Martin, Rossor and Martin, Knapp

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Can we model a cognitive footprint of interventions and policies to help meet the Global Challenge of Dementia?

Martin Rossor MD
University College London
NIHR National Dementia Research Office
National Hospital for Neurology and Neurosurgery
Queen Square
London
WC1N 3BG
Tel: 020 3448 3798
Email: m.rossor@ucl.ac.uk

Martin Knapp PhD
London School of Economics and Political Science
Personal Social Services Research Unit
Houghton Street
London
WC2A 2AE
Tel: 020 7955 6225
Email: m.knapp@lse.ac.uk

The changing global demographics of dementia have led to worldwide predictions of unaffordable treatment and care costs over the coming decades. Recognition of the economic consequences has encouraged numerous countries to develop national dementia plans, as well as international action such as the G8 Dementia Summit in London in 2013.

Dementia is defined as severe cognitive impairment that interferes with activities of daily living. There is a tendency to conflate dementia with Alzheimer's disease, not surprising since it is the commonest form of dementia in older people, progressive, and without interventions to slow that progression. There are nevertheless numerous diseases which may be associated with severe cognitive impairment or dementia, and importantly, many more associated with less severe cognitive impairment, some of which may progress if undiagnosed. The term Mild Cognitive Impairment (MCI) was developed to describe cognitive deterioration that does not fulfil the severity criterion of dementia, although MCI has tended to be used when older people present with a memory problem that might represent early Alzheimer's disease. We would argue, however, that to focus only on late-life dementia misses the societal opportunity to foster cognitive health and to preserve cognitive capital. If one considers all causes of cognitive impairment across the lifespan – including the absence of activities to develop full cognitive potential, such as education – then a deeper and broader debate is opened up. It is important, however, to appreciate that cognition here is not confined simply to memory, but to the entire spectrum of cognitive function including language, perception, creativity, and social activity.

In reframing and extending the debate in this way, it may be helpful to borrow a concept from another major global challenge of modern times: global warming. Can we develop a *"cognitive footprint"* which, as with a carbon footprint, can be either negative (impair cognition) or positive (enhance cognition)? A cognitive footprint can then be used to assess and model potential cognitive impacts of medical and public health interventions through to social and wider public policies? A cognitive footprint could then be identified across many public policy areas: including health, social care, education, criminal justice, transport, sport, employment and doubtless others. The importance of this footprint stems from links between cognitive skills and educational attainment, employment status, earnings, performance in instrumental activities of daily living (IADLs) and (at national level) to income distribution and economic growth.[1]

Thus a range of activities will have an impact on cognition throughout the life course that could be "foot-printed" as illustrated below.

Cognitive Footprint of ancestral health, pregnancy, and perinatal period

Adverse effects during pregnancy of smoking, alcohol, and many drug exposures (e.g. sodium valproate) are widely recognised. More difficult to determine are effects of stress arising from adverse environments of the mother, although emerging evidence suggests that chronic exposure to stress hormones may have a lifelong detrimental effect on offspring.[2] Maternal perinatal mental illness can affect a child's cognitive development.[3] The increasing focus on epigenetic effects also suggests that ancestral environment can affect the health of offspring, and although studies have focused on cardiovascular and metabolic disease, both secondary and primary effects on cognition might be anticipated.[4]

Cognitive Footprint of education

Links between education and cognition are bi-directional: educational attainment is partly determined by prior cognitive ability, but receipt of education (both quality and duration) also influences subsequent cognitive development, even after adjustment for earlier cognition, gender and parental socioeconomic position.[5] Indeed those impacts have a long reach: raising the schoolleaving age in 1947 has been associated with improved cognitive performance in old age.[6] Educational investment can thus reduce a negative subsequent cognitive footprint.

Cognitive Footprint of infectious diseases

Many infectious diseases result in permanent cognitive deficits and many are associated with poor cognitive function.[7] The cognitive footprint will be greater with childhood diseases due to the potential life-long impact. Neurocysticercosis is endemic in Latin America and South East Asia, associated with poor sanitation. It is listed as a Neglected Tropical Disease by WHO, which in July 2014 ranked Taenia solium top of the list of leading food-borne parasites "with greatest global impact". Neurocysticercosis is a leading cause of epilepsy world-wide, which in itself can have secondary effects on cognition. Active neurocysticercosis is recognised as being associated with cognitive impairment,[8] thus childhood exposure to Taenia solium may have a major cognitive footprint over an individual's life-time and partially negate educational investments in developing countries.

Cognitive Footprint of sport

There are, of course, well-known short-term and long-term positive benefits of exercise on cognition as well as other protective effects on health.[9] But a lot of attention is now also being focused by some sports governing bodies on head injuries and their consequences.[10] Many sports (particularly contact sports such as boxing, football and rugby) carry risks of long-term cognitive damage.[11] A major US review of youth sports reported higher rates of concussion and mild traumatic brain injury in school athletes compared to university athletes, and higher rates during competition than during training.[12] Worryingly, this review found a 'culture of resistance' to report possible concussion and to compliance with treatment plans. Protective sports headgear in widespread use often does not offer sufficient protection, while there is also evidence of 'risk-compensation': sports participants take more risks because they feel protected when wearing headgear.[13] This same risk-compensation behaviour has been observed in (non-sport) cyclists[14], which is again relevant since cycle helmets cannot completely eliminate the risk of head or brain injuries.[15] We are not arguing against the benefit of sport, but rather that its footprint needs to consider the negative as well as positive effects on cognition.

Cognitive Footprint of medication

Numerous drugs have adverse effects on cognition, particularly in older people (e.g. anticholinergics for bladder symptoms), and their cognitive effects should be balanced against quality of life improvements. Statins are widely prescribed in middle-to-later life; on the basis of links between vascular disease and subsequent dementia, their use is increasingly encouraged.[16] Whilst the evidence is strongly in favour of their use, the footprint needs to take into account reported symptoms of memory impairment sufficient for the FDA in February 2012 to request safety labelling for statins to include memory impairment. A subsequent systematic review failed to confirm a short-term effect on memory,[17] but small adverse effects over many years may need to be balanced against greater beneficial effects later in life. By contrast, the cognitive effects of exercise and diet may have a greater positive footprint both in the short and long term.

Cognitive function is rarely assessed in clinical trials outside neurology and psychiatry. To assess the footprint of therapeutic interventions, assessment of cognition should be encouraged, either directly or indirectly by accessing alternative data sources such as retail and mobile phone usage data. Not only would this identify adverse effects but potentially identify unintended cognitive *benefits*. An example from the cancer field is the effect of Metformin prescribed for diabetes lowering cancer risk.[18]

Cognitive and Carbon Footprints

One further contribution to the cognitive footprint brings us back to carbon footprints: air pollution can damage cognitive function in older adults,[19] and even low levels of lead exposure can have neurodevelopmental effects over quite short time-scales, such as the suggested impact of leaded petrol on 5 to 8-year olds in Taiwan.[20]

Measures

The concept of a cognitive footprint can drive better appreciation of the many influences on cognition, including the effects of population-level policies, individual-level behaviour, and healthcare treatments. It will need to reflect both positive and negative effects over the life-course, with adverse events in early life having a greater negative effect than those of similar magnitude occurring later in life. What is absolutely clear is that, in a post-industrial society, it is cognitive function that is fundamental to meeting modern challenges and driving innovation.

Cognitive capital built up by a society from investments in, for example, education, healthcare, public health and environmental protection will, over a lifetime, sum to major impacts in many areas. Although there is no simple, direct, global measure of cognition, the effects on, for example, health, psychological wellbeing, and individual and aggregate social and economic achievements can in principle be assessed. Footprints are inherently multidimensional, and a *cognitive* footprint should be assessed in terms of its (net) multiple impacts. Measures are already widely in use for health-related quality of life, disability, wellbeing (including happiness), financial investment, employment and productivity. Those measures have been developed and are employed to inform many different discussions and decisions. Whilst the contributions that cognition makes to each of them may sometimes be challenging to determine – although surely identifiable with the right data and study design – the concept of a cognitive footprint could ignite the debate about the often overlooked effects of a wide range of public policies and private actions on cognitive function. In turn this could stimulate broad public engagement in protecting what is, after all, society's most valuable asset.

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