1 The situation today

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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:

- 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 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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18 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.

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

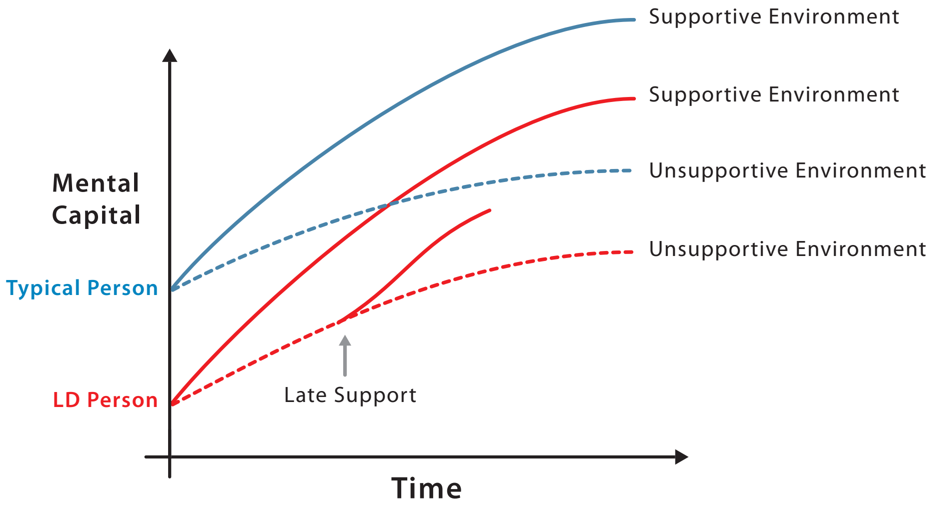
ability to plan behaviour and the ability to inhibit inappropriate responses. Metacognitive skills can be taught to very young children.

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

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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;

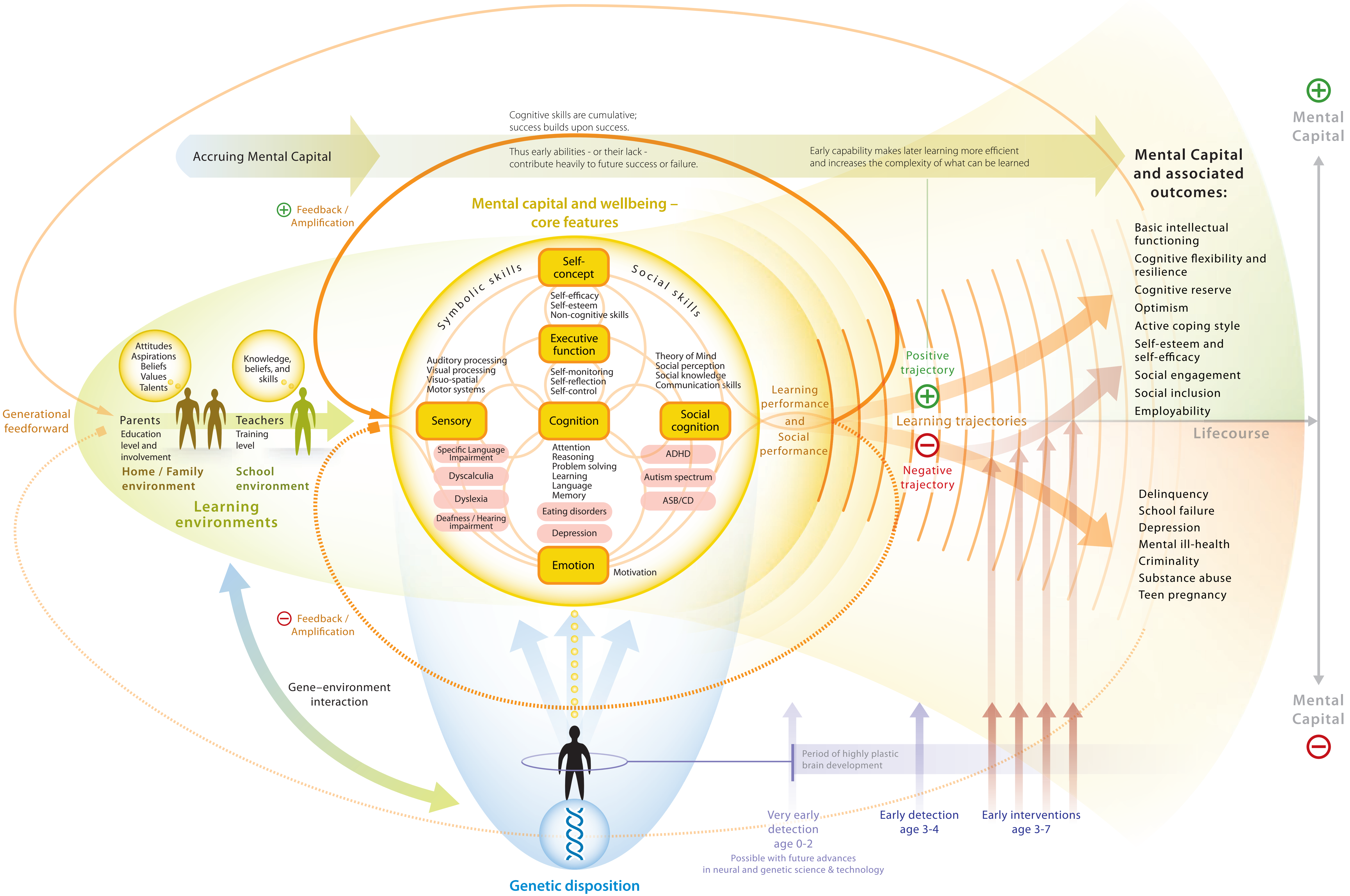
53 For a detailed analysis, see Goswami (2008)

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.