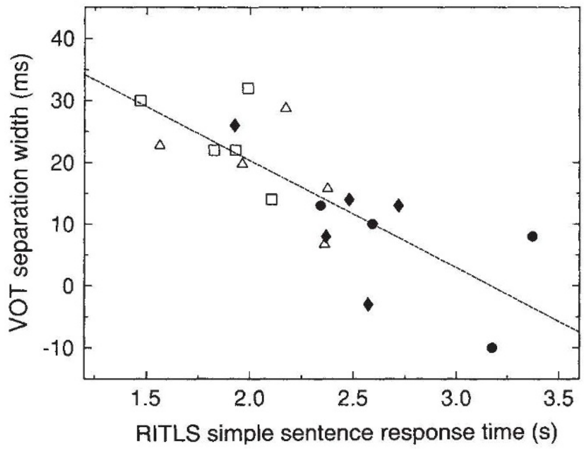
Cognitive defects at altitude

SIR — Hypoxia, occurring at high altitude, is known to cause decrements in normal neural functioning[1]. We propose a method to assess such effects remotely in real time from naturally occurring speech. We studied the effects of extreme altitude on the neural processes that underlie speech motor control, syntactic comprehension and other cognitive functions in five male members of the 1993 American Sagarmatha expedition to Mount Everest.

We measured speech 'voice onset timing' (VOT), which differentiates English 'voiced stop' consonants (/b/, /d/ and /g/) from their unvoiced counterparts (/p/, /t/ and /k/, respectively) in word-initial position. Syntax testing was done with the Rhode Island test of language structure[2] (RITLS). The confrontation naming task, forward and backward digit-span, and the odd-man-out tests from the DATATOP series[3] were also administered at each location to assess memory, attention, and maintenance and shifting of cognitive sets.



VOT separation width plotted against reaction time to the simple items of the RITLS for five subjects at four locations (one point missing due to a recording error). The correlation coefficient and the linear regression equation are also shown. Subjects were tested at base camp (altitude 5,300 m) before (□) and after (△) a summit climb attempt; at camp two (6,300 m; ◆), and at camp three (7,150 m; ●), within a day of arriving at each location. No supplementary oxygen was used at the testing altitudes. Each subject read on each location 60 monosyllabic English words that had voiced and unvoiced stop consonants in initial position. A recording was made through VHF radios using micro DAT recorders to ensure an accurate time basis for the measurement of VOT — of the time between the onset of the burst (produced by lip opening or tongue lowering) and the onset of phonation (produced by vocal fold vibration). For each subject on each location, the VOT separation width was defined as the time interval between the longest voiced and the shortest unvoiced VOT for all three places of articulation combined. The RITLS was administered by showing the subject a page (for each sentence) presenting three line drawings, one of which best exemplified the meaning of the sentence which was then read aloud by the experimenter. The test sentences and the subjects' responses were recorded through VHF radios; response time was determined by measuring the time interval between the end of each spoken sentence, and the subject's announcing the number of the matching sketch. A different 50-item balanced version of the RITLS was used on each location.

VOT separation width (the distance in time units between the longest voiced and the shortest unvoiced VOT), decreased significantly at higher altitudes ($F(3,12) = 6.30$, $P = 0.008$). The response time to the 'simple' RITLS items increased significantly at higher altitudes ($F(3,12) = 14.69$, $P < 0.0005$) and was negatively correlated with VOT separation width ($r = -0.774$, $P = 0.0001$). The figure shows the linear relation between the two types of measurements.

Response times to the complex items of the RITLS were always longer than those to the simple items ($F(1,4) = 30.56$, $P = 0.005$), so response times can be assumed to reflect processing difficulty. The cognitive slowing down exemplified by longer response times to the simple items was not general because the number of words produced in the confrontation naming task (a timed task) was not affected by altitude ($F(3,12) = 1.14$, $P = 0.373$), and neither was the response time to the complex items ($F(3,12) < 1$). The subjects were not cold or uncomfortable at the high camps. Fatigue could not have caused the differences because the final testing at base camp was done after the longest and most strenuous part of the climb (including climbing up to the summit and back down to camp two and to base camp within one day), yet subjects' VOT separation width was longer and syntax response time shorter than at the high camps. Fatigue also does explain the differential deficits we found.

Similar patterns of deficits are found in patients of Parkinson's disease[4] and may be the result of disruption of subcortical basal ganglia pathways to prefrontal cortex[5]. Mild anoxia of subcortical circuits to prefrontal cortex seems to be a plausible explanation of our findings, as basal ganglia are known to be sensitive to hypoxic insults[6]. Whatever the extent of the cognitive deficits turns out to be, it is very important that simple speech measurements may serve to assess them remotely in real time. Further study is necessary to determine the relationships between cognition and speech motor control in other situations and to develop and validate a compact, automatic speech analysis system for remote monitoring. Such systems can be very useful in situations where critical crew behaviour (for example, in aeronautics, space flight or air-traffic control) may be endangered by hypoxia, high carbon-monoxide levels, or drug or alcohol intoxication.

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Interatomic signalling in QED

SIR — In his article[1] "Time machines still over the horizon", Maddox writes misleadingly that vacuum polarization is a phenomenon "for which Feynman, Schwinger and Tomonaga, with the help of apologists such as Dyson, were responsible late in the 1940s". In fact the idea of vacuum polarization is contained in much earlier papers of Dirac and Heisenberg, and quantitative results for the modification of the Coulomb potential by the polarization of the vacuum were derived by Serber[2] and Uehling[3] in 1935. Feynman and Schwinger rederived these results and used them in the calculation of radiative corrections.

Maddox also states that Fermi's work[4] on his two-atom model of light propagation in quantum electrodynamics (QED) was carried out at the suggestion of Heisenberg, when in fact it was Kikuchi[5], not Fermi, to whom Heisenberg suggested the problem; and it was Kikuchi, not Fermi, who "first tackled the problem".

But the most serious error is the claim that "a sixty-year old calculation by Enrico Fermi is discovered to be in error". In his calculation of the probability for an initially excited atom to excite a second atom a distance R away, Fermi replaces an integral involving all (positive) photon frequencies ω by one in which the integration is extended to all negative photon fre-