Are increasing atmospheric carbon dioxide levels lowering our intelligence?

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Abstract

An increasing number of recent studies have produced strong evidence that breathing moderate levels of carbon dioxide (CO_2) reduces human cognitive abilities. At the same time, intelligence tests around the world are showing a decline in scores as time progresses as a result of unknown environmental factors. This paper examines the possible link between these phenomena and explores the potential future impacts on human society. As atmospheric levels of carbon dioxide continue to escalate and drive climate change, the potential impact of CO_2 on human cognition is not recognised as a global risk. Increasing outdoor levels of CO_2 add to indoor concentrations (by ventilation) rising to levels higher than those which produce impaired thinking and reduced intelligence. The problem appears likely to continue exacerbating in the future extending to include outdoor environments with projected future atmospheric levels of CO_2.

Introduction

Carbon dioxide levels in our breathable atmosphere are steadily increasing (Figure 1) and historic evidence suggests that CO_2 levels may be 25% greater now than at any time in the evolutionary past of humans (ie. the period from pre-industrialization back to 25 million years ago). The historic evidence is based on studies of ice cores (Eggleton 2013) and fossil plankton (Zachos et al 2001). In terms of physiology, humans and their ancestors may never have experienced long term exposure to current and projected future levels of CO_2.

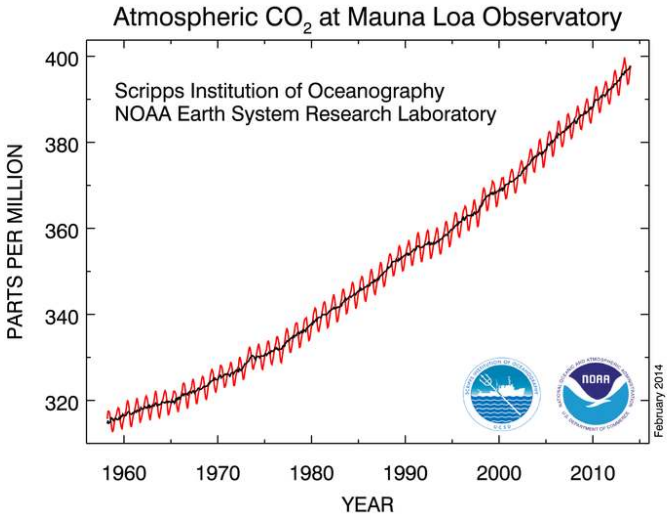

Figure 1. The rapid increase of CO_2 in the atmosphere since the start of direct measurements at Mauna Loa Observatory, Hawaii. (Keeling et al 2001).

One aspect of rising atmospheric CO_2 levels is the impact on human cognition at levels that are commonly encountered in indoor environments. New research has found that CO_2 at moderate levels reduces cognitive ability (Satish et al 2012; Allen et al 2016; Allen et al 2018) and also that human intelligence is becoming reduced as time progresses (Dutton et al. 2016; Bratsberg and Rogeberg 2018). There is a question of whether these two phenomena are linked. If yes, it could mean an immediate future where declining cognitive performance might have an increasing negative impact on social behaviour.

The impact of CO2 on human physiology in indoor environments

Human exhaled breath contains about 4% CO_2 leading to elevated levels of the odourless and invisible gas in indoor environments where there are numbers of people. Studies have shown that CO_2 concentrations in apartments, classrooms, offices, vehicles etc. (Bako-Biro et al 2011, Seppanen et al. 1999, Gładyszewska-Fiedoruk 2011, Gall et al. 2016) can often reach several thousands of parts per million (ppm) and sometimes up to 10,000 ppm (1%). To put this into context, at high concentrations CO_2 is a toxic and deadly gas (Scott et al. 2009); the current safe level of CO_2 as a time weighted average (TWA) for an eight hour working day is 5,000 ppm (OSHA, 2012). The current outdoor level of CO_2 is about 410 ppm. Many studies have shown the association between moderate CO_2 levels and health symptoms such as headaches, dizziness, fatigue, respiratory tract symptoms, eye symptoms, nasal and mucous membrane symptoms (Carreiro-Martins et al. 2014;

Ferreira and Cardoso 2014, Tsai et al 2012, Seppanen et al. 1999). However there is debate over whether CO_2 levels are simply a surrogate for other contaminants such as bio-effluents (body odours), volatile organic compounds (VOCs) and particulate matter that may be the cause of the health symptoms. Although causative investigation studies are few, some studies have implicated CO_2 directly in producing health symptoms (Lu et al. 2015) as well as causing unhealthy levels in blood CO_2 (Vehviläinen et al. 2016). Reviewed studies showed that symptoms increased significantly with carbon dioxide concentrations above about 800 ppm (Seppanen et al. 1999). Other potentially far more serious health impacts are likely as CO_2 levels increase (Bierwirth 2018).

Studies demonstrating CO2 impact on thinking (cognitive) ability

Recent studies have exclusively studied the effect of CO_2 and found that along with physical symptoms in some cases there is a major effect on cognition. Testing of students has found that CO_2 can negatively affect attention, memory, concentration and learning ability impacting on academic performance (Bako-Biro et al. 2011; Coley et al. 2007). Several recent university studies were notable in their strong research design (Satish et al 2012; Allen et al 2016; Allen et al 2018) having testing environments injected with pure CO_2 meaning that the analysis of CO_2 effects was not confounded by the presence of other substances. These studies showed that low level CO_2 (between 950 ppm and 2500 ppm CO_2) affected the cognitive abilities of students, information professionals and pilots in the indoor environment. Satish el al. (2012) tested only variations in CO_2 over periods of 2.5 hours of exposure. For seven of nine scales of decision-making performance (basic activity, applied activity, task orientation, initiative, information usage, breadth of approach, and basic strategy), performance was significantly impaired in a dose-response manner with higher CO_2 levels. For example, compared with mean raw scores at 600 ppm CO_2, mean raw scores at 1,000 ppm CO_2 were 11–23% lower, and at 2,500 ppm CO_2 were 44–94% lower. As part of a larger study that included volatile organic compounds (VOCs), Allen et al. (2016) found that, after $CO_2$was independently modified (from a baseline of 480-600 ppm) for individual 8 hour exposures, cognitive function scores were 15% lower at 950 ppm and 50% lower at 1400 ppm. This study used similar methodology to score cognitive function and the results largely repeated the findings of the earlier work (Satish et al 2012). However one difference was that, at 1500 ppm CO_2, even focussed activity was found to have declined (Allen et al 2016). In a study of pilots' performance, Allen et al. (2018) found that negative impacts on cognitive function were observed between 700 ppm and 1500 ppm CO_2. Another study found similar negative effects on human cognitive abilities, in experiments involving 140 minute sessions, as well as increased fatigue at levels of 3000 ppm CO_2 compared with 600 ppm (Kajtar and Herczeg 2012). This study also measured some physiological parameters with heart rate analysis suggesting significantly increased mental effort at 3000-4000 ppm.

Studies demonstrating declining human intelligence

Numerous studies have shown that scores on intelligence tests (i.e., IQ tests) had substantially increased during much of the twentieth century in many countries around the world (Dutton et al. 2016). This phenomenon has been designated the Flynn Effect after the review by Flynn (1984)with the steady increase in IQ from 1934 often interpreted as due to improving environmental factors (Bratsberg and Rogeberg 2018). However, in the last few decades it has been observed that the effect has been reversed and IQ test scores are now declining (Sundet et al 2004; Bratsberg and

Rogeberg 2018). Various theories have been suggested as a reason for this decline in IQ, for example the impact of immigration or a negative correlation between fertility and IQ.

Recently Bratsberg and Rogeberg (2018) found that the decline in intelligence scores was found within families which would deny the causal theories about immigration or fertility. They drew their results from a massive database of more than 700,000 IQ scores from conscripts in the Norwegian military (Sundet et al. 2004). Using administrative register data and cognitive ability scores covering three decades of Norwegian birth cohorts (born 1962–1991)(see Figure 2), Bratsberg and Rogeberg (2018) showed that the Flynn effect, its turning point, and subsequent decline can all be fully recovered from within-family variation. Their conclusion was that the causes of the ongoing decline in intelligence are environmental and vary within families but they were "unable to identify the causal structure of the underlying environmental effects".

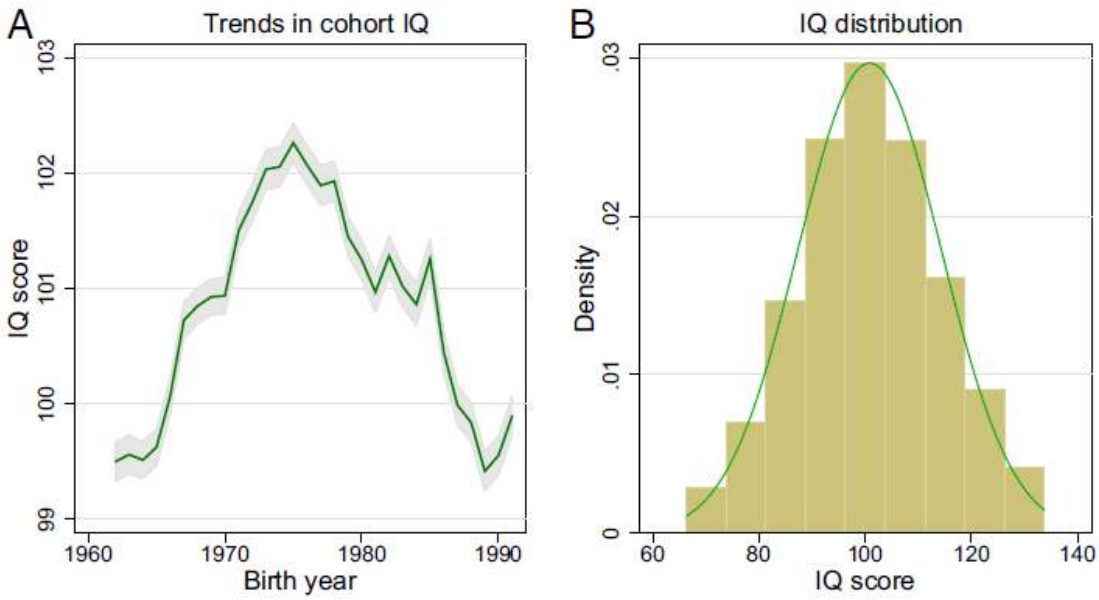

Figure 2. Average IQ score by birth year (A) and distribution of IQ scores (B). n = 736,808 (From Bratsberg and Rogeberg 2018).

Discussion

The studies of cognitive effects were conducted at CO_2 levels that represent typical conditions currently present in offices, classrooms and apartments (Gall et al. 2016). The modest reductions in multiple aspects of decision making, seen as low as 950 ppm (Allen et al. 2016), may not be critical to individuals, but at a societal level or for employers an exposure that reduces performance even slightly could be economically significant. It is possible that such effects occur without recognition in daily life (Satish et al. 2012). It appears that the CO_2 induced decline in cognitive ability is due to increased Cerebral Blood Flow (CBF) and the resulting effects on central nervous system and brain cortical function (Satish et al 2012; Glodzik et al 2013). This physiological effect, shown by observations of impaired thinking, may be only one of a number of health impacts caused by breathing relatively low levels of CO_2 (Bierwirth 2018).

IQ tests, that have been analysed to identify the Flynn effect and its reversal, would likely have been conducted indoors where CO_2 may have had an impact on cognitive abilities. Although there is a lack of information about the testing particulars of the Norwegian conscripts, they were probably tested in groups in indoor environments; this being a situation where CO_2 is elevated to similar and higher levels than those required to produce cognitive decline. The large number of data samples (~700,000) would average out the variability in IQ results due to changing CO_2 indoor conditions. Most (95%) of the conscripts were between 18 and 20 years of age (Sundet et al. 2004) when tested for cognitive abilities which means that the decline in IQ was observed to begin in the mid-1990s (see Figure 2). It is possible that the environmental cause of the IQ decline, now being observed, is due to increases in CO_2. As outdoor CO_2 levels continue to rise (Figure 1), indoor CO_2 concentrations also increase since indoor environments are generally ventilated at a constant rate with outdoor air. This means that any potential health or cognitive impacts due to elevated CO_2 levels in indoor environments will be continually exacerbated. The IQ test results (Figure 2) might indicate that an atmospheric CO_2 threshold concentration has already been breached in relation to human cognitive performance.

Based on the studies of CO_2 cognitive decline, the human IQ decline is only an indoor issue at this stage. If the test subjects were outside in the countryside their IQ scores would presumably be higher, the Flynn effect may still be evident and there would be no sign of a decline. It could be argued that the impact of CO_2 in lowering intelligence is only a temporary effect while we have the outdoor resource of ambient air. However the studies found impairment of cognitive abilities at CO_2 levels just above ambient (between 600 and 1,000 ppm) (although the indoor levels that impacted the IQ scores may have been higher than this). These are levels that could pervade the entire outdoor environment before the end of this century (Smith and Woodward 2014) meaning that the lowering of human intelligence would no longer be temporary. The ever increasing impacts of declining intelligence would have implications at a societal level for human function particularly for jobs with critical responsibility (e.g. surgery, air-traffic controllers, drivers etc.) together with the impact on learning, human development and economies.

Conclusions

It is feasible that the unknown environmental factors currently reducing human intelligence are actually due to increasing CO_2 in indoor environments influenced by rising atmospheric CO_2. Cognitive decline due to CO_2, evidenced by a number of strong studies, would logically produce lower intelligence scores in tests and that is what actual worldwide IQ test scores are showing. At current outdoor levels of CO_2, the intelligence lowering effect is likely to be only when humans are confined to indoor or polluted environments. However as outdoor CO_2 increases to projected levels in the future, there will be no escape from this effect unless significant numbers of humans can live in modified low CO_2 indoor environments. The risk of this reduction of human brain cortical function combined with other major health impacts, due to rising atmospheric CO_2, should be an issue of major concern requiring considerable scientific investigation. However at present there appears to be little or no awareness of these effects at a society level.

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