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Journal

Nature, 398(6729)

ISSN

0028-0836

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Publication Date

1999-04-22

DOI

10.1038/19418

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Peer reviewed

Figure 2 Lateral and ventral views of the orbitofrontal cortex of the monkey. Tremblay and Schultz¹ show that this region of the brain is involved in assessing the relative — but not the absolute — attraction of a reward.

and Schultz¹ adds a new dimension to characterization of the orbitofrontal neuronal activity — the relative attraction of the incentive.

It is important to place these results into the broader context of the part played by the prefrontal cortex in cognition. Studies of the prefrontal cortex have focused on the lateral prefrontal cortex in relation to working memory^{5,6}. Current debates centre on whether dorsal and ventral parts of the lateral prefrontal cortex are functionally segregated according to what information

is retained in working memory, or how that information is kept there^{5,6}. But the orbitofrontal cortex — which occupies quite a large proportion of the prefrontal cortex — is not essential for working memory. If this area of the brain is damaged, working-memory tasks are not impaired. Moreover, clinical and noninvasive studies indicate that the orbitofrontal cortex is important for estimating the pleasantness or value of objects, emotional reactions^{3,7} and motivational operations such as expectation of reward^{8,9}. The lateral prefrontal cortex, which is considered to be more involved in cognitive operations, is also implicated in reward expectancy^{8,9}. It is clear, then, that theories to describe the functions of the primate prefrontal cortex will have to include the motivational parameters that underlie much of our behaviour¹⁰. □

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Atmospheric chemistry

Uncertain road to ozone recovery

Paul J. Fraser and Michael J. Prather

The manufacture and emission of chlorofluorocarbons (CFCs), our inadvertent global experiment in modifying the Earth's stratosphere, has damaged the ozone layer for decades to come. The Montreal Protocol, which was agreed in 1987 and revised several times in the 1990s, and has the aim of reducing global emissions of ozone-depleting chemicals, has gone a significant way to solving the 'ozone problem'¹. However, as described by Montzka and colleagues on page 690 of this issue², the road to ozone recovery remains uncertain.

The authors report the good news that, by 1997, the lower-atmospheric burden of ozone-depleting halogen compounds (chloro- and bromocarbons) had declined by 3% from its 1993–94 peak; and they provide a reminder that this decline is almost entirely due to the rapid atmospheric removal of the solvent methyl chloroform (CH_3CCl_3), global emissions of which are now virtually zero. But concentrations of other halocarbons — carbon tetrachloride

(CCl_4) and CFC-11 (CCl_3F), for instance — are falling more slowly, and those of others such as CFC-12 (CCl_2F_2) are still rising. If the decline in emissions of these other halocarbon species does not gather pace, the overall fall in halogen concentrations in the atmosphere will stall sometime during the next decade.

What are the barriers to ozone recovery? Montzka *et al.* have identified several, namely, emissions of refrigerant CFCs, of HCFCs (hydrochlorofluorocarbons) as interim CFC replacements, and of halons (bromocarbons) as fire-fighting chemicals. In the developed world, a large 'bank' of CFC-12 in old refrigeration and vehicle air-conditioning systems continues to leak slowly into the atmosphere. Although new CFC production declined by a factor of 4–5 from 1986 to 1995 in accord with the Montreal Protocol, the developing world (China, India, Mexico) has increased production by 2–3 fold (largely of CFC-12), so that in 1995 it accounted for 45% of global CFC production³. This figure

is presumably even larger now. The combined effect of these emissions is continuing growth of CFC-12 in the atmosphere (Fig. 1a, overleaf), and this is the biggest single long-term threat to ozone recovery.

Fortunately, HCFC emissions to date have been only 50% of those permitted under the Protocol; in large part this is because HCFCs are due to be phased out by 2030, and some parts of the refrigeration and air-conditioning industry have hesitated to invest in short-term HCFC technologies. Likewise, HCFCs have not replaced CFCs in aerosols or foam plastics, where hydrocarbons or 'not-in-kind' substitutes have filled these niches. Yet HCFC use — and therefore emissions and atmospheric concentrations — are predicted to increase substantially, and legally, under the Protocol over the next decade⁴ as HCFCs continue to be used as CFC substitutes in refrigeration (Fig. 1b).

Another emerging player is halon-1211 (CBrClF_2), a fire-fighting chemical used increasingly in developing countries such as China and Korea, which now account for over 95% of global production of halons³. Under the Protocol, emissions of halon-1211 were thought to have peaked in the late 1980s (ref. 4), but atmospheric observations indicate near constant^{2,5} or possibly growing⁶ emissions (Fig. 1c and d). Using inventories based on atmospheric observations, emissions in the late 1990s are 50–60% higher than those predicted from global production data⁶. Presumably global production has been underestimated, or emissions from the bank are larger than assumed (or both). Studies by Montzka *et al.*² and a group involving one of us⁶ conclude that, in the near term (as opposed to CFC-12 in the long term), halon-1211 emissions pose the largest threat to ozone recovery.

Prompt and continuing progress towards ozone recovery requires that emissions of halocarbons must be reduced faster than is apparent from current observations of the atmosphere. The United Nations Environmental Programme is facilitating such an accelerated phasing out of halon use in China, with production of halon-1211 scheduled to end by 2006, four years ahead of the Protocol⁷. In addition, the technology exists to recycle or destroy the bank of CFC refrigerants that would otherwise vent to the atmosphere when refrigeration systems are scrapped. The uses of HCFCs could be restricted to refrigeration, where their identification and recycling is again possible, and emphasis could be placed on use of very short-lived gases such as HCFC-123 (CHCl_2CF_3) that pose a minor risk to the ozone layer⁸. All in all, it is possible that ozone depletion can be halted in the next decade. But it will require a level of global stewardship that still poses a substantial challenge to all parties to the Montreal Protocol.

100 YEARS AGO

The Groundwork of Science; a Study of Epistemology. By St. George Mivart. The chief definite conclusions which are drawn are that it (the universe) cannot consist of one kind of energy only, that it is impossible that intellect can have been evolved from mere physical force, and that animals show no signs of latent intellectuality. It is further insisted "that the portion of truth which we are able to attain to in our investigations of the cosmos, is but an unimaginably small portion of the whole"; a statement which will, we imagine, not be seriously challenged by workers in science. To the latter, viz. the science workers, Dr. Mivart devotes some attention in the concluding pages of his book. The narrowing effect of extreme specialism upon the mind is an undoubted evil ... But there is the opposite evil of becoming diffuse to the extent of a practically useless attenuation of the mental faculties.

From *Nature* 20 April 1899.

50 YEARS AGO

Mr. H. E. Hadley, well known as the author of many elementary text-books of physics, died on March 6, at the age of eighty-two. Mr. Hadley had lived rather a retired life. He was appointed headmaster of a small science school in Kidderminster, where he combined with physics a lectureship in chemistry. In those days, physics was considered of less importance than chemistry; but Mr. Hadley was always at heart a physicist. ... Mr. Hadley was a contemporary of Sir Richard Gregory and H. G. Wells at [The Royal College of Science, London], and from his training there and association with C. V. Boys he acquired a special genius for making his physical apparatus. His teaching equipment at Kidderminster was largely of his own making, and it would seem that this gave physics an added attraction to his students.

We regret to announce the following death: Mr. Will Hay, well known as an actor and also a distinguished amateur astronomer, on April 18, aged sixty.

From *Nature* 23 April 1949.

Many more extracts like these can be found in *A Bedside Nature: Genius and Eccentricity in Science, 1869–1953*, a 266-page book edited by Walter Gratzer. Contact Lisa O'Rourke. e-mail: l.ourourke@nature.com

Figure 1 Ozone-depleting trace gases now and in the future — observed^{6,15,16} and predicted⁴ atmospheric chlorine loading, in parts per billion of Cl, from various halocarbons. a, CFC-12; b, HCFCs; c, halon-1211 (effective Cl). d, Halon-1211 emissions calculated from atmospheric measurements and from a production-based emissions model⁶.

Ozone depletion is the dark side of the CFC experiment. But, for science, there is a bright side — the great progress in atmospheric chemistry, made over the past 25 years, which stems in part from the scientific and political drive to understand CFCs and ozone depletion, and in part from the study of the rapid yet transient rise of the synthetic halocarbons. For example, the earliest measurements of CFC-11 envisaged its use as a tracer of air motions⁹, and it has become a standard test of global models of atmospheric chemistry¹⁰ (and also a diagnostic indicator of ocean circulation); the first meaningful measure of the mean tropospheric concentration of hydroxyl radicals (OH), which destroy CH_3CCl_3 and HCFCs, is derived from observations of CH_3CCl_3 (refs 11, 12); CFC pollution events in Ireland are used to calibrate European emissions of other greenhouse gases¹³; and study of CH_3Br (a crop and soil fumigant) has shown us the importance of the ocean in determining the atmospheric residence time of a soluble trace gas, and has resulted in revision of the concept of ozone-depletion potential for short-lived gases¹⁴.

What new opportunities will the second phase of the CFC experiment provide? Through its latitudinal gradient, the decay of CH_3CCl_3 will give us a measure of the north–south hemispheric difference in OH concentrations, plus a long-term record of possible OH trends. And, after sources of CFC-11 have diminished sufficiently, its atmospheric decay will provide us with the

first accurate lifetime for a CFC, and the north–south differences at the surface will measure hemispheric asymmetry in stratosphere–troposphere exchange. It is serendipitous indeed that CFCs and related halocarbons have provided, and will continue to provide, some of the benchmarks of progress in atmospheric chemistry. □

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