

Shedding light on the role of poverty in brain development

The links between childhood poverty and future potential have been known for years. Now, as the functional consequences and risk factors are increasingly being understood, neuroscientific studies show how poverty and inequality can directly affect brain development. Kelly Morris reports.

Decades of research have cited poverty as a major risk factor for adverse childhood development. Cognitive testing is increasingly being used in prospective studies to tease out the complex interplay of factors that mediate this association. The key cause is now thought to be adverse effects on brain development itself, and human studies are just beginning to measure the neural correlates of the effects of poverty. As potential interventions start to be considered for randomised, controlled trials (RCTs), experts are urging governments and policymakers to implement practices on the basis of the currently available evidence.

Last year, an international group of experts estimated that 200 million children under 5 years of age in the developing world are not meeting their cognitive and educational potential because of factors such as stress and trauma, poor nutrition, and lack of learning opportunities, says group member Patrice Engle (California Polytechnic State University, USA). Evidence suggests that in richer countries not only family income but also social status—measured collectively as socio-economic status (SES)—is related to cognitive development. “Where there is more inequality, a greater proportion of the population are deprived in relation to the rich”, notes Richard Wilkinson (University of Nottingham Medical School, UK). Thus, rich countries in which inequality is high, such as the USA and the UK, might have similar or even greater proportions of children who fail to meet their neurodevelopmental potential than do some developing countries.

Contributory factors undoubtedly vary according to situation, but the latest clinical research confirms what

has been reported for years in animal studies—that adverse, stressful influences, operating at critical time periods for brain development, can affect not only behaviour and cognitive functioning but also the structural development of the CNS. One major factor is maternal and childhood diet. Malnutrition is at the extreme end of the scale, with nutritional deficiencies also having a considerable impact. The largest prospective longitudinal study—the Avon Longitudinal Study of Parents and Children (ALSPAC)—has found during the past decade that many outcomes, including verbal IQ, visual stereoacuity, motor control, communication, and social development scores are reduced in children whose mothers ate the lowest amounts of oily fish during pregnancy. Unsurprisingly, a low intake of oily fish is also linked with measures of social disadvantage, although breastfeeding also is a confounding factor. The ALSPAC researchers plan to continue this work as the children age.

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One explanation for this finding might be the availability of docosahexaenoic acid and other omega-3 essential fatty acids (EFAs)—vital brain building-blocks found in oily fish and breastmilk that were not constituents of formula feeds during the period studied by the ALSPAC investigators. Omega-3 EFAs might engender better neural function than other EFAs do, which could make the developing brain more

resilient to stress. However, Pauline Emmett, chief ALSPAC nutritionist (University of Bristol, UK), notes that “the link between poverty and diet is not straightforward” and is, in part, mediated by parental education. Well-educated parents tend to follow all guidelines during pregnancy, and those on breastfeeding, she notes, and parental education will also affect postnatal development.

Tomas Paus (University of Nottingham, UK) notes that smoking during pregnancy is strongly linked with low SES, and with cognitive and behavioural effects in children. But the effect of prenatal smoking on the human brain was largely unknown until last year. In MRI studies on adolescents matched for school and maternal education, Paus found that prenatal exposure to smoking was associated with cortical thinning in various areas but only subtle behavioural changes. In a fully controlled study, prenatal smoking “might not have a major effect on cognition”, Paus says. He adds that “the effect of nicotine replacement on the developing brain is unknown”, and advocates addressing smoking cessation as part of a much broader package of maternal health measures.

Charles Nelson (Harvard Medical School, USA) suggests that brain development is influenced not only by genetics and experiences unique to an individual, but also by “expected” experiences common to a species—such as access to patterned light information or a caregiver—so deprivation of expected experiences may have substantial impact. Worldwide, children most affected in this way are those in institutions, who are the most removed from a typical environment. Nelson and others have

For more on ALSPAC research see <http://www.alspac.bris.ac.uk>, *Lancet* 2007; **369**: 578–85, *Am J Clin Nutr* 2001; **73**: 316–22

For more on child development in developing countries see *Lancet* 2007; **369**: 60–70, 145–57, 229–42

found that institutionalisation has profound adverse effects on cognitive development and brain EEG activity, yet it is a widespread approach to rearing children, particularly in conditions of poverty, war, and HIV epidemics.

Children in less adverse situations also show changes in brain-behaviour relationships. Clyde Hertzman (University of British Columbia, Canada) and colleagues recently reported EEG studies showing that low-SES children recruit different and supplementary neural processes compared with those with high SES to achieve the same accuracy on an auditory attention task. Kimberly Noble (Columbia University, USA) has reported a more complex relationship between phonological awareness, reading skill, and brain activity. Phonological awareness is an important mediator of the effect of SES on cognitive functions, and can compensate for the adverse effect of low SES on reading. But functional MRI work has shown that SES changes the relationship between phonological skills and brain activity during reading. Children with low SES have widely different brain activation patterns depending on their level of phonological awareness, whereas these differences in activity are attenuated in children with high SES. These findings may be explained by the influence of phonological awareness on the differential recruitment of brain regions for reading. But cognitive, neurobiological, and social factors seem to be intertwined. "It is my personal belief that one of the largest mediating factors here may be the very large disparity in exposure to reading activities across SES, particularly prior to entering school", says Noble.

Can cognitive recovery occur with intervention? The answer seems to depend on the timing. "Poverty has an impact at all times in a child's life, but the first few years are a period of particular vulnerability and particular opportunity", says Engle. She notes that recognised successful intervention

is based around early learning programmes, but strategies are being developed to work through primary health-care centres, around situations of high risk, including HIV/AIDS and emergencies, and through financial assistance, such as conditional loans.

Nelson and colleagues recently reported very optimistic findings on the potential for cognitive recovery in the most deprived children. Institutionalised children were randomised to remain in an institution or to be fostered as part of a new, high-quality foster-care project. The fostered children showed improved cognitive outcomes and greater cortical EEG activity than those who remained institutionalised. "We know there are sensitive periods in the acquisition of different abilities and in different facets of brain development [so] the reverse should also hold true ... there should be a corresponding sensitive period in which one needs to intervene", says Nelson. The trial IQ data suggest that placing children aged less than 24 months yields the best outcome, although for language this point was closer to 16 months, and for attachment 20–22 months.

Effective dietary intervention is still under study but some experts believe sufficient evidence exists on how to start intervention. The EU/European-Union-funded NutriMENTHE project (University of Granada, Spain) is planning to study the long-term effects of prenatal and early postnatal diet on cognitive performance and behaviour, together with RCTs of specific nutrients introduced during pregnancy, infancy, and childhood. However, despite a UK parliamentary inquiry on the topic and a governmental objective to tackle childhood poverty, Michael Crawford (Mother and Child Foundation, UK) is concerned that focusing on older, school-age children is leaving it too late, because neurodevelopment during pregnancy is the most critical period for future development. In 1972, Crawford predicted that changes in diet, especially intakes of different



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EFAs, which would particularly affect the disadvantaged, would lead to a rise in brain disorders, which is now being seen. He is also keen that scientific evidence on maternal health and diet be applied now, with a new initiative that starts with women as they enter their reproductive phase and reaches up to inter-departmental cooperation on education, health, food production, and further research.

"Our impression", says Wilkinson, "is that more unequal societies involve more status competition and less reciprocity most of the way up". This might explain why richer countries have greater problems with social and behavioural disorders than some poorer ones. So, Paus is keen for further research to identify the modifiable factors that could promote positive or "prosocial" behaviours, some of which might also be associated with disadvantage. But all experts agree that research has now proven the importance of fetal and early life conditions on neurodevelopment. According to a report last year from the Center for the Developing Child at Harvard University, for the first time, "researchers are now able to present a unified framework" to guide policymakers working to boost maternal and child health, family environments, learning and opportunities for children that is grounded in the latest research.

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