Thomas, Michael S.C. (2017) A scientific strategy for life chances. Psychologist Magazine 30 , pp. 22-26. ISSN 0952-8229.

This is a pre-publication version of the following article: Thomas, M. S. C. (2017). The cognitive neuroscience of socio-economic status. *Psychologist Magazine*. The British Psychological Society.

The cognitive neuroscience of socio-economic status*

Michael S. C. Thomas
Director, Centre for Educational Neuroscience
Professor of Cognitive Neuroscience
Birkbeck, University of London
m.thomas@bbk.ac.uk
www.educationalneuroscience.org.uk

* based on a talk given at a mediated workshop held by the LEARNUS think tank on 19th October 2016 (www.learnus.co.uk)

"When neuroscience," said David Cameron, "shows us the pivotal importance of the first few years of life in determining the adults we become, we must think much more radically about improving family life and the early years." It was the 11th of January 2016 and the Prime Minister was laying out the foundations for his so-called Life Chances Strategy, a plan for "how we can transform the life chances of the poorest in our country and offer every child who has had a difficult start the promise of a brighter future." It was strategy that, by a twist of fate, was due to launch on 24th June 2016, the day after the referendum on Britain's membership of the EU. The launch was postponed.[1]

Apart from highlighting how quickly things can change in politics, what was notable about David Cameron's speech was the repeated reference to neuroscience. He mentioned the exuberant growth in brain connectivity in the first two years, linking it to a developmental window of opportunity. He mentioned the brain in the context of early parental care and children's socioemotional development. He mentioned the brain in the context of alcoholism and drug addiction, conditions which can seriously impact on the family environment in which children are raised.

This was no accident. It reflects a growing body of cognitive neuroscience research that has focused on the impact of differences in socioeconomic status on cognitive and brain development, and in particular the impact of poverty and deprivation. It is a field where scientists must tread carefully, to avoid the appearance of making judgements, to avoid taking an overly reductive view of the complex environments in which children grow up, and to make plain the goal of alleviating socioeconomic status related disparities in children's development (Raizada & Kishiyama, 2010). And it should be noted that when we consider the data, what we will see are *partial* associations: for example, being on welfare does not always imply lower levels of education or child outcomes.

What are the effects of socioeconomic status?

Socioeconomic status (SES) is a concept with multiple dimensions. It refers to set of related properties of the child's family and environment revolving around economic resources and social factors, such as power, prestige and hierarchical social status (Hackman & Farah, 2009). The measure usually includes household income, material resources, and the education and occupation of parents. Many properties of the child's environment vary along with SES, including the nature of parental care, the level of cognitive stimulation, as well as the risk of exposure to violence and abuse. Growing up in a family with low SES can lead to poorer outcomes in cognitive and emotional development, educational achievement, and both physical and mental health (Hackman, Farah & Meaney, 2010). When children start school, SES-related differences in children's behaviour and cognitive abilities are already present, and these gaps do not narrow as children proceed through school (Heckman, 2006).

Given the effects of SES appear so pervasive, it is somewhat of a surprise to find that the impact on cognitive development is uneven. Hackman and Farah (2009) found that the effects were most marked in language skills, where perhaps a third of the variation was predicted by SES. (Indeed, in one study in the US, Hart and Risley (1995) found that the vocabulary of 3 year olds from professional families was twice as large as those from families on welfare.) The effects of SES were also observed in the 'executive functions' of cognitive control (attention, planning, decision-making) and working memory, in these cases SES predicting around 6% of the variance. However, visuospatial skills showed no effects of SES.

If low SES impacts on children's cognitive and emotional development, which then affects educational achievement … which then impacts subsequent earning potential, together this is a pathway for the persistence of poverty across generations. And, by the same token, disrupting this pathway is an opportunity to generate social mobility.

A neuroscience approach

The role of neuroscience is to focus on the possible biological mechanisms by which SES has its influence on child development. Neuroscience has a suite of methods. For human research, perhaps the most familiar is brain imaging, measuring the structure and function of the brain. But there are also molecular and cellular methods, study of neural circuits and systems, anatomy, animal models, genetic studies, and computational modelling. Animal models, for instance, provide the opportunity to study the effects of dominance hierarchies in the wild; in the lab, they allow detailed investigation of the neural underpinnings of phenomena such as the effects of early maternal care, nutrition, and prenatal versus postnatal stress.

Let's take an example of a recent study using magnetic resonance imaging (MRI) with children. Noble and her colleagues investigated whether SES correlated with differences in brain structure, in a large sample of 1099 children in the USA (2015). They used MRI to measure both the surface area and thickness of the cortex across children. With a sample of this size, they were able to detect small effects of SES on the surface area, predicting a few percentage points of the variation. Cortical surface is influenced by experience-related synaptic pruning and increased myelination that expands the surface outward. The differences were strongest in families with the lowest incomes, rather than being a constant relationship across the SES range. They were also most marked in the temporal and frontal regions of the brain. This pattern fits with SES having stronger effects on language (temporal regions) and executive functions (frontal). It may also reflect the fact that these brain regions have the most extended trajectory of development across childhood, so there is more opportunity for the environment to impact them. Looking at particular brain structures, Noble et al. found that parental education was significantly associated with the volume of the left hippocampus. The hippocampus is linked with declarative and episodic memory. This relationship was steepest at lower levels of parental education. However, no association was found with right hippocampus, a reminder that these small effects on structures are hard to find.

Other studies have looked at the function of the brain, for example, measuring electrical activity on the scalp. They have found subtle differences in the way the brain focuses attention. For example, Stevens, Lauinger and Neville (2009) showed that when children were asked to listen to one sound and ignore another, the brains of the children from lower SES families were less able to screen out the irrelevant sounds, showing larger electrical responses to the unattended channel. This was suggestive of deficits in selective attention.

Causal pathways

What are the current explanations of how low SES impacts on development? Causal accounts seek to capture both what is added (stress, childhood adversity experiences) and what is lost (cognitive stimulation) (Sheridan & McLaughlin, 2016). Researchers have distinguished three main biological pathways through which SES effects may influence brain development (Hackman, Farah & Meaney, 2010). First, they may influence the child prenatally, such as in the influence on foetal development of the mother's stress levels and nutrition during pregnancy. Second, they may affect the way the parents interact with and nurture their children after they are born. Third, they may affect the level of cognitive stimulation, or the richness of children's experiences, as they grow up. At the moment, we don't know which of these pathways is most important, whether indeed it may differ across groups (for example, in rural settings versus urban settings), and the extent to which the relevant pathways depend on the absolute versus relative levels of income, education, and health factors in a society.

Here's where it gets complicated for researchers. A sensible strategy might be to find out which measure of the child's environment is the strongest predictor of, say, his or her cognitive ability or language skills. That should tell us which causal pathway is most important. Perhaps it's prenatal diet. Perhaps it's the amount of language spoken to the child. Unfortunately, many factors collide in low SES families. A family with low income may have parents with fewer years of education, a home environment with less structure and fewer resources (toys and books), stressed parents may have less time to spend with their children and interact with them differently (less sensitivity to emotional needs, less verbal communication, more discipline), homes may be in worse neighbourhoods with more pollution, mothers may be more likely to have had low birth weight babies and have become depressed afterwards. If all these factors are correlated, it is hard to discern which is producing the strongest effects on brain and cognitive development.

Correlations aren't the best way to unpick causes. To find out how a system works, it's best to intervene experimentally. Change one factor and see what else changes. Studies of SES generally only investigate natural variation. This is where animal models have been useful, because aspects like diet, stress, and maternal behaviour can be experimentally manipulated. For example, work with rats has explored how moving a rat pup from a mother with low nurturing behaviour (grooming, licking) to a mother with high nurturing behaviour alters the rat's subsequent stress response as an adult (Weaver et al., 2004). Animal models have their limitations, however. Although animals have dominance hierarchies and can experience stress, these are not quite the same thing. Human hierarchies are multi-dimensional and buffered by internal standards (people tend to identify most closely with the hierarchy in which they have the highest rank); stress in a rat is different from the kind of psychosocial stress experienced by families who are struggling economically; and animal models do not offer direct parallels to the development of language and higher-cognitive skills (Sapolsky, 2005).

One recent longitudinal study of the relationship between SES and children's development of executive function skills such as attention and planning took advantage of the fact that in some families, SES can change over time (Hackman, Gallop, Evans & Farah, 2015). When this happens, the tight correlation between predictors is broken, and the more influential factors emerge. Here, it seemed that the nature of the early relationship between mother and infant, including the mother's sensitivity in responding to the infant's needs, was of greater importance. Indeed, high-quality parent-child interactions have been linked with more positive, resilient outcomes in children who nevertheless live in impoverished and stressful environments (Masten, Morison, Pellegrini, & Tellegen, 1990).

It may be, however, that SES has its affects via multiple pathways. This might be one explanation for the uneven effects observed across cognitive development. Here's one hypothetical scenario: the higher incidence of some disorders such as ADHD observed in low SES children (e.g., Hjern, Weitoft & Lindblad, 2010) is caused by prenatal factors; early parental interactions impact most on children's socioemotional development and behavioural regulation; cognitive stimulation is the most important factor in language development and then educational outcomes most strongly reliant on language skills; but the child's everyday experience in perceiving and interacting with the physical world is enough for robust development of visuospatial skills, making them insensitive to SES differences.

Challenges

Beyond the difficulties of carrying out the science itself, there are also challenges involving on the one hand interpretation, and on the other hand communication of the research to policymakers. In terms of interpretation, it is important to distinguish aspects of behaviour in children from low SES backgrounds that are natural and perhaps *protective* adaptations to the environment they find themselves in, from aspects that are deficits produced by environments with fewer resources. The child in a more dangerous, less predictable environment perhaps needs to be more vigilant, and cannot afford to focus his or her attention. The child in a world with few resources may adopt a 'scarcity mindset', focusing on immediate goals rather than long-term planning (Shah, et al., 2012). These adaptations, however, may hold the child back in the classroom, where selective attention is necessary and where behavioural regulation around long-term plans is necessary to achieve educational goals. By contrast, animal models have produce evidence that variations in maternal care and environmental stimulation can lead to changes in neural signalling supporting plasticity, including in dendritic branching and synaptic density in the hippocampus and cortex (e.g., Champagne et al., 2008; van Praag, Kempermann & Gage, 2000). This makes it likely that some effects of low SES will produce poorer learning and memory as a deficit rather than an adaptation.

In terms of communication of researchers to policymakers, back in the 1990s, Bruer argued that the neuroscience evidence on early development then available had been misconstrued to such an extent that it had created a 'myth' of the unique importance of the first three years of development (Bruer, 1999).

Under the myth, the first three years provide caregivers and educators with 'a unique, biologically delimited window of opportunity during which the right experiences and early childhood programs can help children build better brains' (1999, p.12). But Bruer pointed out that the (then) existing neuroscience mostly addressed the effects of gross neglect, and evidence of critical periods in development was derived mainly from animal studies of sensory deprivation. It couldn't support the more general claims about early development across entire human populations. Since then, scientists have worked harder to delimit the implications of their research[2], to which we finally turn.

Implications for policy

Researchers are now more aware of the perils of too simplistic links to policy implications; nevertheless, the essence of cognitive neuroscience research is to point towards interventions to reduce the impact of family differences on SES on child development. As Bruer himself said, 'What science can add to the policy debate are insights about the causes, mechanism, and leverage points that we could most effectively exploit to reach our goal.' (1999, p.26). Researchers such as Hackman and colleagues (2010), Raizada and Kishiyama (2010), and Sheridan and McLaughlin (2016) have pointed to several implications.

First, just because the effects of low SES are measurable in the brain does not imply they cannot be reversed. Outside of cases of severe neglect, many cognitive differences shown by children from very low SES families respond well to training techniques, such us those that focus on executive functions and engage with parents.

Second, a mechanistic perspective highlights multiple points of possible intervention (directly on SES, indirectly on experiences or biological processes that mediate SES effects, indirectly on brain development by training specific neurocognitive functions, and directly on outcomes educationally or therapeutically); and they allow fostering of factors of resilience such as the caregiver-child relationship.

Third, measures of brain function make the greatest contribution where they can show that two individuals with similar behaviour are actually exhibiting it for different reasons. This might imply that, for example, childhood emotional regulation difficulties caused by adverse childhood events are best addressed by therapies addressing traumatic experiences, while those caused by lack of cognitive stimulation are best addressed by learning opportunities scaffolded to encourage self-regulation.

Neuroscience is now influencing policy dialogues. It remains the responsibility of researchers to assure the quality of the information that is shared as well as the limits of its interpretation. While David Cameron's Life Chances Strategy has slipped out of view, its key elements may yet reappear, perhaps within the more graduated approach favoured by the new Prime Minister 'to give a fair chance to those who are just getting by – while still helping those who are even more disadvantaged' (speech by Teresa May, 9th September 2016).

Notes

1. A joint meeting of the Education and Work & Pensions Select Committees in the summer of 2016 nevertheless considered evidence around the relationship between early years education and proposed the Life Chances Strategy; and evidence around cross-departmental co-ordination on early years interventions and interaction with the benefits system and public services. See: https://www.parliament.uk/business/committees/committees-a-z/commons-select/education-committee/inquiries/parliament-2015/foundation-years-and-the-uk-governments-life-chances-strategy-15-16/
2. I gave evidence on this specific point to the above Select Committee: 'Can I also make a follow-up point about the importance of early years' intervention? From the point of view of brain plasticity and when the brain is most plastic, there is sometimes a risk of overplaying the idea that the first few years are the most important. These years are clearly important but so are the following years. In many respects, brain plasticity is a lifelong property. Particularly, we know that many parts of the brain are still developing into adolescence. Adolescence is the time when many high-level cognitive skills are developing, skills that are going to be needed in the workplace and are important for later life success. We need support in the educational structures around the development of those later skills as well as those in the early years.'

References

Hackman D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic status and executive function: developmental trajectories and mediation. *Developmental Science*, *18(5)*, 686-702. doi:10.1111/desc.12246.

Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, *13*, 65–73. doi:10.1016/j.tics.2008.11.003

Hackman, D. A., Farah, M. J., & Meaney, M. J. (2010). Socioeconomic status and the brain: Mechanistic insights from human and animal research. *Nature Reviews Neuroscience*, *11*, 651– 659. doi:10.1038/nrn2897

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Brookes.

Heckman, J. J. (2006). Skill formation and the economics of investing in disadvantaged children. *Science*, Vol. 312, Issue 5782, pp. 1900-1902. Doi:10.1126/science.1128898

Hjern, A., Weitoft, G. R., & Lindblad, F. (2010). Social adversity predicts ADHD-medication in school children--a national cohort study. *Acta Paediatr*. 2010 Jun;99(6):920-4. doi: 10.1111/j.1651-2227.2009.01638.x.

Noble, K., G., Houston, S. M., Brito, N., H., Bartsch, H., … & Sowell, E. R. (2015). Family income, parental education and brain structure in children and adolescents. *Nature Neuroscience*, *18*, 773–778. doi:10.1038/nn.3983

Raizada, R. D. S., & Kishiyama, M. M. (2010). Effects of socioeconomic status on brain development, and how cognitive neuroscience may contribute to levelling the playing field. *Frontiers in Human Neuroscience*, *4(3)*. doi:10.2289/neuro.09.003.2010

Sapolsky, R. M. (2005). The influence of social hierarchy on primate health. *Science*, *308*, 648-652. 10.1126/science.1106477

Sheridan, M. A., & McLaughlin, K. A. (2016). Neurobiological models of the impact of adversity on education. *Current Opinion in Behavioral Sciences*, 10, 108-113. doi:10.1016/j.cobeha.2016.05.013

Shah, A. K., Mullainathan, S., & Shafir, E. (2012). Some consequences of having too little. *Science*, Vol. 338, 682–5

Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: An event-related brain potential study. *Developmental Science*, *12(4)*, 634–646. doi:10.1111/j.1467-7687.2009.00807.x

Weaver, I. C. G., Cervoni, N., Champagne, F. A., … & Meaney, M. J. (2004). Epigenetic programming by maternal behavior. *Nature Neuroscience*, 7, 847 - 854. doi:10.1038/nn1276