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LETTER TO THE EDITORS

Artificial neural network posturography detects the transition of vestibular neuritis to phobic postural vertigo

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Dear Sirs,

Artificial neural networks (ANNW), described in detail by Duda et al. [1], can be efficiently used to master complex data sets by applying computational analysis for routine clinical uses, for example, to classify the risk of falls in the elderly on the basis of an analysis of balance control during gait [2]. In an earlier study we used ANNW posturography to identify typical postural sway patterns that allow the diagnosis of various balance disorders [3]. Body sway was measured by means of posturography during ten test conditions of increasing difficulty. These included standing with eyes open or eyes closed, with head extended backward, standing on a slab of foam rubber, and tandem stance. Sixteen values were selected from the calculated parameters of each single condition, such as sway path, root mean square values, and Fourier analysis. This means that a total of 160 values were entered into the artificial neural network (for methods, see [3]). In this way a standard three-layer, feed-forward ANNW that uses a back-propagation algorithm was trained with training cases, validated with validation cases, and its accuracy was tested on new cases with various diagnoses. The sensitivity and specificity were about 0.9 for patients with vestibular neuritis or for patients with phobic postural vertigo. Once designed and tested, ANNW-posturography can be considered a black box, which each examiner can apply to predict a specific diagnosis even without a preceding clinical examination.

Here we would like to present an example of two patients to demonstrate the clinical relevance of this method. In case 1 the method was able to disclose the transition that a patient with acute vestibular neuritis underwent to phobic postural vertigo within months after disease onset. In case 2 it confirmed the patient's recovery from static postural control despite the permanent unilateral vestibular loss.

Case 1: a 70-year-old male patient presented with typical signs and symptoms of an acute, left-sided vestibular failure. A unilateral deficit of vestibular function was diagnosed by a pathological head-impulse test that revealed the presence of corrective (catch-up) saccades and by caloric irrigation that showed non-responsiveness of the left horizontal semicircular canal. Since there were no other neurological deficits, he was diagnosed to have left-sided vestibular neuritis. This diagnosis was further supported by ANNW posturography with a probability of 93% (Fig. 1a). Dizziness and imbalance recovered gradually within weeks to months due to central compensation, although there was no restitution of peripheral vestibular function. The patient was again able to ski. Five months later, however, he presented with new complaints of subjective postural and gait unsteadiness, which were invisible to the observer. He had attack-like exacerbations of the fear of falling without any real falls. The patient now exhibited

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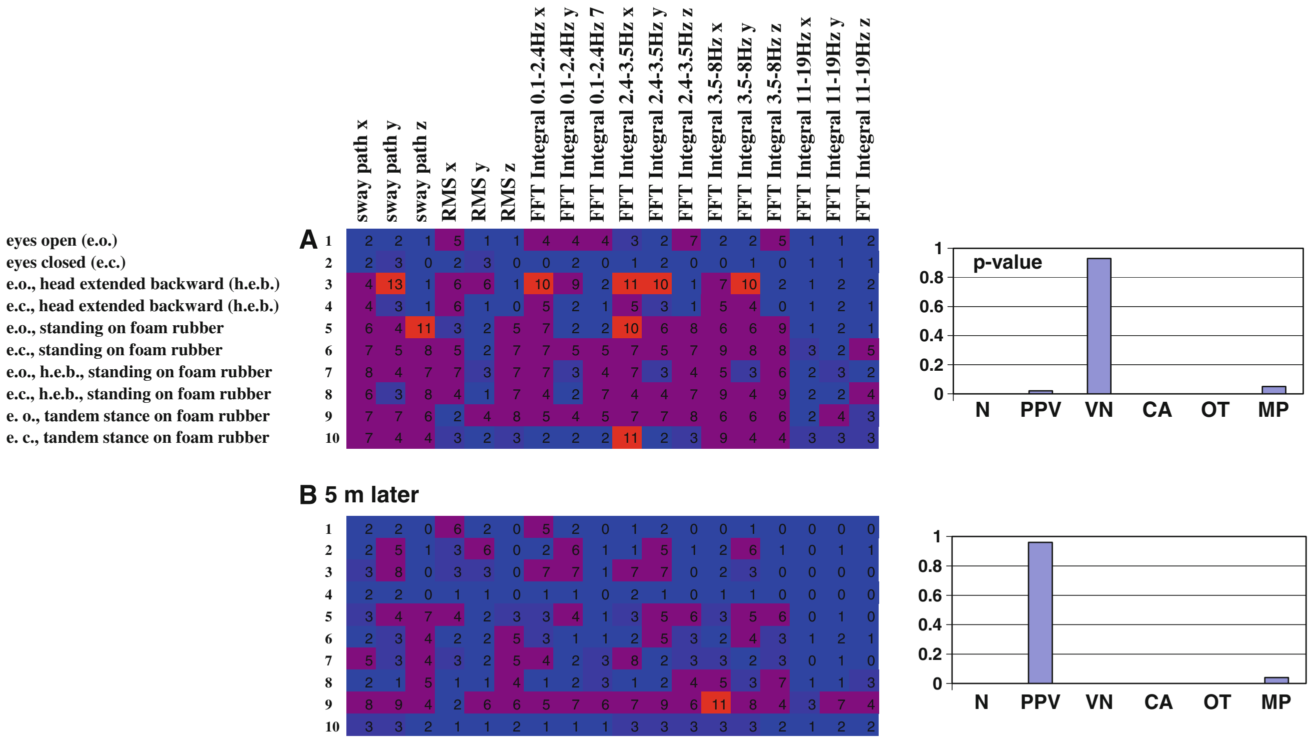

Fig. 1 Color-coded confidence plots of artificial neural network posturography for a patient with acute vestibular neuritis (*left*; **a**) and a transition to phobic postural vertigo (**b**) 5 months later. The abscissa represents differences between the patient's means and the normal subjects' means in multiples of the normal subject's standard deviations (SD) of the calculated sway path (SP), root mean square values (RMS), and fast Fourier transformation (FFT) activities. A value of 11, for example, indicates that the patient's mean is higher than the normal subjects' mean + 11 × SD of the normal subjects' mean. The color code is as follows. The range of $1 < SD < 2$ is *blue*, the range of $2 < SD < 3$ is *violet*, the range of $4 < SD < 9$ is *pink*, and $SD > 10$ is *red*. The ordinate represents the conditions of posturographic measurements from 1 to 10. **a** The diagnostic probability of an acute vestibular neuritis is $p = 0.93$. **b** The diagnostic probability of (secondary) phobic postural vertigo in the same patient is $p = 0.96$. *N* Normal subjects, *PPV* phobic postural vertigo, *VN* vestibular neuritis, *CA* cerebellar ataxia, *OT* primary orthostatic tremor, *MP* Parkinson's disease

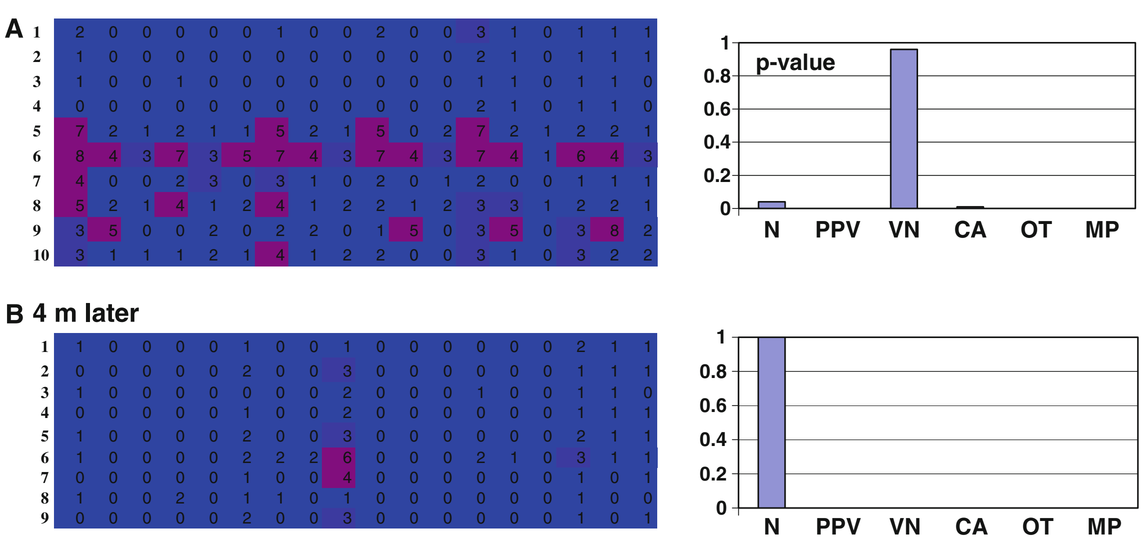

Fig. 2 Color-coded confidence plots of ANNW posturography as in Fig. 1 for a 46-year-old female patient with an acute left-sided vestibular neuritis (**a**) and 4 months later with central compensation without recovery of the peripheral vestibular deficit (**b**). As indicated by the *right columns*, the diagnosis is acute vestibular neuritis with a probability of $p = 0.96$ (**a**) and 4 months later, normal postural sway with a probability of $p = 1$ (**b**)

the clinical symptoms and features of somatoform phobic postural vertigo [4]. This is sometimes difficult to distinguish from residual dynamic vestibular deficits after central compensation of a permanent unilateral vestibular loss has taken place. However, ANNW posturography confirmed this diagnosis with a probability of 96% (Fig. 1b).

Recovery from vestibular neuritis is a result of a combination of (1) restoration of labyrinthine function (frequently incomplete); (2) substitution of the functional loss by the contralateral vestibular system, somatosensory neck proprioception, and visual afferents; and (3) central compensation of the peripheral vestibular tonus imbalance. Usually even in cases in which the peripheral deficit remains, all "static" symptoms (without head movement) resolve, for example, vertigo, spontaneous nystagmus, and postural imbalance. The latter was documented in *Case 2*, a patient with left-sided vestibular neuritis who also did not recover peripheral vestibular function (Fig. 2a, b). The only remaining deficit manifests in the form of a "dynamic" dysfunction: retinal slip of images of the visual scene with oscillopsia during rapid, high-frequency head movements and walking or running because of the insufficiency of the vestibulo-ocular reflex [5]. Due to these residual complaints, another syndrome like phobic postural vertigo may go undetected.

Huppert and co-workers [6] have shown that vestibular disorders often precede the development of phobic postural vertigo. In 21% of their patients phobic postural vertigo was associated with disabling vestibular disorders, in particular benign paroxysmal positioning vertigo and vestibular neuritis. Thus, ANNW posturography provides a new diagnostic tool with high sensitivity and specificity that allows differentiation between the remaining functional deficit after incomplete recovery of peripheral vestibular function in vestibular neuritis and the transition to a secondary phobic postural vertigo. The latter can be effectively treated by behavioral therapy [4].

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Conflict of interest None.

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