feelSpace

Report of a Study Group

UNIVERSITÄT OSNABRÜCK
IKW (Institut für Kognitionswissenschaft) info@feelSpace.de
Abteilung Neurobiopsychologie http://www.feelSpace.de

Peter König, Alper Açik, Boris Bernhardt, Christine Carl, Torsten Dierkes, Isabel Dombrowe, Susan Gelesz, Christian Honey, Lina Jansen, Christiane Kabisch, Tobias Kringe, Lena Kurzen, Christopher Lörken, Robert Märtin, Saskia Nagel, Kyoung Ho Park, Hannes Saal, Moritz Stefaner, Christian Stößel, Verena Willenbockel

Can we create a new sensory modality by providing systematic stimulation with a vibrotactile device?

Former experience with sensory substitution devices has shown that strong integration of new information into perception is possible when fair training is assured. These experiments rely on already existing senses (see box).
We innovate the idea by integrating input that does not correspond to natural sensory modalities. This should lead to the creation of a new sensory modality. We use long-term stimulation with orientation information on humans.

The medium is a custom made belt equipped with a compass, a micro-controller and 13 vibrators (see box below). The user feels his orientation in space via vibrotactile stimulation. Thereby, we augment the user's perceptual space with information which is usually given only indirectly. We expect the tactile perception to disappear whilst conscious information processing is displaced by direct access to a new "sense of direction".

Sensory Substitution

A sensory substitution device transforms sensory inputs from one sensory modality to another one, maintaining the characteristics of the substituted modality.
E.g. the use of a camera and transduction of the picture into systematical tactile stimulation is realized in the ‚Tactile to Visual Sensory Substitution' device [1]. Pictures taken by a camera are transduced into tactile stimulation at the back or the tongue of blind subjects. Tests have shown that blind subjects can navigate in natural and virtual environments after training.

Noe & O'Regan's sensorimotor account to perceptual consciousness

The theory of perception from Alva Noe and Kevin O'Regan, suggesting a strong connection of perception and action, provides the basis for our work. The idea: The special experience associated with one sensory modality is not established by the activation of specific brain areas. Instead it is determined by systematic changes in the stimuli as result of an action. Thereby, a modality becomes a particular way of actively exploring the environment. It is not bound to a particular sensory apparatus [2].

Hypotheses.

We are testing four hypotheses to get a precise statement about the degree of integration.

1 Weak Integration

In principle, the sensory information provided by the belt can be processed. Thereby, training can improve performance.

2 Strong Integration

Orientation information provided by the belt can be firmly integrated in human perception. Sensory input of the belt inconsistent with other sensory inputs produces measurable responses.

3 Subcognitive Processing

After training, attention is not needed any longer to process belt information.

4 New Modality

Mastery of the belt-imposed sensorimotor contingencies results in qualitatively new experiences.

Tests.

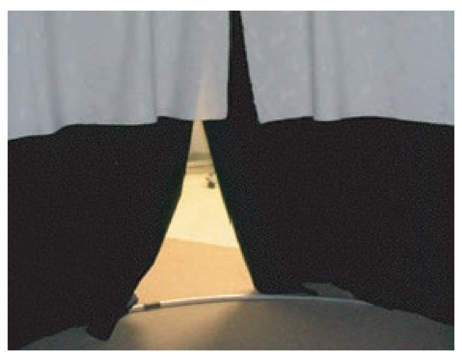
For six weeks, four subjects are wearing the belt permanently during their daily activities. The training period is accompanied by weekly orientation exercises and interviews. Test results are evaluated with respect to control group performance as well as intra-personal differences in the different conditions (test without belt, with belt and with conflicting information).

Orientation in outdoor environment

Blindfolded subjects are guided along a path and have to return to their starting point (Homing Task).

Navigation in virtual environment

Subjects have to collect numbered items by navigating through an unknown virtual labyrinth. The belt can inform the user about his virtual orientation.



Orientation in enclosed environment

Subjects perform homing and route reproduction tasks in a circular environment (Blue Velvet Arena), designed to separate allothetic and idiothetic modes of navigation.

Nystagmography and posturography

We use electro-nystagmography and posturography to measure the effect of conflicting heading information on the vestibulo-ocular reflex as well as on body sway.

Subjective reports

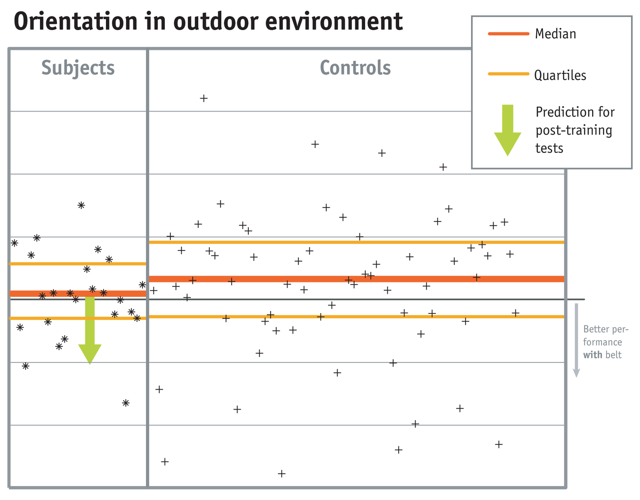
During training, subjects keep a diary about their experiences and spatial perception and are interviewed periodically.

Performance measure:

- Orientation in outdoor environment:
  - Distance from goal
  - Angular deviation from optimal return path
- Navigation in virtual environment:
  - Time to collect single items
  - Overall task time
- Orientation in enclosed environment:
  - Distance from target or start location
  - Angular deviation from ideal homing or reaching vector
- Nystagmography and posturography:
  - Duration of rotatory and post-rotatory nystagmi
  - Number of nystagmi
  - Degree of body sway
- Subjective reports:
  - Changes in qualitative experience

Hypotheses: 1 — 1 2 3 — 1 2 — 2 3 — 4

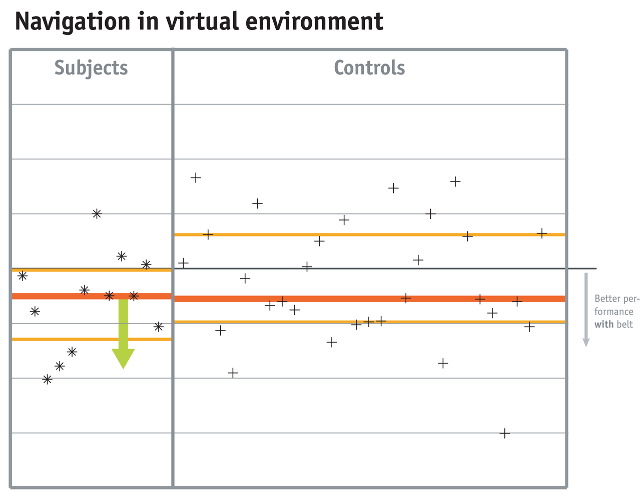
Orientation in outdoor environment



Trials
Logarithmic error ratio of belt vs. non-belt conditions

Subjects were tested in different homing tasks, once with belt, and once without. The 'with-belt' error for each task was divided by its 'without-belt' counterpart. The log of these ratios is plotted; together with 25th, 50th, and 75th percentiles (orange & red lines) of these ratio distributions.

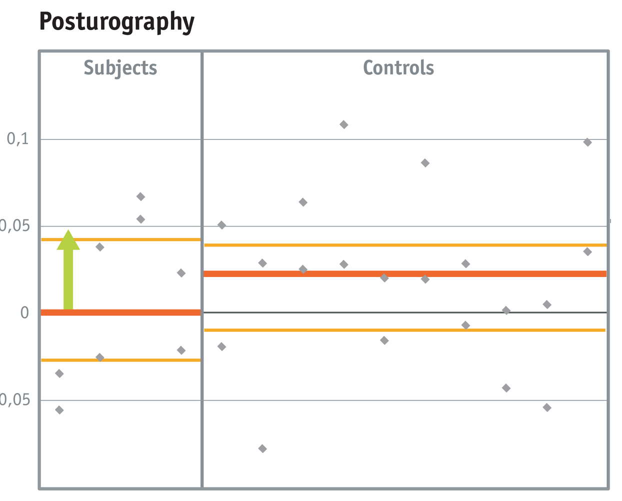
Navigation in virtual environment



Trials
Logarithmic ratio of belt vs. non-belt condition trial times

Subjects had to collect numbered items in 3 different virtual maps. Each map was navigated three times, including trials with belt information coupled to the 'virtual north pole' and trials without belt. The 'with-belt' time for each task was divided by its 'without-belt' counterpart. The log of these ratios is plotted; together with 25th, 50th, and 75th percentiles (orange & red lines) of these ratio distributions.

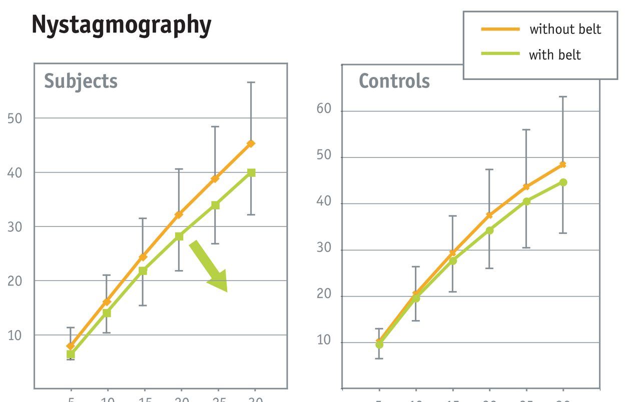
Posturography



Participants
Logarithmic ratio of 'belt simulates a rotation' vs. 'non-belt' body sway

Subjects had to stand still on a posturograph for 30 seconds, while the change of their center of balance was measured. The length of the sway path was computed.
There were two trials : 'eyes open' and 'eyes closed'. Each trial consisted of two conditions : 'belt simulates rotation' and 'belt is switched off '. Each datapoint in the plot displays the logarithmic ratio of the two conditions in one trial (log(rotating/off)). As a result, for each participant there are two datapoints, each representing the ratio in one of the two trials. Additionally, we plotted the 25th, 50th, and 75th percentiles.

Nystagmography



Time in seconds
Cumulative sum of nystagmi

The two plots display the timecourse of the postrotatory nystagmus after three minutes of rotation. The left and right plot display subject and control data, respectively. The duration of the postrotatory phase is 30 seconds, divided into six segments. In each segment, the averaged cumulative sum of observed nystagmi is depicted. Additionally, the standard deviations are shown.

Exemplary report of one of the subjects after three weeks of training.

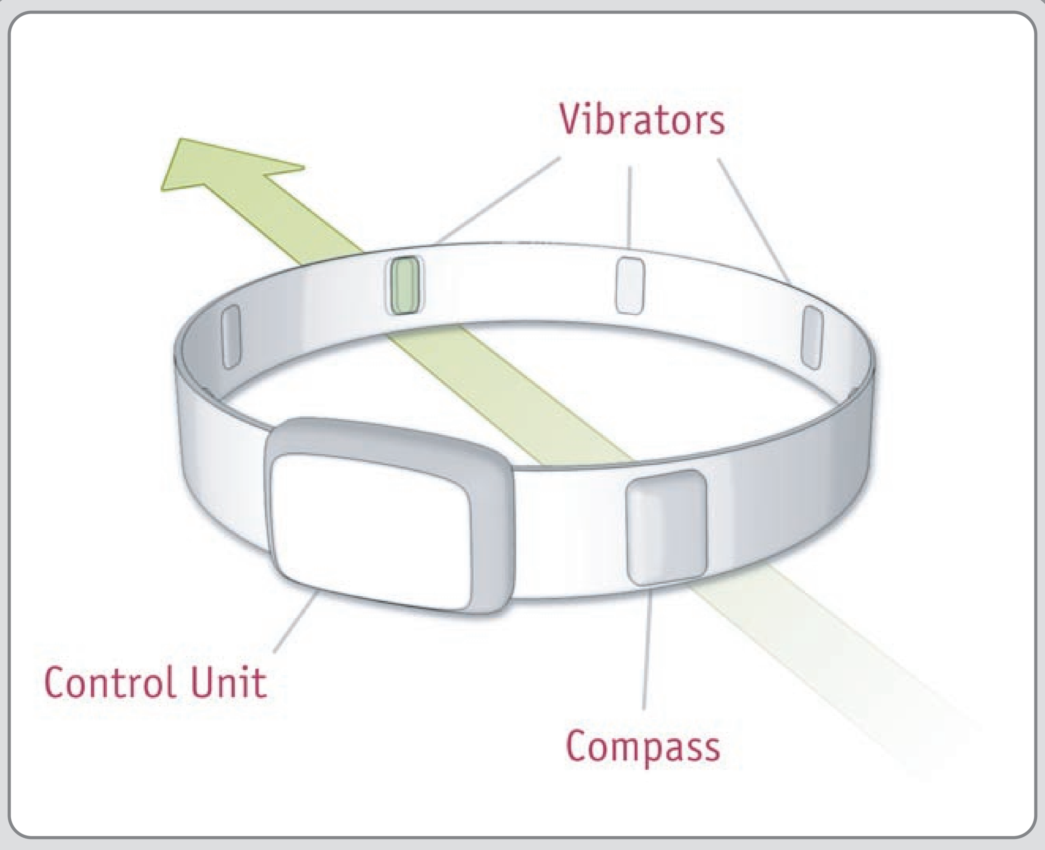
- *The initial training period required intensive and exhaustive learning over several days.*
- *Navigational orientation changed from graph to two-dimensional map.*
- *The actual spatial context is felt as being enlarged.*
- *Spatial relationships are memorized effortlessly.*
- *"No effect without action" – mere stimulation without simultaneous exploratory activity remains without effect.*

Pre-Training Results.

Pre-training tests showed no significant performance improvements for trials with belt compared to trials without belt in any of the groups. The absolute performance baselines showed comparable average performance for subject and control group.

Post-Training Results.

Post-training test results will be available by the end of March 2005. First reports and observations allow for an optimistic view on the expected results. Trend predictions are plotted into the graphs (see above).



Hardware

Compass: Gyro-enhanced high precision triaxial electronic compass (model: MicroStrain® 3DM-GX1™)

Vibrators: Small and power-saving vibration motor (model: 1E120)

Belt: Orthopaedic rip fracture belt (model: Thuasne Cemen 2900)

Controller: Micro-controller based integration of compass data and activation of vibrators, providing PC interface (model: C-Control Main Unit II, Conrad Electronic GmbH)

Perspectives.

Results about the effect of long-term usage of the belt will be available by the end of March 2005. We hope to gain insight into the limits and possibilities to create new sensory modalities. If our subjects report strong integration effects, which is additionally confirmed by behavioral and physiological test results, our findings will provide a valuable contribution to current research issues such as the nature of perception and neural correlates of consciousness. Future research might include fMRI measurements to investigate how the training process is realized at the neural level.

Acknowledgements

We would like to thank PNI Corporation, the University Hospital Münster, Kamil Vlcek & Jan Bures of the "Academy of Sciences of the Czech Republic" and Hanspeter Mallot and the Hexatown team at MPI Tübingen for their support.

References

[1] P. Bach-y-Rita (1972): *Brain Mechanisms in Sensory Substitution.* New York: Academic Press.
[2] J. K. O'Regan and A. Noe (2001): *A sensorimotor account of vision and visual consciousness.* Behavioral and Brain Sciences, 24(5):883–917.