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Learning difficulties:

Future challenges

MENTAL CAPITAL AND WELLBEING PROJECT

Mental Capital and Wellbeing: Making the most of ourselves in the 21st century

Learning difficulties: Future challenges

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This report is intended for:

Policy makers and a wide range of professionals and researchers whose interests relate to childhood development and learning difficulties. The report focuses on the UK but is also relevant to the interests of other countries.

This report should be cited as:

Goswami, U. (2008)
Foresight Mental Capital and Wellbeing Project.
Learning difficulties: Future challenges.
The Government Office for Science, London

The author and the Government Office for Science would like to thank the many experts from around the world who contributed to the work of this report. In particular: Professor Uta Frith, Professor Sir Michael Rutter and Professor Eric Taylor for their advice in the peer review process; the authors of the commissioned supporting papers; the firm shiftN who worked on the futures and systems aspects; and the large number of individuals and organisations and parts of Government who freely contributed advice and assistance, and who generously allowed their research results to be used.

The Foresight Programme is run by the UK Government Office for Science under the direction of the Chief Scientific Adviser to HM Government. Foresight strengthens strategic policy-making in government by embedding a futures approach.

Contents

Executive summary

The aim of the Foresight Project on Mental Capital[1] and Wellbeing[2] (www.foresight.gov.uk) is to advise the Government on how to achieve the best possible mental development and mental wellbeing for everyone in the UK in the future.

The starting point of the Project was to generate an understanding of the science of mental capital and wellbeing and to develop a vision for how the size and nature of the challenges exposed by the Project could evolve over the next 20 years – using the baseline assumption that existing policies and expenditure remain unchanged. To make the analysis tractable, the work was divided into five broad areas:

- Mental capital through life
- Learning through life
- Mental health
- Wellbeing and work, and
- Learning difficulties.

A comprehensive assessment of the scientific state-of-the art for these areas was undertaken by commissioning around 80 reviews. This report draws together the findings for "Learning difficulties" and identifies key challenges for the future. The final Project report, due for publication in October 2008, assesses policy choices and possible interventions across all five areas.

The evidence has shown that recent advances in genetics and neuroscience have led to important new insights into the heritable neural bases of many common learning difficulties. In particular, brains with learning difficulties are brains that are less efficient in particular and measurable aspects of processing; other aspects of processing are frequently preserved. Learning difficulties are biological in origin, but environments and genes interact, so that environments determine the impact of carrying certain genes, with co-action of genes and environments affecting the developmental trajectory[3].

An assessment of the situation today (Chapter 1) highlights the increased risk that children with learning difficulties suffer from mental ill-health, social exclusion, unemployment and criminal behaviour. Overall learning difficulties are estimated to affect up to 10% of children. Also, children affected with LDs (e.g. dyslexia, Attention Deficit Hyperactivity Disorder (ADHD), and Specific Language Impairment[4]) can show more than one disorder. For example, between 10–50% of children with SLI may also

1 Mental capital refers to the totality of an individual's cognitive and emotional resources, including their cognitive capability, flexibility and efficiency of learning, emotional intelligence (e.g. empathy and social cognition), and resilience in the face of stress. The extent of an individual's resources reflects his/her basic endowment (genes and early biological programming), and their experiences and education, which take place throughout the lifecourse.

2 "Wellbeing" throughout this report refers to "mental wellbeing". Mental wellbeing is a dynamic state in which the individual is able to develop their potential, work productively and creatively, build strong and positive relationships with others, and contribute to their community. It is enhanced when an individual is able to fulfil their personal and social goals and achieve a sense of purpose in society.

3 Karmiloff-Smith (SR-D13). This is one of a number of science reviews commissioned by the Project. See Appendix B for a full list.

4 Snowling (SR-D2); Butterworth (SR-D4); Simonoff (SR-D11); Bishop (SR-D1)– see Appendix B

have developmental dyslexia. These children are essentially at the low end of the continuum of ability for reading, mathematics, distractibility or language. All of these learning difficulties have a brain basis and tend to run in families. Less common inherited learning difficulties (e.g. autism spectrum disorders[5]) also appear to represent the lowest point on an ability continuum. Thus those with appreciable but non-clinical difficulties with social cognition (e.g. a less severely-impaired ability to read the feelings and intentions of others) may still experience severe effects on their mental capital. For example, some children excluded from school for apparently wilful disruptive behaviour exhibit similar behaviours to children identified with disorders of social cognition[6].

The review of scientific developments has enabled the creation of a conceptual model describing the typical and atypical development of learning (Chapter 1). This model has been used as a conceptual framework for Chapter 2, which considers the multiple factors that influence the outcomes of learning difficulties in individuals. In turn, this analysis has provided signposts to possible strategies for interventions – both today and in the future (see below, and Chapter 3).

Scientific advances in genetics and neuroimaging offer a potential opportunity, within the next 20 years, to identify those children with learning difficulties in infancy. Genetic tests may be able to offer individualised diagnoses of a child's risk at a probabilistic level[7]. Cognitive neuroscience is already uncovering neural markers, or biomarkers, for detecting the different learning difficulties, measurable in infancy[8]. These advances will eventually enable environmental intervention from infancy. Such environmental interventions should be broadly conceived, and could include technological interventions (e.g. a cochlear implant for a deaf infant), improving caretaking behaviours, sensory interventions (e.g. to reinforce the acoustic information in language), new educational interventions (e.g. learning environments that enhance self-regulation skills, technology-enhanced learning of basic reading and numerical skills) and pharmacological cognitive enhancers[9].

Early detection and intervention would alter developmental learning *trajectories* for these children with consequent benefits throughout the lifecourse. This is clear from two fundamental principles of learning: early capability makes later learning more efficient; and enhancing early capability at the outset of learning also increases the complexity of what can be learned[10]. Enhancing mental capital at the beginning of learning will increase cognitive flexibility and cognitive reserve[11], as well as neural resilience[12], thereby improving future learning and future mental capital and wellbeing.

Current scientific knowledge provides clear guidance with respect to the cognitive and behavioural identification of future learning difficulties in the early primary years, and also guidance for optimal education and support (see Future Scenarios – Chapter 3). Importantly, the kinds of interventions that help children with learning difficulties can be similar for a number of learning difficulties.

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5 Baron-Cohen (SR-D10) – see Appendix B
6 Skuse (SR-D9) – see Appendix B
7 Plomin (SR-D7) – see Appendix B
8 Friedrich (SR-D14) – see Appendix B
9 See Project report, Kirkwood et al. *Mental capital through life: Future challenges* (Appendix A refers)
10 Heckman (2006)
11 Barnett and Sahakian (SR-E4) – see Appendix B
12 Elliott et al. (SR-E7) – see Appendix B

Developmental difficulties that affect learning, and that can be equally negative with respect to future mental capital and wellbeing, can be dramatically increased by adverse early social experiences, typically within dysfunctional and socially-disadvantaged environments (e.g. anti-social behaviour and conduct disorders[13]). Interventions that improve anti-social behaviour disorders will benefit a number of other learning difficulties (e.g. interventions aimed at improving "executive function", namely strategic control over one's cognitive and emotional processes[14]). Finally, there are later-onset disorders such as depression[15] and eating disorders[16] which emerge in adolescence and may also impair learning. These disorders also impact negatively on mental capital and wellbeing, and typify the overlap between learning difficulties and mental health (also considered by the Project – see Appendix A).

The evidence considered in this analysis shows that the interaction between learning difficulties, mental capital and mental wellbeing is profound and important. It also highlights those scientific developments which enable the development of new approaches to identification and treatment over the next 20 years. The final Project report[17] considers the interventions for learning difficulties which are likely to have the greatest potential for improving mental capital and wellbeing.

13 Hughes (SR-D8); Wolf and Buss (SR-E20) – see Appendix B

14 Greenberg (SR-A9); Bishop (SR-D1); Snowling (SR-D2); Hughes (SR-D8); Skuse (SR-D9); Baron-Cohen (SR-D10); Simonoff (SR-D11); Goodyer (SR-D15); Treasure (SR-D16) Barnett and Sahakian (SR-E4); Bradshaw (SR-E6); Paulus and Tapert (SR-E8); Sebastian et al. (SR-E15) – see Appendix B

15 Goodyer (SR-D15) – see Appendix B

16 Treasure (SR-D16) – see Appendix B

17 To be published in October 2008

1 The situation today

1.1 Introduction

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1.4 The most frequent learning difficulties of childhood

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1 The situation today

Chapter 1 considers the prevalence of common learning difficulties in children and assesses their impact though the lifecourse. Reciprocal effects and co-morbidity are also assessed.

Current scientific understanding of learning difficulties is also reviewed, and a model for typical and atypical learning is presented. This model forms a conceptual basis upon which the rest of this report is based.

1 The situation today

1.1 Introduction

The aim of the Foresight Project on Mental Capital[18] and Wellbeing[19] (www.foresight.gov.uk) is to advise the Government on how to achieve the best possible mental development and mental wellbeing for everyone in the UK in the future.

The starting point of the Project was to generate an understanding of the science of mental capital and wellbeing and to develop a vision for how the size and nature of the challenges exposed by the Project could evolve over the next 20 years – using the baseline assumption that existing policies and expenditure remain unchanged. To make the analysis tractable, the work was divided into five broad areas:

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A comprehensive assessment of the scientific state-of-the art for these areas was undertaken by commissioning around 80 reviews. This report draws together the findings for the last of these areas and identifies key challenges for the future. The final Project report, due for publication in October 2008, assesses policy choices and possible interventions across all five areas.

The evidence has shown that recent advances in genetics and neuroscience have led to important new insights into the heritable neural bases of many common learning difficulties. In particular, brains with learning difficulties are brains that are less efficient in particular and measurable aspects of processing; other aspects of processing are frequently preserved. Learning difficulties are biological in origin, but environments and genes interact, so that environments determine the impact of carrying certain genes, with co-action of genes and environments affecting the developmental trajectory[20]. We begin by setting out the current trends in the prevalence of learning difficulties in the UK.

1.2 Prevalence

The common learning difficulties of childhood have relatively high prevalence rates, even when conservative criteria for identification are employed (see Table 1.1).

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19 "Wellbeing" throughout this report refers to "mental wellbeing". Mental wellbeing is a dynamic state in which the individual is able to develop their potential, work productively and creatively, build strong and positive relationships with others, and contribute to their community. It is enhanced when an individual is able to fulfil their personal and social goals and achieve a sense of purpose in society.

20 Karmiloff-Smith (SR-D13) – this is one of a number of science reviews commissioned by the Project. See Appendix B for a full list.

Incidence rates range from 1% for autism to 5-10% for anti-social behaviour and conduct disorder. Learning difficulties are inherited, with environmental experiences affecting both basic liability and developmental trajectories, and many learning difficulties reflect the low end of a continuum of ability (e.g. the low end of the normal distribution of reading, number or distractibility). Because they reflect a developmental continuum, this means that there is no sharp dividing line between having a learning difficulty and not having one.

A good analogy is drawing a dividing line concerning whether a child is "small" or not. Smallness is heritable, but to decide whether a particular child is "small" requires a comparison with the peer group, and a consideration of the functional effects of being "small". It may be decided that only children in the lowest 5% of the distribution of height should be identified as small, or alternatively it may be decided that children in the lowest 10% of the distribution should be identified as small. In the former case, children who are near to the low end of the distribution and who are still rather small compared to their peers would not be identified as "small". If "smallness" carried other costs, this could matter for these particular children. Applying this analogy to learning difficulties, we can see that children close to the tail of a particular normal distribution will also show considerable difficulties, despite not meeting the particular criteria used to define the prevalence of a specific learning difficulty (methodologies and criteria used to determine these prevalence rates vary for different learning difficulties, as reflected in Project science reviews – see Appendix B for full list). Overall learning difficulties are estimated to affect up to 10% of children. Also, children affected with learning difficulties (e.g. dyslexia, Attention Deficit Hyperactivity Disorder (ADHD), and Specific Language Impairment[21]) can show more than one disorder.

Table 1.1: Estimated prevalence of learning difficulties in children in the UK[22]

Condition	Estimated percentage (%)
Dyslexia[23]	4 – 8
Attention Deficit Hyperactivity Disorder (ADHD)[24]	3 – 6
Anti-social behaviour/Conduct disorder (ASB/CD)[25]	5 – 10
Dyscalculia[26]	3.6 – 6.5
Specific Language Impairment (SLI)[27]	7
Autism[28]	1
Deafness[29]	1 – 2

Unfortunately, specific learning difficulties are rarely identified until relatively late in childhood. This is because parents and teachers are commonly ill-informed about learning difficulties, and specialised support is absent or is difficult to access. Late identification means

21 Snowling (SR-D2); Butterworth (SR-D4); Simonoff (SR-D11); Bishop (SR-D1)– see Appendix B
22 Based on age ranges from around 5 to 12 years.
23 Snowling (SR-D2) – see Appendix B
24 Simonoff (SR-D11) – see Appendix B
25 Hughes (SR-D8) – see Appendix B
26 Butterworth (SR-D4) – see Appendix B
27 Bishop (SR-D1) – see Appendix B
28 Baron-Cohen (SR-D10) – see Appendix B
29 Woll (SR-D5) – see Appendix B

that poor self-esteem and negative beliefs about self-efficacy are already established in the child. Consequently, cognitive resilience[30] and cognitive reserve[31] are adversely affected.

Currently, identification of dyslexia or dyscalculia typically occurs at around 8–9 years. By this age, an atypical learning trajectory is relatively entrenched. Similarly, there is poor understanding of why children with anti-social behaviour or with difficulties in social cognition behave as they do, and poor knowledge about how best to help these children. Anti-social behaviour is a growing concern for schools, and exclusion from learning is an increasingly common response[32].

1.3 Learning and learning difficulties: current understanding

Recent research on what babies hear and see has revealed that the brain learns from every sensory event, extracting statistical patterns such as which visual features co-occur together (e.g. wings and beaks co-occur systematically). This very simple event-based learning is largely unconscious, but it is a crucial part of cognitive development. The infant brain essentially learns about correlations and systematic co-occurrences across sensory modalities like hearing, vision and touch, enabling construction of a complex cognitive system from basic sensory stimulation. By watching visual events, listening to language and other sounds and studying goal-directed behaviour, the infant rapidly develops a linguistic and conceptual system and the ability to read intentions[33].

Prior to the development of cognitive neuroscience, it was believed that infants must be born with "pre-knowledge" of complex skills such as language, as it seemed implausible that the brain could learn language or concepts such as causation from environmental stimuli alone. Yet event-based learning does enable the extraction of causal information, and causal learning is a crucial part of cognitive development. It is now accepted that very complex learning is achieved by means of simple on-off brain cells that activate in networks, using elegant and powerful mathematical algorithms discovered by research in machine learning (e.g. causal Bayes nets and explanation-based learning).

The human brain also learns by imitation and by analogy, and the acquisition of language boosts learning enormously. Children can use language to reflect upon and change their own cognitive functioning (this is called metacognition). Whereas animals can also have a basic self-concept (e.g. elephants can recognise themselves in mirrors[34]), can achieve causal learning (e.g. rats learn in accordance with causal Bayes nets[35]), and can learn some linguistic labels (e.g. some dogs "know" 200 words[36]), they appear incapable of learning by imitation and analogy, and do not develop language. Language is the core symbolic system underpinning human cognitive activity, vastly increasing the efficiency of memory, reasoning and problem solving. Symbolic systems (language, writing, numbers, pictures, maps) enable the individual to develop a cognitive system that goes beyond the constraints of biology (e.g. oral memories hold less information than books). Symbol systems also enable explicit self-regulation: humans can use language to organise and improve their own cognitive performance. Hence mental capital can be improved by using metacognitive strategies and executive functions. Executive functions are "executive" abilities such as the intentional monitoring and self-regulation of thought and action, the

30 Elliott et al. (SR-E7) – see Appendix B
31 Barnett and Sahakian (SR-E4) – see Appendix B
32 Skuse (SR-D9) – see Appendix B
33 Goswami (2008)
34 Plotnik et al. 2006
35 Blaisdell et al. 2006
36 Kaminski et al. 2004

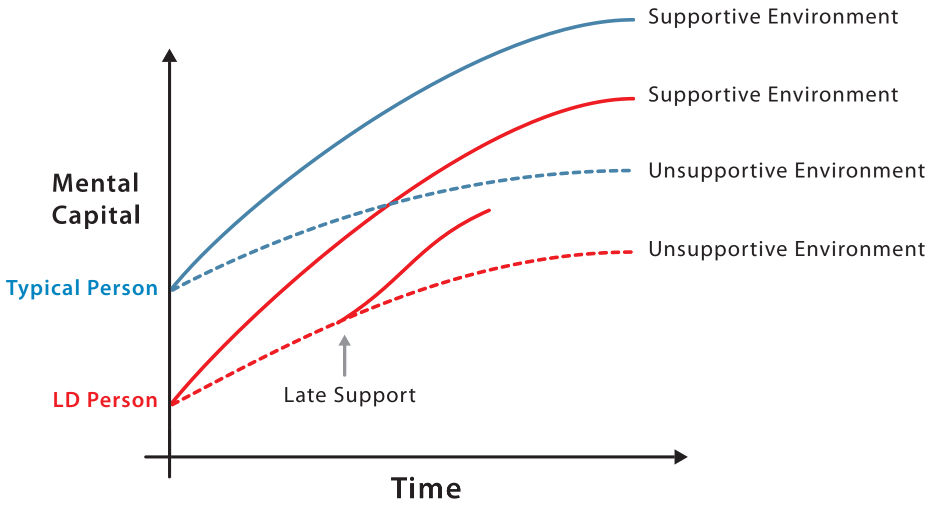
ability to plan behaviour and the ability to inhibit inappropriate responses. Metacognitive skills can be taught to very young children.

A neuro-cognitive analysis of learning has led, in turn, to a new understanding of learning difficulties. Most of the expert reviews that were commissioned to inform this report emphasise the neurodevelopmental origins of the common learning difficulties. Brains with learning difficulties are brains whose biology makes them less efficient in particular and measurable aspects of processing. Even individuals with very low intelligence or with inherited genetic disorders that impair global IQ learn language and concepts, and function in the world in largely similar ways to non-affected individuals (but at a significantly impaired overall level[37]).

Recent research suggests that quite small perturbations or inefficiencies in the sensory processing systems that yield the information used by the brain in learning are associated with major effects on learning trajectories[38]. For example, very subtle impairments in auditory processing are associated with impaired language acquisition, and can be detected using simple brain responses to sound[39]. Similar auditory impairments are implicated in developmental dyslexia and in specific language impairment[40]. Subtle impairments in visual processing (e.g. "reading information in the eyes") are found in autism spectrum disorders. Children with autism and with anti-social behaviour and conduct disorders tend to have difficulties with language, executive function and "theory of mind" (understanding the mental states of others).

It is becoming possible to identify neural and genetic markers for risk for all the common learning disorders. This new science raises the possibility of very early intervention, enabling learning across the lifespan to follow a different trajectory. This possibility is illustrated in Figure 1.1.

Figure 1.1: A schematic representation of developmental learning trajectories



1.4 The most frequent learning difficulties of childhood

Analysis of the state-of-science reviews suggest that the common learning difficulties of childhood cluster into two groups:

37 Holland (SR -D3) – see Appendix B
38 Karmiloff-Smith (SR-D13) – see Appendix B
39 Friedrich (SR-D14) – see Appendix B
40 Lyytinen (SR-D12) – see Appendix B; Corriveau et al. (2007); Goswami et al. (2002)

a. **Disorders of basic learning of symbolic systems.** These comprise developmental dyslexia (difficulties with reading and writing), developmental dyscalculia (difficulties with number), Specific Language Impairment (SLI), and deafness. There are significant gender differences: boys are more often affected in developmental dyslexia than girls (4:1) and in SLI (3:1). However, in developmental dyscalculia and deafness, which can give rise to developmental language and literacy difficulties, there are no gender differences.

   Developmental dyslexia and SLI are associated with subtle problems in auditory processing [41], and with the impaired acquisition of grammar and phonology. (Phonology is the smallest sound units of a language whereby substitutions create new meanings e.g. cap – cup); phonology is important for acquiring literacy[42]). Sensory disorders such as deafness, in which the input system for receiving and representing auditory information is defective, cause similar language-based problems, with consequential effects for social cognition (understanding the feelings and intentions of others)[43]. Developmental dyscalculia is associated with impairment to the neural representation for magnitude, which is the core of our "number sense"[44].

   Each disorder of symbolic learning requires a different specific, targeted intervention. These interventions may either target the impaired system (e.g. phonology for developmental dyslexia), or seek further to boost systems that are already well-functioning (e.g. "speech-reading" for deaf children) either to bypass or supplement impaired systems.

b. **Disorders of social cognition and executive function.** These may be grouped according to an impaired ability to intuit the psychological states of others (their mental states, beliefs, and emotions), and/or an impaired strategic ability of the child to self-regulate his or her own mental states and behaviour by, for example, sustaining attention or by controlling anger.

   In autism spectrum disorders, the key difficulty lies in understanding the mental states of others. This ability is also impaired in anti-social behaviour and conduct disorders, which additionally show impaired development of the ability to inhibit thoughts and actions and to change behaviour flexibly in response to social and environmental cues. Children with ADHD are overactive, showing fidgeting and motor restlessness, impulsive in their behaviour, often acting without considering the consequences of their actions, and have difficulties with sustained and selective attention. Difficulties with social cognition and executive function also mean that the child has difficulty in adapting his or her own social behaviour to the current context. These difficulties impair the child's ability to form friendships, to function efficiently in the classroom and eventually to parent effectively. Difficulties continue into adulthood for one- to two-thirds of these children, and are associated with adjustment problems such as nicotine abuse and with low educational attainment[45].

   In childhood, the failure to understand "what is going on" that is part of impaired social cognition, can cause anger and frustration, which may be "acted out" (e.g. temper tantrums, non-compliance and defiance, aggression, violence and deliberate

41 Friedrich (SR-D14) – see Appendix B, though there is still debate

42 Lyytinen (SR-D12) – see Appendix B

43 Woll (SR-D5) – see Appendix B

44 Butterworth (SR-D4) – see Appendix B

45 Fontaine et al., 2008

provocation). Impaired social cognition also characterises children who are depressed, and depression is a common precursor of eating disorders[46]. Those with eating disorders also show impaired executive function, particularly with respect to attentional flexibility ("set shifting".).

There are gender differences, with boys more often affected in ADHD (4:1), autism spectrum disorders (4:1), and anti-social behaviour and conduct disorders (4:1), but not in depression nor eating disorders in childhood. Gender differences emerge in the latter two disorders in adolescence, with greater vulnerability for girls in both cases.

1.5 Reciprocal effects and co-morbidity

Due to the two principles of learning identified above (early capability makes later learning more efficient, and enhancing early capability at the outset of learning increases the complexity of what can be learned), each disorder of learning will also have reciprocal effects on the mental capital and wellbeing of the individual. For example, self-concept is an emergent property of cognition, emotion and motivation. Hence the cognitive difficulties experienced by a child with a learning difficulty may lead to poor self-esteem, or to frustration resulting in disengagement from learning and lack of motivation to learn (e.g. as in developmental dyslexia[47]). Developmental dyscalculia raises the risk for depression threefold, and doubles the risk of unemployment[48]. The later in life that a learning difficulty is identified, the wider the range of interventions that will be required. Developmental trajectories are more readily intercepted than reversed[49].

Developmental learning difficulties can also be co-morbid (occur together). Some co-morbidities may arise from shared causation, although this needs to be established (e.g. the co-morbidity between developmental dyslexia and SLI may reflect associated auditory-sensory processing problems, and estimates of joint occurrence for the two disorders range between 10-50%[50]). Similarly, the co-morbidity between eating disorders and obsessive-compulsive disorders may reflect atypical development of the neural systems for emotional regulation. Other co-morbidities more probably reflect shared cognitive *consequences* of difficulty: for example, the co-morbidity between ADHD and anti-social behaviour/conduct disorder (40–70%) is likely to reflect the poor executive function skills shared by both disorders, resulting in impulsivity, distractibility and difficulties in sustaining attention. Executive function develops in the early primary years, particularly between the ages of 3 and 7. While poor executive function appears to be a primary impairment for ADHD, for anti-social behaviour and for conduct disorders, it appears to be secondary (to a primary impairment) in social cognition and language development arising from dysfunctional family relationships.

In addition to these two clusters of learning difficulties, which present across the IQ range, there are *learning disabilities* that are defined on the basis of very low IQ (<70, which is two standard deviations below average[51]). These are most usually typified as generalised intellectual disabilities[52] rather than learning difficulties, as they are typically generalised across cognition, social cognition and executive function, are resistant to

46 Goodyer (SR-D15); Treasure (SR-D16) – see Appendix B

47 Snowling (SR-D2) – see Appendix B

48 Butterworth (SR-D4) – see Appendix B

49 Hughes (SR-D8) – see Appendix B

50 McArthur et al. (2000)

51 Holland (SR-D3) – see Appendix B

52 Mild range = IQ 70 – 50; severe range = IQ <50

intervention, and characterise a very heterogeneous group who require high levels of support throughout life. Generalised intellectual disability can occur because of genetic syndromes (e.g. Down's syndrome, Fragile X syndrome), other prenatal abnormalities, severe birth complications or postnatal environmental hazards. Individuals with generalised intellectual disabilities will show considerable variation in overall mental capital and wellbeing depending on social and environmental factors such as family support, resources and opportunities, and stigma and social exclusion. For example, some people with Down's syndrome can lead independent lives despite their low IQ. However, life expectancy is reduced for those with generalised intellectual disabilities. This is not the case for the two clusters of learning difficulties described above.

1.6 A learning model for typical and atypical development

All forms of learning important for human cognition are present in rudimentary form from birth. As noted earlier, these comprise neural statistical learning, learning by imitation, learning by analogy and causal learning. Developmental cognitive neuroscience reveals how powerful these learning mechanisms are. Automatic statistical learning processes in sensory systems provide the foundation for constructing a cognitive system[53]. For example, simple perceptual information about motion can distinguish mechanical agents (regular, predictable motion) from biological agents (self-initiated, erratic motion), thereby underpinning conceptual development (natural kinds versus artefacts) and the development of intention-reading.

However, in order to learn efficiently, the sensory systems of the brain (vision, audition, touch etc.), the motor systems (reaching, grasping, moving one's eyes) and the emotional/reward system must be developing normally. In many developmental learning difficulties, one or more of these systems may be developing atypically. This has a profound impact on developmental trajectories.

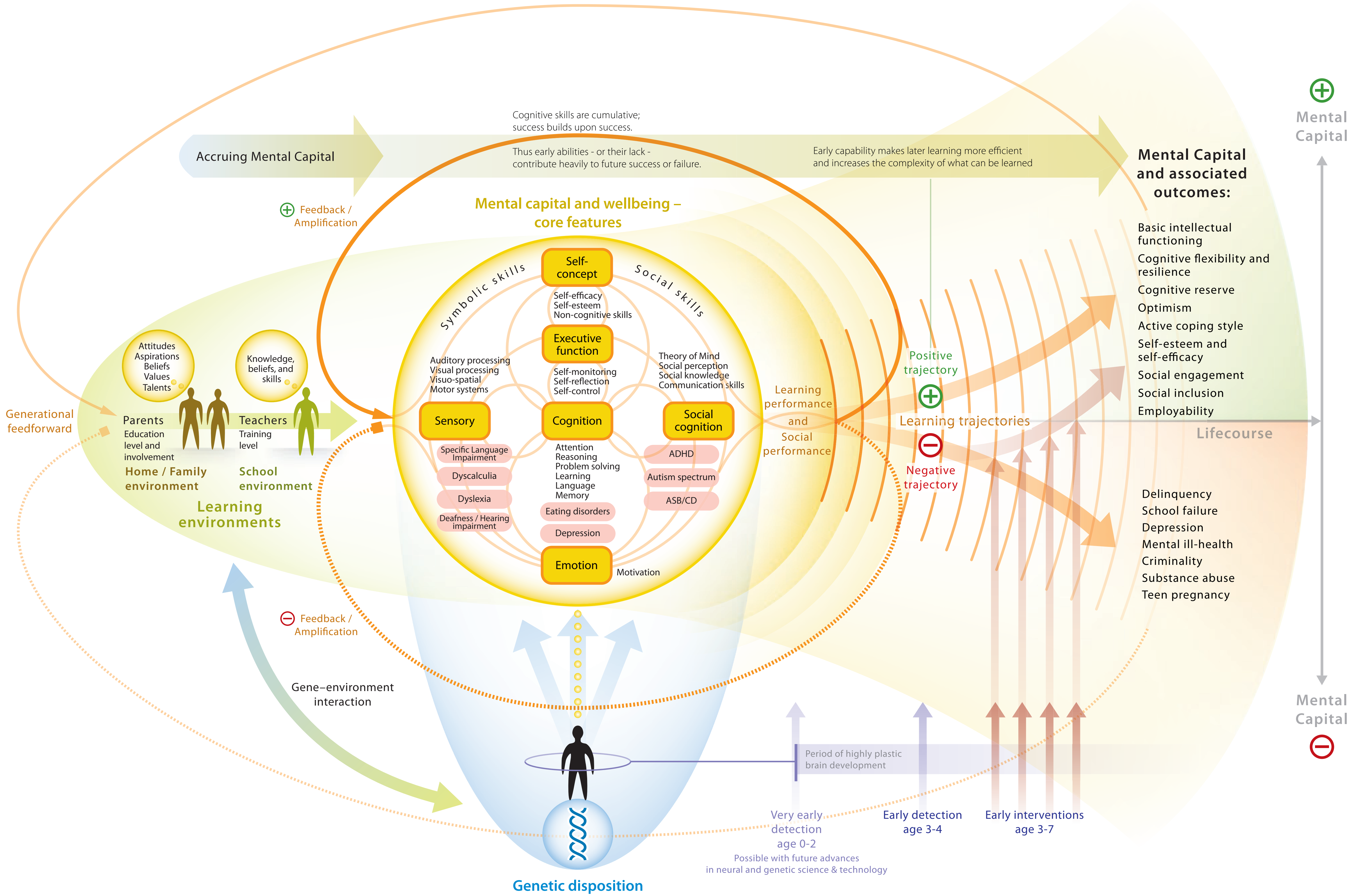
Examples of sensory processing have been briefly discussed, but emotional processing can be equally important. Eating disorders are seen as primarily emotional in origin, with those affected having atypical emotional awareness and emotional "intelligence"[54]. As another example, children with anti-social behaviour and conduct disorders show a hostile "attribution bias", tending to (mis)attribute anger to the actions and statements of others[55]. The cognitive systems developed by children with sensory or emotional processing difficulties may end up looking very different from the cognitive systems of typically-developing children, even though at the outset differences may be quite small.

A conceptual model of the most important factors influencing the development of a child's mental capital and wellbeing has been developed within the Foresight Project and is presented in Figure 1.2. This model has helped to conceptualise the various factors and their interrelationships and was developed by reference to relevant state-of-science reviews that were commissioned by the Project[56], as well as through consultations with leading experts. The model is intended to help in:

a. analysing developmental trajectories for different learning difficulties, so that the likely utility of intervening at different points in development can be assessed;

53 For a detailed analysis, see Goswami (2008)
54 Treasure (SR-D16) – see Appendix B
55 Schultz et al. 2004
56 See Appendix B

Figure 1.2: A conceptual model for learning difficulties



b. identifying the kinds of intervention likely to be useful for each learning difficulty – some interventions may benefit a number of learning difficulties; and

c. identifying developmental interactions and synergies.

The core components of the model are introduced below. In Chapter 2 the causal factors (termed "drivers") that affect learning and which relate to this model are discussed[57].

First, it should be emphasised that the different core aspects of mental capital and wellbeing depicted in Figure 1.2 will not hold the same status across development. For example, by adulthood, social cognition and executive function will be conceptualised as different aspects of general cognition[58]. In contrast, for children, general cognition is understood as encompassing learning, memory, attention, language, reasoning and problem-solving. Social cognition and executive function initially develop somewhat independently of these basic cognitive abilities.

Social cognition is the ability to interpret the psychological states of others, and executive function is intentional self-regulation. The development of social cognition and executive function depend to some extent on adequate language development, and also on specific developmental factors such as intention-reading (e.g. children with autism spectrum disorders have poor intention-reading skills and therefore poor social cognition). Executive function encompasses: the ability strategically to inhibit certain thoughts or actions; the ability to develop conscious control over one's thoughts, feelings and behaviour; and the ability to respond flexibly to change, all of which develop gradually in children.

Executive function also encompasses another important concept in developmental psychology: "metacognitive" behaviour – sometimes called "learning to learn"[59]. Metacognitive behaviour is self-reflective learning behaviour, and encompasses the ability of a person to reflect on their information-processing skills, the ability to monitor their cognitive performance, and the ability to be aware of the demands made upon them as an individual by different kinds of cognitive tasks. Adults are assumed to be capable of self-reflective behaviour, and to have adequate social cognition; hence in the adult mental capital and wellbeing models executive function and social cognition are merged with cognition.

The self-concept is conceptualised here as an emergent property of the child's cognitive, social-cognitive and executive function abilities, along with their sensory/emotional functioning and neurobiological make-up[60]. Developmental psychology shows that a child's self-esteem, sense of identity and "inner working model" of their value as a person who is deserving of love and support from others depends on responsive care-giving and security of attachment, and quality of social relationships[61]. In Figure 1.2, the self-concept is also intended to encompass what are sometimes termed "non-cognitive skills", such as tenacity, diligence, optimism, active coping style

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57 A detailed explanation of the model can be found in a separate Project report, S1: Systems Maps – See Appendix B. That report will also include models that relate to other parts of the Foresight Project – see Appendix A.

58 See also the Foresight Project summary reports: Kirkwood et al. *Mental capital through life: Future challenges* Feinstein et al. *Learning through life: Future challenges* Jenkins et al. *Mental health: Future challenges* and Dewe and Kompier et al. *Wellbeing and work: Future challenges* (Appendix A refers).

59 Hargreaves (2005)

60 Wolff and Buss (SR-E20) – see Appendix B

61 e.g. Fonagy and Target (1997); Fonagy et al. (2002)

and the ability to focus on a personal goal. Some of these skills are also described as "motivation" or subsumed by executive function.

2 Causal drivers of learning difficulties with reference to the model

2 Causal drivers of learning difficulties with reference to the model

This chapter introduces six important factors that affect the development of an individual's mental capital and wellbeing. They are: sensory processing; cognition; social cognition; executive function; emotional/motivational processing; and self-concept.

The role and importance of each is considered, and placed within the context of the conceptual model which was introduced in Chapter 1.

2 Causal drivers of learning difficulties with reference to the model

The six core features that contribute to the development of an individual's mental capital and mental wellbeing defined in the model (Figure 1.2) are: sensory processing; cognition; social cognition; executive function; emotional/motivational processing; and self-concept.

The state-of-science reviews that were commissioned suggest that developmental disorders of the basic learning of symbolic systems are associated primarily with difficulties in sensory and cognitive processing. In contrast, the developmental disorders of social cognition and/or executive function are associated primarily with impaired social cognition and impaired executive function, which may co-occur with impaired emotional processing. All learning difficulties have an impact on self-concept, although individual differences in self-concept (e.g. persistence) will also moderate or amplify the effects of impairments in the other core features.

2.1 Sensory processing

The effective functioning of the sensory and motor systems of the brain is critical to all subsequent learning. The main sensory systems involved in learning difficulties are hearing, vision and touch. Visual and auditory cortex undergo rapid synaptic development and pruning, with adult levels of synaptic density reached by 2-4 years of age. Motor cortex also develops rapidly, with major development occurring in the first decade of life. As we shall see, sensory interventions are likely to be of most benefit very early in development, as they will affect subsequent cognitive development. An example is cochlear implants for children who are born deaf.

2.1.1 Auditory processing

Developmental dyslexia and Specific Language Impairment (SLI) are reliably associated with subtle impairments in auditory processing. Regarding **developmental dyslexia**, Lyytinen[62] reports on the world's first large-scale prospective longitudinal study to identify at-risk infants on the basis of familial genetic risk, and to follow these children from birth. Using neural imaging (EEG), the study found impairments at the group level in auditory sensory processing early in infancy, for both speech and non-speech sounds, which predicted language and reading development. Both this Finnish study and comparable English studies have identified the auditory cues of duration and rise time (rise time is the rate of change of the amplitude of sounds) as impaired in children and adults with developmental dyslexia[63]. Theoretically, impairment of these auditory cues would affect the ability to learn language efficiently utilising prosodic cues (rhythmic cues) in the speech stream. As mothers and other caretakers use a special prosodic register ("Motherese", or infant-directed speech) to talk to babies, these subtle auditory impairments would affect the developmental trajectories for language development. In particular, these sensory processing difficulties would impair the development of the phonological (sound-based) representations of speech. The phonological lexicon is considered part of the cognitive system (i.e. it is part of the language system).

62 Lyytinen (SR-D12) – see Appendix B

63 Goswami et al. (2002); Richardson et al. (2003), (2004); Hämäläinen et al. (2005)

Regarding **Specific Language Impairment (SLI),** there are competing auditory hypotheses. Karmiloff-Smith[64] refers to one controversial hypothesis, that children with SLI experience problems with processing rapid sequential transitions (i.e. brief, rapidly successive acoustic stimuli that vary in frequency[65]). However, Bishop[66] notes that a technological intervention designed specifically to target this presumed difficulty in rapid auditory processing (called FastForword®) has not fulfilled its early promise. This suggests that the rapid auditory processing hypothesis is probably incorrect, supporting the conclusions of recent literature reviews[67]. An alternative possibility is that, like children with developmental dyslexia, many children with SLI have subtle problems in processing auditory cues to prosody and rhythm, cues like rise time and duration. Some support exists for this possibility[68], but there are very few studies. Finally, there is some suggestion from brainstem auditory recordings that children with "language disorders" have atypical brainstem timing[69]. However, these studies include children with many different kinds of developmental disability. As shown clearly by longitudinal studies of German infants[70], neural markers of impaired auditory sensory and language processing are predictive of speech and language impairments. More research is required to pinpoint exactly which aspects of auditory sensory processing contribute to these neural markers (biomarkers) and to understand the mechanisms underlying these associations. Nevertheless, sensory neural markers are predictive of the atypical development of one aspect of cognition (language).

Children who are **deaf** have severe impairments in their auditory sensory processing, although technological innovations such as cochlear implants can improve the auditory sensory information that is available to the brain[71]. It is important to clarify that cochlear implants do not provide access to the kind of auditory input available to the non-deaf ear, as only selected frequency channels are transmitted. Although cochlear implants lead to speech perception benefits, deaf children with implants may still show atypical developmental trajectories, developing poor language, literacy and number skills, and impaired social cognition[72]. Impaired social cognition appears to arise as a secondary consequence of deafness, because 90% of deaf children are born to hearing parents, and therefore early communication is severely impaired. Deaf children who are born to deaf parents show typical developmental milestones in social cognition, for example showing normative development of "theory of mind"[73].

Children at risk for developmental dyslexia and for SLI appear likely to benefit from interventions designed to improve auditory sensory processing, but more research is needed to identify the core deficits, as current auditory interventions are not effective[74]. Current research suggests that enriching early language environments, in particular around phonology and rhythm (e.g. singing nursery rhymes), would be beneficial for at-risk children. Indeed, enriching early language environments would be beneficial also for children with social cognitive impairments, and with executive function deficits. The key interventions for deaf children are probably communicative

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64 Karmiloff-Smith (SR-D13) – see Appendix B
65 Tallal (2004)
66 Bishop (SR-D1) – see Appendix B
67 McArthur and Bishop (2001)
68 Corriveau et al. (2007)
69 Banai et al. (2005)
70 Friedrich (SR-D14) – see Appendix B
71 Woll (SR-D5) – see Appendix B
72 Ibid
73 Woolfe et al. (2002)
74 Bishop (SR-D1) – see Appendix B

ones. Shared mode of communication (speech or sign) is the best predictor of outcome for deaf children. Woll[75] also notes that most deaf children are educated in mainstream settings with "communication support workers" who are in fact not fluent in, nor aware of, more subtle aspects of deaf communication.

2.1.2 Visual processing

There are a variety of visual sensory processing mechanisms that can be impaired developmentally, and that are implicated in learning difficulties. For example, Dawson et al.[76] have reported impaired processing of faces in **autism spectrum disorders** (faces are "special" visual stimuli and are processed by dedicated neural networks in the brain). Impaired face processing would interfere with the normative development of social cognition, which depends on the ability to read intentions from information in the face. Others[77] report *enhanced* low-level visual processing of individual perceptual features in children with **autism spectrum disorders**, and note that aspects of visual attention are also enhanced in these children. This sensory enhancement can cause cognitive difficulties, for example, children with autism can experience acute distress when visual features change (e.g. their mother has a haircut). Many developmental disorders are associated with impairments in aspects of visual processing such as in the perception of coherent motion that depend on neurons called magnocells. Magnocellular processing is impaired in developmental disorders including **autism**, **developmental dyslexia** and **Williams syndrome**[78].

Currently, the higher-level cognitive consequences of impaired magnocellular processing are unclear. For example, one theory has argued that impaired magnocellular processing causes developmental dyslexia through impaired ability to control eye movements, which leads to confusions in the position of letters[79]. This is unlikely, as children with autism and Williams syndrome can be extremely accurate (i.e. hyperlexic) readers[80]. Hence the magnocellular deficit associated with these disorders does not impair reading development in all of them. In general, there is little coordinated research into the role of visual processing in learning difficulties. As noted by Karmiloff-Smith[81], an early deficit in one part of the brain may have important effects on other parts of the developing brain; hence such research is urgently required. Furthermore, scientists currently tend to explore their own preferred sensory hypothesis, without investigating other aspects of sensory processing in the same children, and without making comparisons to children with a different learning difficulty. These research trends reduce our overall understanding of whether sensory processing deficits may be causal in learning difficulties.

2.1.3 Visuo-spatial processing

The parietal lobe of the brain is specialised for processing visuo-spatial information, such as the spatial relations between objects. It is also critical for processing information about quantity, and is thought to be the primary locus for basic representations of magnitude[82]. Shared networks of neurons respond to physical size and numerical

75 Woll (SR-D5) – see Appendix B
76 Dawson et al. (2002)
77 Plaisted et al. (2003)
78 Braddick et al. (2003)
79 Stein and Fowler (1981)
80 Goswami (2003)
81 Karmiloff-Smith (SR-D13) – see Appendix B
82 Dehaene (1997)

magnitude, as well as other physically continuous quantities such as luminance[83]. Part of this network may be specialised for processing the specific number of objects in a display, and the acquisition of symbolic number (e.g. school arithmetic) may develop in part from this basic capacity, termed "number sense" by Butterworth[84]. This parietal system appears to be impaired in children with **developmental dyscalculia**[85]. It is also impaired in **Turner syndrome**, where affected individuals show difficulties with number processing, and often with visuo-spatial processing also[86]. Visuo-spatial processing is just beginning to be explored in other developmental learning difficulties[87].

2.1.4 Motor systems

There is relatively little research into aspects of motor development (reaching, grasping, eye movement, fine motor control) and learning difficulties. It is clear that impairments in motor development frequently co-occur with language difficulties[88], but whether the relationship is causal is disputed. The literature on dyspraxia is diffuse, but **developmental co-ordination difficulties** are now receiving more research attention[89].

Regarding **Williams syndrome**, Karmiloff-Smith[90] notes that the ability to plan where to move one's eyes (visual saccadic planning) can be impaired in Williams syndrome. Although planning eye movements may appear to be remote from language development, she shows that this impaired motor ability is associated with late onset of language, perhaps because triadic interaction (mutual gaze between infant, carer and object) is affected. Much more research is needed on the development of basic motor abilities and the understanding of potential effects on higher-level cognition and social cognition. Another neglected area of research is the effect of physical activity per se (outdoor games, exercise) on cognitive development. As argued originally by Piaget[91], and shown by cognitive neuroscience, action is central to cognition. The key role of action is conceptualised via the notion of the "embodied mind", namely that minds develop within bodies, and therefore physical action will help to shape cognitive development in children[92].

2.1.5 Sensory processing: synthesis

Perturbations in sensory processing in the visual, auditory, motor and spatial systems are associated with higher-level cognitive deficits in language, social cognition, reading and number. The early interconnectivity of the brain means that atypical processing can affect other parts of the developing brain. Research is needed to understand how "low-level" sensory processing mechanisms support the development of "high-level" cognitive skills. Each type of sensory processing should be investigated in children with learning difficulties, as even if cognitive behaviour in one area appears to fall within the normal range, it may be supported by *different* sensory processing mechanisms. Similarly, studying learning in children with major sensory-motor difficulties may be informative. Intervention in low-level sensory processing mechanisms in infancy, when

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83 Pinel et al. (2004)
84 Butterworth (SR-D4) – see Appendix B; Castelli et al. (2006)
85 Butterworth (SR-D4) – see Appendix B
86 Molko et al. (2004)
87 Annaz (2006)
88 Bishop (SR-D1) – see Appendix B
89 Sugden and Chambers (2005)
90 Karmiloff-Smith (SR-D13) – see Appendix B
91 Piaget (1952)
92 Thelen (2000)

the brain is highly plastic, could potentially alter the developmental trajectory for higher-level cognition (as in cochlear implants for some deaf children). This should be a focus for future research in learning difficulties. With respect to generalised intellectual disabilities, where IQ < 70, it seems likely that all sensory systems function in an impaired way. However, there is an absence of relevant data.

2.2 Cognitive processing

Traditionally, developmental psychologists have analysed learning difficulties in terms of cognitive difficulties rather than in terms of sensory processing difficulties. However, recent work in neuroscience is revealing how sensory processing difficulties affect cognitive trajectories, and also that there is significant cognitive modulation of sensory processing as children develop. The brain is very complex, and so the core aspects of mental capital and wellbeing shown in Figure 1.2 will vary in their interactions across development. This complicates our understanding of causation. Nevertheless, in terms of behaviour (e.g. performance in reading or in maths), traditional cognitive analyses have been very fruitful. Cognitive perspectives enable three types of analysis:

a. The determination of what is most usefully remediated in children with a learning difficulty (e.g. phonology for developmental dyslexia, basic number concepts for developmental dyscalculia).

b. The identification of causal route(s) to the learning difficulty, and whether there are alternative causal routes to the same cognitive profile. For example, individuals may follow different developmental pathways to the same learning difficulty, as in a profile showing poor executive function, which may be due either to attentional impairments (ADHD) or to social cognition impairments (autism spectrum disorders).

c. To ascertain whether associations are causal or not (e.g. the association between impaired magnocellular processing and developmental dyslexia is an association and not a cause[93]).

2.2.1 Language

The core aspects of language are semantics (what words mean), syntax (grammar), phonology (the sounds comprising words), and pragmatics (competent communication):

Semantics: Children with **SLI** show core impairments with semantics, for example having difficulties in vocabulary tasks.

Syntax: Children with **SLI** show core impairments in grammar[94]. For example, they are poor at understanding the "rules" that govern the internal structure of words, such as when to add verb endings like –ing and –ed, or when to use plurals. Deaf children also have difficulties with grammar.

Phonology: Children with **developmental dyslexia** show core impairments in phonological processing[95]. They have difficulty in making judgements about similarity in sounds (e.g. whether words rhyme), they have difficulty with the rapid output of

93 e.g. Eden and Zeffiro (1998)

94 Bishop (SR-D1) – see Appendix B

95 Snowling (SR-D2) – see Appendix B

phonological patterns (e.g. naming familiar colours), and they have difficulty in tasks requiring short-term memory (a phonological system). Children with **SLI** and **deaf** children also show impairments in phonology.

Pragmatics: Difficulties with pragmatics are found in many learning difficulties. Pragmatics encompass awareness of social aspects of dialogue, for example: what is "rude" or "polite" in a given context; awareness of differences in the social status and familiarity of conversational partners, which may require speech to be modified; and awareness of when statements are not to be taken literally (e.g. the meaning of "hold your tongues" is context-dependent). Pragmatics are impaired in **autism spectrum disorders**, in children with **anti-social behaviour and conduct disorders**, in children **excluded** from school, and in children with **ADHD**. This does not mean that the impairments are equivalent in kind across the disorders. As well as linguistic knowledge, the pragmatics of communication require some insight into the mind of the conversational partner.

Language development is core to the development of other cognitive processes, such as memory, reasoning and problem solving, as well as for executive function (see section 2.4 below). For example, good language skills improve memory because children are able to construct extended, temporally-organised representations of experienced events that are narratively coherent. Children can enter school having been exposed to significantly less language than their peers, and with very different-sized vocabularies. Hart[96] estimated that children from families with high socio-economic status (SES) in the USA had been exposed to around 44 million utterances by the age of 4 years, compared to 12 million utterances for lower SES children. This study however did not investigate whether this enormous difference in the brain's exposure to language had a direct impact on language learning.

2.2.2 Memory

The more cognitive forms of memory are those in which aspects of past experience can be brought consciously and deliberately to mind. The retrieval of events and experiences from our past is usually called "episodic memory" and is impaired in **childhood depression**[97]. Negative events are recalled more easily than positive events, and this memory bias is a cognitive hallmark of vulnerability to clinical depression. In contrast, our generic, factual knowledge about the world is called "semantic memory". No learning difficulty of childhood is currently thought to involve impairments in semantic memory. "Working memory", a system for short-term recall that maintains information on a temporary basis, can be impaired in either its visuo-spatial aspects (e.g. retaining a particular configuration of pieces on a chess board) or in its phonological aspects (e.g. retaining a phone number prior to dialling it). Visual working memory is impaired in children with **ADHD**. Verbal working memory is impaired in children with **developmental dyslexia** and in children with **SLI**. Verbal working memory is thought to depend on the efficiency of the phonological system, as verbal information is retained temporarily using a speech-based code.

2.2.3 Learning

It was noted earlier that there are four core types of human learning, namely neural statistical learning, causal learning, learning by analogy and learning by imitation. None of these core processes *per se* are currently thought to be impaired in specific learning

96 Hart and Risley (1995)

97 Goodyer (SR-D15) – see Appendix B

difficulties like developmental dyslexia, developmental dyscalculia, autism spectrum disorders or ADHD. Rather, learning specific types of *input* appears to be impaired in specific learning difficulties, for example because certain types of sensory information are processed less efficiently by the brain. Hence, there is a specific problem in learning about phonology in developmental dyslexia, and a specific problem in learning the pragmatic aspects of language in autism spectrum disorders.

The exception is **generalised intellectual disabilities**. By definition, these disabilities present with low general IQ and so there is an impairment in learning. Again, however, there is an absence of relevant data. The efficiency of the different types of learning has not been compared in children or adults with intellectual disabilities. On the other hand, the literature on generalised intellectual disabilities frequently notes an inability to transfer learning (e.g. a specific skill taught, like crossing the road, does not generalise to new roads). This would possibly implicate learning by analogy as a fundamental impairment[98].

2.2.4 Attention

Human attention is usually understood as those aspects of cognitive function which allow selective information processing, enabling the individual to focus on relevant stimuli rather than all the stimuli present in the environment at any one time. In particular, studies with adults show that attention plays a key role in modulating sensory processing. This is called "top-down processing" or "cognitive modulation of sensory processing".

The study of attention is divided into visual attention, auditory attention and spatial attention, with neural regions such as the frontal eye field (control of eye movements) and the parietal cortex (spatial cognition) particularly important in attentional control[99]. The emotional system also modulates attention, often involuntarily[100]. By definition, attention is the key cognitive system impaired in **ADHD**, where the core symptoms are problems with sustained and selective attention, impulsivity and overactivity[101]. Children with ADHD also have difficulty in completing tasks or paying adequate attention to details. Particular aspects of attention are impaired in **childhood depression**, where attentional biases to negative events are found, and in **anti-social behaviour and conduct disorders**, where attentional biases to hostile information may be found (these children can be excessively vigilant in attributing anger to the actions of others). These attentional biases probably reflect the impact of emotional disturbance rather than a problem with attention *per se* (e.g. hypersecretion of cortisol, see section 2.5 below). Attention is not impaired in children excluded from school[102].

2.2.5 Reasoning and problem solving

Children with specific learning difficulties like developmental dyslexia and developmental dyscalculia may show preserved or above-average reasoning and problem-solving behaviour, as the popular discrepancy definition of dyslexia and dyscalculia requires that general intelligence is normal or high in these disorders (i.e. in a discrepancy definition there is a discrepancy between attainment in one symbolic skill such as reading or number and attainment in other areas of the curriculum).

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98 e.g. Feuerstein (2006)

99 Chambers and Mattingley (2005)

100 Vuilleumier (2005)

101 Simonoff (SR-D11) – see Appendix B

102 Skuse (SR-D9) – see Appendix B

However, it is increasingly apparent that children with lower reasoning and problem-solving skills can also show the specific difficulty with phonology that is the major characteristic of dyslexia; hence it is beginning to be recognised that dyslexia occurs across the full IQ range. Children with learning difficulties that have a linguistic component such as SLI and deafness, and children with disorders of social cognition that involve impaired executive function, such as anti-social behaviour and conduct disorders, may show impaired reasoning and problem solving in some contexts. This is unlikely to be due to a primary impairment in reasoning ability, as these disorders also reflect the full IQ range. It is most likely to reflect a consequent impaired ability to use language to reflect upon and plan cognitive behaviour and to generate possibilities for solving problems (i.e. the core problems lie with metacognition and executive function, see 2.4). Again, **generalised intellectual disabilities** (where IQ < 70) are the exception to this causal framework. Where IQ is low, reasoning and problem solving are poor.

Cognitive processing: synthesis

Analysing learning difficulties at the level of cognition can provide accessible behavioural descriptions for teachers and parents. We can describe a child as having specific difficulties with language, as in SLI, or specific difficulties with attention, as in ADHD. Beyond this level of description, it is difficult to pinpoint broad cognitive deficits in learning difficulties, because most learning difficulties are specific to certain aspects of cognitive processing.

General difficulties in learning, memory or reasoning do not appear to characterise any of the major learning difficulties of childhood. Nevertheless, cognitive analyses of learning difficulties are important for understanding causal developmental pathways, for distinguishing cause and effect, and for decisions about remediation. Cognitive difficulties, such as the specific difficulty with phonology experienced by children with developmental dyslexia, can be used as diagnostic tools in identifying learning difficulties, even prior to schooling. Phonology is also the best target for intervention for dyslexic children at the current time, as more research is required in order to understand the nature of the sensory processing difficulties that may underpin atypical phonological development in this population.

At present this general approach (remediation of the main cognitive deficits) applies to all of the learning difficulties of childhood discussed in this report. The exception is generalised intellectual disabilities, where there are difficulties in all aspects of cognition. For most learning difficulties, cognitive interventions currently offer the best way of altering learning environments and intercepting the developmental trajectory while the brain is still highly plastic.

2.3 Social cognition

The development of social cognition is sometimes described as developing a "theory of mind". As we have said, a theory of mind entails an awareness that others have mental states that might differ from your own. For example, they might believe something to be true that you know to be false. Understanding the mental states of others enables you to predict their behaviour on the basis of their beliefs, emotions and desires. Essentially, therefore, having a theory of mind enables an analysis of psychological causation. Social cognition appears to develop out of infant behaviours such as gaze following, joint attention, the monitoring of goal-directed actions and the monitoring of intentions. Accordingly, it is difficult for **blind** children to develop good social cognition. However, infants do not develop an understanding of mental states from visual scenes alone. Rather, rich linguistic communicative experiences are required for the development of adequate social understanding. For example, explicit family discourse about feelings is related to theory of mind development[103].

The core cognitive deficit in children with **autism spectrum disorders** is thought to be an impairment in theory of mind, or in understanding the mental states of others[104]. Children with autism have difficulties in imagining another person's thoughts and feelings, and also have difficulties in having appropriate emotional reactions to those feelings. Baron-Cohen[105] has described this as a kind of "mind-blindness". Impairments in theory of mind are usually measured by tasks exploring the understanding of false belief and intentional deception. Theory of mind tasks that are more difficult include tasks requiring understanding of irony, "white lies" and "double bluff". Although theories of the underlying cause of impaired theory of mind in autism vary, it is generally accepted that parenting and family communication factors are not implicated. Children **excluded** from school may also show impairments in theory of mind tasks.

Children with **anti-social behaviour and conduct disorder** also show aspects of impaired social cognition, such as impaired theory of mind in early childhood[106]. For these learning difficulties, parenting and family communication factors are important. For example, hostile parent-child relationships and inconsistent, ineffectual parental control strategies may lead to the child's difficulties[107]. Family interactions are central to the development of social understanding, and in families characterised by violence and aggression and punitive child control, the development of social understanding will be impaired. These effects can be exacerbated by violent siblings and peers. Hughes and Dunn[108] reported that "hard-to-manage" preschoolers were significantly more likely to engage in violent pretend-play at the age of four years, and showed deficits in moral awareness and in social understanding at age six. Developmental processes are impaired further when language development is poor and executive function skills are delayed (see section 2.4).

In older children and adolescents with anti-social behaviour and conduct disorders, the main risk factors are both cognitive (impulsivity, low empathy, executive function and attention problems) and social (parental conflict, poor parental supervision, an anti-social parent, a broken home[109]). Low family income, low intelligence (< 90) and large family size are additional risk factors. Farrington's "Integrated Cognitive Antisocial Potential" theory places cognitive processes at the centre of a causal model for anti-social behaviour and conduct disorders[110]. Farrington also argues that lifecourse theories are those best accepted for anti-social behaviour and conduct disorders, supporting the developmental trajectories approach that is adopted here.

Finally, **deaf** children show impaired social cognition, with delayed development of theory of mind. Here the underlying cause is thought to be poor early communication with parents and caretakers[111]. Most deaf children are born to hearing parents, and so miss out on many rich early communicative experiences. They experience a relatively

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103 Dunn et al. (1991)
104 Baron-Cohen (SR-D10) – see Appendix B
105 Baron-Cohen (1995)
106 Hughes (SR-D8) – see Appendix B
107 Ibid
108 Hughes and Dunn (2000)
109 Farrington (2006)
110 Ibid
111 Woll (SR-D5) – see Appendix B

isolated early social environment; they miss out on family discourse about the mind, and their need to lip-read (and hence watch the lips) also makes it more difficult to "read the mind in the eyes". For deaf children, impaired social cognition appears to be an indirect effect of impaired sensory processing (see 2.1 above).

Social cognition: synthesis

The development of social cognition depends on a number of factors, including: basic sensory and other processes; sympathetic, responsive and consistent parenting experiences; and rich linguistic communicative experiences in which psychological reactions are discussed and analysed, typically within the family setting. Atypical experience regarding any one of these factors can impair the development of social cognition.

If the basic processes important for the development of social cognition are impaired, such as gaze-following and the ability to share attention, then social cognition will be affected, as in autism spectrum disorders. If the child has intact gaze following and joint attention skills but lives in a family environment or other environment where child-carer interactions are hostile, highly inconsistent or punitive, the development of social cognition will also be impaired, as may happen in anti-social behaviour and conduct disorders. Frequently, these types of environment are also characterised by an absence of rich communicative linguistic interaction about the mental and emotional states of family members, compounding the developmental difficulties in learning about social cognition. Poorer emotional regulation and weaker inhibitory control tend to result from such environments. However, loving families can also fail to provide the rich communicative interactions required for the typical developmental trajectory to be followed. For example, if the parents of a deaf child are not able to use sign language, the child will show delayed or impaired social cognition because of poor communication rather than poor family environment. Again, this will result in an atypical developmental trajectory for social cognition.

Interventions aimed at improving social cognitive development are likely to benefit a number of learning difficulties. However, different kinds of intervention may be required for different learning difficulties. For example, Baron Cohen[112] notes a technological intervention for improving "emotion reading" in autism spectrum disorders based on videos of toy trains. Children with autism are fascinated by mechanical objects, but research is needed to see whether such videos would also be effective for teaching emotional regulation to children with anti-social behaviour and conduct disorders, who may not be so engaged by toy trains. Indeed, Blair[113] has recently argued that "cognitive" empathy (theory of mind, which is impaired in autism) should be distinguished from "emotional" empathy (responding to the emotional displays of others, impaired in anti-social behaviour and conduct disorders).

2.4 Executive function and metacognition

There is enormous development in executive function and metacognition during the primary school years in all children[114]. Metacognition can be distinguished by contrasting it with social cognition. Whereas metacognition is concerned with what the child knows about his or her own mind, social cognition is concerned with what the

112 Baron-Cohen (SR-D10) – see Appendix B

113 Blair (2008)

114 Hughes (1998); Carlson and Moses (2001)

child knows about somebody else's mind[115]. The developmental assumption is that as children gain reflective knowledge about their mental processes their strategic control or executive function abilities also improve. Developments in metacognition and executive function tend to be associated with language development, the development of working memory (which enables multiple perspectives to be held in mind) and non-verbal ability[116].

Just as attention modulates sensory processes, executive function and metacognition regulate cognitive processes in a top-down manner. Developmental theorists like Vygotsky[117] ascribed language a key role in this modulation of cognition. Vygotsky argued that once speech became internalised ("inner speech"), it became fundamental in organising the child's cognitive activities and in regulating the child's behaviour. Neuroscience has shown that the frontal cortex plays an important role in strategic control over behaviour and in the inhibition of inappropriate behaviours, and hence in executive function. The frontal cortex continues to develop into early adulthood. Adults who experience damage to the frontal cortex later in life show characteristic "executive deficits". For example, they show cognitive inflexibility (e.g. they find it difficult to move back and forth between tasks, or to "set shift"), and an inability to inhibit responding (e.g. they cannot prevent themselves repeating a now-inappropriate motor response).

In children, executive function abilities are typically measured by tasks like delaying the gratification of a desire (e.g. waiting to take a sweet from beneath a glass until an experimenter rings a bell) and by "conflict" tasks in which a highly salient response is the wrong response (e.g. the child must say "day" to a picture of the moon, and "night" to a picture of the sun). Metacognitive development is measured by tasks such as deciding how much study time to allocate to particular memory tasks, or by measuring how much difficulty children experience in keeping track of the sources of their memories.

Despite the fact that there are major developments in metacognition and executive function in the primary school years, there are also clear impairments in executive function and metacognition in children with certain learning difficulties. Children with **ADHD** show executive impairments in tasks requiring response inhibition, such as the day-night task, and impulsivity (lack of regulatory control over actions and thoughts) is a core feature of the disorder[118]. Adolescents with **eating disorders** also show core executive impairments, for example in set-shifting tasks, and the set-shifting deficit is suggested as defining the behavioural phenotype, along with a bias towards focusing on details and the emotional difficulties discussed below[119]. Children with **autism spectrum disorders**, **SLI**, **anti-social behaviour and conduct disorders** and **depression** can also show executive deficits.

In the above cases, the executive deficits are not seen as causal to the disorder. For example, some children with autism spectrum disorders show excellent executive skills[120]. For children with anti-social behaviour and conduct disorders, poor language development affects the development of age-appropriate executive skills, as poor language skills mean that the child is less effective at regulating his or her thoughts,

115 Schneider and Lockl (2002)

116 Hughes (1998)

117 Vygotsky (1978)

118 Simonoff (SR-D11) – see Appendix B

119 Treasure (SR-D16) – see Appendix B

120 Baron-Cohen (SR-D10) – see Appendix B

emotions and actions via inner speech. Hughes[121] suggests that executive function is thereby an important *mediating* factor in the development of anti-social behaviour and conduct disorders. In depression, there are executive difficulties in terms of decision-making when there is unexpected negative feedback about performance, but not when the negative feedback is expected[122]. In SLI, poor language skills similarly make it more difficult for children to use language to regulate their own cognitive activity.

Executive function and metacognition: synthesis

Self-regulation, inhibitory control and the understanding of one's own cognitive skills develop in all children from the age of around three years. These abilities are critical for enhancing mental capital and wellbeing, as they enable the child to organise, manage and control their behaviour. Self-reflective children can modulate their own emotional responses and inhibit inappropriate actions, improving their social experiences. They can also optimise their own learning by reflecting upon and regulating their memory and reasoning strategies. In order to enhance mental capital and wellbeing in children with learning difficulties, therefore, interventions designed to foster and develop executive skills and metacognition seem likely to be beneficial whether executive deficits are a core component of the disorder, or an associated component. Direct teaching of skills such as self-monitoring and planning is feasible in the preschool years with typically-developing children, for whom it is also thought to lead to the enhancement of mental capital via improving self-directed learning. Hence early interventions designed to facilitate the development of executive function and metacognition may offer a "win-win" strategy, in that both children with learning difficulties and typically-developing children should benefit. Note that these "interventions" may in fact comprise fostering child-centred activities such as socio-dramatic pretend play, and creating music and art (see 3.1).

2.5 Emotion

Historically, it was believed that certain categories of emotion (e.g. sadness, happiness, anger) were universal biological states triggered by dedicated neural circuits. More recently, it is becoming accepted that both language and social cognitive development play integral roles in emotional appraisal, emotional learning and emotional regulation[123]. Therefore, as with executive function, emotion as a core aspect of mental capital and wellbeing in developmental disorders of learning will be different in status from emotion as a core aspect of adult mental capital and wellbeing.

Different emotions and components of emotions appear at different ages[124]. Furthermore, language development and the development of social cognition and executive function will affect what children learn about emotion and emotional self-regulation. The development of reward systems in the brain, considered in adult psychology as motivational systems, are bound up with the development of emotional self-regulation in children. Adult psychology distinguishes motivation in terms of cognitive incentives ("wanting") from emotion in terms of conscious pleasure ("liking"). Wanting and liking are less clearly separable in young children, who have been argued to operate on the basis of a simpler "desire" psychology[125].

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121 Hughes (SR-D8) – see Appendix B
122 Goodyer (SR-D15) – see Appendix B
123 e.g. Ochsner and Phelps (2007); Feldman Barrett et al. (2007)
124 Rothbart et al. (2000)
125 e.g. Wellman (2002)

Therefore, for this review, the model in Figure 1.2 considers emotion and motivation together as one factor. With development, these constructs become more independent, in particular because adults can reflect more efficiently on their conscious experience of emotions (their "feelings") as well as on their emotional "states" (the functional aspects of their emotions). Hence in the adult model of mental capital and wellbeing used in other parts of the Project (see Appendix A), emotion and motivation are distinguished from each other. Finally, the study of emotion in infants and young children is usually the study of temperament. Temperamental *reactivity* and *self-regulation* are the core constructs used in this literature for investigating individual differences and changes in emotion-cognition interactions across development[126]. Individual differences in early temperament are thought to be important for later mental capital and wellbeing because they determine personality development[127].

Scientists who study temperament usually define it in terms of individual differences in behaviour tendencies that are biologically based and present from birth. Reactivity refers to the excitability, responsivity or arousability of behavioural and physiological systems such as fear or anger, while self-regulation refers to behavioural and neural processes that function to modulate underlying reactivity. In infants, reactivity is measured in terms of alertness and soothability, which are thought to be linked to neural systems such as those which regulate dopamine and serotonin. Temperamental reactivity is usually measured by responses to stimulation (e.g. whether a baby reacts quickly to its arms being restrained) and responses to objects (e.g. the infant's emotional response to a novel object can be positive (approach and exploration), or negative (fearful or angry). Temperamental self-regulation can be measured by self-calming actions (e.g. thumb sucking) or attention-shifting (e.g. directing visual attention away from fear-inducing objects), and eventually by more cognitively-guided actions (e.g inhibiting ongoing emotions, such as consciously deciding to stop crying).

The reactivity/self-regulation framework for temperament means that both responses to potential rewards or punishments (part of the adult motivational system) and the elicitation of positive versus negative affect (part of the adult emotional system) are combined in terms of their developmental effects on temperament. This is clear from Rothbart's[128] definition of the key dimensions of childhood temperament, which are fear, anger/frustration, positive affect, approach, activity level and attentional persistence. As children get older, developments in language and executive function enable the conscious self-regulation of reactive tendencies. Children become better at monitoring, modulating and regulating more reactive aspects of temperament, such as the speed with which they become angry or frustrated. Emotional regulation undergoes another major change during puberty, when hormonal changes increase reactivity, and further cortical reorganisation of the frontal cortex takes place[129].

Parenting styles also affect temperament and poor maternal care-giving is known to heighten sensitivity to stress via long-lasting alterations to the stress hormones (corticosteroids), which persist into adulthood. Chronic stress has severe effects on later cognitive functioning[130]. Traditionally, early temperament has been linked to personality dimensions, such as extraversion or neuroticism, rather than to learning difficulties.

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126 Rothbart (1991)

127 Henderson and Wachs (2007)

128 Rothbart et al. (2000)

129 Sebastian et al. (SR-E15) – see Appendix B

130 Wolf and Buss (SR-E20) – see Appendix B

Indeed, none of the state-of-science reviews[131] that have informed the present work highlighted emotion or motivation as key causal factors in explaining learning difficulties, with the exception of the reviews on **eating disorders** and **childhood depression**. Both of these disorders can affect learning rather than being disorders of learning. Here emotion and motivation are key causal constructs. In eating disorders, both "wanting" and "liking" are important in determining food intake[132]. "Wanting" affects the regulation of food intake via metabolic signals of need, whereas "liking" mediates the hedonic or rewarding nature of food and hence the regulation of intake. Treasure[133] suggests that emotional dysregulation of the hedonic system is primary in eating disorders.

In depression, there is obviously depressed mood, and this is associated with hypersecretion of the stress hormone cortisol and with impairments in serotonin function. In terms of temperament, depression is associated with high emotionality. As noted earlier, both disorders show associated executive deficits, for example in decision-making. Effective emotional regulation by parents is a *protective* factor in anti-social behaviour and conduct disorder[134]. Having a learning difficulty can also affect emotional responsivity: for example, anxiety can be heightened in developmental dyslexia or developmental dyscalculia. Typically, heightened anxiety is restricted to specific learning contexts rather than being globally affected (e.g. the child experiences strong "maths anxiety" only in the context of maths).

Emotion: synthesis

Emotion and motivation do not seem to be primary causal drivers for any of the common learning difficulties of childhood. However, they are important in disorders that onset in late childhood and adolescence such as eating disorders and depression. Further, having a learning difficulty can have a negative emotional impact, for example by heightening anxiety. Such emotional effects may in turn *compound* the learning difficulties that are being experienced by the child. Improving children's abilities to regulate emotion is therefore likely to have a protective effect with respect to learning difficulties. This has already been demonstrated by research on children with anti-social behaviour and conduct disorders.

2.6 Self-concept

The child's social relationships and the quality of those relationships are central to the development of a positive concept of the self. Two different developmental literatures offer important insights. One is the literature on attachment, starting with Bowlby's[135] analysis of security of attachment as a key variable in explaining social and emotional development. A core notion in attachment theory is the "internal working model" of the self, which is thought to be developed from parenting and other caretaking experiences. Later work within an attachment perspective has highlighted the importance of contingent responsiveness and warm sensitivity. Contingent responsiveness involves responding to the attentional focus of the child, maintaining the child's interests and not seeking to redirect their attention. Early attachments can be classified as secure (positive and intrinsically rewarding), avoidant (the child avoids interactions as the parenting experienced causes them distress), resistant (the child is

131 See Appendix B

132 Treasure (SR-D16) – see Appendix B

133 Ibid

134 Hughes (SR-D8) – see Appendix B

135 Bowlby (1969), (1973)

very demanding in interactions to try to alter inconsistent or insensitive parenting), and disorganised (the child has no coherent coping strategy). The development of the internal working model also involves social-cognitive understanding of other people and their psychological characteristics, particularly in terms of their likely behaviour towards the self[136]. Securely-attached children tend to achieve better results in school and have a more positive self-concept; hence, a secure self-concept is important for maximising mental capital and wellbeing.

A complementary developmental perspective is offered by Vygotksy, who recognised the importance of social relationships and social contexts in learning and development. A key theoretical construct was the "zone of proximal development", or ZPD. The ZPD captures the idea that the child can always progress further developmentally with the support and scaffolding of a parent or teacher. Hence the optimal conditions for development involve warm, responsive, supportive and contingent caretaking. Experiencing "three-term chains" of events are particularly beneficial (the child shows an action; the mother or carer responds promptly to the action; the child experiences a supportive consequence)[137].

The self-concept is an important explanatory concept in psychopathology. If the child's caretaking experiences are coercive, rigid, frightening or severely neglecting, then it is difficult to develop a positive self-concept, and the child is vulnerable to developing a psychopathology. As the developing child is conceptualised as organising and interpreting experience via "I myself", a positive self-concept is necessary to ensure the experience of continuity through time, and to create a sense of initiative (or motivation) and distinctness of experience (things that happen to "me"[138]). When there is a deformation of the child's sense of himself or herself, all of these factors are affected negatively. Fonagy and Target point out that the self-concept is also intrinsically related to the capacity for emotional regulation, for impulse control, for self-monitoring and for the experience of self-agency (i.e. aspects of social cognition, emotion and executive function). Therefore, the self-concept is represented in Figure 1.2 as an emergent property of the development of executive control, cognition, social cognition, emotion regulation and motivation.

Children who have been maltreated or who have experienced particularly adverse caretaking (e.g. children in care) are thought to construct a disorganised self-concept, so that there is no central and effective experience of "self". Fonagy and Target suggest that the maltreated child develops fractionated internal working models of the self. So, for example, a child with a conduct disorder may show non-reflective and impulsive behaviour whenever there is an element of conflict present in a relationship, but not across all social situations. Children with negative self-concepts are thought to lack positive perceptions of social relationships, to lack a mature moral sensibility, and to be poor at understanding complex emotions. Fonagy and Target argue that it is as though their "control system" for regulating the self and experiencing self-agency is not delayed but different. In general, children with early family environments that are severely adverse are less likely to develop self-concepts that are secure, autonomous and based on self-worth, and hence are likely to have impaired mental capital and wellbeing. These children will also show impairments in the so-called "non-cognitive" skills such as tenacity, diligence and the ability to focus on a personal goal.

136 Symons (2004) provides a useful overview

137 Bornstein and Tamis-LeMonda (1989)

138 Fonagy and Target (1997)

Related to the self-concept literature is the motivation literature. With regard to learning difficulties, the research of Dweck[139] is particularly important. She has emphasised the importance of children's self-theories of intelligence for the maximisation of their mental capital and wellbeing. Her research shows that some children have an "entity" or "fixed" theory of intelligence. They view their intelligence as fixed, and so they consider effort as negative (if learning requires effort, they cannot be intelligent) and they adopt performance goals (e.g. they aim to score well on tests). Other children have an "incremental" or "growth" theory of intelligence. This leads them to conceptualise intelligence as a malleable quality that can be changed by effort. Children with incremental theories adopt learning goals and feel that they need to work harder if they do not understand something. Clearly, children with incremental theories of intelligence are better placed to increase their mental capital and wellbeing via effort. In fact, Dweck's research also shows that receiving praise for effort rather than for performance increases the motivation to learn.

An impaired self-concept is not the primary cause of any of the learning difficulties considered in this review. However, an impaired self-concept is very likely to be associated with all of the learning difficulties, because of the impact of failures on the child's inner working model of the self. For example, children with developmental dyslexia and developmental dyscalculia can find their repeated learning failures very dispiriting, causing low self-esteem. Children with depression and adolescents with eating disorders also tend to suffer low self-esteem and to have a negative view of themselves. Conversely, a secure and positive self-concept will clearly have an impact on how disorders of sensory processing, cognition, social cognition or emotion affect the mental capital and wellbeing of the individual. Children with a secure self-concept are more likely to be resilient to learning failures, and more able to separate their specific cognitive difficulties from their overall experience of the self.

Self-concept: synthesis

The self-concept is not a primary causal driver of any of the learning difficulties discussed in this report, but it is a central concept for overall mental capital and wellbeing. Many learning difficulties have a negative effect on self-concept. Hence poor self-esteem may in turn act to compound any learning difficulties that are being experienced by the child. Conversely, this means that improving the self-concept of children with learning difficulties can have a positive impact on their mental capital and wellbeing. This is because enhancing self-agency and motivation to learn can improve the child's response to remediation and their social and schooling experiences.

2.7 Causal drivers of learning difficulties – summary

The developmental learning trajectories of children are affected by the brain, and the major causes of learning difficulties in childhood can be analysed in terms of different aspects of brain function. These can be identified as sensory processing, cognitive processing, social cognition, emotional processing and executive function/metacognition. Together with self-concept, these factors determine the mental capital and wellbeing of the individual. The common learning difficulties of childhood often reflect inefficient processing in one particular aspect of function. This was illustrated above for each learning difficulty and is summarised tentatively in Table 2.1. The exception to this is generalised intellectual disabilities.

139 Dweck (1999), (2006)

Table 2.1: Summary of core features across learning difficulties

	Dyslexia	Dyscalculia	SLI	Hearing Impairment	Autism Spectrum Disorder	ASB/CD	ADHD	Eating Disorders	Depression	Generalised Learning Disabilities
Sensory processing										?
Auditory processing	X		X	**X**						
Visual processing					X					
Visio-spatial processing		**X**								
Motor systems	?		?							
Cognitive processing										**X**
Language										
Phonology	**X**		**X**	X						
Grammar			**X**	X						
Semantics			**X**							
Pragmatics			**X**		X	X	?			
Memory										**X**
Semantic										
Episodic									X	
Working – Visual		?					X			
Working – Verbal	X	?	X							
Learning										**X**
Attention			?			X	**X**		X	?
Reasoning and Problem Solving										**X**
Social Cognition				X	**X**	X	X			X
Emotion					X	X	X	**X**	**X**	
Executive/Metacognition	•		X	•	X	**X**	**X**	**X**	X	**X**
Self-Concept	•	•	•	•	•	•	•	X	•	•

X core impairment X impaired ? possibly impaired • ruled out as causal feature

For specific learning difficulties, quite small inefficiencies in particular processes can have major effects on development, because the entire learning trajectory is affected across the lifespan. Consequently, if early environments can be improved by targeting these specific factors, there is potential for an impact on the entire developmental trajectory and the enhancement of mental capital and wellbeing. Currently, science provides the strongest support for interventions at the cognitive level. Future research should focus on understanding how different aspects of sensory processing affect cognitive development. Sensory system function determines the development of cognitive systems. There is insufficient understanding of the interactions between sensory and cognitive development, particularly in terms of developmental mechanisms. Once underlying mechanisms are understood, then interventions suitable for very early application become possible. A recent example is the development of cochlear implants. Here increased understanding of how the ear worked at the sensory level enabled the insight that language could develop without full frequency spectrum information, a sensory insight that made it practicable to implant a device that only processed parts of the signal processed by a functioning ear, but enough parts to enable oral language development. Genetics and cognitive neuroscience seem most likely to identify neural and genetic markers at the sensory level.

3 Future scenarios

3.1 The impact of important drivers

3 Future scenarios

This chapter looks ahead to the next 20 years and considers important factors that will affect the prevalence and impact of learning difficulties. The interactions of these "drivers" are presented in three "influence diagrams" relating to functional literacy, functional numeracy, and also executive function.

Drawing upon the diagrams, possible approaches to the identification and treatment of learning difficulties are introduced. They form the basis for further work which will be presented in the final Project report, to be published in October 2008.

3 Future scenarios

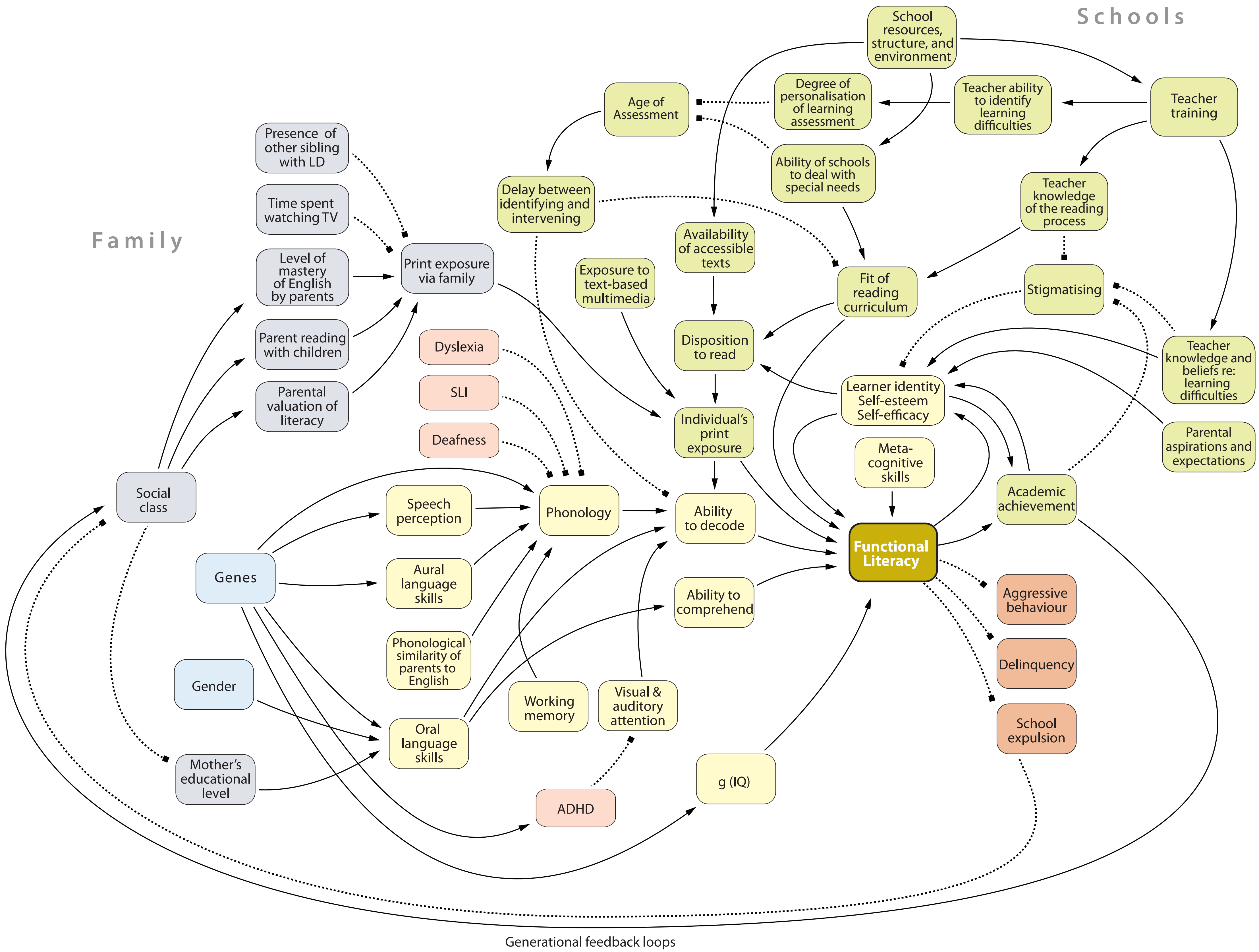
The previous chapters have demonstrated that learning difficulties hamper the development of mental capital and wellbeing in many children in the UK today. As shown, genetic influences are operative, but environments and genes interact, so that environments determine the impact of carrying certain genes. Environments also affect the overall developmental trajectory. This means that learning difficulties can be ameliorated by environmental interventions. Environmental interventions offer a means for resetting developmental trajectories, and research suggests that as the mechanisms whereby (say) inefficiencies in sensory processing cause cognitive problems are identified, more efficient interventions can be designed.

The research commissioned for this area of the Project has also enabled the development of a conceptual model for describing learning difficulties in the developing brain (Figure 1.2). A key objective of the Project is to use this analysis to inform our understanding of how the prevalence and impact of these learning difficulties could evolve in the UK over the next 20 or so years with a view to identifying effective strategic interventions. Clearly the course of development will depend on the interactions of many varied factors – termed "drivers".

These varied factors are captured by the conceptual model. Using the conceptual model as a starting point, experts involved in the Project then developed "influence diagrams" which form visual representations of the interactions of important drivers in the case of functional literacy, functional numeracy and also for executive function (see Figures 3.1, 3.2 and 3.3 respectively; note that the complexities of gene-environment correlations, gene-gene interactions and gene-environment interactions are not represented on the diagrams). By considering how the various drivers might change in the future, these diagrams have been used to explore how mental capital and wellbeing might evolve in the face of different learning difficulties (most importantly developmental dyslexia, developmental dyscalculia, and ADHD, which all have high prevalence). In particular, this has been achieved by considering how the drivers might develop in three alternative, but equally plausible, future socio-economic scenarios. Taken together, the influence diagrams and the scenarios form a tool with which to explore uncertainties in the future, and to test the robustness of possible interventions.

Further details of the scenarios may be found in the final Project report. Also, descriptions of the scenarios and the three influence diagrams will be provided in Project contractual reports that will be made available through www.foresight.gov.uk. However, the following outlines some of the key findings, and provides a preliminary discussion of the implications for possible interventions – these are currently the subject of detailed analysis and will be reported more fully in the final Project report, to be published in October 2008.

Figure 3.1: Influence diagram for functional literacy



3.1 The impact of important drivers

Consideration of the scenarios shows that major drivers such as globalisation and growth of information technology are likely to result in a world in future decades where the knowledge economy is primary, where there will be increasing complexity and intensification of work, and increasingly individualised management of a person's career and old age. For individuals with learning difficulties, such a future world presents a bleak outlook. Those who lack functional literacy and numeracy and/or who lack the ability to plan flexibly and to self-regulate their cognitive and emotional behaviours (i.e. who lack effective metacognitive and executive function skills) are unlikely to be able to participate effectively in or contribute to the "knowledge economy".

Looking across the other parts of the Project (see Appendix A), it is striking that the same factors emerge with respect to mental capital and wellbeing, namely attributes of the individual, characteristics of families and aspects of wider social context. "Influencing skills" and "literacy skills" have been identified as important by those parts of the Project considering the future of work, since they are crucial for the future economic performance of the UK. Therefore, for learning difficulties, a key theme for future policy development should be to seek to enhance the attributes of affected individuals. As noted above, this is most effective when done early, while the sensory systems in the brain are still building the cognitive system. This should become achievable in the next 10–20 years, although there are important ethical considerations.

The fundamental importance of functional literacy and functional numeracy skills both to the individual's mental capital and to future UK economic performance suggests that current priority should be given to establishing the conditions so that all children can acquire these skills. Similarly, significant benefits are likely to accrue to all children from improving environments with respect to the development of cognitive and emotional self-regulation (executive function).

The influence diagrams for literacy and numeracy (Figures 3.1 and 3.2) show possible nodes for cognitive interventions. For example, they indicate that the enhancement of phonological processing for developmental dyslexia and the improvement of counting and the "number sense" for developmental dyscalculia would be particularly beneficial. The diagrams show that early interventions should focus on the biological systems and precursor skills for literacy and numeracy in tandem with boosting social and/or environmental support, rather than provide extensive focused practice of the target skills themselves (e.g. training in "phonics"). This strategy is likely to be more effective when interventions are being provided for younger children. Clearly, any interventions would require piloting in order to optimise their efficacy. Critically, the effectiveness of any planned intervention should then be assessed under optimal research conditions such as Randomized Controlled Trials before it is launched universally[140].

Regarding cognitive and emotional regulation, the enhancement of self-regulation skills through the delivery of early years education in ways facilitating the development of executive function would improve cognitive flexibility and "influencing skills". These skills develop dramatically between the ages of 3 and 7 years. Fostering development of such skills would better equip individuals for coping with an increasingly complex and individualised world. The influence diagram for executive function, provided as Figure 3.3, shows that important nodes for intervention include the language, arts, music and drama curricula, and socio-dramatic pretend play. Metacognition and executive function skills can be learned, via pretend play, language arts, drama and music, and also via

140 Rutter (2006)

modelling (by thinking about the way in which teachers teach young children in terms of how learning is encouraged and reinforced, to foster independence[141]). Teaching these skills does not require yet more "modules" to be added to the curriculum. Rather, effective communication of metacognitive and self-regulatory skills can be achieved by the continuing professional development of teachers, and strong endorsement of the key roles of play and the mainstream arts in the early curriculum.

The two core emergent themes from this analysis of learning difficulties are thus the need for *early detection of* and *early intervention in* learning difficulties. Early detection is fundamental to intervening in the learning trajectory before learning problems become severe, enabling learning trajectories to move closer to those of typically-developing children.

Possible opportunities for early intervention in the next 1–2 decades include the exploitation and development of new technologies, new techniques for cognitive enhancement (e.g. neurocognitive activation to improve impulse control in children with ADHD[142]), and the development of cognitive neural protheses such as cochlear implants[143]. Technological interventions can be very effective when there is scientific agreement on the underlying cause of a learning difficulty, as in the case of cochlear implants for children who are born deaf[144]. In some learning difficulties, there is sufficient scientific consensus regarding the principal causal factors for the development of technological interventions aimed at remediating one causal factor. An example is "The Transporters" videos developed to enhance emotion-reading abilities in young children (typically boys) with autism spectrum disorders[145]. In other learning difficulties, such as developmental dyslexia, there is insufficient scientific consensus for technological interventions aimed at remediating early causal factors (e.g. impaired auditory processing[146]), but sufficient consensus for technological interventions aimed at remediating learning performance[147]. For example, Finnish researchers have developed a technological intervention for teaching dyslexic children to retrieve letter-sound correspondences fluently and automatically, using a video game[148].

Regarding early detection, the possibilities offered by advances in genetics and in cognitive neuroscience are illustrated by Plomin[149] and Friedrich[150]. Plomin predicts the development of "gene chips" that will genotype each child's unique sequence of three billion DNA bases, although this would give a probabilistic rather than deterministic estimate of individual risk. Friedrich outlines innovative cognitive neuroscience research in Germany that uses neural markers (biomarkers) in infancy as predictors of individual risk for later learning disorders of language. Research with the greatest potential with respect to causation in learning difficulties is *prospective longitudinal research combined with intervention studies*. For cognitive neuroscience markers of learning difficulties, such prospective longitudinal studies are already in progress in other countries[151].

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141 Whitebread et al. (2005)

142 Foster (SR-E29) – see Appendix B

143 Ibid

144 Woll (SR-D5) – see Appendix B

145 Baron-Cohen (SR-D10) – see Appendix B

146 Lyytinen (SR-D12) – see Appendix B

147 Ibid

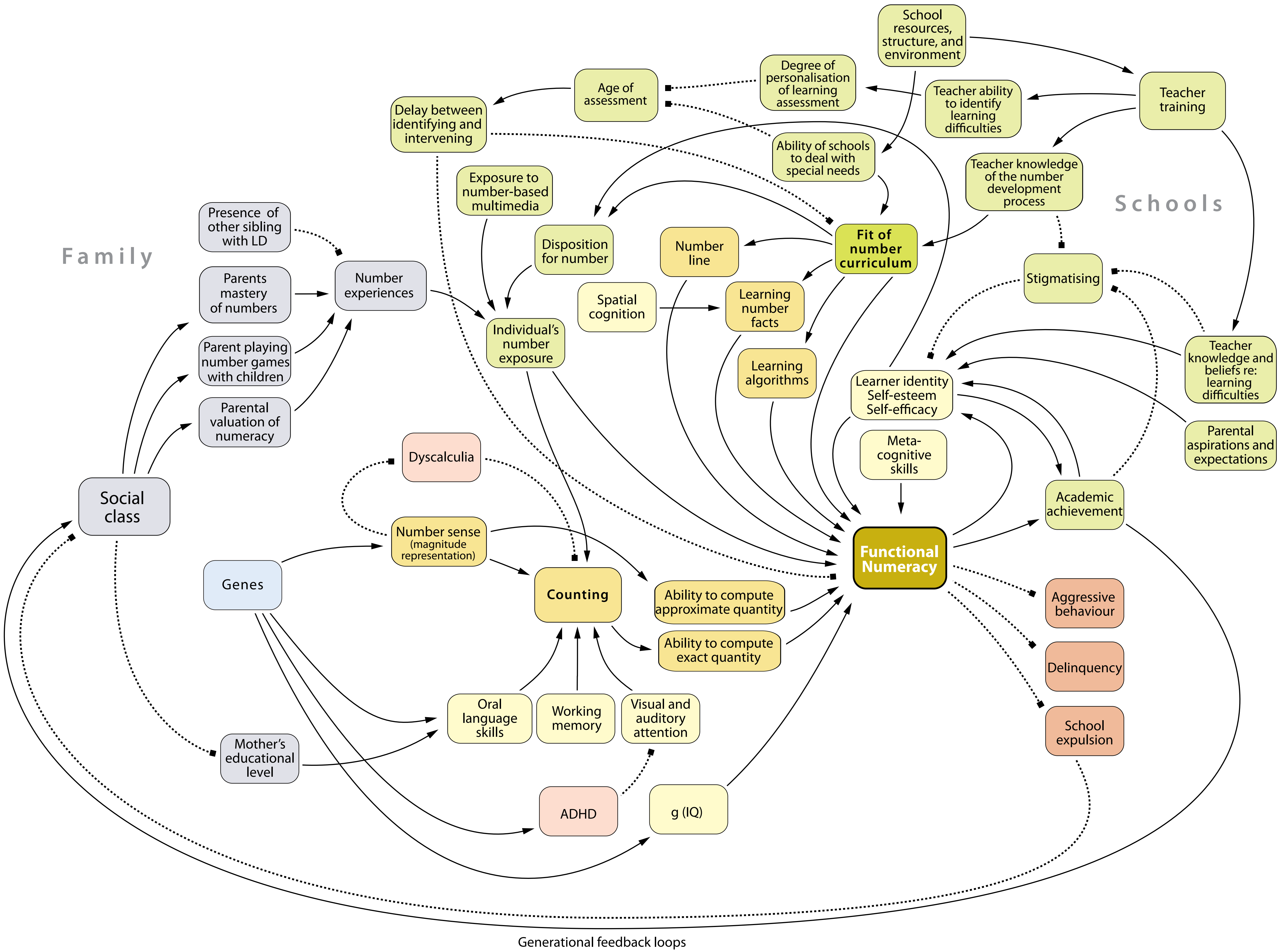
148 Ibid

149 Plomin (SR-D7) – see Appendix B

150 Friedrich (SR-D14) – see Appendix B

151 e.g. Germany for SLI, Finland for dyslexia; see Friedrich (SR-D14); Lyytinen (SR-D12) – see Appendix B

Figure 3.2 Influence diagram for functional numeracy

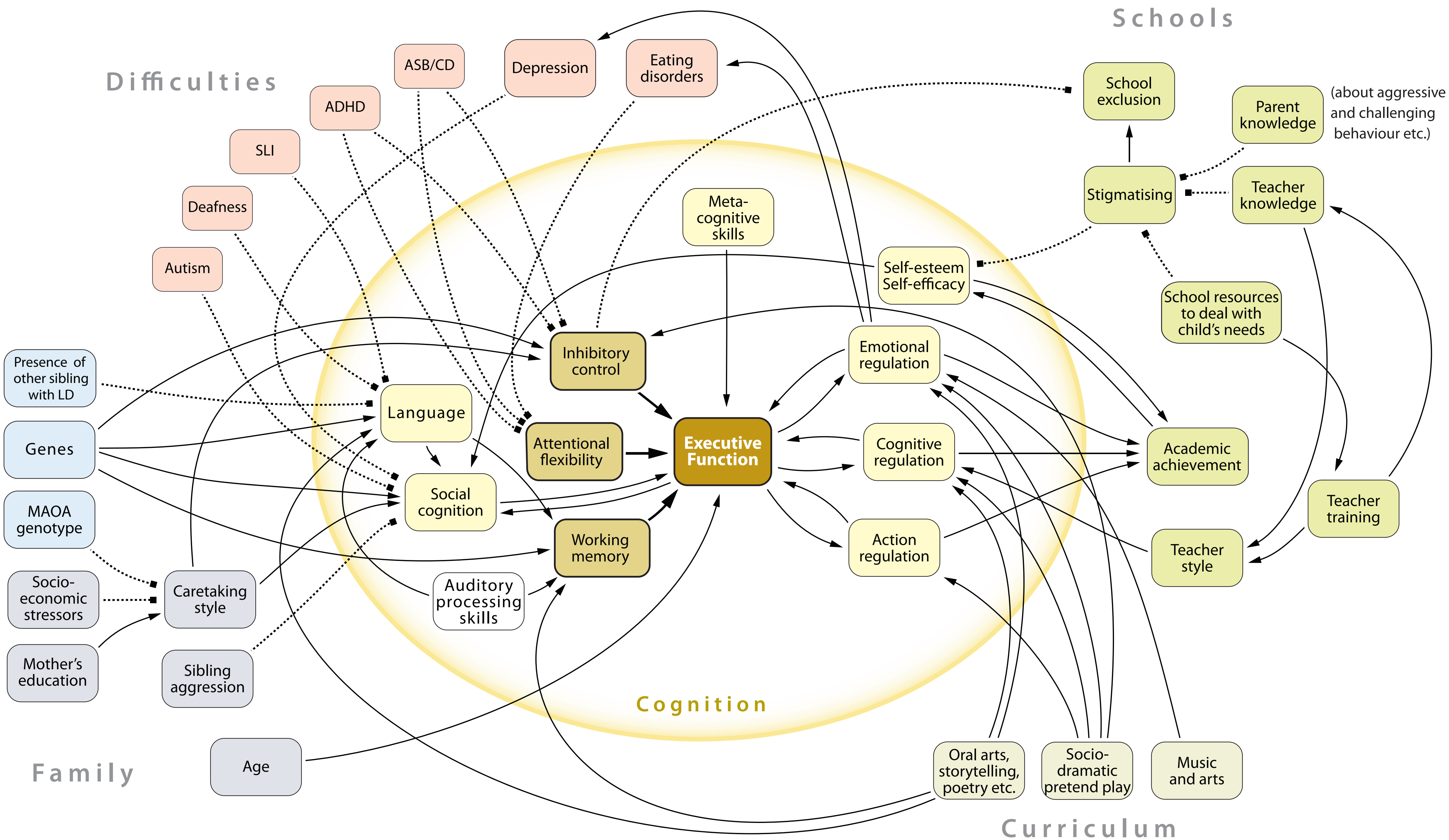


Social/behavioural interventions are also likely to be effective interventions for learning difficulties, because children can improve their own learning through self-reflection and self-regulation. They can also be effective because children find them enjoyable. Technological interventions must be very intrinsically motivating if children are to persevere with them (surprisingly, many deaf children turn off their cochlear implants for large parts of the day).

In this review, interventions based on improving language and executive function were identified as likely to be of benefit to children with many different kinds of learning difficulties. In fact, such interventions are likely to benefit all children, even those without learning difficulties. Such interventions could begin in nursery, and could be delivered initially through play and the arts (music, drama, story-telling, socio-dramatic pretend play).

With regard to research, a key gap is research on how individual differences in basic sensory processing mechanisms contribute to cognitive outcomes. More sensory research is needed to identify targets for intervention in infancy. The author's personal scientific view is that coordinated research into sensory processing in typical and atypical development, studying all sensory systems across different learning difficulties, would yield significantly improved understanding of developmental mechanisms with consequent benefits for early intervention.

Figure 3.3: Influence diagram for executive function



4 Conclusion

4 Conclusion

Learning difficulties are developmental. A developmental framework is therefore essential for understanding how learning difficulties impact on future mental capital and wellbeing. A learning difficulty affects learning *trajectories* throughout the lifespan. As an example, Farrington[152] points out that the anti-social child has the potential to become the anti-social teenager, who is at risk of becoming the anti-social adult who is at risk of producing another anti-social child. Across learning difficulties, more research into underlying mechanisms is needed, so that developmental trajectories are better understood and consequently more effective interventions can be developed. For example, recent research in cognitive neuroscience is revealing how differences in subtle aspects of very basic sensory processes such as seeing and hearing affect the cognitive trajectories important for high-level processes such as reading and mathematics.

Developmental trajectories are easier to intercept than to reverse. Initial differences between children may be small. Yet even a small initial difference in basic sensory processing can end up having large cognitive consequences. For example, a small difference in how the brain processes auditory information may lead eventually to a specific reading difficulty. This may then have a serious impact on the development of mental capital, because reading is the key to accessing the entire educational curriculum and to later participation in the knowledge economy. As children get older, their cognitive difficulties affect their self-concept and their emotional development, with erosive effects on wellbeing and increased risk for social exclusion and unemployment. As the learning difficulty is biological in origin, it may be passed to the next generation. However, biology simply confers a risk or a vulnerability to having a particular learning difficulty. It is the environment that determines the impact of carrying certain genes and the eventual developmental trajectory.

As many learning difficulties are genetically-driven, prevalence rates are unlikely to change markedly in the future. Therefore, environmental strategies are required to reduce the impact of an inherited vulnerability to a learning difficulty. Interventions that address underlying causes early in the developmental trajectory are most likely to be effective. The earlier that learning difficulties are detected, and the earlier that interventions are put into place, the better the child's eventual mental capital and wellbeing and the more valuable their contribution to society. The principle of early detection and early intervention is therefore a starting point for consideration of possible strategies for intervention. The outcome of that analysis will be presented in the final report of the Project, to be published in October 2008.

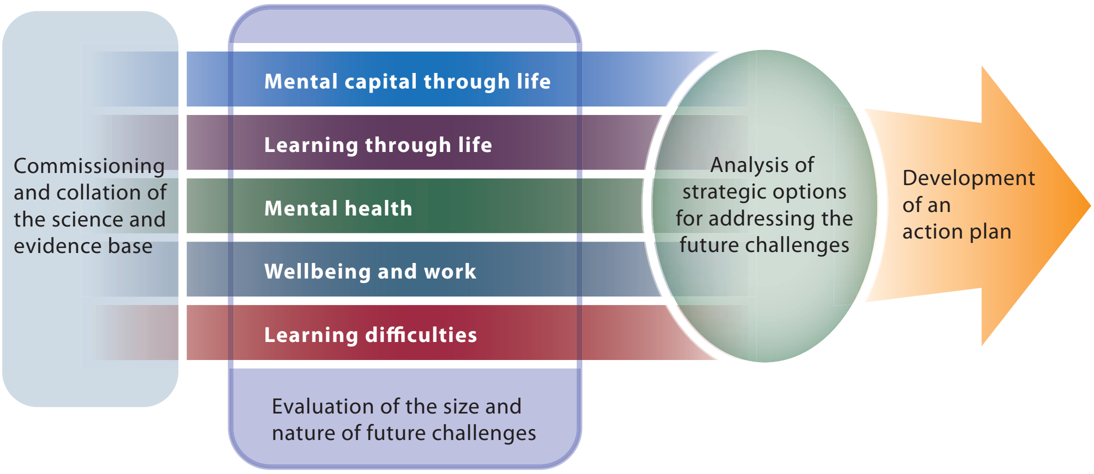
152 Farrington (2006)

Appendix A: Overview of the work of the Foresight Project on Mental Capital and Wellbeing

The aim of the Project is to advise the Government on how to achieve the best possible mental development and mental wellbeing for everyone in the UK.

The principal parts of the Project are set out in Figure A.1 and are described below. Further information may be found on the Project website (www.foresight.gov.uk). All the Project papers and reports will also be made freely available through this website in October 2008 – either electronically or in hard copy.

Figure A.1: The principal parts of the Project



Analysis of future challenges

The starting point was to generate a vision for the size and nature of future challenges associated with mental capital and wellbeing, and to assess how the situation may change over the next 20 years. This analysis was predicated on the assumption that existing policies and expenditure remain unchanged. To make the analysis tractable, the work was divided into five broad areas, as indicated in Figure A.1. The present report documents the findings from one of these – Learning difficulties. Details of the reports of the five areas are listed in Table A.1.

Table A.1: The challenges ahead – reports of the findings		
Designation	**Title**	**Authors**
CR-E	Mental capital through life: Future challenges	T. Kirkwood J. Bond C. May I. McKeith M. Teh
CR-A	Learning through life: Future challenges	L. Feinstein J. Vorhaus R. Sabates
CR-B	Mental health: Future challenges	R. Jenkins H. Meltzer P. B. Jones T. Brugha P. Bebbington M. Farrell D. Crepaz-Keay M. Knapp
CR-C	Wellbeing and work: Future challenges	P. Dewe M. Kompier
CR-D	Learning difficulties: Future challenges	U. Goswami

The five areas were chosen to closely map onto the interests of important Government Departments, although it was recognised from the outset that the areas were interrelated. Therefore, consideration across the five has also been undertaken – the results of that will be reported in the final Project report.

Supporting evidence and analysis

The above analysis was informed by:

- Consideration of the underpinning science associated with each of the five areas. This was informed by approximately 80 commissioned reviews – these set out the current state-of-the-art of science in diverse fields, and also scientific developments of particular interest (Appendix B provides a full list).
- Reviews of certain socio-economic factors. These were performed when the existing literature was deemed insufficient for the purposes of the Project. In particular, these reviews addressed the relationship of the physical environment to wellbeing, and the evolving use of information and communication technologies (see Appendix B).
- Economic analysis. This has taken a broad view of the direct and indirect impacts of important issues – such as specific learning difficulties and mental health problems.
- Systems analysis relating to each of the five areas (e.g. see Figures 1.2, 3.1, 3.2 and 3.3) An account of the Project systems work is being prepared in a separate report (see Appendix B; S1: Systems maps).

- The development of hypothetical future scenarios. These have been used to explore future uncertainty in the five areas (listed in Figure A.1), and to test the robustness of possible interventions. An account of the scenarios and their use within the Project will also appear in a separate report (available through www.foresight.gov.uk).

In addition to the above, the work also drew extensively upon the existing literature as well as several workshops and meetings with relevant organisations.

Analysis of strategic options

Having identified important challenges for the future, the Project identified and analysed possible interventions and strategic options for addressing them. Here the analysis of possible costs and benefits took a lifecourse approach, recognising that interventions affecting today's children might affect them for the rest of their lives.

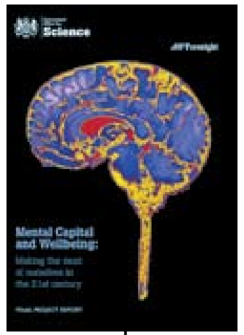
Consideration has also been given to the social and ethical context within which the proposed interventions would be offered. Issues concerning ethics, governance, and public attitudes have been addressed. The results from this part of the Project are presented in the final Project report.

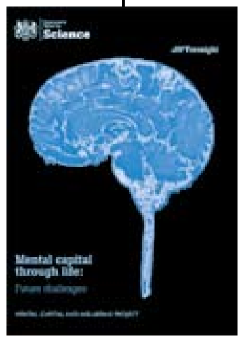
Stakeholder engagement

From the outset, the Project has involved a wide range of leading organisations from both the public and private sectors. The intention has been to work closely with them to develop a comprehensive plan to take forward the findings of the Project. That plan will be announced at the launch of the final Project report in October 2008.

Appendix B: Structure of the Project reports and supporting papers

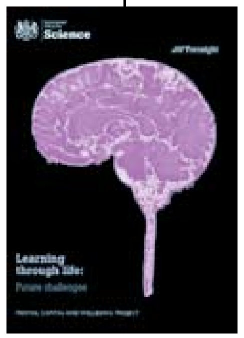
Mental Capital and Wellbeing: Making the most of ourselves in the 21st century
Final Project Report





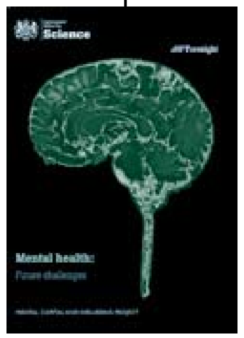
Mental capital through life: Future challenges

SR-E1: *Neuroscience of education*
SR-E2: *Human reward*
SR-E3: *Neuroeconomics*
SR-E4: *Cognitive reserve*
SR-E5: *The adolescent brain*
SR-E6: *Behavioural economics*
SR-E7: *Resilience*
SR-E8: *Adolescent drug users*
SR-E9: *Pharmacological cognitive enhancement*
SR-E10: *Stem cells in neural regeneration and neurogenesis*
SR-E11: *Early detection of mild cognitive impairment and Alzheimer's disease: An example using the CANTAB PAL*
SR-E12: *Anxiety disorders*
SR-E13: *Neurocognition and social cognition in adult drug users*
SR-E14: *Normal cognitive ageing*
SR-E15: *Social cognition in teenagers – inclusion*
SR-E16: *HPA axis, stress, and sleep and mood disturbance*
SR-E17: *Nutrition, cognitive wellbeing and socioeconomic status*
SR-E18: *Nutrition and cognitive health*
SR-E20: *Effect of chronic stress on cognitive function through life*
SR-E21: *Depression and its toll on mental capital*
SR-E22: *Fitness and cognitive training*
SR-E24: *Effects of exercise on cognitive function and mental capital*
SR-E25: *Technology solutions to prevent waste of mental capital*
SR-E27: *Housing as a determinant of mental capital*
SR-E29: *Cognitive neural prosthetics*
SR-E31: *Cellular and molecular logic of neural circuit assembly*



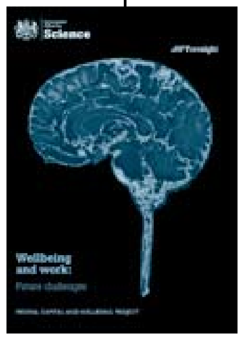
Learning through life: Future challenges

SR-A2: *Learning at work*
SR-A3: *Skills*
SR-A4: *Participation in learning*
SR-A5: *Evidence-informed principles from the Teaching and Learning Research Programme*
SR-A7: *Estimating the effects of learning*
SR-A9: *Self-regulation and executive function*
SR-A10: *Lifelong learning across the world*
SR-A11: *Non-cognitive skills*
SR-A12: *Future technology for learning*



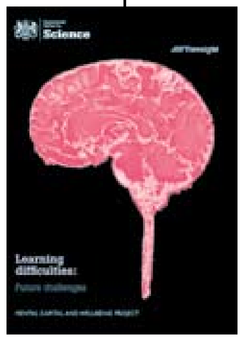
Mental health: Future challenges

SR-B1: *Genetics and social factors*
SR-B2: *Mental health of older people*
SR-B3: *Positive mental health*
SR-B4: *Mental disorders in the young*
SR-B5: *Prisoners*
SR-B6: *The homeless*
SR-B7: *Children in local authority care*
SR-B8: *The costs of mental disorders*
SR-B9: *Serious and enduring mental illness*
SR-B10: *Personality disorders*
SR-B11: *Violence*
SR-B12: *Ageing*
SR-B13: *Migrants*
SR-B14: *Substance abuse*
SR-B15: *Depression*



Wellbeing and work: Future challenges

SR-C1: *Workplace stress*
SR-C2: *Mental wellbeing at work and productivity*
SR-C3: *Management style and mental wellbeing at work*
SR-C4: *Flexible working arrangements and wellbeing*
SR-C5: *New technology and wellbeing at work*
SR-C6: *Stress management and wellbeing*
SR-C7: *Working longer*
SR-C8: *Leisure: the next 25 years*
SR-C9: *Training in the workplace*
SR-C10: *Careers*
SR-C11: *Violence at work*

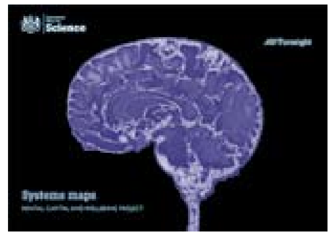


Learning difficulties: Future challenges

SR-D1: *Specific language impairment*
SR-D2: *Dyslexia*
SR-D3: *Adult learning disabilities*
SR-D4: *Dyscalculia*
SR-D5: *Deafness*
SR-D7: *Genetics and diagnosis of learning difficulty*
SR-D8: *Conduct disorder and anti-social behaviour*
SR-D9: *Social cognition and school exclusion*
SR-D10: *Autism and autism spectrum disorders*
SR-D11: *Attention Deficit Hyperactivity Disorder*
SR-D12: *New technologies and interventions*
SR-D13: *Trajectories of development and learning difficulties*
SR-D14: *Early neural markers of learning difficulty*
SR-D15: *Childhood depression*
SR-D16: *Eating disorders*

Cross-Project papers

SR-X2: *Science of wellbeing*
SR-X3: *Neurobiology of wellbeing*
SR-X5: *Neural circuit assembly*
DR-1: *ICT as a driver of change*
DR-2: *Physical environment and wellbeing*
ER-1: *Ethics*



S1: Systems maps

Note 1: Some reference numbers were assigned to topics; however, the reports/papers were not subsequently commissioned.

Note 2: The Project commissioned some additional "discussion papers" as referred to in the text of the final report.

These will be made available through www.foresight.gov.uk in due course.

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This review has been commissioned as part of the UK Government's Foresight Project, Mental Capital and Wellbeing. The views expressed do not represent the policy of any Government or organisation.

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Printed in the UK on recycled paper with a minimum HMSO score of 75
First published September 2008.
The Government Office for Science.