A Functional Measure of Navigation

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Introduction

- Spatial navigation is the ability to move safely towards a destination.
- Under ideal conditions, human beings rely heavily on vision.
- In the absence of vision, individuals navigate in a memorized environment; this is a complex task that requires the integration of cognitive and sensorimotor functions.
- We have already shown that healthy subjects commit errors of distance and direction when navigating laterally without vision towards previously seen targets (Paquet et al. J. Otolaryngol, in press).
- Previous studies showed that abilities to navigate forward are not affected by significant vestibular deficits (Glasauer et al 1994, Péruch et al. 2000).
- However, we predict that a unilateral vestibular deficit can be detected when navigating in the lateral direction.
- Our question is whether lateral navigation abilities are stable over time in normal, healthy individuals, with the ultimate aim of developing a valid and reliable measure to establish the effects of vestibular pathologies on navigation.

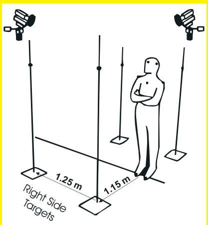

Figure 1: Experimental setup

Objectives

- Develop a test of blind spatial navigation, that can be used in a clinical environment.
- Establish test-retest reliability of navigation variables measured with a 7-day interval in young healthy individuals navigating laterally without vision.

Subjects

Ten healthy subjects, from 20 to 40 years of age, with no history of neurological or neuromuscular disorders.

Methods

- Test and retest sessions were separated by exactly 7 days.
- Subjects stood in front of an initial target (Figure 1).
- They then looked at another target located 1.25 m to their right, closed their eyes and side-stepped rightward until they estimated that they were standing in front of the second target.
- Subjects used *non-natural short steps* to avoid step counting.
- After stopping, they were instructed to return to the initial target *without opening* their eyes, to avoid receiving feedback on their performance.
- The same task was repeated for navigation in the leftward direction. Right and left trials were alternated for a total of 40 trials at each session.
- The position of 9 reflective markers located on the head and body (figure 2) were acquired at 120 Hz with a 6 infrared camera Vicon 512 three dimensional motion analysis system.

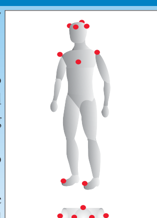

Figure 2: Placement of markers.

Variables

1. **Total distance traveled (TDT)**: the distance traveled by the subject following the path of the trajectory;
2. **Angular deviation (AD)**: angle formed by the line joining:
   (A) the initial and end targets,
   (B) and the line joining the two shoulders;
3. **Area under the trajectory (AUT)**: area between the subject's actual trajectory and the line joining the targets.
4. **Displacement error (DE)**: the medio-lateral distance between the end target and sternum at the final position, in the plane of progression (positive indicates overshoot and negative undershoot).

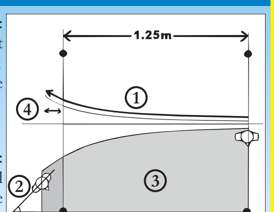

Figure 3: Demonstration the four variables measured

Statistical Analysis

Intraclass correlation coefficients (ICC) were calculated to establish the level of reliability of the dependent variables from test to retest sessions.

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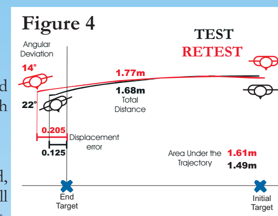
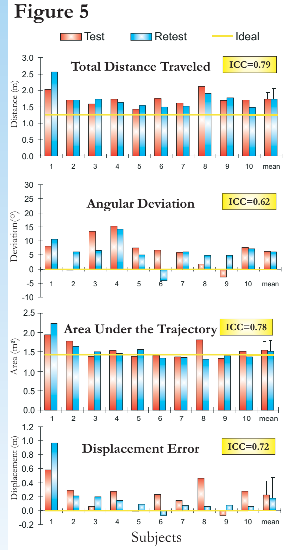
Results

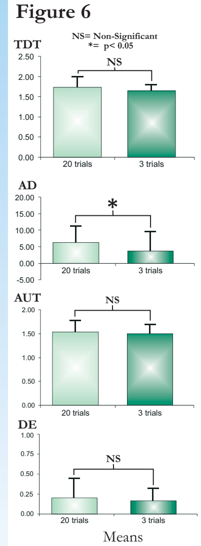
Example of results from one subject

Figure 4:
Mean trajectories of the sternal marker obtained during rightward navigation for subject 3 at both test and retest sessions.

Figure 5:
Mean values (n=20) for total distance traveled, angular deviation, area under the trajectory, as well as displacement error are indicated for each subject.







Averaged results for all subjects

- **TDT**
  Test: 1.74 ± 0.20 m
  Retest 1.74 ± 0.32 m
  ICC = 0.79
- **AD**
  Test: 6° ± 6°
  Retest 6° ± 5°
  ICC = 0.62
- **AUT**
  Test: 1.6 ± 0.2 m^2
  Retest: 1.5 ± 0.3 m^2
  ICC = 0.78
- **DE**
  Test: 26.5 ± 20 cm
  Retest: 18.1 ± 29 cm
  ICC = 0.72

Figure 6:
Paired T-tests were performed post-hoc to investigate the difference between using the mean of 20 trials or using the mean of the first 3 trials for each of the 4 variables. These means were found not to be statistically significantly different, except for the angular deviation variable ($p < 0.05$).

Discussion

Three of our four navigation variables demonstrated very good reproducibility over a 7-day period (ICC > 0.70). The ICC of angular deviation was lower (0.62), but the amount of change from test to retest was less than 1°, which is too small to be *clinically* significant. The results show that measurement of the first 3 trials will yield similar results, making this test accessible to use in clinical settings

Total Distance Traveled
This variable demonstrated very good reproducibility (ICC = 0.79). Subjects traveled an average of 1.74 m when asked to move 1.25 m. This overshoot is larger than during blind *forward* walking (Loomis et al. 1993) and is probably due to the fact that lateral walking is a less natural task than forward walking.

Angular Deviation
Healthy subjects were able to side-step in a straight line, with deviations of less than 10° on average. These small deviations were consistent over a 7-day period. This variable can easily be obtained in the clinical setting with a goniometer measuring angular deviation of the feet at the level of the floor.

Area Under the Trajectory
This variable was very reliable (ICC = 0.78). It is a crude measure of trajectory path, and its consistency suggests that subjects used similar types of trajectories to reach their destination.

Displacement Error
It showed very good reliability (ICC = 0.72). This variable can easily be determined in the clinic with the use of a tape measure.

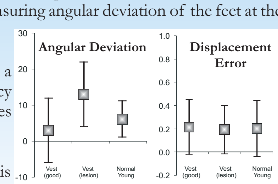


Figure 7: Preliminary analysis of navigation errors obtained in 5 patients with a unilateral vestibular lesion. Angular deviation is larger when navigating towards the side of the lesion, as compared with towards the intact side. *(Data from Paquet et al. J. Otolaryngol, in press)*

Conclusion

- Our results indicate that the performance of healthy subjects on the task of blind lateral navigation is reasonably consistent, considering that complex sensorimotor and cognitive functions are involved.
- Our test is promising to quantify changes in navigation abilities over time in individuals with spatial orientation impairments in the clinic. We are planning to develop a test battery of spatial navigation that will be appropriate for clinical settings.

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