6	6
	Amplitude [cm]				
	head	38 [13-84]	59 [42-97]	22 [3-36]	37 [6-80]
	gaze	58 [1-159]	132 [10–172]	30 [0–121]	28 [0–167]
	Latency [s]				
	head	0.51 [0.32-1.10]	0.34 [0.26-0.54]	0.78 [0.57-1.71]	0.46 [0.34-1.07]
	gaze	0.47 [0.32-1.03]	0.41 [0.30–0.67]	0.62 [0.39–1.45]	0.60 [0.33–1.15]
	Duration [s]				
	head	0.53 [0.32-0.92]	0.82 [0.58-0.93]	0.39 [0.08-0.57]	0.45 [0.06-0.96]
	gaze	0.41 [0.08-0.97]	0.81 [0.43–1.11]	0.20 [0.00–0.31]	0.41 [0.00–0.97]
	Clearance [cm]	9 [6-10]	7 [5–9]	7 [6–10]	9 [6–10]
F+P	Pattern type	Number of subjects	Number of subjects	Number of subjects	Number of subjects
	1	21	11	5	5
	2	13	3	3	7
	3	8	2	4	2
	Amplitude [cm]				
	head	79 [30-120]	86 [64-113]	39 [5-123]	80 [29-141]
	gaze	155 [37-198]	176 [119–240]	80 [3–185]	107 [34–201]
	Latency [s]				
	head	0.42 [0.32-0.98]	0.38 [0.30-0.53]	0.76 [0.33-1.33]	0.45 [0.31-1.07]
	gaze	0.50 [0.29-0.81]	0.28 [0.23–0.51]	0.57 [0.48–1.08]	0.66 [0.39–1.19]
	Duration [s]				
	head	0.94 [0.58-1.13]	1.00 [0.73-1.14]	0.73 [0.14-0.95]	0.95 [0.54-1.15]
	gaze	0.87 [0.30-1.11]	0.93 [0.77–1.35]	0.51 [0.20–0.83]	0.83 [0.20–1.06]
	Clearance [cm]	5 [3-6]	5 [4–7]	4 [3–6]	4 [3–5]

Except for the gaze pattern types, where the number of subjects is presented, all other values are median values and inter-quartile ranges (between brackets). The results are listed for all subjects together and for each group separately. Abbreviations: N = condition N (target two steps ahead);

F = condition F (target four steps ahead); N+P = condition N+P (target two steps ahead, low foot-clearance requested); F+P = condition F+P (target four steps ahead, low foot-clearance requested); Pattern 1 - gaze-turn on the obstacles; Pattern 2 - gaze-turn into the direction of the obstacles; Pattern 3 - no gaze-turn to the obstacles.

Table 2: Statistical significance for comparison between groups and conditions

		Gaze pattern	Amplitude head	Amplitude gaze	Latency head	Latency gaze	Duration head	Duration gaze	Clearance
N vs N+P	All subjects	0.001	<0.001	<0.001	0.683	0.767	<0.001	<0.001	<0.001
	Elderly	0.414	0.056	0.016	0.838	0.790	0.033	0.050	0.002
	Middle-aged	0.024	0.007	0.009	0.866	0.917	0.028	0.109	0.034
	Young	0.015	0.003	0.003	0.445	0.889	0.019	0.009	0.001
F vs F+P	All subjects	0.007	0.002	0.001	0.217	0.300	0.001	0.002	<0.001
	Elderly	0.038	0.221	0.071	0.142	0.307	0.142	0.169	0.002
	Middle-aged	0.248	0.114	0.182	0.036	0.917	0.037	0.050	0.005
	Young	0.096	0.006	0.008	0.153	0.374	0.034	0.060	0.007
N vs F	All subjects	0.243	<0.001	<0.001	0.100	0.153	0.317	0.993	0.011
	Elderly	0.206	0.006	0.028	0.508	0.790	0.689	0.374	0.950
	Middle-aged	0.059	0.017	0.032	0.249	0.043	0.333	0.906	0.028
	Young	0.096	0.050	0.034	0.400	0.249	0.722	0.307	0.031
N+P vs F+P	All subjects	0.819	<0.001	<0.001	0.456	0.557	0.881	0.451	0.368
	Elderly	0.564	0.001	0.003	0.969	0.666	0.087	0.271	0.629
	Middle-aged	0.739	0.068	0.028	0.484	0.128	0.721	0.760	0.844
	Young	0.705	0.133	0.003	0.477	0.530	0.345	0.530	0.310
Elderly vs middle-aged	N	0.002	0.019	0.006	0.077	0.011	0.010	0.014	0.126
	N+P	0.231	0.122	0.257	0.002	0.001	0.085	0.027	0.189
	F	0.272	0.007	0.072	0.023	0.246	0.011	0.003	0.516
	F+P	0.131	0.137	0.135	0.404	0.012	0.090	0.038	0.241
Elderly vs young	N	0.009	0.864	0.020	0.245	0.033	0.172	0.010	0.467
	N+P	0.673	0.434	0.783	0.221	0.010	0.334	0.462	0.001
	F	0.606	0.132	0.303	0.251	0.616	0.274	0.131	0.548
	F+P	0.127	0.739	0.315	0.747	0.016	0.575	0.228	0.009
Middle-aged vs young	N	0.485	0.046	0.367	0.261	0.874	0.318	0.525	0.650
	N+P	0.430	0.080	0.279	0.187	0.133	0.439	0.080	0.186
	F	0.638	0.189	0.782	0.191	0.700	0.511	0.376	0.755
	F+P	0.741	0.268	0.487	0.664	0.764	0.246	0.410	0.376

Shown are the p-values of the statistical tests. In the upper part of the table, the comparisons between the conditions are shown for all subjects together and for each group. In the lower part of the table, the comparisons between the groups are listed. Values highlighted in grey are significant ($p<0.025$). Abbreviations: N = condition N (target two steps ahead); F = condition F (target four steps ahead); N+P = condition N+P (target two steps ahead, low foot-clearance requested); F+P = condition F+P (target four steps ahead, low foot-clearance requested)

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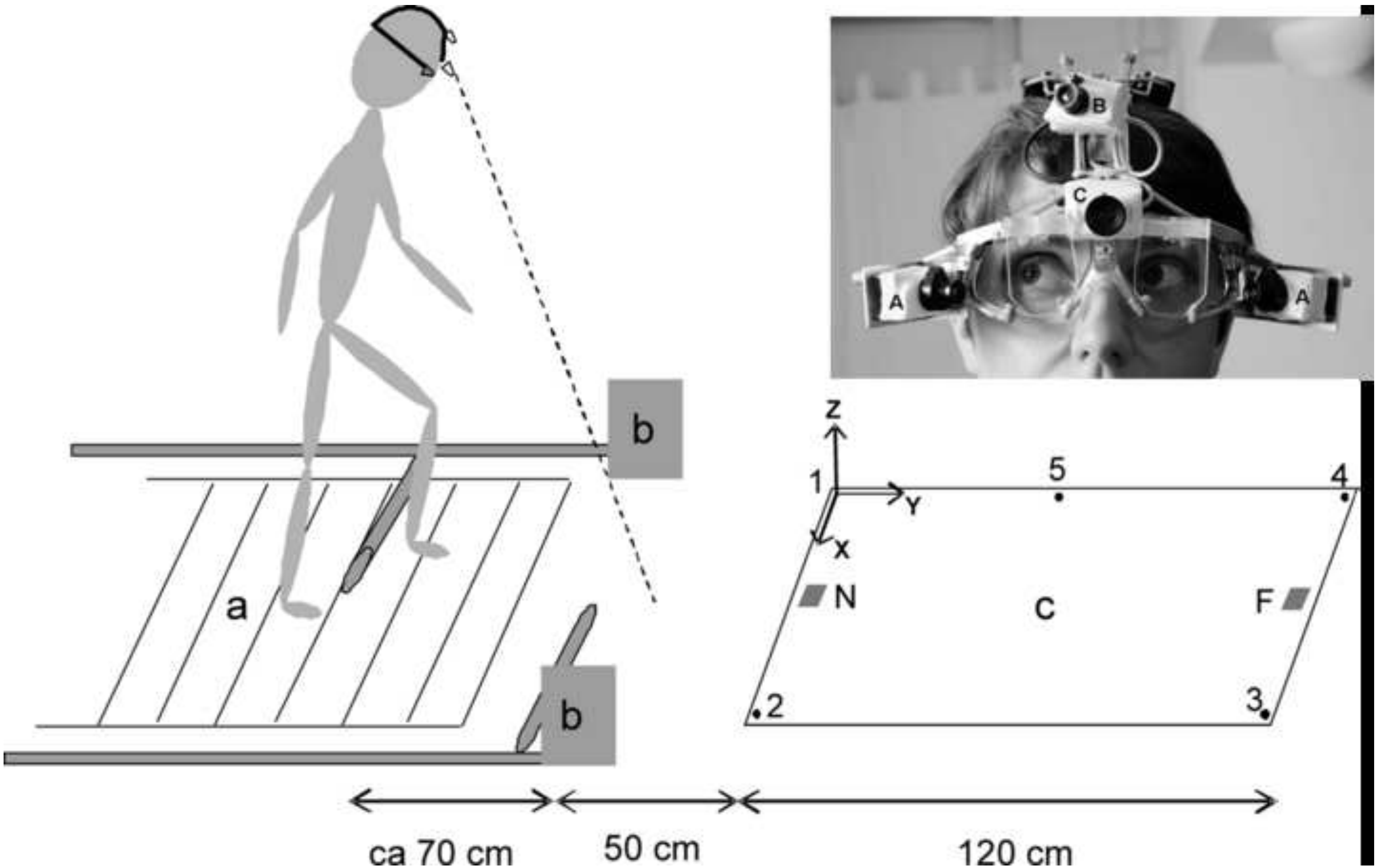

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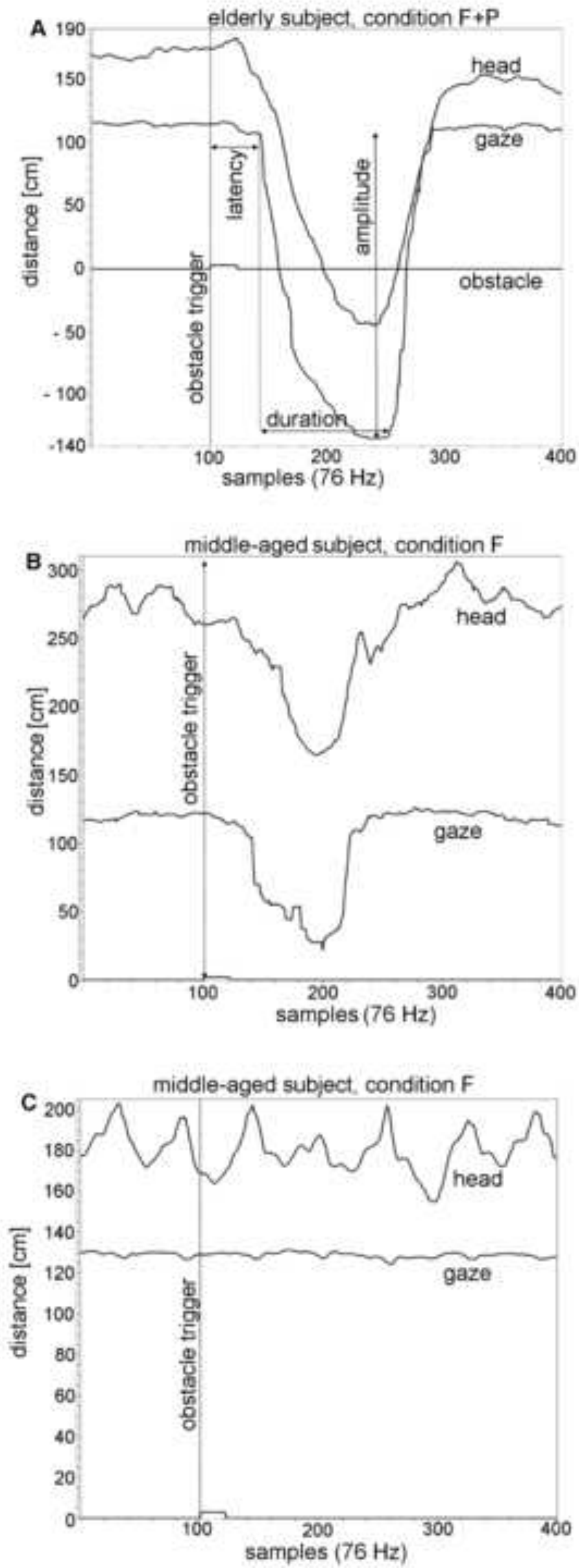

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