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significantly changing BP and respiratory rate. Similar HR changes with high frequency stimulation of the STN in patients with PD were recently reported.<sup>4</sup> The basal ganglia project to several nuclei that may modify autonomic outflow<sup>5</sup> as well as the pedunculopontine nuclei, part of the mesencephalic locomotor region, which when stimulated in cats increase HR and BP.<sup>2</sup> High frequency stimulation inhibits neuronal activity around the implanted electrode affecting fibers of passage as well as cell bodies; thus, the neurons involved in the response cannot be ascertained.<sup>5</sup> Interestingly, however, stimulation of the globus pallidum pars interna (GPi), unlike the effect of STN stimulation, produced no change in HR in patients with PD<sup>4</sup>; in anesthetized cats, GPi stimulation produced bradycardia rather than tachycardia,<sup>6</sup> suggesting that the tachycardia triggered by stimulation of the STN may be a specific response.

Hyperactivity of STN neurons is a typical feature of PD<sup>5</sup> that impairs motor function and may also affect central command. Abnormalities in central command may explain, at least in part, some frequent autonomic deficits in patients with PD, particularly their impaired cardiovascular adaptation to rapid assumption of upright posture.<sup>7</sup> High frequency electrical stimulation reduces STN hyperactivity and improves motor performance. It also increases HR concomitantly with the reduction of akinesia, an appropriate autonomic response when initiating movement. Thus it is tempting to speculate that in patients with PD STN stimulation may also improve central command.

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## Selective deficit of time perception in a patient with right prefrontal cortex lesion

Giacomo Koch, MD; Massimiliano Oliveri, MD, PhD; Giovanni A. Carlesimo, MD, PhD; and Carlo Caltagirone, MD

The neural systems underlying subjective perception of time are of increasing interest for neuroscientists. Previous studies in humans and in animals have documented a role of the cerebellum and basal ganglia as an internal clock of discrete temporal units.<sup>1,2</sup> Recent data from focal lesion investigations have suggested that the frontal and the parietal lobes also are critical for time perception, especially for their role in attention and in maintaining the representation of subjective time in the working memory.<sup>3,4</sup> Neuropsychological and functional imaging studies have supported the importance of the prefrontal cortex in the perception and in the comparison of time intervals.<sup>5</sup>

We describe the case of a patient who had a selective impairment in the perception of events' duration.

**Case report.** A 49-year-old man reported mental confusion and difficulty with concentration. Neurologic examination showed very mild left hemiparesis that regressed in a few days. After this acute episode, the patient spontaneously had trouble estimating

the duration of events, judging them as shorter than they actually were. He had difficulty evaluating how much time had elapsed since the beginning of a determinate event. He said he was not able to judge when the working day was over, leaving the office earlier than the scheduled time.

Cranial MRI showed an ischemic lesion in the right frontal lobe (dorsolateral prefrontal cortex, BA 46/9), and the patient was admitted to a neurologic unit. Angio-MRI revealed occlusion of the right internal carotid artery.

**Methods.** The patient obtained normal scores in a neuropsychological test battery evaluating short and long-term memory (Rey Word List, Immediate and Delayed Recall; Figure of Rey-b, Immediate and Delayed Recall; Digit Span; Corsi Span, Forward and Backward; Verbal Supraspan; Immediate Visual Memory), visuospatial abilities (Raven Progressive Matrices), attention (Tri-axial Making Test), language (Verbal Fluency, Phrase Construction), executive functions (Tower of London; Wisconsin Card Sorting Test), praxia (copy of drawings). He did not present frontal signs, such as impersistence and iterativity.

To evaluate the deficit in time estimation, we submitted the patient and eight healthy control subjects (mean age: 45 ± 5 years) to a verbal time estimation test in which they reported the duration of a trial indicated by visual markers.<sup>6</sup> Subjects sat fac-

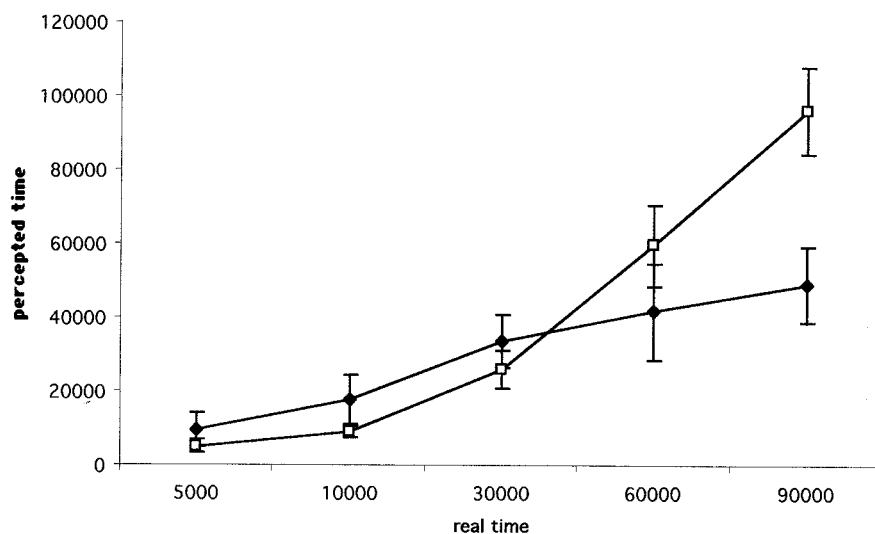


Figure. Mean perception of time intervals in patient (black circles) and control subjects (white squares). Values in the two axes are expressed in milliseconds. Error bars indicate 1 SEM.

ing a computer screen in a quiet room. Number stimuli (1 through 9) were presented in a random sequence on the screen, each of them for a period ranging from 200 to 2000 msec, until the selected time interval was completed. Time intervals were 5, 10, 30, 60 and 90, seconds. Each time interval was repeated randomly four times, with a total sequence of 20 trials. At the end of each trial the monitor presented the sentence, "How many seconds did the trial last?" Participants were requested to report verbally the duration of the interval.

During each trial, subjects were required to read the numbers aloud to prevent subvocal counting and to divert attention to timing. To reduce session length and to maintain constant cooperation, we did not test longer intervals.

**Results.** The patient was significantly less accurate as compared with control subjects in the evaluation of the longer interval (90 seconds), showing a clear tendency to underestimate the real time (time duration more than 2.5 SD shorter compared with the controls' mean) (figure). The patient's performance at the other time intervals did not significantly differ from that of the control subjects.

**Discussion.** Results of recent research with patients with focal lesions suggest that the right frontal cortex is involved in time perception. This report describes the case of a single patient in which altered temporal processing emerges as a selective deficit after lesion of the right dorsolateral prefrontal cortex.

The role of the dorsolateral prefrontal cortex in time perception has been related to the encoding of temporal information into memory, and some studies have considered time as a fourth dimension of the working memory.<sup>3</sup> Our data indicate that the right dorsolateral prefrontal cortex could also be involved in the evaluation of long time intervals, outside the working memory boundaries. One hypothesis is that the right frontal cortex could work as

an accumulator of a central internal clock, receiving inputs from the basal ganglia and the cerebellum to form a conscious representation of time intervals. In addition, although neuropsychological investigation failed to show signs of pathologic distractibility, we cannot exclude a contribution of defective attentional control to the patient's poor time estimates.<sup>3</sup>

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## Receptive amelia in a trained musician

Steven A. Sparr, MD

Clinical case studies of patients with isolated disorders of musical perception are exceedingly rare, and help elucidate the localization of various components of music in the brain. We report a highly trained musician who experienced profound inability to discern melody due to right temporal lobe injury.

**Case history.** A 91-year-old retired musicologist of great accomplishment with a history of diabetes mellitus and coronary artery disease suddenly developed difficulty reading the left side of his newspaper, unsteady gait, and difficulty dressing.

Initial examination showed no evidence of aphasia or dementia. He had a dense left homonymous hemianopia, mild left hemiparesis, and elements of left hemispatial neglect. On the evening of admission he experienced auditory hallucinations of a choir singing. All of these deficits cleared over the next 24 to 72 hours.

During his hospitalization his auditory abilities were studied in detail. He was unable to identify the melody of any of a wide variety of well-known musical pieces presented by recording or live by piano. He did not recognize relatively simple tunes played on a single instrument or vocal music, which contained the additional clues of verbal lyrics. He could repeat a series of three notes or fewer, but consistently failed to reproduce a series of four notes or more. He made errors in identifying instruments playing; at one point he identified the horn section as a "harp."

At the same time, he had no difficulty humming a tune from memory. He was able to replicate the pitch of single notes. Given two notes, he had no difficulty indicating which note was higher. He readily distinguished consonant from dissonant chords. He could replicate the rhythm of a series of handclaps. Indeed, with many of the recorded pieces that he could not recognize, he was able to establish the rhythm and accurately pretend to lead the orchestra in time.

When presented with sheet music, he was immediately able to discern the melody of the composition, and readily categorized its style. He was able to explain the melodic lines and interactions of various instruments in a Stravinsky score.

With respect to other nonlinguistic auditory functions, he was unable to identify recorded sound effects, spoken or singing voices of famous personalities, or the emotional tone of a voice (receptive

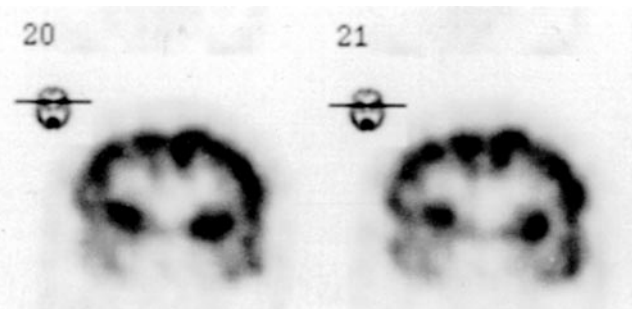
aprosodia). He made errors of up to 30 degrees in attempting to point to a sound source while blindfolded.

Carotid duplex revealed a hemodynamically significant stenosis of the right internal carotid artery. CAT scan and MRI of the brain failed to show an infarction. SPECT scan revealed decreased perfusion of the right temporal lobe (see the figure).

On follow-up examinations his ability to identify melodies improved to approximately 20% correct by 1 month after discharge, and ultimately to 70% accuracy by 3 years. However, even when he recognized a composition, recognition was not immediate. Throughout this time period he remained unaware of his deficits and denied any difficulty with musical perception.

**Discussion.** Our patient was found to have profound inability to discern melody despite intact perception of pitch, rhythm, and harmony. The cause was likely an ischemic injury of the right temporal lobe.

Clinical case studies have reported patients who developed receptive amelia after unilateral ischemic<sup>1,2</sup> or hemorrhagic<sup>3</sup> injury of the right temporal lobe. None of these patients had formal musical training. An amateur musician<sup>4</sup> experienced distortions in musical timbre and impaired recognition of the identity of voices and environmental sounds after right temporal lobe infarction, although he continued to recognize melodies. Another patient with some musical training<sup>5</sup> developed progressive loss of melody recog-



*Figure. SPECT scan shows diminished perfusion of the right temporal lobe (left side of image).*

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