2 Causal drivers of learning difficulties with reference to the model

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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

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].

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.