14th International WCPT Congress

Barcelona, Spain 2003

WORLD CONFEDERATION FOR PHYSICAL THERAPY
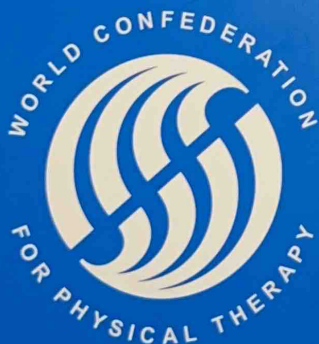
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WORLD PHYSICAL THERAPY 2003

7-12 June

Final Programme

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.
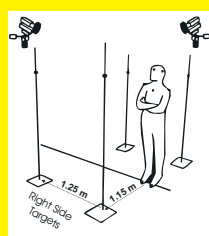
Objectives

- 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.

Figure 1:
Experimental setup

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).
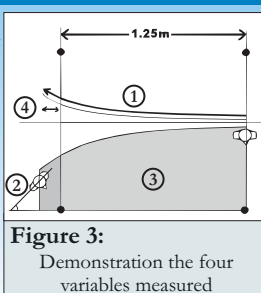
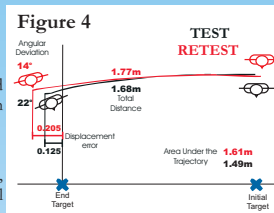**Figure 3:**
Demonstration the four variables measured

Statistical Analysis

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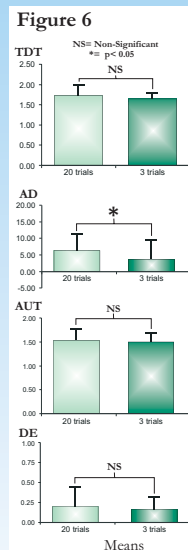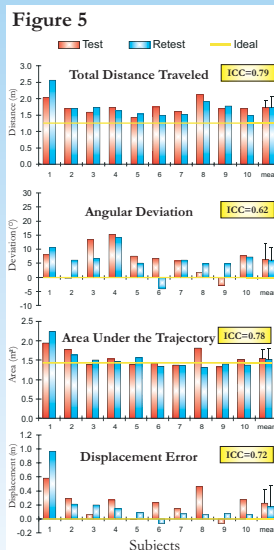
Results

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.

Figure 4

Figure 5
- Total Distance Traveled — ICC=0.79
- Angular Deviation — ICC=0.62
- Area Under the Trajectory — ICC=0.78
- Displacement Error — ICC=0.72

Figure 6
NS= Non-Significant
*= $p < 0.05$

Averaged results for all subjects

- **TDT**
  Test: 1.74 ± 0.20 m
  Retest: 1.74 ± 0.32 m
  ICC = 0.79

- **AD**
  Test: $6° \pm 6°$
  Retest: $6° \pm 5°$
  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.
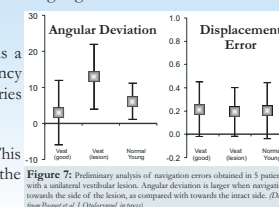
Figure 7: Preliminary analysis of navigation errors obtained in 5 patients with a unilateral vestibular lesion. Angular deviation is larger when navigating towards the side of the lesion, as compared with towards the intact side. (Data from Paquet et al. J. Otolaryngol, in press)

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.