Effect of orienteering experience on walking and running in the absence of vision and hearing

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Purpose. This study aimed to examine differences between track and field (T&F) runners and foot-orienteers (Foot-O) in the walking and running tests in the absence of vision and hearing. We attempted to determine whether experienced foot orienteers show better ability to maintain the indicated direction compared to track and field runners.

Methods. This study examined 11 Foot-O and 11 T&F runners. The study consisted of an interview, a field experiment of walking and running in a straight line in the absence of vision and hearing, and coordination skills tests.

Results. Participants moved straight min. 20 m and max. 40 m during the walking test and min. 20 m and max. 125 m during the running test and then they moved around in a circle. Significant differences between groups were found for the distance covered by walking. Differences between sexes were documented for the distance covered by running, angular deviations. Relationship between lateralization and tendencies to veer were not found. Differences were observed between Foot-O and T&F groups in terms of coordination abilities.

Conclusions. Participants moved in circles irrespective of the type of movement and experience in practicing the sport. Orienteers may use information about their tendencies to turning more often left or right to correct it during their races in dense forests with limited visibility or during night orienteering competition.

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13 Abstract

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16 and foot-orienteers (Foot-O) in the walking and running tests in the absence of vision and hearing.
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18 indicated direction compared to track and field runners.
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25 sexes were documented for the distance covered by running, angular deviations. Relationship
26 between lateralization and tendencies to veer were not found. Differences were observed between
27 Foot-O and T&F groups in terms of coordination abilities.
28 **Conclusions.** Participants moved in circles irrespective of the type of movement and experience
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30 left or right to correct it during their races in dense forests with limited visibility or during night
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32

33 Introduction

34   Movement is the biological need of every living organism. Countless species travel over
35 shorter or longer distances in order to survive in constantly changing environmental conditions.
36 The reasons for these migrations may vary, but most of them are to acquire food, new territory or
37 to reproduce. The research on the mechanisms behind the ability to move and navigate led to the
38 discovery that temporal and spatial orientation is very diverse in all living organisms. In order to

39 navigate, living organisms use magnetic field, angular changes in relation to celestial bodies,
40 ultrasounds, wind drifts, sky polarization patterns, gravitational receptors in hearing organs,
41 ferromagnetic mineral magnetite produced in internal organs or specialized nerve cells in the brain
42 acting as an "internal GPS system" (Shapiro 2015). In order to move, humans use coordination
43 skills (Raczek, Mynarski & Ljach, 2002), including temporal and spatial orientation, rhythmization
44 of movements, balance control, kinaesthetic differentiation, quick motor response, coupled
45 movements, high frequency of movements, and motor adjustment.

46   Human navigation has attracted the interest of researchers for years and has been analyzed
47 many times, both based on field experiments and in the laboratory and virtual settings. The studies
48 on mechanisms behind the human ability to navigate also have concerned tests conducted among
49 blind and healthy people in the absence of vision (Bestaven, Guillaud & Cazalets, 2012; Paquet et
50 al., 2007; Souman et al., 2009). Human navigation has been examined based on walking tests in
51 the absence of vision and hearing, to a previously seen goal at distances ranging from 4 m to 60 m
52 (Commins et al., 2013; Day & Goins, 1997; Ellard & Shaughnessy, 2003; Israël et al., 2013;
53 Loomis et al., 1992; Rieser et al., 1990; Thomson, 1983; Uetake, 1992) along a previously
54 prepared track (straight, round and triangular). Other experiments concerned the movement of
55 study participants straight ahead, at a given distance or within a specified time (Bestaven, Guillaud
56 & Cazalets, 2012; Kallie, Legge & Schrater, 2002; Maus & Seyfarth, 2014; Paquet et al., 2007;
57 Pollatou et al., 2009; Souman et al., 2009). These studies have shown that a human can go straight
58 ahead with minimal errors of the accuracy of reaching the destination or maintaining a straight
59 line. When moving on distances ranging from 2 m to 4 m, humans can reproduce a specific
60 distance in the absence of vision accurately, but longer distances tend to be underestimated (Israël
61 et al., 2013). As argued by Thomson (1983) while navigating to the previously seen destination,
62 human creates a kind of map of the surroundings used to cover the required distance and reach the
63 goal. Research has shown that a person navigating their way in an open area for time and direction
64 given can go straight for approx. 20 m (Loomis et al., 1992; Rieser et al., 1990; Souman et al.,
65 2009). Then he or she begins to follow a circle with a diameter of 10 to 100 m (Maus & Seyfarth,
66 2014) or to 20 m (Souman et al., 2009) and eventually returns to the same point. Experiments in
67 an enclosed room have shown that a human can go straight to max. 30 m, and then follows a circle
68 between 19 m and 658 m in diameter, but in 80% of cases, this diameter is smaller than 300 m
69 (Bestaven, Guillaud & Cazalets, 2012).

70   It was observed that women tend to turn in one particular direction during the walking tests
71 (Bracha et al., 1987; Day & Goins, 1997) and are characterized by a higher average rotation rate
72 compared to men. Bracha et al. suggested that this is caused by gender hemisphere lateralization
73 but Nielsen et al. (2013) stated that small increases in lateralization with age were seen, but no
74 differences in gender were observed, as confirmed by Agcaoglu et al. (2015). Furthermore, some
75 researchers did not find a specific tendency to turn right or left during participants' attempting to
76 walk straight ahead in the absence of vision (Kallie, Legge & Schrater, 2002; Kallie, Schrater, &
77 Legge, 2007; Mohr et al., 2004; Rieser et al., 1990; Vuillerme, Nougier, & Camicioli, 2002), or
78 the turns were too small to be further analysed (Thomson, 1983). As claimed by Day and Goins

79   (1997), the tendency for turning left or right can be considered an additional manifestation of
80   lateralization in human motor activity. However, other researchers have demonstrated no effect of
81   lateralization on the tendencies of the study participants for turning (Bestaven, Guillaud &
82   Cazalets, 2012; Cratty, 1967; Lenoir et al., 2006). Some researchers have also emphasized the
83   negative effect of fear of the dark, fear of being lost or unknown environment on walking speed
84   (Bestaven, Guillaud & Cazalets, 2012; Souman et al., 2009). Practicing orienteering helps reduce
85   these anxieties (fear of the dark, fear of being lost in unknown terrain). That is why they may be
86   minimized by orienteering experience.
87   Orienteering is a sport in which athletes have to cover the distance from the start to the finish
88   line in the shortest time possible, choosing their way of reaching the individual control points
89   marked on a special map, with the start and finish locations. The route usually runs through
90   mountainous, wooded and often uninhabited terrain. Orienteering is a sport combining physical
91   exercise with mental effort, and requires maintaining balance and agility in order to overcome
92   obstacles effectively. One of the elements of orienteering training is running in the specific
93   direction, i.e. the run from one point to another in a straight line. Running in the specific direction
94   can be performed using a compass, the so-called running to azimuth or on a hunch (using the
95   natural terrain objects seen in front of or behind the runner) and by measuring distances with the
96   number of steps (stepping). The effect of following a given direction accurately is most important
97   when covering a section of a run in a thick forest, where it is challenging to maintain the direction
98   of the run due to the limited visibility of the destination (e.g. a dense forest or night run).
99   Furthermore, maintaining direction is one of the techniques used to find control points in a terrain
100   with few reference points. The correct finding of control points has a positive effect on the final
101   result of the competition.
102   No previous studies have attempted to verify whether orienteering experience may influence
103   the ability to go straight in the absence of vision and hearing. This represents a unique feature of
104   the present study. Moreover, it was challenging to test sighted people with running blind. The
105   results of this study may have both theoretical and practical implications. They may be used to
106   support the thesis that it is possible to program the human's "internal GPS". On the other hand,
107   the results show that practising orienteering (moving in unknown terrains) may help sense the
108   changes of direction and prevent them. Such conclusions could strengthen the thesis that
109   orienteering should be practiced by children and adults to help them develop senses responsible
110   for spatial orientation. Finally, the results of this study may demonstrate why practicing
111   orienteering helps elite orienteers to be better than novice athletes, especially in maintaining
112   direction when visibility is limited.
113   Souman et al. (2009) confirmed in their research that the phenomenon of people who follow
114   a circular route after getting lost is not a myth. However, their results have inspired us to verify
115   whether many years of experience in orienteering affects the ability to move correctly in a given
116   direction in the absence of vision and hearing. Furthermore, we decided to verify whether the speed
117   of movement would affect the results of the experiment. For this purpose, an innovative running
118   test was conducted in an open area, in the absence of vision and hearing.

Materials & Methods

Study participants

The experiment examined 22 people aged 24.5 years on average (± 4.34 yr.), including 11 foot orienteers (Foot-O) aged 24.09 (± 4.78 yr.) and 11 track and field (T&F) runners aged 24.91 (± 4.04 yr.). Each group consisted of five women and six men living in the Lower Silesia region of Poland. The Foot-O group consisted of athletes including world and Europe champions with many years of experience (first-class athletes), while the T&F control group was selected from long-distance runners with performance level at distances of 5 km and 10 km equivalent of that for orienteering (3 female second class long-distance runners). Study participants included: 21 right-legged people and one left-legged person and 18 right-handed people, three both-handed people, and one person declaring left-handedness.

Procedures

This study was approved by the university research ethics committee (Senate Committee on Ethics of Scientific Research of the Physical Education Academy in Wroclaw, Ref: 6/2013). The research consisted of three parts: interviews, an experiment in the airport and a test of selected coordination skills. Due to their specific character, the examinations were conducted in the airport in Szymanów and the facilities of the Physical Education Academy in Wroclaw, Poland.

The research was scheduled for autumn and spring, with atmospheric conditions favorable for the experiments. The experiment in the airport was conducted after sunset, in good and windless weather. Before starting the walk and run tests in the absence of vision and hearing, all participants were familiarized with the aim of the experiment and the experimental methodology. All subjects signed the participant consent form, which contained information about expected effects, possible benefits and risk for participants. Subjects were allowed to discontinue participation in the experiment at any time during the tests without giving a reason and were informed about this option before the beginning of the experiment. None of the participants decided to withdraw from the test. The method of data collection and research procedure were designed based on the research by Souman et al. (2009).

Interview

Each participant took part in an interview which concerned their age, athletic experience, the highest athlete class and lateralization of upper and lower limbs.

Experiments in the airport

The experiment in the airport consisted of two tests. Participants were asked to walk five times in a given direction within five minutes and run one two-minute section. During the walking tests, 5-minute duration was used because authors tried to reproduce the conditions of the experiment carried out by Souman et al. (2009), which was an inspiration for this research. During the running tests, 2-minute duration was used due to the high speed of movement of the participants, and, above all, the safety of people participating in the experiment. Subjects were blindfolded with a light-impermeable band and had their ears covered (earplugs and noise-cancelling headphones) to isolate them from any stimuli that would make it easier for them to find the right way. The face and neck of the participant were tightly covered with the shawl and hood of the jacket according to the recommendations by Cratty (1967) and Souman et al. (2009). The

160 velocity of movement and distance covered by study participants were measured using a GPS
161 device (Garmin, model 76S with a recording frequency of 1 Hz). The tests were carried out when
162 the accuracy of the device indicated a minimum of 1.8 m. Angular deviation was obtained by
163 checking the appropriate trigonometric formula that was calculated based on the angle between
164 the vector (X2-X1, Y2-Y1) and the vector (X3-X2, Y3-Y2). X's and Y's are the co-ordinates of
165 the subsequent positions of subjects. The average curvature [rad/m] of the trajectory was
166 calculated by dividing the change of angular deviation by the distance covered. The inverse of thus
167 calculated curvature is the radius of the circle-like trajectory.
168   The task of the researchers was to watch, supervise and care for the person taking part in the
169 experiment. People participating in the experiment walked and run at a comfortable and natural
170 speed adjusted to the abilities and sense of safety of the participants. The oral instruction was the
171 same as in Souman et al. (2009) research. In the case of the person's approaching an obstacle,
172 a fence or a neighboring field, the supervisor stopped the participant and guided him or her to
173 a different direction. The experiments were conducted after dusk.

Coordination tests of motor skills

175   Coordination tests of motor skills according to Raczek, Mynarski & Ljach (2002) were
176 performed to verify if there are any links between the results of field experiments and the level of
177 coordination skills: temporal and spatial orientation, rhythmization of movements, balance and
178 kinaesthetic differentiation.
179   Spatial orientation ability was measured by the "Walk to the goal" test (Raczek et al. 2002).
180 The participant's task was to cover a 5 m section excluding the sense of sight with a black, light
181 tight scarf and reach the center (X) of a circle with a diameter of 1 m, drawn at the end of the route.
182 The distance was measured in centimetres from the point between the participant's feet to the
183 center of the circle. The test was performed five times. The result of the test was "the average result
184 of five trials in centimetres" (Raczek et al. 2002, 157). Furthermore, in order to verify whether the
185 deviation from the direction of the walk was affected by the distance covered, five "Walk to the
186 goal" tests were performed in the absence of vision over a distance of 10 meters. The test procedure
187 was the same as in the case of the 5 m.
188   The rhythmization of movements ability was measured by the "Run at a given pace" test
189 (Raczek et al. 2002, 165-167). The test began with the measurement of the time of the test run at
190 30 meters, then the participant had to overcome 30 m by inserting the feet into the 11 hoops. The
191 result was the difference in times in both trials. Before starting the main test, each person
192 performed a warm-up and a single test of both gears on both hoops and a distance of 30 meters.
193 The participant accelerated to the run from a gravel path away from the pitch of 10 meters to
194 perform the test at maximum speed. The track before each test was set in the same way according
195 to the formula. All hoops were identical and had a diameter of 60 cm.
196   Balance ability was tested by the "Walk on the balance beam" test (Raczek et al. 2002, 164).
197 The participant's task was to walk over the balance beam two meters long for 45 seconds back and
198 forth. The examined person made three attempts, and the result was the average distance expressed
199 in meters calculated from two best trials lasting 45 seconds or until the loss of balance. Subjects
200 walked in sports shoes with a rubber sole on the wooden balance beam 10 cm wide.

201   The ability of kinaesthetic differentiation was measured by the "Standing long jump from
202   place at 50% of maximum effort" test (Raczek et al. 2002). The examined person repeated
203   a standing long jump three times, each time trying to get the maximum result. Then the participants
204   made a jump with closed eyes trying to reach half of their previous distance. Later the participants
205   obtained feedback in the form of a difference of the result in relation to the maximum jumps. Then,
206   the test with closed eyes was done twice. The result was "the percentage of error or accuracy in
207   differentiation of the strength according to the formula: the difference between the pattern and the
208   result obtained x 100/50% max result (pattern)" (Raczek et al. 2002, 152-153).
209   These types of tests were chosen due to their reliability, repeatability, and the expected
210   relationships between them and walking and running tests in the absence of vision and hearing
211   carried out in the airport.

212 **Statistical analyses**

213   Statistical analysis was performed using the STATISTICA 13.1 PL software package
214   (StatSoft Polska). All statistical tests were verified with a significance level set at $\alpha=0.05$.
215   The results were considered statistically significant when $p \leq 0.05$. Because of the size of the
216   groups and skewness of distributions non-parametric tests were used for analysis. The Mann-
217   Whitney U-test was used to compare differences between groups Foot-O and T&F in walking,
218   running and coordination tests, whereas the Friedman test was used to analyze all tests results
219   [ranks]. The relationships between the tests results in the given groups were tested by the ρ-
220   Spearman's rank correlation coefficient for quantitative variables (velocity of movement and
221   angular deviations in walking and running tests). The chi-squared tests was used for qualitative
222   variables such as the tendencies for turning and correlation between lateralization and the results
223   of walking and running.

224 # Results

225 **Analysis of angular deviation, distance and speed for walking and running tests in the**
226 **absence of vision and hearing**

227   The analysis of the results showed that in all walking and running tests, the participants
228   followed the set direction for about 20 m to 40 m during the walking test and about 20 m to 125 m
229   during the running test, and then they began to turn and move in circles. The participant who was
230   observed to have accumulated the angle of at least equal to π [rad] was adopted as the person
231   moving in circles. In other words, the participant was starting to walk or run around if there were
232   changes in the rate of increasing the angle from the value close to zero to a constantly increasing
233   value in the plot of the dependence of the accumulated angle on the distance traveled. The results
234   of the running test for all the subjects are shown in Figure 1. All test results were transformed to
235   start from one starting point with coordinates (0.0) to the East. For this reason, the axes in the
236   coordinate system should be interpreted as corresponding to cardinal directions: East-West (X
237   axis), North-South (Y axis).

238

239   Figure 1:
240   Results of running tests in the absence of vision and hearing

241   There were no significant differences between Foot-O and T&F groups in angular
242   deviations in walking (p = 0.896) and running (p = 0.264) tests in the absence of vision and hearing
243   (Figure 2). No correlations were observed between the results of walking and running tests in
244   angular deviations for the entire group (p = 0.790), and the differences were statistically
245   significant. Comparison of all results of walking and running tests for both groups revealed that
246   the difference was significant (U = 132.00; Z = 2.57; p = 0.010). It means that higher angular
247   deviation was observed during walking compared to running. Examination of angular deviations
248   between walking and running separately for Foot-O and for T&F groups showed no differences in
249   angular deviation in the Foot-O group (p = 0.264), but they were present in the T&F group (U =
250   24.00; Z = 2.36; p = 0.018).

251   Figure 2:
252   Results of mean angular deviations from a given direction of movement during walking and
253   running tests in the absence of vision and hearing related to sport

254   Significant differences in angular deviations were observed between women (Me = 0.039)
255   and men (Me = 0.018) during walking (U = 27.00; Z = 2.14; p = 0.032) but they were not observed
256   during running (p = 0.489). Women changed the set direction of movement to a greater degree and
257   reached higher mean value of angular deviations (Figure 3), i.e. they turned more from the given
258   direction of movement, and thus followed the circular path more often.

259   Figure 3:
260   Results of mean angular deviations from a given direction of movement during walking and
261   running tests in the absence of vision and hearing related to participant sex
262
263   Compared to group Foot-O (Me = 348.6), a significantly longer total distance (U = 30.00;
264   Z = -1.97; p = 0.049) during the walking tests was covered by group T&F (Me = 402.2) (Figure
265   4). During the running tests, the only significant differences were observed between sexes, with
266   men (Me = 386) covering a significantly longer distance (U = 19.00; Z = -2.67; p = 0.008) than
267   women (Me = 272).
268
269   Figure 4:
270   Distance covered during walking and running tests in the airport in the absence of vision and
271   hearing related to sport
272
273   Mean speed during walking in the airport in the absence of vision and hearing was 1.35 m/s
274   (± 0.18 m/s), whereas the mean running speed was 2.50 m/s (± 0.58 m/s). No significant
275   differences were observed in both walking and running tests, whereas the analysis of mean
276   movement speeds revealed significant correlations in group T&F (ρ = 0.67; p = 0.023), in group
277   of men (ρ = 0.63; p = 0.028). No difference in walking (p = 0.249) and running speed between
278   men and women was observed (p = 0.223).

279 **Comparison of walking and running tests in the absence of vision and hearing with**
280 **coordination tests**
281   Analysis of ranks (the Friedman test) of all tests conducted in the airport (walking and running
282 in the absence of vision and hearing) and results of the coordination tests conducted for groups
283 Foot-O and T&F did not show any significant differences between these groups. The group Foot-
284 O turned out to be significantly better than group T&F in terms of coordination abilities (Table 1).
285
286 Table 1:
287 Analysis of differences between groups (Foot-O and T&F) in tests (walking, running and
288 coordination)
289
290   Furthermore, the analysis showed that the ranks of tests performed in the airport and the
291 average rank of the tests of coordination abilities for the examined groups were consistent, i.e. no
292 significant differences were found between the obtained results (Table 2) but on the other hand,
293 the results of Spearman's rank correlation test between coordination ability and walking
294 ($p = 0.672$) and between coordination ability and running ($p = 0.691$) were insignificant.
295
296 Table 2:
297 Comparison of the results (ranks) of tests in the absence of vision and hearing with coordination
298 tests within groups (Foot-O and T&F)
299
300 **Relationships between tendencies for deviating from a given direction in different walking**
301 **and running tests in the absence of vision and hearing**
302   In terms of the tendency for deviating from a given direction, it was observed that in
303 walking and running tests in the airport, the respondents usually turned to the same direction (side).
304 Some of them turned right (50%) or some left (45.45%), and one person (4.55%) had no preferred
305 direction of turning. There was no difference between tendency to turn right or left between
306 walking trails in the airport ($p = 0.479$), but no correlation was observed between walking and
307 running in the airport ($p = 0.402$). The results collected from walking tests on the 5 m and 10 m
308 distance in the absence of vision and hearing of the same athletes (one of the coordination task)
309 showed the tendency to turn left (49.59% of all subjects), right (43.05%) and going straight ahead
310 (7.36%). Again no correlation was observed between tendencies to turning to the same direction
311 (side) on these two different distances ($p = 0.451$).
312 **Relationships between lateralization and the results of walking and running tests in the**
313 **absence of vision and hearing**
314   Limb lateralization determined based on interviews shows that study participants included
315 21 (95.45%) right-legged people and one left-legged person and 18 (81.82%) right-handed people,
316 three both-handed people, and one person declaring left-handedness. Analysis of the data
317 (chi-squared maximal likelihood test) on lateralization of the upper and lower limbs in the

318 participants and their tendencies for deviating from a direction of walking or running revealed no
319 significant correlations between the variables studied (Table 3).
320
321 Table 3:
322 Tendencies for deviating from a given direction in the absence of vision and hearing (walking and
323 running) in the context of lateralization
324

Discussion

326 Scientists try to determine the reasons of moving into circles instead of going straight. Many
327 experiments have confirmed the tendency of people for deviating from the route. Uetake (1992)
328 claimed that these gait asymmetries are caused by a small structural or functional imbalance of the
329 limbs. Some researchers found the effect of the asymmetry on walking in a circle (Maus &
330 Seyfarth, 2014) while others have not shown such correlations (Bestaven, Guillaud & Cazalets,
331 2012; Cratty, 1967; Souman et al., 2009). The tendency to deviate from a given direction of
332 movement may be influenced by the way of shifting the center of gravity, since the study
333 participants who turned left during the walking tests transferred the body weight to the left,
334 whereas those who transferred the body weight to the right turned right (Bestaven, Guillaud &
335 Cazalets, 2012). Souman et al. (2009) argued that deviations from the straight-ahead direction are
336 caused by the accumulation of sensorimotor system disturbances.
337   This study attempted to examine differences between groups Foot-O and T&F in walking
338 and running tests in the absence of vision and hearing to check if orienteering training may improve
339 ability to keep direction and prevent people from turning left or right. Surprisingly, there were no
340 differences in angular deviations between these two compared groups. What could be reason of
341 such results? Authors do not know exactly why orienteering experience did not help maintain the
342 direction but it is possible to propose some hypothesis. The first one comes from the statement that
343 people need some visual or auditory feedback to compensate postural or limb strength asymmetry
344 which leads to deviation. The other hypothesis is that women who practiced orienteering were less
345 skilled than women in the T&F group because of poorer selection and this influenced the results.
346   T&F group turned out to be also significantly better in terms of walking distance in the
347 absence of vision and hearing, whereas no significant differences were observed in the running
348 test. This result may seem unexpected in light of the experiences gained by Foot-O athletes from
349 participating in competitions and night orienteering training since all studies to date have shown
350 the importance of experience and its impact on the speed of walking and running in cross-country
351 settings (Ceugniet, 1991). Worse results achieved by orienteers (compared to runners) in walking
352 distance were again substantially affected by significant differences in sexes (women moved much
353 slower than male orienteers). Distance covered might be influenced by instruction given to
354 participants about choosing a comfortable speed during the experiment because speed and distance
355 were not factors with high significance.
356   Significant differences in the distance travelled between men and women seem unsurprising
357 as they are related to differences resulting from sexual dimorphism. The level of anxiety may have

358   influenced the speed of movement due to moving in the absence of vision and hearing but it needs
359   further research. The mean walking speed (1.35 m/s) was similar to the mean speed (1.32 m/s)
360   observed by Bestaven, Guillaud & Cazalets (2012), which suggests that sport's experience does
361   not help subjects move faster than average people do when they are deprived of hearing and sight.
362   Furthermore, the comparison between women and men showed that the direction of movement
363   changed in women group to a greater degree. Women deviated more often from the straight line
364   and usually followed a circle with a smaller radius than men. These results are consistent with the
365   findings reported by other scientists, who demonstrated better abilities to navigate and assess the
366   direction in men (Grön et al., 2000) and more frequent deviating from the direction in women in
367   daylight (Bracha et al., 1987). It is difficult to state what causes that women have higher tendencies
368   to deviation. Maybe it is caused by their higher body asymmetries and structural or functional
369   imbalance of the limbs or maybe by some psychological factors but it needs further research.
370   Participants (both groups of athletes) achieved comparable results in mean value of angular
371   deviation (respectively during the walking (0.026 rad/m) and running (0.017 rad/m) tests to those
372   documented by Cratty (1967), who found that the participants turned on average by 0.021 rad/m
373   during walking. In the test of running to a given direction in the absence of vision and hearing, no
374   differences in angular deviations were observed in group T&F compared to group Foot-O but there
375   were statistical differences within T&F group between walking and running. This could be caused
376   by their running experience. It was also observed that study participants could walk in a set
377   direction over a distance of about 20 m to about 40 m, and then they turned right or left and started
378   to walk in a circle. Therefore, the results are consistent with those obtained by other researchers
379   (Bestaven, Guillaud & Cazalets, 2012; Loomis et al., 1992; Maus & Seyfarth, 2014; Rieser et al.,
380   1990; Souman et al., 2009). Much better results were obtained in straight line since it was observed
381   in the running test that the participants covered as much as 125 m while maintaining the given
382   direction. Furthermore, it was found that during walking, the study participants followed around
383   a circle with a diameter of 8.7 to 25 m, whereas during running, this was from 90.91 m to 400 m.
384   The results of the walking tests were similar to those documented by other researchers (Bestaven,
385   Guillaud & Cazalets, 2012; Maus & Seyfarth, 2014; Souman et al., 2009), with the diameters of
386   the circle in which the participants moved during the running tests larger than those reported by
387   Maus and Seyfarth (2014) and comparable with those presented by Bestaven, Guillaud & Cazalets
388   (2012). The results obtained in the study confirm the tendency of people to follow a circle but they
389   show that during running, study participants can cover a longer distance in a given direction
390   compared to walking. Our results are opposite to those published by Maus and Seyfarth (2014)
391   who found that a shorter step during walking reduces the tendency for turning, whereas any change
392   in speed leads to a change in the direction of the turn. It is likely that people who practice running
393   are more confident when they run than when they walk in the absence of vision and hearing.
394   Humans show tendencies for deviating from a given direction of movement, both to the left
395   and to the right (Bestaven, Guillaud & Cazalets, 2012; Cratty, 1967; Kallie, Legge & Schrater
396   2002; Lenoir et al., 2006; Maus & Seyfarth, 2014; Pollatou et al., 2009; Rieser et al., 1990; Shapiro,
397   2015; Souman et al., 2009; Thomson, 1983; Uetake, 1992; Vuillerme, Nougier & Camicioli,

398 2002). Furthermore, Lenoir et al. (2006) showed that the tendencies for turning left while running
399 are more significant than when walking (tests carried out with vision). Tendencies to deviate from
400 a given direction of movement were also observed in tests of walking and running in a given
401 direction in the airport area and during coordination tests of 5 m and 10 m "Walk to the goal". The
402 analysis of the results of the above tests did not show any correlations in terms of the tendency for
403 deviating from a given direction. However, the results of the analyses are consistent with the results
404 documented by previous researchers (Vuillerme, Nougier, & Camicioli, 2002), who also did not
405 find a specific tendency to turn right or left while walking in a given direction of movement in the
406 absence of vision. The results are also consistent with the observation of Paquet et al. (2007) who
407 found the lack of repeatability in the aspect of the tendency for turning from a given direction of
408 movement during walking tests in the absence of vision.
409   Specific coordination tests were performed to eliminate the influence of coordination abilities
410 on results of walking and running in the absence of vision and hearing. It happened that orienteers
411 (both men and women) are better coordinated than T&F athletes. The biggest difference was
412 observed for the balance beam test. It was probably caused by better ability of orienteers to
413 maintain balance. They practice balance during many training sessions and events held in natural
414 settings (running on uneven ground, walking on fallen trees through the streams and rivers, moving
415 on the rock edges etc.). Results of statistical tests (Friedman's and Spearman's) showed that there
416 were neither dependence between coordination abilities and level of angular deviations in walking
417 and running nor significant differences. Finally, it can be stated that the different level of
418 participants' coordination of Foot-O and T&F groups did not influence the results of the
419 experiment.
420   The results collected from walking and running tests in the airport in the absence of vision and
421 hearing concerning the tendency to turns are inconclusive. It can be observed that more than 50%
422 athletes have tendencies to always turn to the same direction (12 people) in walking trails. They
423 turned five times to the same side (left or right). So the tendency to turning in one specific direction
424 is probably highly individual and maybe connected with some asymmetry. These results are
425 similar to those obtained by Bestaven, Guillaud & Cazalets (2012) for walking tests, with 50% of
426 the tests ending on the left, 39% on the right and 11% in a straight line. Lenoir et al. (2006)
427 observed that 43.9% of the walking tests ended on the left, 41.1% were neutral and 15% ended on
428 the right, while in the running tests, 68.2% of the tests ended on the left, 13.1% were neutral, and
429 18.7% ended on the right. Similarly, no correlation was found between tendencies to turning in
430 walking and running and no correlation between tendencies to turning between walking in the
431 airport and walking on the distance 5 m and 10 m in the coordination task.
432   Right-handed and right-legged individuals were prevalent in participants in our study and in
433 studies published by other researchers (Bestaven, Guillaud & Cazalets, 2012; Day & Goins, 1997;
434 Lenoir et al., 2006). Analysis of the data on lateralization of the upper and lower limbs of the study
435 participants and their tendencies for turning from a given direction revealed no significant
436 correlations between the variables. Therefore, the results obtained are consistent with those

437 obtained by other researchers (Bestaven, Guillaud & Cazalets, 2012; Cratty, 1967; Lenoir et al.,
438 2006).
439   Based on the results of the walking tests, no tendencies were observed for the right-handed and
440 right-legged participants to turn from a given direction. Right-handed and right-legged persons
441 turned left or right during the running tests, which is consistent with the findings of Day and Goins
442 (1997). The results contradict the reports that right-handed people turn left whereas left-handed
443 people turn right (Bracha et al., 1987) or the fact that during running, more frequent turning
444 direction is to the left compared to walking (Lenoir et al., 2006).
445   The effects of sport-specific orienteering training on temporal - spatial orientation can be
446 observed in terms of estimating the distance to the goal more accurate mapping of the road, and
447 smaller angular deviations from the direction of walking in a given direction. A detailed analysis
448 of the results of the tendencies for turning was presented to orienteering runners in order to
449 eliminate errors when running in a given direction in the terrain with difficult visibility and
450 runnability (vegetation density and type of ground affecting the running speed). This may help
451 runners cover the route faster and find the subsequent control points more efficiently.
452   It is interesting how the human "internal GPS" can be programmed and how the effects of such
453 training can be measured. These findings showed that walking and running tests in the absence of
454 vision and hearing are not reliable and the authors must look for other solution to this problem.

Conclusions

456   Significant differences between sexes were observed for angular deviations in the walking
457 test in a given direction in the absence of vision and hearing, distance covered and the tendency
458 for turning to a specific direction in the test of "blindfolded" running. No correlations were
459 observed between limb lateralization and the results of the field experiment. The study showed
460 that the tendency for following a circular path observed in people who got lost also applies to
461 experts in navigation such as orienteering runners when they are deprived of vision and hearing.
462 Although orienteering athletes devote much time to training to maintain a given direction (also in
463 the terrain with limited visibility and at night), no significant differences were found between
464 group Foot-O and group T&F in terms of angular deviations during the walking tests and during
465 the running test in the airport in the absence of vision and hearing. However, an analysis of the
466 results concerning the tendencies for turning can help eliminate deviation from the direction in
467 densely forested and challenging terrain. The present study has some limitations that should be
468 taken into account. Firstly, the analysis of the results may be limited by a small number of
469 respondents. Consequently, verification using the chi-squared (maximal likelihood) test led to the
470 difficulty of rejecting the zero hypothesis and thus demonstrated a statistical significance of the
471 observed phenomena. Secondly, the sports skill level of the examined athletes was diverse, which
472 to some extent could have affected the results.
473   Further research on the level of abilities to maintain balance in orienteers should be
474 conducted in the future since the results of the experiment presented in this study show that
475 orienteers have an advantage over long-distance runners in the level of coordination abilities.

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Figure 1

Results of running tests in the absence of vision and hearing

(T&F-W1) The first women from track and field group. (T&F-W5a and T&F-W5b) The trail divided into two parts a and b, because the fifth woman from track and field group has been stopped before the obstacle. (Foot-O-W1) The first women from foot-orienteering group. (T&F-M1) The first men from track and field group. (Foot-O-M1) The first men from foot-orienteering group.

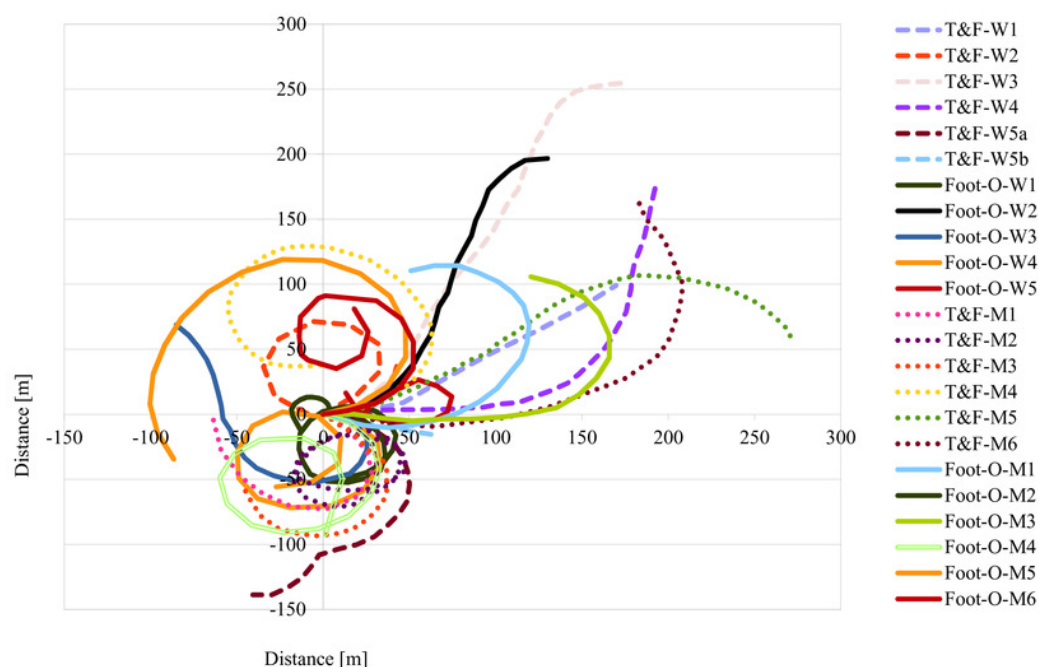



Figure 2

Results of mean angular deviations from a given direction of movement during walking and running tests in the absence of vision and hearing related to sport

(Foot-O) Foot-orienteering group. (T&F) Track and field group.

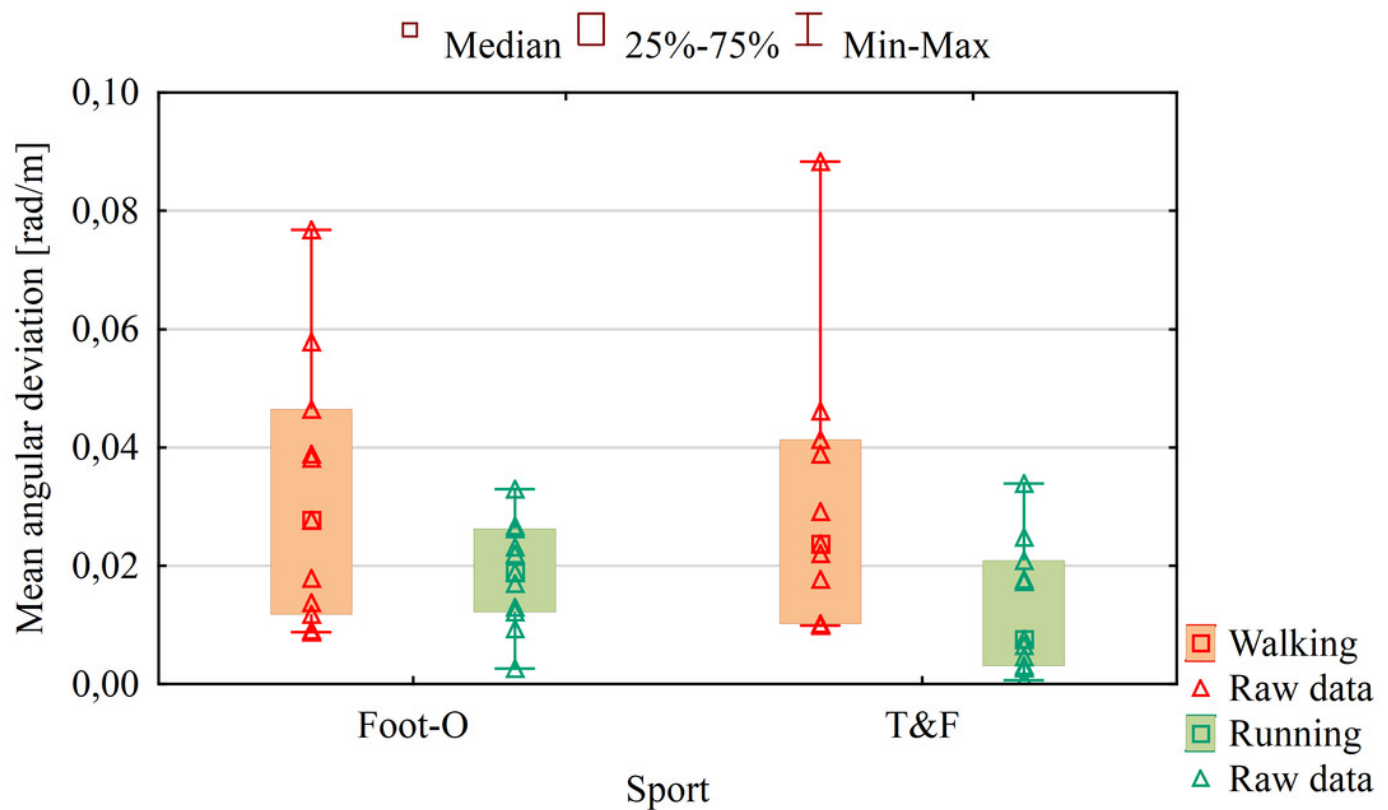



Figure 3

Results of mean angular deviations from a given direction of movement during walking and running tests in the absence of vision and hearing related to participant sex

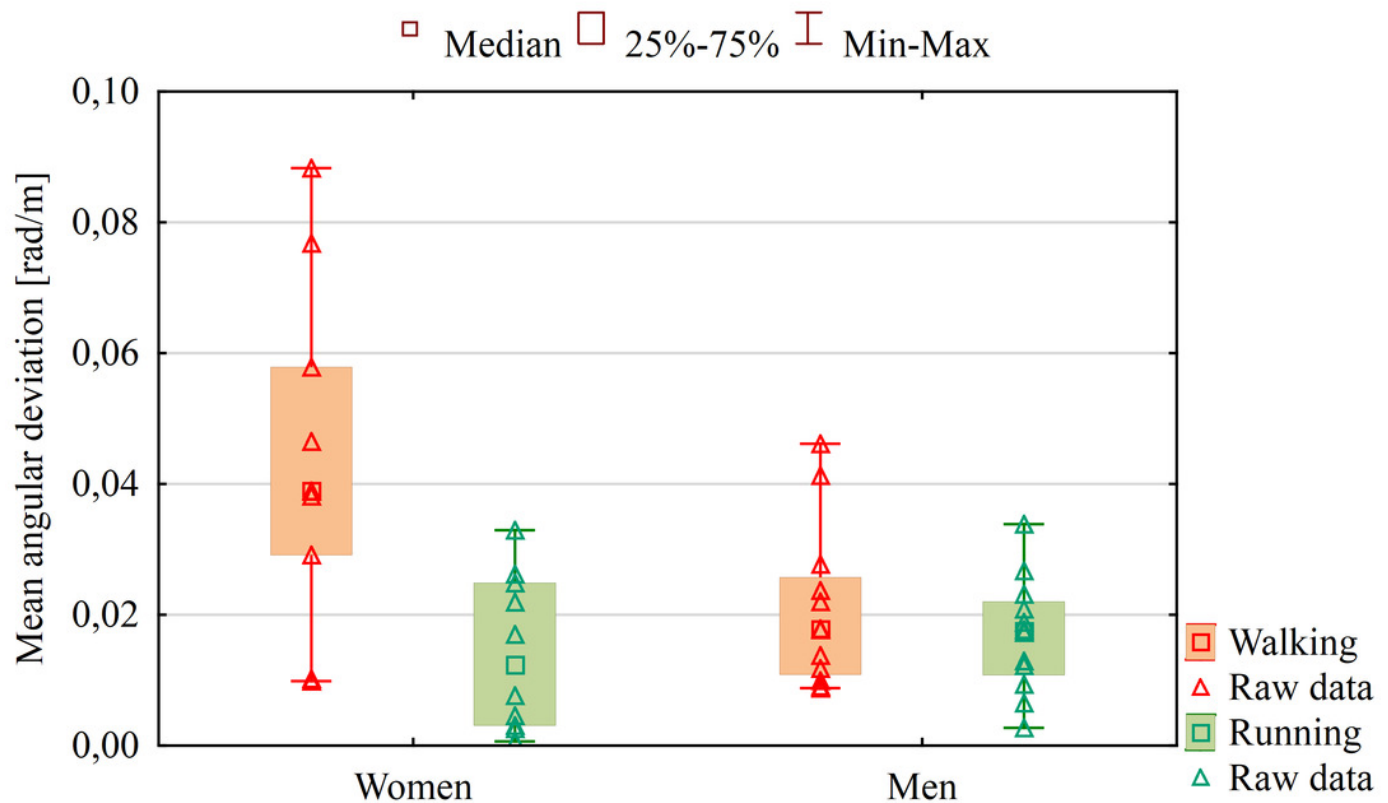
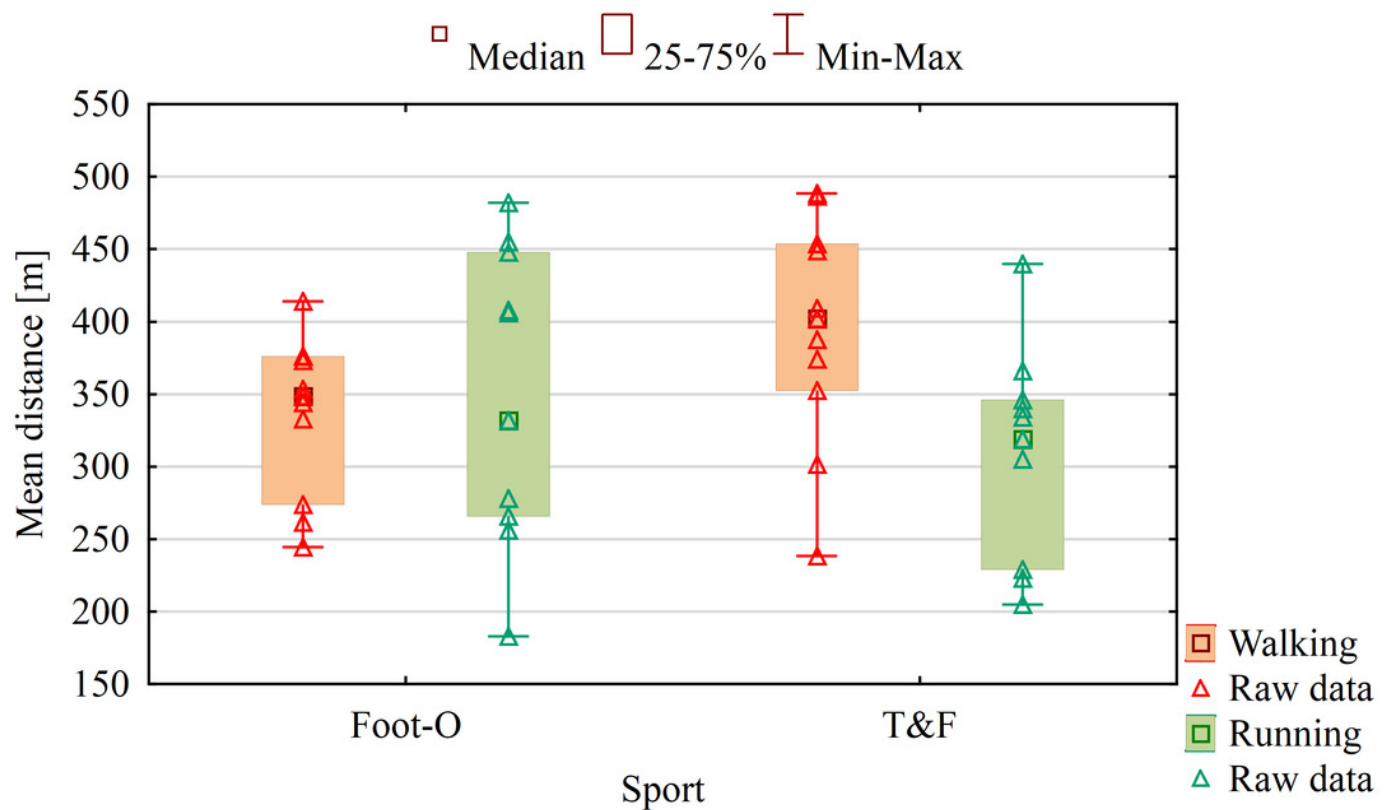



Figure 4

Distance covered during walking and running tests in the airport in the absence of vision and hearing related to sport

(Foot-O) Foot-orienteering group. (T&F) Track and field group.

Analysis of differences between groups (Foot-O and T&F) in tests (walking, running and coordination)

(Foot-O) Foot-orienteering group. (T&F) Track and field group. (U) The Mann-Whitney U test result. (Z) The Z test result. (p) Statistical significance.

Differences between groups [rank]	Tests					
	Walking		Running		Coordination	
	Mean	SD	Mean	SD	Mean	SD
Foot-O	5.72	2.83	6.82	3.06	4.27	2.87
T&F	6.36	3.85	5.27	3.52	7.82	2.76
U	54.50		43.00		21.50	
Z	-0.36		1.12		-2.54	
p	0.717†		0.263†		0.011*	

*Significant at the 0.05 probability level

†Nonsignificant

Comparison of the results (ranks) of tests in the absence of vision and hearing with coordination tests within groups (Foot-O and T&F)

(Foot-O) Foot-orienteering group. (T&F) Track and field group. (SD) Standard deviation. (χ^2) The chi-squared test result. (p) Statistical significance.

Comparison of the results within groups [rank]	Tests							
	Walking		Running		Coordination			
	Mean	SD	Mean	SD	Mean	SD	χ^2	p
Foot-O	5.72	2.83	6.82	3.06	4.27	2.87	3.526	0.172†
T&F	6.36	3.85	5.27	3.52	7.82	2.76	0.905	0.636†
Women	5.50	3.03	5.50	3.03	5.50	2.98	0.229	0.892†
Men	6.50	3.61	6.50	3.61	6.50	3.59	1.111	0.574†

† Nonsignificant

Tendencies for deviating from a given direction in the absence of vision and hearing (walking and running) in the context of lateralization

(χ^2) The chi-squared test result. (p) Statistical significance.

Differences between lateralization and turning tendency	Tests			
	Walking		Running	
	χ^2	p	χ^2	p
Upper limb	1.835	0.766†	2.149	0.708†
Lower limb	3.132	0.209†	1.434	0.488†

† Nonsignificant