The effect of indoor carbon dioxide on cognition

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Primary Objective: The main research question of this study is: What is the impact of an eight-hour exposure to an elevated concentration of indoor carbon dioxide on cognitive performance of individuals?This leads to the following hypothesis: The...

Ethical review	Approved WMO
Status	Recruitment stopped
Health condition type	Other condition
Study type	Interventional

Summary

ID

NL-OMON52064

Source
ToetsingOnline

Brief title
CO2CE

Condition

- Other condition

Synonym
air quality; power of concentration

Health condition

N/a, the study is about the cognitive performance of healthy participants

Research involving
Human

Sponsors and support

Primary sponsor: Nutrition and Movement Sciences (VBW)
Source(s) of monetary or material Support: Ministerie van OC&W

Intervention

Keyword: CO2, cognitive performance, cross-over design, indoor air quality

Outcome measures

Primary outcome

The main study parameters is the test scores of the CANTAB cognition tests.

Secondary outcome

The secondary parameters are the choices in the lotteries determining risk and time preferences, the answers from questionnaires about risk and time preferences, the changes in metabolic energy expenditure, as well as the following physiological parameters: heart rate variability, CO2 blood concentration, O2 saturation level, physical activity level, blood pressure, skin temperature, and breathing rate. Subjects will also receive a heuristics battery survey at the end of the test day, which measures the sensitivity to bias behavior. This includes measuring if automatic processes are tended to make more often than deliberative decisions in order to solve a problem.

Study description

Background summary

There is an increasing evidence that the level of carbon dioxide (CO2) inside buildings can have a negative effect on the cognitive performance and long-term health of occupants. While in the past, CO2 has been used as a proxy for other harmful substances in the air, more research indicates that CO2 itself could directly cause cognition impairments and adverse physiological responses. It is

assumed that a high level of ambient CO2 leads to an increased concentration of CO2 in the blood, caused by a changing breathing pattern which results in insufficient lung ventilation. This higher level of blood CO2 leads to a respiratory acidosis, characterized by a blood ph-level below 7.35 and an increased concentration of bicarbonate in the blood. Ultimately, this can lead to certain chemical and biological reactions in the brain, which impair cognitive performance. Nevertheless, the underlying physiological mechanisms in the brain are still unknown. Moreover, the cognitive impairment due to CO2 exposure might lead to changes in individual behavior, in particular regarding individuals* risk taking and time preferences which are key determinants in economic decision-making. However, current evidence is still inconclusive at which concentration levels CO2 starts to become harmful. There is also only limited knowledge about the effect of moderately high CO2-levels over a period of several hours. Additionally, from the best of our knowledge, there is currently no study which investigated the effect of moderate indoor CO2 concentration on human energy metabolism. Human energy metabolism is an important health factor in determining the risk for individuals to develop metabolic diseases such as cardiovascular disorders, stroke and type 2 diabetes. A lower level of energy metabolism is also associated with increasing risk for obesity.
This interdisciplinary study aims to contribute new insights to different streams of literature by examining the isolated effect of medium exposure (over several hours) to CO2 on both, cognitive and behavioral responses a well as physiological channels. This contributes to closing several research gaps. Firstly, the study will enhance our understanding if a typically occurring, moderate indoor CO2 concentration of 0.3% affects cognition and health. Secondly, the close monitoring of subjects* physiological conditions will allow insights into underlying mechanisms causing cognitive impairments. Thirdly, we will investigate the role of long-term exposure (several hours) to elevated levels of CO2 that are representative for conditions in offices, which allows translating the results into direct implications for firms and policy. Understanding under what conditions health, cognitive capacities and optimal decision-making of office workers can be optimized is key for future productivity growth and sustainable employment.

Study objective

Primary Objective:
The main research question of this study is: What is the impact of an eight-hour exposure to an elevated concentration of indoor carbon dioxide on cognitive performance of individuals?
This leads to the following hypothesis: The exposure to an indoor carbon dioxide concentration of 3000 ppm over a time period of eight hours significantly reduces the test scores on the CANTAB cognition tests, compared to an exposure to a concentration of 800 ppm of carbon dioxide.

Secondary Objective(s):

Does an eight-hour exposure to an elevated concentration of indoor carbon dioxide leads to:
1. A higher breathing rate per minute?
2. An elevation in blood pressure and arterial blood CO2 concentration?
3. A decrease in heart rate variability and arterial blood O2 saturation level?
4. A greater difference in proximal and distal skin temperature?
5. A change in substrate oxidation?
6. More risk-averse behavior of individuals?
7. A higher internal discounting factor individual use to evaluate future payments?
8. A higher tendence to make decisions in an unconscious, automatic response.

Study design

A randomized cross-over design is used. This is preferred over a treatment-control group design, because physiological parameters such as heart rate variability, blood pressure and skin temperature differ between individuals. A cross-over design allows to determine if the indoor level of CO2 has an influence on these factors within an individual. Furthermore, also the economic preferences a person has to make when deciding about investment decisions, determined by his or her risk and time preferences, differ between individuals. Nevertheless, this study allows to determine if a change in indoor CO2 concentration has an impact on these economic preferences in terms of shifting a person*s behavior towards becoming more or less risk averse, as well as more or less patient to wait for a future payoff. The amplitude of this shift will differ among individuals. To draw generalized conclusions, it is important that the shift is going into the same direction for each individual, e.g. every participant is becoming more risk avers when the level of indoor CO2 is higher. A cross-over design allows to investigate this aspect.
In this study, participants will be exposed to two different conditions on two separate days in the respiratory chambers of the Metabolic Research Unit of Maastricht University (MRUM) (see figure 1 below for a timeline). In both conditions, participants will spend eight hours in the respiratory chamber, conducting cognition tests multiple times. The light condition chosen in the climate chamber will be set at 4000 Kelvin and 500 lux which is recommended as visual comfortable office lighting based on the European Lighting Standard. The temperature level is set at 21°C, which is according to a recent review about the impact of temperature on cognitive performance the level for which human performance is closest to optimal. The only difference between the two conditions is the level of carbon dioxide (CO2) in the chamber, which is either 800 ppm of CO2 concentration in the air (low-CO2 condition) or 3000 ppm of CO2 concentration in the air (high-CO2 condition). Studies have confirmed that CO2 intoxication and serious harm for humans occur only at levels greater than 100,000 ppm (10% of ambient air) and no immediate damage on health can be expected from prolonged exposure to CO2 levels below 30,000 ppm (3% of ambient

air).

Intervention

The indoor CO2 concentration in the respiratory chambers will vary between the two tests days. It will be either 800 ppm (0.08%) high, or 3000 ppm (0.3%) high.

Study burden and risks

Participants have to come once for a screening session (3 hours) and two times to the MRUM lab and stay there for a period of 11.5 hours. They have to conduct a cognition test, fill out a questionnaire and play a lottery game two times per day. Additionally, they have to wear devices to measure heart rate variability, blood pressure, CO2 blood concentration, O2 saturation level, skin temperature, and breathing rate. Human energy expenditure will be measured using indirect calorimetry. The CO2 levels in the room will stay within a range for which no immediate danger for health is expected. The highest concentration of CO2 of 3000 ppm is a concentration commonly observed in schools or office buildings with relatively poor ventilation. Minor symptoms like headache, dizziness and sleepiness could occur at the end of the 8.5 hours session.

Contacts

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Trial sites

Listed location countries

Netherlands

Eligibility criteria

Age
Adults (18-64 years)

Inclusion criteria

- Adults: 25 to 50 years old
- White-collar workers: Participants that conduct cognitive task and low physical effort on a daily basis
- BMI between 18.5 and 25
- Generally healthy, no medication, except for contraceptives for woman
- Non-smokers or person who quit smoking more than five years ago

Exclusion criteria

- Persons who are unemployed
- Persons with a disorder or disease (Parkinson, Attention Deficit Hyperactivity Disorder (ADHD), Alzheimer, diabetes, cardiovascular disorder, respiratory impairments (for example asthma), hypertension, obesity, or any other condition that can impair the lung function)
- Athletes: no individuals who do endurance sports on a professional basis or more than 5 times a week for more than 2 hour
- Any medication or medical condition that might interfere with the physiological outcome parameters or in some regards impair cognition
- Individuals with a high level of caffeine consumption (determined by the validated Caffeine Consumption Questionnaire [Irons et al])
- Shift workers
- Color blindness
- Pregnancy

Study design

Design

Study type:	Interventional
Intervention model:	Crossover
Masking:	Single blinded (masking used)
Control:	Uncontrolled

Primary purpose:	Basic science

Recruitment

NL

Recruitment status:	Recruitment stopped
Start date (anticipated):	29-10-2021
Enrollment:	20
Type:	Actual

Ethics review

Approved WMO Date:	28-07-2021
Application type:	First submission
Review commission:	METC academisch ziekenhuis Maastricht/Universiteit Maastricht, METC azM/UM (Maastricht)
Approved WMO Date:	17-01-2022
Application type:	Amendment
Review commission:	METC academisch ziekenhuis Maastricht/Universiteit Maastricht, METC azM/UM (Maastricht)
Approved WMO Date:	07-03-2022
Application type:	Amendment
Review commission:	METC academisch ziekenhuis Maastricht/Universiteit Maastricht, METC azM/UM (Maastricht)

Study registrations

Followed up by the following (possibly more current) registration

No registrations found.

Other (possibly less up-to-date) registrations in this register

ID: 25220
Source: NTR
Title:

In other registers

Register	ID
CCMO	NL77015.068.21
OMON	NL-OMON25220