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Inter-office Memorandum

Date: August 22, 1978

Subject: Guillerm, R. et al
Effects of Carbon Monoxide on
Performance in a Vigilance Task
(Automobile Driving)

From: Frank G. Colby

To: Mr. H. C. Roemer

I mentioned to you in my memo of July 19 that I had obtained the attached paper, on a confidential basis, from a source other than Dr. Guillerm or our friends in France, with the condition that this would not be quotable. In the meantime, I have received authorization from the R&D Director of S.E.I.T.A. to use this paper "in any way you wish".

FGC:les

Attach.

cc: S.B.W.
A.R.
C.W.N.✓
R.H.B.
D.K.H.
E.J.J.

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Effects of carbon monoxide on performance in a vigilance task (automobile driving)

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SUMMARY

An experiment was carried out to study carbon monoxide effects on human vigilance. In order to obtain realistic results, closed circuit nocturnal automobile driving for a duration of 5 hours was chosen. Driving precision, visual reaction time (VRT), E.E.G. and cardiac frequency were simultaneously registered. Laboratory studies were first conducted to establish a method of maintaining a level of 7 and 11 % COHb for a period of 5 hours. The results indicate that at these two levels of COHb, driving precision, V.R.T., α rhythm frequency and cardiac frequency are not significantly modified.

Key words : carbon monoxide exposure, acute, carboxyhemoglobin, vigilance, car driving precision, visual reaction time, ECG, EEG.

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The purpose of the study was to determine at which level in the blood carbon monoxide is capable of affecting vigilance and brain electrogenesis.

As a matter of fact, there is a great discrepancy of results reported in the literature. To appreciate this, it is sufficient to quote, for example, the work of SCHULTE (1963), BEARD and GRANDSTAFF (1970) and that of WRIGHT et al (1973). These authors have noted a performance deterioration from a COHb level of 3 % and up, whereas some other authors such as HANKS (1970), MIKULKA et al (1970), STEWART et al (1973) have observed no such deterioration below 12 %.

As far as electrobiology is concerned, only a few investigations have been conducted. HOSKO (1970) reported no deterioration of spontaneous electroencephalographic activity below a COHb level of 33 %, whereas he and also STEWART et al (1970) described changes in visual evoked response with COHb levels greater than 15 %.

We have carried out an experiment in an attempt to gather additional information concerning the effects of CO on man's performance and EEG.

To avoid all laboratory constraints and the artificial nature of laboratory simulations we selected as a vigilance test nocturnal driving of a car on a circuit. This method of vigilance analysis makes it possible to avoid any training effect and it ensures good motivation on the part of the subjects.

MATERIALS AND METHODS

An automatic car is used to determine the precision of a long duration drive (5 hours) at night at a constant prescribed speed (60 km/h) on a closed circuit* measuring 3.4 km. The driving precision is determined based on variations of the car from a white line drawn on the track center line ; the subject has to keep the car center line on this white line for 5 hours.

A set of photodiodes attached to the bumper (Fig.1) makes it possible to know, at every moment, the position of the car center line with respect to the white line as follows : the light emitted by small red lamps attached between photodiodes is reflected by the white line and energizes the corresponding photodiode.

* Circuit Paul Ricard — Le Castellet - (France)

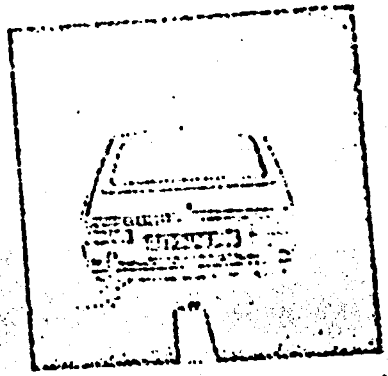

Fig. 1 : View of the back of the car with the set of photodiodes

An automatic coding system installed within the car makes it possible to quantify the deviations and thus to estimate the driving quality objectively. This technique has been described by CAILLE and BASSANO (1976).

To complete this system the simulation of obstacles on the road is used to determine the visual response time (VRT) of the subjects. This simulation is carried out by means of a light that comes on randomly on the car bonnet and that the driver must switch off as quickly as possible by depressing a pedal which is near the clutch pedal.

Concurrently, the EEG data, which are known to reflect the activity level of some brain areas relating to vigilance and ECG, are continously recorded.

The four parameters thus measured (driving precision, VRT, ECG and EEG) are transmitted by telemetry and recorded in a control tower, on paper and on magnetic tape for subsequent processing. The experimentators are in the control tower and can thus constantly monitor the variations of the different parameters during the test.

The experiment is carried out with 8 non-smoking subjects. Each subject has to drive the car for five hours during four non-consecutive nights so arranged as to avoid possible effects of tiredness, repetition and experimental conditions.

The experimental conditions include one night of habituation to the circuit, one reference night and two nights with COHb levels set and kept at 7 and 11 % respectively.

COHb is determined with a pure-oxygen rebreathing system based on that of SJOSTRAND (1948) and developed by GUILLERM et al in 1959 : partial pressures of oxygen and CO in the alveolar air are measured while they are in equilibrium with the blood (within about 6 minutes) ; this method is as reproducible and accurate as COHb determination in blood samples.

Before the test, the rapid adjustment of the COHb level to the above mentioned values is carried out within 10 minutes according to a laboratory developed rebreathing technique. In order to compensate for the detoxication the COHb level is kept at the adjusted value during driving through inhalation, at regular intervals, of a mixture of air and CO; the mixture is so designed as to require short periods of inhalation : 5 or 10 minutes ; to disturb the subject as little as possible this readjustement is carried out only every hour by means of a light and low resistance mouth respirator (Fig. 2) connected to the bottle containing the mixture of air and CO which is located on the back seat of the car. Orders are given to the subject by radiotelephone.

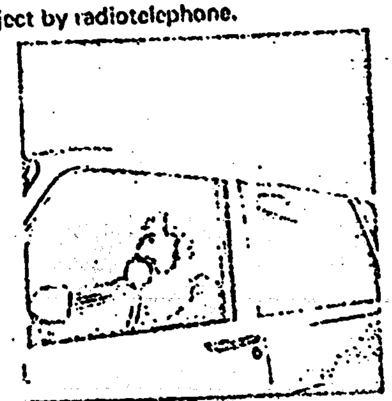

Fig. 2 : Experimental conditions during adjustment of the COHb level

A 30 - minute break was made after three driving hours to allow the subjects to relax and, if need be, to go to the lavatory; we took advantage of this break to check COHb levels.

RESULTS

COHb levels

The COHb values obtained after adjustment, during the break and after the 5 hour test are presented in table I. Results indicate that the COHb levels on the whole are satisfactory throughout the period of five hours.

Desired COHb	Initial level	Control after 3 hours	Final level
7 %	8.2 % (± 0.19)	7.23 % (± 0.20)	7.34 % (± 0.20)
11 %	12.15 % (± 0.61)	11.4 % (± 0.38)	11.03 % (± 0.34)

Table I – Results of the obtained COHb levels after adjustment (mean of 8 subjects ± ES)

Driving precision (Fig. 3)

The values (arbitrary units) shown on the graph correspond to deviations from the mean. In any case the time history of the driving performances is the same : there is an improvement during the first hour followed by a gradual deterioration ; after the relaxation break, the performance variations are similar but they occur in a much shorter time. Such variations clearly denote an effect of tiredness. It becomes evident and this is proved statistically, that the COHb levels of 7 and 11 % cause no significant changes in the driving precision.

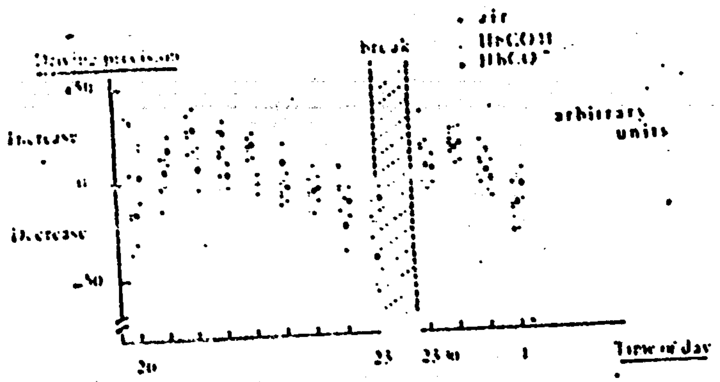

Fig. 3 : Variation of driving precision
The data shown correspond to deviations from the mean (mean of 8 subjects ± ES)

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Visual reaction time : (Fig. 4)

Changes are relatively mild on the whole and VRT is not significantly affected by COHb levels of 7 and 11 %.

In any case, after a relative stability during the first hour, there is a slight increase in the VRT which reveals a gradual building up of tiredness.

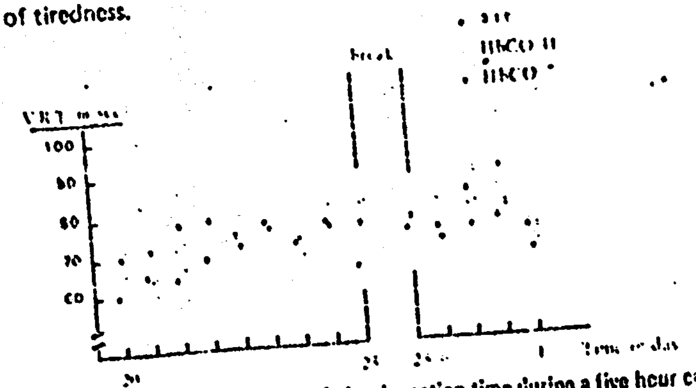

Fig. 4 : Variation with time of visual reaction time during a five hour car ride (mean of 8 subjects ± ES)

EEG :

A small and non-significant deterioration of the cortical activity is observed during driving, independent of experimental conditions;such a deterioration results in a synchronization of the α waves the frequency of which is reduced by less than 0.5 hertz. (TABLE II).

COHb level \ α waves frequency	Before	During	After
	5 hour car ride		
0	9.7 ± 0.1	9.5 ± 0.1	9.3 ± 0.1
7 %	9.5 ± 0.1	9.3 ± 0.1	9.2 ± 0.1
11 %	9.7 ± 0.1	9.4 ± 0.1	9.6 ± 0.1

TABLE II : α wave frequency (mean of 8 subjects ± ES) before,during,and after 5 hour car ride.

Heart rate : (Fig. 5)

The data show a significant decrease in heart rate (10 beats/min. ; p. 001) during the five hours of driving independently of the experimental situation ; this decrease denotes a gradual building up of tiredness probably combines with the circadian rhythm.

The presence of carbon monoxide in the blood causes no significant changes in heart rate, at most a slight increase with COHb levels of 7 and 11 % during the second part of the test.

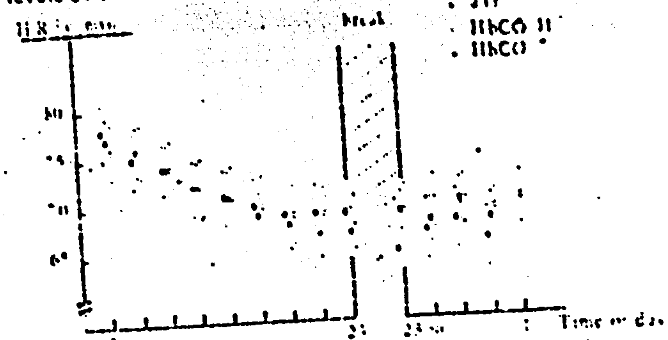

Fig. 5 : Variation with time of heart rate during a five hour car ride (mean of 8 subjects ± ES)

DISCUSSION

1°) This study attempted to answer the question of whether there are CO effects on performance in man. The analysis of our results suggests the absence of effects of subacute carbon monoxide intake at COHb levels of 7 and 11 % upon the psychosensoriel performances. These results conflict with several other studies which reported performance decrements with COHb levels below 5 % (BEARD and WERTHEIM, 1967 ; WRIGHT et al 1973). However it can be said that other research groups and in particular STEWART et al (1973) studying the same parameters failed to find any decrements below 12 % and that «BEARD was unable to reproduce his original finding when using a double blind procedure» (cited by STEWART, 1975).

Finally RAY and ROCKWELL (1970) have shown a decrement in driving performance with COHb levels up to 8 %, but they used only 3 subjects which we consider insufficient. For this reason we used 8 subjects to perform better statistical analyses on the data. Our results agree well with those of Mc FARLAND (1973) who did not observe any decrement of the ability to drive motor vehicules with COHb levels of 6, 11 and 17 %.

2°) It is known that CO effects and its toxicity are the result of tissue hypoxia caused by the inability of the blood to carry sufficient oxygen. The absence of significant effects on psychosensorial performances and EEG at levels of 7 and 11 % suggests that hypoxia is not sufficient to induce variations of neuronal metabolism. This is consistent with the case of hypobaric hypoxia where more important oxyhemoglobin desaturation is required to affect vigilance and brain electrogenesis. Finally, it is possible that during acute and subacute carbon monoxide exposures, there is an efficient mechanism of compensation of the decrease in oxygen transport capacity of the blood by an increase of cerebral blood flow (Mac MILLAN, 1975).

3°) Under all experimental conditions, we observe a gradual deterioration of the operational behaviour and of the cortical activity ; this denotes a gradual building up of tiredness which clearly shows the realistic aspect of the test as well as the functional value of the measured parameters. These results must be compared with the results obtained with the same technique by CAILLE and BASSANO (1976) when studying the effects of depriving regular smokers of tobacco. These results have shown that the deprivation of tobacco in extraverted subjects (selected for their well-modulated brain activity) results in a deterioration of the operational behaviour and in a synchronization of cortical structures. Smoking one cigarette makes it possible to return to the normal level of brain activity. To explain these variations a subsequent experiment carried out in the laboratory with smokers deprived for 24 hours has shown that the effects of inhaling nicotine alone (by inhalation of aerosols in the form of bitartrate) in equal quantity to that contained in one cigarette are for the most part similar to those of the entire cigarette (internal report, not published).

All our results (effect of carbon monoxide – effect of depriving smokers of tobacco – effect of inhaling nicotine) show that the effect of nicotine contained in the smoke seems to be more important than that of CO.

This conclusion is of significant pratical importance especially as regards the beneficial effect of smoking on driving performance in normal smokers with a COHb level not greater than 11 %.

(We thank P. CAILLE for his technical assistance).

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