Seeking Connection, Autonomy and Emotional Feedback: a Self-Determination Theory of Self-Regulation in Attention Deficit Hyperactivity Disorder

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Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most prevalent and highly debated diagnosis for mental disorder in practice today. Two decades of research have substantially contributed to evolving conceptualisations and understanding of the condition. However, this evolution has not extended to theoretical research. Current cognitive behavioural-based theories aim to identify the aetiology of ADHD and experience challenges in accommodating the full spectrum of both neurobiological and behavioural research evidence. Characterisations historically associated with mental illness have generated public stigma, influencing low self-esteem, negative self-concept and identity development in ADHD individuals. Neurodiversity research and activism recognises a diversity of non-normative development, and highlights the need for alternatives to deficit models of functioning. Recent research in psychology recommends developing approaches beyond symptom control and seeking to develop positive psychological factors and well-being. We propose that the perspective presented by self-determination theory (SDT) on human motivation, self-regulation and self-determination offers a new understanding of ADHD research evidence and symptomology. According to this theory, humans have a natural tendency toward growth and self-actualisation. We propose a framework grounded in SDT that provides an alternative understanding of ADHD neural processing, motivation and engagement, self-regulation, and a potential foundation for treatment approaches with self-determination and positive identity outcomes.

Keywords: Attention Deficit Hyperactivity Disorder, ADHD, self-regulation, motivation, neurodiversity

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Scientific objectivity is a critical element when interpreting clinically relevant data. While it is debatable whether pure objectivity is attainable, it is a helpful heuristic for fostering scientific integrity, particularly scientific experimentation, inference, and theory choice (Reiss & Sprenger, 2017). In understanding and working with neurodevelopmental disorders, the combination of psychological theory and interpretation of research are critical influencers in clinical treatment development and design. Highlighted is the essential nature of identifying assumptions, beliefs, theories, and goals to guide decision-making in Attention Deficit Hyperactivity Disorder (ADHD) (Nigg, Karalunas, et al., 2020; Toplak et al., 2008).

Negative Self-Concept in ADHD

Initially characterised as a childhood disorder of behavioural control, ADHD is now identified as a neurodevelopmental disorder of self-regulation with significant impact in multiple dimensions across the lifespan (Barkley, 2002; Bokor & Anderson, 2014; Solanto et al., 2008). Undiagnosed and untreated ADHD confers a serious increased risk of adverse outcomes including substance use, psychosis and conduct disorders (Erskine et al., 2016; Groenman et al., 2017; Kessler et al., 2006) educational and occupational failure (Nigg, Sibley, et al., 2020), and late-onset psychiatric problems including self-harm and suicide (Forte et al., 2020; Ljung et al., 2014). If not addressed, ADHD can also have a significant economic impact beyond the individual, in terms of increased healthcare costs, decreased productivity, and risk of offending (Champ et al., 2021; Kooij et al., 2019). Subthreshold cases of ADHD in childhood may meet full diagnostic criteria in adolescents (Kooij et al., 2019). However, due to the decline of hyperactive and impulsive symptoms with age, some individuals may not have symptoms severe enough to be diagnosed until adulthood, when executive function and attentional difficulties become more salient. Many adults never receive a diagnosis; instead, they have symptoms attributed to motivational or intellectual deficits (Goodman, 2007). Studies examining healthy individuals' perceptions of ADHD show symptoms being childish and inappropriate; presentation of behaviours increased tendencies of peer rejection and feelings of hostility; and debates on antisocial tendencies, prejudices around symptom aetiology, and immediate and long term effects of the medication may contribute to stigmatization (Mueller et al., 2012). The literature on the stigma associated with mental illness emphasizes that the labelling of behaviour as symptoms of a mental disorder can create public stigma, leading to a reduced ability to use cognitive resources to perform well (Forbes & Schmader, 2010). Public stigma frequently results in self-stigma: an internalisation of a "new degraded identity" which negatively affects self-esteem, self-efficacy and impacts behavioural goals (Corrigan et al., 2006; Fabrega, 1990; Kooij et al., 2019).

Additionally, repetition and frequency of negative feedback on ADHD behaviours from authority figures often generate a negative self-concept at an early age (Young et al., 2008; Young & Bramham, 2012). This association results in low self-esteem and a lack of trust in making decisions or taking action without external validation of appropriateness of behaviour or choice, which creates an unconscious reliance on external structures or individuals for support. Psychology defines this as contingent self-esteem (Blom, 2011; Crocker & Wolfe, 2001; Ryan & Deci, 2000).

Theoretical Aetiology of ADHD

A substantial amount of research has been conducted over the last 20 years, with significant advancements in neuroimaging, genetics, pharmacology, psychology and the social sciences, dramatically changing the aetiology and understanding of the symptoms and impact of

ADHD. Despite these advancements, aetiological theories are unable to account for all evidence entirely. While there are recognised neurobiological differences in ADHD, the role

Table 1: Comparison of aetiological theories

Key Differences	**Theoretical Models of ADHD**						
	Barkley	Brown	Sonuga-Barke	Sonuga-Barke	Sagvolden	Nigg et al.	Champ et al
Definition of impairment	Challenges in self-regulating arousal concerning goal-directed behaviour and difficulties maintaining attention for tasks with little to no reinforcement or immediate reward	Challenges with engagement in successful self-regulating behaviour using attention and memory to guide action	Challenges with inhibitory control delayed gratification generating motivational deficits resulting in preference for immediacy	Challenges with inhibitory control delayed gratification generating motivational deficits resulting in preference for immediacy	Challenges with altered reinforcement of novel behaviour and deficient extinction of reinforced behaviour	Challenges with accurate predictions resulting in difficulty adjusting behaviour to what is presented when something unexpected happens	Challenges with acquisition and application of cognitively dominant skill sets, susceptibility to salient and affective stimuli, and maintenance of motivation and task engagement in autonomy depriving and thwarting contexts and environments
Neurobiological origin	Deficits in hierarchical maturational development of Executive Function (EF) and control. Caused by abnormalities in structure, function and bio-chemical operation of fronto-parietal and fronto-striatal neural networks	Developmental impairment of unconscious automatic cognitive network guidance systems of dynamic EF clusters. Caused by differences in parieto-temporal activation and frontostriatal and fronto-cerebellar connectivity, impairments in default mode deactivation, neurodevelopmental delay in maturation, and inadequate release and control of dopamine and norepinephrine	Dysregulation of action and thought resulting from poor inhibitory control associated with the meso-cortical branch of the dopamine system projecting in the cortical control centres (EF). Altered delay of reward gradient linked to the meso-limbic dopamine branch associated with the reward circuits (e.g. nucleus accumbens)	Dysregulation of action and thought resulting from poor inhibitory control associated with the meso-cortical branch of the dopamine system projecting in the cortical control centres (EF). Altered delay of reward gradient linked to the meso-limbic dopamine branch associated with the reward circuits (e.g. nucleus accumbens)	Dysregulation of tonic/phasic dopamine control causes stunted dopamine phasic responses despite low tonic levels. Affects the functioning of the anterior cingulate, dorsolateral prefrontal and motor circuits and subsequently a variety of behaviours	Developmental impairments in reinforcement, reward and effortful regulation reliant on affect-related neural systems that detect events' emotional significance. Caused by deficits in maturation of top-down cortical projections from prefrontal cortex impairing differentiation of cognitive and neural systems	Affect dominant and inefficient cognitive self-regulatory processes, overinclusive processing style and altered temporal processing. Caused by reduced volumes in cognitive control networks and prolonged development and hypofunctioning dopaminergic systems impacting time awareness and resulting in hyperconnectivity to salience network and semi-suppression of default mode network in cognitive task engagement
Foundation of model	Neuro biopsychosocial theory of EF as psychological construct separate from neurological functions	Clinical interview research of individuals with ADHD and their families	Laboratory testing of individuals with ADHD	Laboratory testing of individuals with ADHD	Behavioural research with animal models	Developmental behavioural temperament theory of personality traits	Organismic-dialectical theory of human motivation and development
Impact of impairment	Disruption to EF extended phenotype levels adversely impacting behavioural control	Impairments to EF in unconscious automaticity creates disruption in	Negative feedback on impulsive behaviours and poor performance over time	Negative feedback on impulsive behaviours and poor performance over time	Individual variations in dopamine functioning on learning processes and	Breakdowns or disruption in linking the known correct behaviour with the	Variable interest dependant experience of need frustration or amotivation in

	resulting in impaired sense of self, inability to contemplate the future or delay gratification, impaired verbal problem solving and reasoning, and impaired intrinsic motivation	activation (organising, prioritising, estimating and activating action), focus (focusing, sustaining and shifting attention), effort (regulating alertness, sustaining effort and processing speed), emotion (managing frustration and general regulation), memory (utilising working memory and accessing recall), and monitoring and self-regulating action	generates delay aversion, or negative emotional response to delay. Behaviours are functional expressions of motivational delay avoidance or escape. Cognitive deficits with provision, protection and use of time arise as secondary effects of delay aversion related to patterns of task engagement	generates delay aversion, or negative emotional response to delay. Behaviours are functional expressions of motivational delay avoidance or escape. Cognitive deficits with provision, protection and use of time arise as secondary effects of delay aversion related to patterns of task engagement	behaviour result in developmental delays in identifying connections between situational or instructional demands and behaviour, leading to problems anticipating appropriate situationally relevant behaviours and lack of development of self-directed speech for guiding behaviour	current context leads to inaccurate expectations, resulting in less top-down cognitive control being recruited, affecting planning, maintenance of thoughts and actions over time, and regulation of affect	task engagement. Distortions in embodied time leads to over- or under-estimation interfering with use of cognitive dominant organisational skills. Overreliance or unconscious dependence on dopaminergic stress response as a motivational coping strategy

of executive function (EF) is debated (Barkley & Brown, 2008; Posner et al., 2020; Surman et al., 2015); heterogeneity remains unresolved (Cordova et al., 2020; Nigg, Karalunas, et al., 2020; Posner et al., 2020); and context variability, or interest-based maintenance of task engagement, is representative of ADHD challenges with self-regulation (Brown, 2014; Hirvikoski et al., 2011; Roberts et al., 2014). It is noticeable that there has been little re-examination of the theoretical underpinnings of ADHD aetiology in light of these advancements. A recent scoping review highlighted that a single aetiological perspective based on cognitive behavioural theory forms the foundation for cross-disciplinary research in guidance and treatment approaches for ADHD (Champ et al., 2021). Cognitive Behavioural theoretical perspectives conceptualise ADHD as having weak intrinsic motivation due to neurobiological impairments with emotional self-regulation leading to challenges initiating and persisting with goal-directed behaviour (Barkley, 2014a). This ADHD deficit-focused perspective is guided by cognitive behavioural models of self-regulation developed from mechanistic frameworks which prioritise goal achievement supported by cognitive control of emotional response and behaviours (Carver & Scheier, 2016; Gross, 2013, 2015). These models are grounded in psychological (or motivational) hedonism, which claims that all human action and behaviour aims at only increasing pleasure and avoiding pain (Gosling, 1998; Moore, 2019). In these models, self-regulation is synonymous with self-control, and a reduction in resources for self-control is identified as ego depletion, or deficits. Focus on counteracting these deficits, or self-control strengthening, is a primary outcome of research and frameworks in these approaches (Maranges & Baumeister, 2016). In ADHD, attributable behavioural motivations are seen as approach and avoidance dynamics (Elliot, 2006) presented as deficits in attention, response inhibition, and arousal resulting in low motivation, stimulus seeking and task avoidance, among others, ultimately informing treatment design, aims, and outcomes. While treatment approaches include some techniques for identification and development of strengths alongside symptom reduction and control, they only support clarification of prevelence for diagnostic purposes, fewer impairments (Brites et al., 2015; Crosbie et al., 2013; Greven et al., 2016, 2018; Smalley et al., 2007) or identification of individual supportive strengths, as demonstrated in Cognitive Behavioural Therapy (CBT) and Acceptance and Commitment Therapy (ACT), and do not recognise any universal strengths associated with ADHD. (Barkley et al., 2008, 2010; Brooks, 2001; Champ et al., 2021; Demontis et al., 2019; Dipeolu, 2011; Ramsay et al., 2016; Ramsay & Rostain, 2008a; Table 1).

An emerging body of research on neurodiversity recognises diverse neurological presentations and promotes the perspective that non-normative patterns of neurodevelopment are not psychologically unhealthy (Armstrong, 2010; Rosqvist et al., 2020a). Defined as the the infinite variation in neurocognitive functioning within the human species, neurodiversity seeks recognition for any significant embodied divergence from dominant cultural norms of neurocognitive functioning (Walker, 2021). Neurodiverse activism criticises the discourse of patterns of cognitive "normality" and promotes a recognition of conditions that impact the identity of an individual alongside differences in perceiving and responding to the world (Fenton & Krahn, 2007; Rosqvist et al., 2020a; Waltz, 2020). Recent research in psychology also suggests that treatment approaches focusing on deficits and residual symptoms may not be the best approach to improving mental health, and it may be necessary to develop positive psychological factors and emotions that cultivate health, well-being, and support psychological growth (Dell et al., 2021; Jacob, 2015; Liberman, 2008; Slade, 2010). Self-determination theory (SDT) is an organismic-dialectical approach to human motivation and development (Ryan & Deci, 2017). SDT views self-regulation as an evolving process of internalisation and integration of intrinsically motivated self-determined actions leading to self-organisation (Ryan & Deci, 1999). In contrast to cognitive behavioural theory, the roots of SDT lie in the core concept that living things have an organisational nature with inherent growth tendencies. From this perspective the SDT definition of well-being, or flourishing, consists of more than just the experience of hedonic positive emotions. It originates from pursuing a life of activity that is subjectively satisfying developed from and expressing the most reflectively valued and well integrated human potentialities, a eudaimonic view of wellness (Deci & Ryan, 1985; Ryan & Deci, 2017; Ryan et al., 2013). According to this theory, this inherent human tendency to act volitionally and engage with the environment to achieve integration requires social and environmental support to satisfy basic psychological needs, and developing an individual awareness of these needs is central to healthy self-regulation (Ryan & Deci, 2017). SDT's alternative theoretical perspective on human motivation offers the opportunity to re-evaluate the potential strengths of ADHD, re-interpret ADHD research, and develop new treatment approaches with outcomes that include integration and flourishing. In order to understand the development of the aetiology of ADHD, we begin with a short history of theoretical development. An overview of the current main theories of ADHD is followed by a critical review based on current research. Finally, we discuss SDT as a theory and present a potential framework for an SDT based ADHD aetiology and treatment approach.

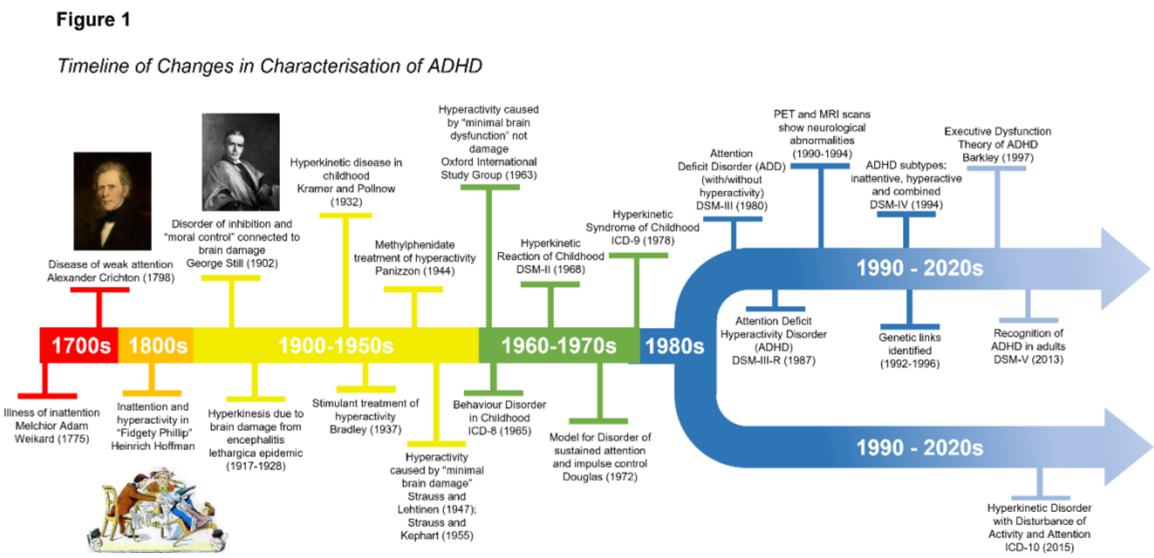
Theoretical Development: Disorder to Syndrome

"Disorder: */dɪsˈɔːdə/ noun* An illness or condition that disrupts normal physical or mental functions" (Oxford University Press, n.d.-a)

The clinical view of approaching, understanding and working with ADHD has a complicated history, heavily derived from social cognitive and cognitive behavioural theory and practice. Initially, identification of this collection of behaviours arose from a frame of mental illness. In North America in the 1960s, the first shift in the perspective around these behaviours appeared: the concept of hyperactivity changed from an extreme state of excessive activity to a behavioural syndrome of more significant than moderate activity and an extreme but common disturbance in childhood. This concept diverged significantly from Europe, particularly Great Britain, which continued to view hyperactivity as uncommon, extreme and usually associated with brain damage. This shift would substantially impact differing views of prevalence, diagnostic criteria, and treatment for the next 20 years (Prendergast et al., 1988) (see Figure 1).

Figure 1

Timeline of Changes in Aetiology of ADHD



Dissatisfaction with a lack of objective measures for these behaviours led to more detailed research. The work of Virginia Douglas (Douglas, 1972, 1980a, 1980b, 1983; Douglas & Peters, 1979) effectively presented the first model of Attention Deficit by introducing several key concepts of deficits. Barkley (Barkley, 2014b p.13) later summarised these as:

1. "the investment, organization, and maintenance of attention and effort;
2. inability to inhibit impulsive responding;

3. inability to modulate arousal levels to meet situational demands; and
4. unusually strong inclinations to seek immediate reinforcement" .

The impact of this paper and the subsequent research that followed resulted in a change in the Diagnostic and Statistical Manual of Mental Disorders (DSM III) of the name "hyperkinetic impulse disorder" to "Attention Deficit Disorder" (ADD) and to ADHD in the DSM IV (APA 1980, 1987). Douglas' original research formed the foundation for investigations into an underlying deficit in self-regulation (Barkley, 1997a) and further research by Douglas pointed out the high degree of relationship between these deficits and response to stimulant medication across all four domains (Douglas, 2005).

"Syndrome: */ˈsɪndrəʊm/ noun* A group of symptoms which consistently occur together, or a condition characterised by a set of associated symptoms" (Oxford University Press, n.d.-b)

While there was general agreement that ADHD must be associated with cognitive deficits, Douglas' model identified a pattern of behaviours but could not explain their origin. Continued empirical research began to cast doubt on the central focus on problems with attention in ADHD due to the situational variability of symptoms and the lack of substantial evidence for deficits involving perception, filtering, and processing of information. Also critical was the separation of ADHD, Conduct Disorder, and Oppositional Defiant Disorder (Wender, 1995). Early studies of "hyperactivity" failed to distinguish these disorders as separate and characterised ADHD with these behaviours as standard. Therefore this literature is more relevant to childhood "externalising behaviour problems: e.g. hyperactivity and aggression or hyperactivity and conduct disorders" (Loney & Milich, 1982 p. 143) rather than ADHD alone. Investigators were increasingly examining motivation and sustained efforts to conceptualise problems experienced by those with ADHD (Barkley, 2014b; Douglas, 1989; Slusarek et al., 2001).

ADHD Evidence: Genetic and Neurobiological Research

In the late 20th and early 21st century, research on ADHD continued to be cognitively focused and advances in imaging and neurobiological studies influenced how ADHD was perceived. There was a removal of the association between ADHD and brain damage symptoms due to a lack of neurological abnormality evidence (Barkley, 2014b; Ramsay, 2010b). Single-photon emission computed tomography (SPECT) indicated decreased blood flow in the prefrontal regions and connecting pathways to the limbic system via the striatum, specifically the anterior caudate and cerebellum. SPECT imagery of dopamine transporter indicated lower dopamine transporter levels in medication-naive patients (Fusar-Poli et al., 2012; Volkow et al., 2009). Positron emission tomography (PET) demonstrated that methylphenidate blocks dopamine and norepinephrine transporters, increasing dopamine in the synapse and amplifying the saliency value of stimuli (Volkow et al., 2005). Structural brain imaging showed reduced total/whole brain and grey matter volume (Albajara Sáenz et al., 2019), with abnormal volumes in grey matter in several areas, including the right frontal and prefrontal areas (Depue et al., 2010; Pironti et al., 2014), anterior cingulate (Amico et al., 2011; Frodl & Skokauskas, 2012; Makris et al., 2010), basal ganglia and cerebellum (Almeida Montes et al., 2010; Makris et al., 2015; Proal et al., 2011; Seidman et al., 2011) and visual cortex (Ahrendts et al., 2011). Several studies have identified subcortical brain volume differences with the most consistent findings showing reduced volumes in areas of the basal ganglia, specifically involving the right lentiform nucleus (putamen and globus pallidus) and the caudate nucleus (Ellison-Wright et al., 2008; Hutchinson et al., 2008; Norman et al., 2016; Valera et al., 2007). Significantly smaller volumes were identified in the accumbens, amygdala, caudate, hippocampus, and putamen in children confirming brain maturation delay; however the effect sizes were small with the exception of the amygdala (Hoogman, Bralten, et al., 2017). Cortical thickness also appeared reduced in adults with

ADHD (Almeida et al., 2010; Duerden et al., 2012; Proal et al., 2011) as well as volume and surface area in young people, although developmental patterns were similar to controls (Ambrosino et al., 2017; Silk et al., 2016). Evidence for structural deficits involving interconnections between large scale brain networks from diffusion tensor imaging (DTI) (Cortese et al., 2013; Konrad et al., 2010; Liston et al., 2011; Van Ewijk et al., 2014) was attributed to microstructural abnormalities in white matter tracts in the cingulum, isthmus, fronto-occipital, frontostriatal, temporal and temporo-occipital fasciculi with atypical hemispheric connection most commonly identifed in the corpus callosum (Aoki et al., 2018; Cortese et al., 2013; Dramsdahl et al., 2012; Konrad et al., 2012; Onnink et al., 2015; Philip Shaw et al., 2015). There were also indications of more significant inattention symptomology associated with lower microstructural integrity in the left uncinate and inferior fronto-occipital fasciculi than controls (Shaw et al., 2015).

Functional MRI (fMRI) meta-analysis identify dysfunctions in several areas of the motor inhibition network (Lei et al., 2015). Studies indicated hypoactivation compared to controls in the frontoparietal executive control network, putamen, and ventral attention are described as “deficient fronto-striatal activation” (Cortese et al., 2012, p. 1051). Hyperactivations in regions of the default mode and optical networks and consistent underactivation compared to controls in fronto-cerebellar networks for timing functions (Hart et al., 2012) as well as abnormally enhanced activation in default mode regions (Hart et al., 2012), in inferior frontostriatal networks during cognitive tasks (Hart et al., 2013) and in dorsolateral fronto-striato-parietal networks during attention tasks (Cai et al., 2021; Hart et al., 2013) were perceived as faulty regulation of relationships between default mode and task-positive networks (McCarthy et al., 2014; Sonuga-Barke & Castellanos, 2007). Differential task activations during inhibition, attention or working memory tasks appeared in regions overlapping the intrinsic frontoparietal, dorsal attentional, visual, motor and default mode networks in ADHD compared to controls (Castellanos & Proal, 2012; Lei et al., 2015). Abnormally enhanced functional connectivity between limbic and orbitalfrontal regions during emotional processing, both positive and negative, indicates emotional hyper-responsivity (Rubia, 2018) and local efficiency and clustering of the right insula is positively associated with emotional dysregulation, particularly with the ADHD hyperactive presentation (Viering et al., 2021).

Genetic studies also indicated that ADHD has high heritability (Franke et al., 2012; Kooij et al., 2019), a co-occurrence or overlap with autistic spectrum disorder (ASD) (Ghirardi et al., 2018; Miller et al., 2019), intellectual disability (Faraone et al., 2017), communication and learning disorders (Thapar et al., 2017), and heritable phenotypes including anxiety and depression and health risk behaviours such as smoking, obesity (Demontis et al., 2019) and alcoholism (Derks et al., 2014). A strong correlation between ADHD diagnosis and trait scores in the general population demonstrated that ADHD represents the extreme of a continuously distributed trait (Demontis et al., 2019; Faraone & Larsson, 2019; Middeldorp et al., 2016). Literature published during and after this time show a shift in how professionals and researchers describe ADHD based on this ongoing research:

"The genetic explanation of ADHD has an important implication that can easily go overlooked: ADHD may simply represent an extreme form of a normal human trait and not a pathological condition in most cases." (Barkley, 2005 p. 75-76)

"Consequently, rather than being a disorder of the 21st Century, ADHD is an ageless syndrome, likely having been present ever since there has been a human brain." (Ramsay, 2010b, p.11)

Current Theories of ADHD

Douglas' model (1972) set the stage for self-regulation as a core deficit in ADHD, but it constituted a psychological model of behaviour rather than a theory of ADHD. Russell Barkley (1997) postulated the first unifying theory of ADHD, which places a core deficit of behavioural inhibition at the source of ADHD behaviours. Strongly based on Skinnerian principles, Barkley reframed issues with attention and impulsivity as stimulus control problems in a relationship between a stimulus and behaviour (Barkley, 1989; Mash & Barkley, 2006). Barkley's executive dysfunction theory suggests deficits in four key areas: working memory, emotional regulation, internalisation of language, and reconstitution, or creation of novel, complex goal-directed behaviours. (Barkley, 1997b, 1998; Willcut, 2014). As an extended phenotype theory, Barkley's model is built upon observation of perceived chronic difficulties in behaviour, measured as "excessive or inappropriate for their age or development level" (Roberts, Milich, & Barkley, 2014, p.63). These symptoms present in two dimensions: Hyperactivity/Impulsivity and Inattention.

Executive Function Theory Perspective on Self-Regulation

Barkley's theory (1997b; 2012) defines executive function as a psychological construct separate from the traditionally presented neurological functions. At its core are four critical theorists: Bronowski, Fuster, Goldman-Rakic, and Damasio. Bronowski's theory of the uniqueness of human language (1977) describes four unique human mental abilities attributed to the prefrontal cortex (PFC): prolongation, separation of affect, internalisation and reconstitution. Fuster's theory of prefrontal lobe functions (1997) emphasises executive functions' temporal integration and orientation toward the future. Goldman-Rakic (1995) argues that activation and use of visual representations of the world and the storage of those representations for behaviour regulation are significant functions of the PFC. Damasio (1994, 1995) postulates that a critical component of decision-making in the prefrontal lobes is a cost-benefit analysis supported by emotional and motivational information provided by somatic markers. Barkley's theory uses constructs from behavioural and social–cognitive theories of personality and functioning, goal theory, socio-economic theory, neuropsychological models of executive functioning and evolutionary psychology.

Barkley's foundation of self relies on Skinnerian Radical Operant Conditioning (Skinner, 1953). In this theory of personality, the concept of self, or everything an organism does in response to a stimulus, is defined as behaviour (Skinner, 1971). Barkley cites Von Mises' economic model (1948/1990) and Objectivism (Piekoff, 1993) as sources for definitions of means or action toward goals or values. Goals are states resulting in decreased dissatisfaction or unease relative to the present state and future states we seek to attain, fulfil, and retain. Barkley defines wants and desires as these future states that we value because they increase satisfaction, happiness, and welfare (Piekoff, 1993). Energisation and direction of behaviour is motivated by movement to change the present state to a future improved state, toward or away from pleasure or pain – a hedonic view of wellness which is a common theme in social-cognitive theories of functioning (Carver & Scheier, 2016; Mischel & Shoda, 1995). According to Von Mises (1948/1990), the utility or use-value of a goal is subjective or objective, with subjective being individually evaluated. The degree to which the individual perceives a goal to alleviate dissatisfaction will determine its value and drive goal-directed actions and behaviour. The course of action pursued to attain that goal is defined as the means to that end. Barkley equates this individual evaluation for choices and actions with self-regulation or self-control. Executive function and self-regulation in this model are therefore directly linked to forward projections of effect in linear time: an executive act is any action an organism takes to modify behaviour predicting it will change future outcomes (Barkley, 2015).

The Six Executive Functions

For Barkley, the ability to evaluate subjective goals correlates to executive functions (EF), which he defines as "those self-directed actions needed to choose goals and to create, enact and sustain actions toward those goals" (Barkley, 2012, p. 60), a view echoed in neuropsychology (Eslinger, 1996; Wagner & Heatherton, 2011). Barkley describes six forms of EF that are interactive and serve the common purpose of internalising self-directed behaviour to rehearse actions to test probable consequences mentally. In particular, it allows for assessing emotional responses, defined by Barkley as somatic markers (Damasio, 1994, 1995), to determine social acceptability. Muscular-skeletal manifestations of behaviour initially observable in childhood are inhibited by EFs through maturation to form private behaviours in adulthood to align with social-cultural norms. Management of social conduct by EF, specifically the PFC, is highlighted as the evolutionary purpose of self-regulation (Barkley, 2012; Eslinger, 1996). Therefore these abilities facilitate adaptive functioning by anticipating and preparing for future action through an internal trial-and-error process (Barkley, 2015).

The six forms of EF or self-directed actions hierarchically arrange as follows:

1. Self-Directed Attention (Self-Awareness). Self-directed attention is the first to arise and forms the conscious sense of "self". Barkley places self-awareness as the "central executive" seat responsible for the coordination of cognitive processes, similar to Stuss & Alexander (2000) and in contrast to other models of EF. This EF provides the awareness of values and wants and the capacity to generate and consider options available to the individual over time, making it the "seat of human free will" (Barkley, 2012, p.29). Evidence for self-awareness as a brain function primarily centred in the PFC and connected networks is drawn from three sources: diminished self-awareness following brain injuries, specifically to the PFC (Stuss & Alexander, 2000), Demasio's neurobiological triumvirate model (2000), and neuroimaging research (Herwig, 2010).

2. Self-Restraint (Executive Inhibition). Executive inhibition provides the delay or temporal gap required for self-directed actions, or goal-directed behaviour, to arise. Separation of the event from the sensorimotor responses of future activity exemplifies the decoupling of stimulus-response behaviour required for attention to be shifted away from the present moment environment and directed toward the self and the goal, or contemplated future (Barkley, 2015). This EF represents the separation of affect in Bronowski's theory (1977), and Barkley locates this at the automatic level of brain functioning, incorporating the frontal-striatal circuitry and basal ganglia (Saint-Cyr, 2003).

3. Sensing the Self (Nonverbal Working Memory). This EF is conceptualised as a self-directed action to use visual imagery or imagination. Often compared to Baddeley's (1986; Baddeley & Hitch, 1994) visual-spatial sketch pad, Barkley combines this concept with Vygotsky's (1978, 1987) theory of the development of private speech to suggest a visual form of self-guidance and direction, or "cool EF" (Castellanos et al., 2006) that becomes progressively internalised with maturation. This EF has two roles: the frontal lobe enables access to past sensory experiences and links them to covert prospective preparatory motor elements to mentally rehearse options for future responses (Fuster, 1997; Goldman-Rakic, 1995); experiences can then be self-elicited in the absence of the primary stimulus for behavioural re-enactment, or mimesis. Barkley considers the ability of this EF to bridge cross-temporal elements crucial for self-control. The foundation of this EF is a prolongation, from Bronowski's theory (1977), linked with the right dorsolateral PFC and posterior visual association areas (D'Esposito et al., 1995, 1997).

4. Speech to the Self (Verbal Working Memory). Baddeley's (1986) construct of a phonological loop is the basis for this EF, to which Barkley again adds Vygotsky's model of internalisation of speech which forms the ability of self-control via language through covert self-description self-instruction, self-questioning and problem-solving. This loop invents rules and meta-rules for oneself (Diaz & Berk, 1992), but Barkley also suggests it is responsible for maintaining moral conduct or internalising socially prescribed rules. This "cool EF" (Castellanos et al., 2006) represents internalisation in Bronowski's theory (1977), and activates the same prefrontal regions used for audible speech (Ryding et al., 1996).

5. Self-Directed Appraisal (Emotion/Motivation to the Self). Arising from the first three EFs, this EF represents affective and motivational valences, or hedonic tone, associated with visual and verbal information. These valences are Damasio's (1994, 1995) "somatic markers". They indicate the intrinsic "goodness" or "badness" of an event, object, or situation related to homeostasis, generating the motivation to move toward satisfaction and away from dissatisfaction. Like the previous EFs, Barkley defines these valences as emotional displays that eventually move from visible to covert through maturation, transforming from reactions to an internalised motivationally guiding force, or the "wellspring of intrinsic motivation" (Barkley, 2015 p.415). With the support of the previous three EFs, emotions are responses to environmental stimuli and states created as needed as self-motivation or "hot EF"(Castellanos et al., 2006). These states initiate and sustain action toward future goals, attributed to bidirectional networks linking the dorsolateral PFC, orbitofrontal cortex, anterior cingulated cortex and amygdala (Damasio, 1994, 1995; Etkin et al., 2006; K. N. Ochsner et al., 2009; K. N. Ochsner & Gross, 2005; Rushworth et al., 2007).

Combined with the previous three EFs, mainly nonverbal working memory, this EF provides the persistence (sustained attention) and willpower to support the attainment of future goals. Barkley defines this capacity to inhibit immediate behaviour favouring future outcomes, or delay gratification, as a conscious executive appraisal. From this perspective, the ability to contemplate "later" versus "now" makes the action of choice a biological function to support goal-directed behaviour. This action includes emotional self-regulation in choosing to inhibit strong emotional displays to appropriately respond to a social context, meet social demands and maintain relationships.

6. Self-Play (Reconstitution). The final EF completes Barkley's model basis on Bronowski (1977). This EF conveys the ability to take apart (analysis) and recombine (synthesis) information to form novel combinations of behaviours, defined in Barkley's model as problem-solving. Behavioural innovation, flexibility, generativity, and planning for goal-directed action from a present state to the desired state are all attributed to this EF, and Barkley describes this as a process of action fluency (Piatt et al., 1999), or the ability to retrieve verbs impaired in frontal lobe injury. Barkley locates this alongside verbal and non-verbal working memory in separate dorsolateral PFC regions (Lee et al., 1997; Stuss & Alexander, 2000).

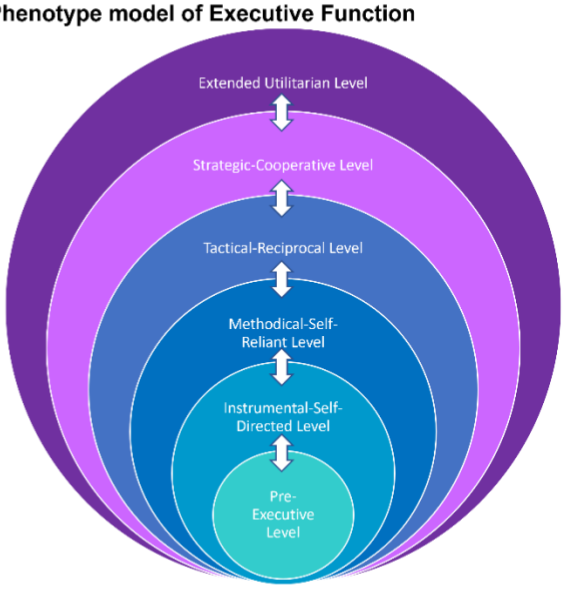
Extended Phenotype Model of Executive Function

As self-regulatory processes, Barkley suggests each EF contributes to adaptive functioning in the species' phenotype (Dawkins, 1982), which critically impacts social activity and individual survival and welfare. Figure 2 represents the effect of the outward extension of the EF phenotype into personal, social, community and cultural activities (Barkley, 2012).

Figure 2

Barkley's Extended Phenotype model of Executive Function

Figure 2: Barkley's Extended Phenotype model of Executive Function



Note: Adapted from Barkley, R. A. (2012). Executive Functions: What They Are, How They Work, and Why They Evolved. Guildford Press

Pre-executive and Executive Levels of Functioning

The extended phenotype model is hierarchical and includes six functioning levels, dependent on attaining the previous level for emergence, identified as means of self-control, or classes of action self-directed to make choices and improve the future.

Pre-executive. The Pre-Executive level of the model contains the "automatic" or largely unconscious level of human activity seen in feedback loop theory (Carver & Scheier, 2016), Gross's emotional self-regulation model (Gross, 2007, 2013; K. N. Ochsner & Gross, 2005), attentional control models (Rueda et al., 2011), and the concept of effortful control (Eisenburg et al., 2011). It represents neuropsychological functions responsible for the operant conditioning behaviour with stimulus structure – response – consequence (Skinner, 1953), moment-to-moment actions directed to the temporal "now" and in the immediate environment outside of self-awareness or self-consciousness. Primary emotions occur at this level that may heighten attention and redirect behaviour to immediate well-being situations. However, Barkley perceives this as a primitive, unthinking, un-reasoning animal-like level of existence and does not consider these responses forms of self-regulation and therefore not EF (Barkley, 2012).

Instrumental-self-directed level. The six self-directed actions of EF are at the Instrumental-Self-Directed level of the model. Self-direction and internalisation are taken from Vygotsky's model (Diaz & Berk, 1992; Vygotsky, 1978, 1987), causing this level to arise from the pre-executive through human development musculoskeletal movements' expression and action to become private and "cognitive". This representation of the executive level exerts effortful control to cause the "top-down" regulation of automatic actions through generation and sustainment of mental representations of the future (Carver & Scheier, 2016; Eisenburg et al., 2011). In current cognitive theory, "top-down" self-regulation is influenced by cognitive regulation skills managed by executive functions demonstrated as intentional cognitive control (Carver & Scheier, 2016). Emotional regulation is considered a less intentional and more reactive "bottom-up" influence which can be helpful and unhelpful. Metacognition, or self-monitoring, is considered essential to self-regulation for self-evaluation, task difficulty, performance, and strategy acquisition (Fernandez-Duque et al., 2000). The integration of cognitive regulation and emotional regulation to regulate behaviour and actions are the central work of self-regulation, and these domains influence one another in a bi-directional relationship (Blair & Ursache, 2011).

Barkley cites Gross's (2007) modal model and Carver & Scheier's (2016) feedback loop theory as two equivalent self-regulation models. In Gross's modal model, Barkley compares the executive level pathways of emotional control as methods the EFs use to influence automatic behaviours via five vectors: situation selection, situation modification, attentional redirection, event reappraisal, and response modification/suppression (Gross, 2007). The first two stages are proactive, decreasing the likelihood that an unwanted primary action/emotion will occur. The remaining three are reactive and potentially less effective as a primary action/emotion has been elicited, and there is a limited resource pool of willpower which can become depleted in the process (Bauer & Baumeister, 2011). This process can be used both to self-regulate strong negative emotions and enhance or prolong positive emotions through methods such as mental contrasting – visual images of the desired state/goal contrasted with the present state – thus creating a form of emotional self-control (Gollwitzer & Oettingen, 2011). In Carver & Scheier's multi-system feedback loop model, Barkley compares EFs self-directed action to the discrepancy reduction monitoring between the present and desired state/goals. As emotions in Barkley's model provide motivational indicators of progress toward goals, Carver & Scheier's model (2016) uses emotional markers to measure variation in rates and velocity of progress toward goals. Barkley also maps EF's components to the two-level emotional feedback loop model as the executive level of effortful, conscious, deliberative, and rational goal-directed action that alters or overrides the automatic, experiential, unconscious and intuitive level if one's actions become inappropriate to the situation or goal.

Barkly has a particular and economic view of self-directed behaviours, differentiating between leisure and labour (Von Mises, 1948/1990). Self-directed actions that are pleasurable or reduce dissatisfaction can be ends in themselves but are not EF if there is no modification to goal-directed behaviour and a delayed end. Barkley classes these as potentially maladaptive because they may interfere with long term goals and welfare, such as mind-wandering/daydreaming interfering with completing a task on time (Barkley, 2012).

Methodical-self-reliant level. This model's level extends the analysis and synthesis into recombination from the self-directed level to sequences of actions within the physical environment, such as routines. Barkley (2012, 2014a) argues that this is the basis for human productivity and innovation to effectively attain goals and increase one's quality of life and long-term welfare through environmental reorganisation. The ability to self-organise and act beyond internal executive cognitions is the hallmark of this level.

Tactical-reciprocal level. This level represents social reciprocity and the organisation of the social environment for goal achievement. Effective moral and ethical rules of social conduct require inhibition of self favouring others and long-term welfare for circumstances where goals cannot be achieved alone. The ability to engage in behaviours that support effective social exchange for mutual benefit over the longer-term such as sharing, taking turns, and accepting social etiquette, which Barkley (2012) states is challenging for individuals with PFC injuries (Harlow, 1848, 1868; Luria, 1966) and affects individual self-regulation (Finkel & Fitzsimons, 2011; Fitzsimons & Finkel, 2011; McCullough & Carter, 2011).

Strategic-cooperative level. Barkley separates this level from the previous level as he equates cooperation with a conscious understanding of the division of labour and increased sacrifice of self-interest to obtain greater personal benefit leading to acceptance of interdependence. Conscience, sympathy, empathy, guilt, remorse and a sense of belonging are defined as psychological capacities arising from and facilitating social cooperation (Barkley, 2012). Specialisation in skills based on talent through foresight and reasoning arises at this level and trust, investment, and behaviour based on laws and ethics. Social mutualism, or placing others' self-interest over or ahead of one's own, characterises this level.

Extended utilitarian level. Barkley's final level acts as a feedback mechanism for EF's successful use or self-regulation from the previous levels. Evidence for successful individual use of EF is demonstrated in the extension of life expectancy, economic and social success, and long-term welfare of offspring. Conscientious behaviour, or considering the consequences to self and others over impulsiveness and selfishness, prevents premature death, promotes positive judgement and feedback from others, ensures professional advancement, improves parenting abilities and ensures economic resources to support future generations. Barkley supports this with research on the negative impact of ADHD on daily life activities generally (Barkley, 2011), and specifically including marriage and relationships (Barkley, 2008; Ninowski et al., 2007) and parenting (Banks et al., 2008; Barkley, 2006b; Murray & Johnston, 2006).

Executive Function Theory Perspective of ADHD

Barkley's theory prioritises two key elements: the core of EF or self-regulation: the self-direction of self-regulation of actions across time for goal attainment, and internalisation of those self-directed actions (Barkley, 2012). From this perspective, Barkley believes that ADHD demonstrates apparent deficits. There are observable challenges in self-regulating arousal concerning goal-directed behaviour and difficulties maintaining attention for tasks with little to no reinforcement or immediate reward (Barkley, 1997b p.68). According to Barkley, deficits in the hierarchical maturational development of EF in ADHD are predicted to disrupt this extended phenotype's various levels, adversely impacting the sources of control over behaviour. In other words, ADHD will interfere with the biological action of choice and, therefore, a loss of freedom and self-determination (Barkley, 2012). This interference results in an:

- Impaired sense of self, including self-awareness and self-monitoring
- Inability to contemplate the future, resulting in reduced hindsight, forethought, and the creation of anticipatory action toward future events. This inability impacts the ability to organise and execute actions to achieve goals concerning time and engage in imitation and vicarious learning

- Inability to delay gratification, leading to impulsivity, or inability to subordinate self-interest to others or long-term personal goals; and distractibility, or failure to inhibit responses to a task or goal-irrelevant events
- Reduced behavioural self-control because of greater public and less private self-speech and reflection before acting, impairing verbal problem solving and reasoning. Barkley implies this includes difficulty following rules and instructions and other ethical guides for conduct
- Impulsive, emotional expression and reactivity, interfering with top-down emotional regulation processes in the service of long term goals, including situation selection and modification, attention deployment, cognitive reappraisal, and response suppression or modification (Gross, 2007). Somatic marker-based decision-making would also be impaired (Damasio, 1994, 1995)
- Impaired intrinsic motivation or diminished internal ability to induce drive or motivational states towards goals, resulting in a dependence on the external environment for motivation. Without external motivators, sustained attention and persistence become erratic
- The decline in problem-solving and innovation ability leading to over-reliance on automatic or inadequate strategies or complete abandonment of goal pursuits

Alternative Neuropsychological Origins of ADHD

Since the Executive Dysfunction model's publication, several theoretical models attribute additional and alternative cognitive and behavioural sources for developing ADHD symptoms. Presented are four theories reviewed by Johnson et al. (2009). Included is Brown’s EF model, often cited in treatment literature.

Brown's Executive Function Cluster Model

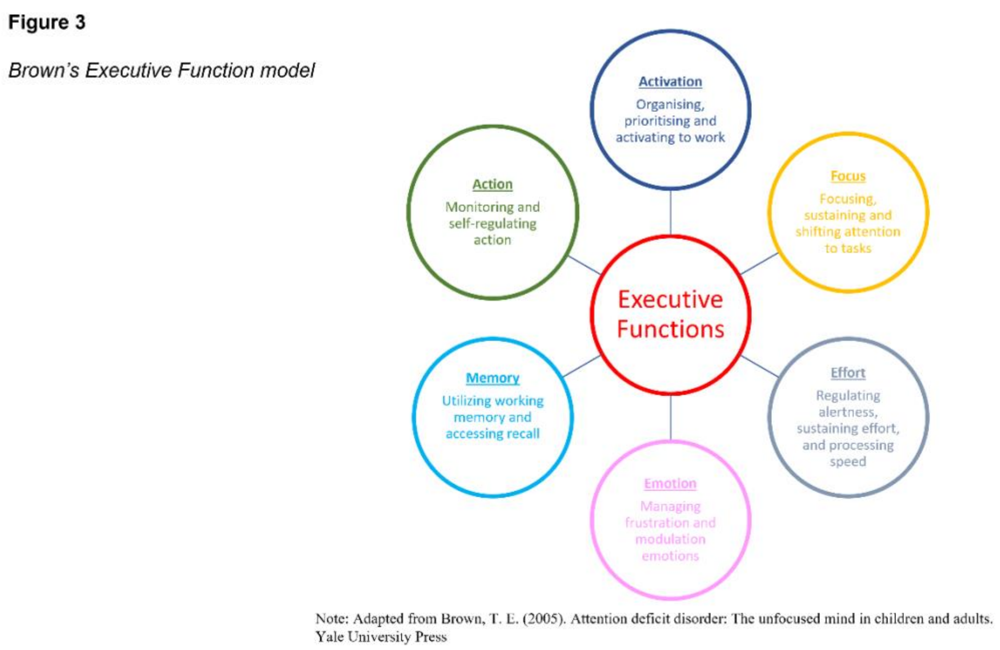
Like Barkley, Brown's model (2005, 2013, 2014) also places executive function impairments and their relationship with self-regulation at the core of ADHD (Brown, 2006). However, the definition of executive functions, the origin of impairments, and their impact on individuals are considerably different. Instead of Barkly's heavily theoretical approach, Brown's cognitive behavioural model builds from research based in intensive clinical interviews with individuals diagnosed with ADHD and their families. Brown identifies ADHD as a complex syndrome of developmental impairments of executive functions (Brown, 2013). Defined as capacities enabling engagement in successful independent self-serving behaviour (Lezak et al., 2004), executive functions (EFs) in this model are not hierarchical but clusters of cognitive functions that interact dynamically and continuously for self-management in the following ways:

- Activation: Organising, prioritising, estimating time and activating action to work.
- Focus: Focusing, sustaining, and shifting attention to tasks.
- Effort: Regulating alertness, sustaining effort, and processing speed.
- Emotion: Managing frustration and regulating emotions.
- Memory: Utilising working memory and accessing recall.
- Action: Monitoring and self-regulating action.

This self-management system of the brain provides the mechanism for self-regulation, defined as the ability to change oneself and exert control over one's inner processes specifically by organizing actions toward goals, managing emotional distress, obeying laws, and internalizing social standards of both moral and competent behaviour (Vohs & Baumeister, 2004). Brown's model views the coordinated efforts of EFs as a networked guidance system, much like a computer (Carver & Scheier, 2016) or the conductor of an orchestra as opposed to a separate concept of conscious sense of self, a difference that Barkly challenges as a passive view of the organism in existing models of EF (Barkley, 2012). Brown sets this management system firmly in the unconscious or System 1 of Kahneman's (2011) behavioural "thinking fast and slow" theory via "automaticity", defined as rapid

Figure 3

Brown's Executive Function model



activation of attitudes, emotions or behaviours that emerge in a specific context without directed conscious thought (Bargh, 1994; Brown, 2014). Brown (2014) cites LeDoux (1996) and Dodge (1991), who highlight the primacy of unconscious emotional processing as the energetic, motivational force, or "hot EF" (Castellanos et al., 2006) that drives cognitive activity and shapes experience and action. Circuits of the limbic system, specifically the amygdala, are designated as instantaneous processers that assess emotional reactions and appraise the level of reward or threat concerning instinct and memories of past experiences to designate how much attention should be allotted (Damasio, 1999). Brown differentiates his model from Barkley's by broadening his emotional modulation scope from inhibition of negative emotions to include value for positive emotions, such as interest, attraction, and desire. Dopamine, a neurotransmitter particularly sensitive to pleasure and reward, is highlighted as a signaller of important stimuli to the pre-frontal cortex (PFC), which selects action plans, including storing in working memory (Brown, 2005). Dopamine increase triggers interest and indicates reward, and therefore motivation which creates a feedback loop to sustain engagement - a hedonic view of well-being. This system effortlessly draws upon personal memory of past experiences and learned skills to automatically produce complex responses in a variety of contexts, reducing the need to make conscious deliberate decisions. The ability to use emotion-based stored working memory to hold things in mind and utilise that information to direct current action, or make choices, via “cool EF” (Castellanos et al., 2006) is crucial for the guidance of executive functions and self-regulation (Brown, 2005).

In this model, ADHD persistence in impairments is attributed to executive functions' location in unconscious automaticity (Brown, 2013), making medication treatment essential. The situational variability of impairments and adaptive problems in day to day activities that characterise ADHD are presented as evidence of impairments in cognitive management networks, not independent cognitive functions (Brown, 2006). Neurobiologically, four areas are highlighted as interfering with effective self-regulation. Limitation to the interactive communication networks due to white matter differences is suggested as the origins of working memory deficits (Castellanos & Proal, 2012; Cortese et al., 2012, 2013). This deficit is evidenced by a single fMRI study in children where performance differences in parieto-temporal activation and frontostriatal and fronto-cerebellar connectivity during vigilant attention were normalised compared to controls with methylphenidate (K. Rubia et al., 2009). Differences in increasing deactivation of the default mode network during active attention tasks (Fassbender et al., 2009) are identified as impairments in the coordination of dynamic shifts in rate and rhythms of bran cell oscillations (Brown, 2014). This impairment is evidenced by a single fMRI study in children of increased default mode suppression with methylphenidate (Peterson et al., 2009). Neurodevelopmental delay in maturation (P. Shaw et al., 2007), or less maturity in emotional management than peers, is highlighted as damaging to learning, relationships and self-esteem in years when education and preparation for adult life are key. Inadequate release and control of dopamine and norepinephrine and its impact on the delay of reinforcement (Swanson et al., 2011) are suggested as origins in deficits in motivation and sustained effort. Studies indicating improvements in utilisation of working memory and functional connectivity using methylphenidate are presented as beneficial (Prince & Wilens, 2009), although Brown admits few studies address the impact of medication treatment on emotion regulation (Brown, 2014).

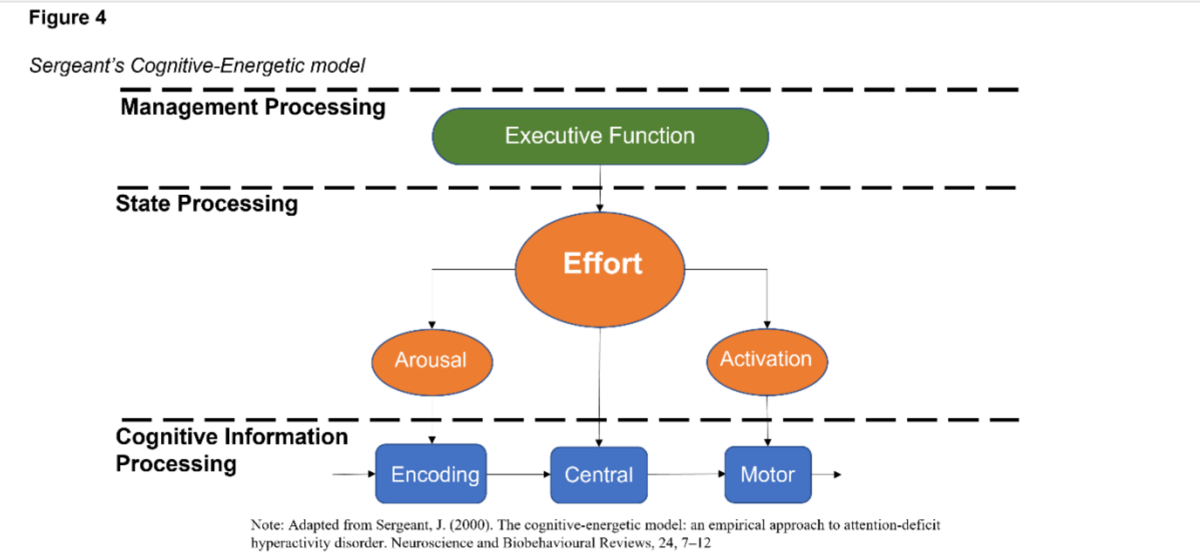
Sergeant's State Regulation Hypothesis

Like Barkley, Sergeant (2000; 2005) identifies inhibition as a central deficit in ADHD. However, disinhibition is not unique to ADHD, and therefore the State Regulation Hypothesis of ADHD (Sergeant et al., 1999) focuses on the activation of inhibition and highlights the energetic state as an origin for performance deficits. Based in human vigilance and performance research, the Cognitive-Energetics Model (Sanders, 1983) is used to act as a bridge between "top-down" and "bottom-up" theories of functioning and address the heterogeneity found in ADHD (Sergeant, 2005; Sergeant et al., 2003). Sanders (1983) identifies three levels of information processing: management, energetic, and cognitive processing, divided into two functional categories: process, or computational mechanisms of attention; and state, or energy for activation. Cognitive information processing operates in four stages: encoding, search, decision, and motor organisation. State processes categorised into three energetic pools: effort, arousal and activation.

The effort is the energy necessary to meet task demands and is required when the organism experiences stress, an intervening variable response when the organism's current state does not meet the required state for task performance. Emotions, defined as physiological feedback, are indicators of stress. The effort is given state primacy in this model as it excites and inhibits the arousal pool and the activation pool, highlighting its role in motivation and response contingencies (e.g. threat/reward) - a hedonic view of well-being. The effort is associated with the hippocampus, and pupil dilation measures cognitive load and effort engagement (Sergeant et al., 1999).

Figure 4

Sergeant's Cognitive-Energetic model



Arousal is a phasic, or rapid, adaptation to stimuli that indicates a rate of change, described as "time-locked" (Pribram & McGuinness, 1975; Sergeant et al., 1999). Arousal is associated with the mesencephalic, reticular formation, and amygdala regions of the brain. Activation is a tonic or slow physiological readiness to respond to stimuli associated with the basal ganglia and corpus striatum. The process by which stimuli may be maintained and manipulated in a short-term buffer is termed working memory (Baddeley, 1996). Planning, monitoring and error detection and correction are the management mechanism's role, or EF, associated with the prefrontal cortex. These levels' interaction demonstrates how the Cognitive-Energetic model encompasses both "top-down" and "bottom-up" self-regulation processes.

Sergeant (2005) highlights that deficits in ADHD have been identified at all three levels of the model: cognitive response mechanisms, energetic activation and effort mechanisms, and management, or EF, system deficits. The influence of effort highlights Sergeant's relationship between effort and the activation pool over response choice, motor preparation, or motivation. Research has demonstrated that individuals will delay motor preparation until they gain maximum payoff for effort with minimum energy allocation (Hackley & Miller, 1995). Children with ADHD have exhibited sensitivity to response contingencies, rewards, and deficient response organisations in laboratory testing, particularly when stimuli are presented slowly, which is demonstrated as a rapid decline in task efficiency concerning the event rate (Sergeant et al., 1999). Because the event rate influences motor activation in the Cognitive-Energetic model, Sergeant defines ADHD as an energetical state dysfunction with insufficient effort allocation. Allocation of energetic resources is probably strongly associated with the availability of particular neurotransmitters (Sergeant et al., 2003). Thus symptoms will increase or decrease depending on task parameters and the state of the individual with ADHD, and for Sergeant, this could explain ADHD heterogeneity.

Sonuga-Barke's Delay Aversion/Dual Pathway Theory

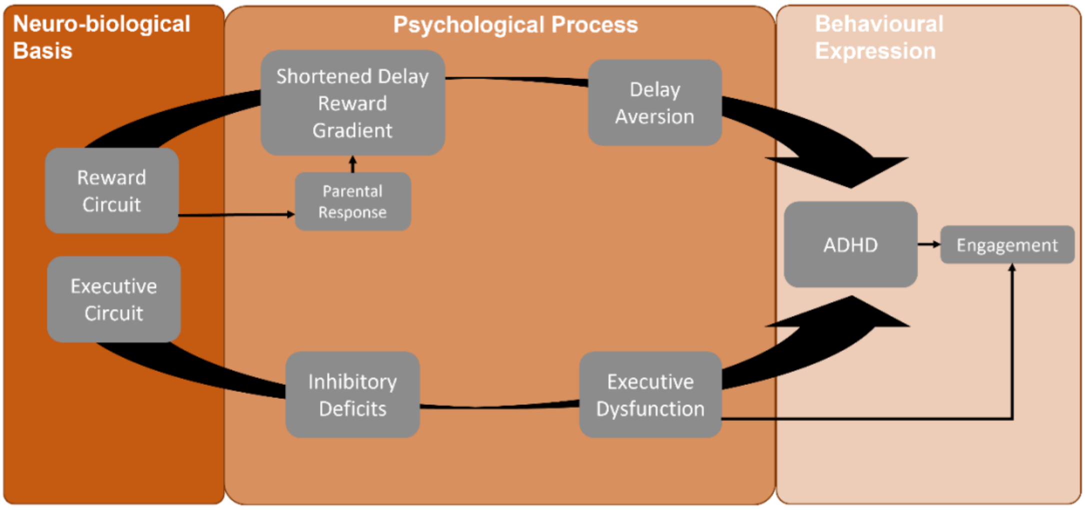
In contrast to EF deficit models, Sonuga-Barke's delay aversion/dual pathway theory (2004; 2003; Sonuga-Barke et al., 1992; 1994) began as a simple single deficit model based on motivational factors. Based on laboratory evidence, this theory initially identified ADHD impulsivity as the expression of a natural preference for immediacy in children with ADHD, particularly when a choice is an option. Because this preference is expressed even when rewards are offered following delay, it is interpreted as a biologically-based shortened delayed reward gradient (Sonuga-Barke, 2003). It is suggested that children with ADHD have automatic "bottom-up" hyper-vigilance to emotionally or motivationally relevant environmental cues indicating opportunities to escape from delay (Sonuga-Barke et al., 2004). The ability to delay gratification has high social-cultural importance in terms of socialisation, and this model theorises that parental intolerance of "impulsiveness" creates an association over time of delay with negative responses. Consequently, children with ADHD develop a negative emotional response to delay or delay aversion (Sonuga-Barke, 2003).

Figure 5

Sonuga-Barke's Delay Aversion/Dual Pathway model

Figure 5

Sonuga-Barke's Delay Aversion/Dual Pathway model



Note: Adapted from Sonuga-Barke, E. J. S. (2003). The dual pathway model of AD/HD: An elaboration of neuro-developmental characteristics. Neuroscience and Biobehavioural Reviews, 27, 593–604

Inattention and hyperactivity are also expressions of this preference, presented as a "top-down" process designed to modify the subjective experience of time passing and reduce the experience of delay. The aim is to effectively "speed up time" in situations without choice by moving attention to non-task related aspects in the environment (Sonuga-Barke et al., 1996; Sonuga-Barke, 2003). Neurobiologically, delay aversion is placed within a motivational or affective reward circuit to include the ventral striatum (nucleus accumbens), frontal regions (notably the anterior cingulate) and orbitofrontal cortex. The circuit is completed by connections in the ventral palladium, structures in the thalamus, and the amygdala. The mesolimbic neurotransmitter dopamine, which we have seen is involved in ADHD, is a key modulator for reward signalling in this circuit (Sonuga-Barke, 2004).

In light of evidence that children with ADHD also demonstrate EF deficits, Sonuga-Barke incorporated Barkley's (1997b) response inhibition hypothesis rather than current EF theories. Defined as "higher-order, top-down, cognitive processes that allow appropriate task set, maintenance and shift, and that facilitate the flexible pursuit of future goals" (Sonuga-Barke, 2004 p.1232), EFs generally and response inhibition specifically are regarded in this model as critical for self-control, emotional regulation, and cognitive flexibility. It is suggested that motivational and cognitive development could be impacted by the experience of challenges in effective engagement with tasks and environments that require inhibition-based executive processes. As with delay, the negative social-cultural responses to task failure may lead to "executive-task aversion", impacting intrinsic motivation and reducing interaction with these tasks, therefore limiting opportunities to develop executive skills. Neurobiologically, EFs are placed within an executive circuit to include the prefrontal cortex, the dorsal neostriatum (caudate nucleus), the basal ganglia, and the dorsomedial thalamus excitatory glutaminergic cells. The mesocortical neurotransmitter dopamine is a key circuit modulator (Sonuga-Barke, 2004).

This model argues that neither the executive circuit nor the reward circuit could fully account for the behavioural self-regulation challenges evidenced in ADHD. However, a head-to-head study of the two models indicates that both are distinct, separate processes and can be identified in ADHD (Solanto et al., 2001). Sonuga-Barke suggests a dual-pathway model recognises the heterogeneity that comes with ADHD and may indicate additional ADHD subtypes. More recently, a third pathway has also been suggested involving temporal processing deficits (Sonuga-Barke et al., 2010).

Sagvolden's Dynamic Developmental Theory

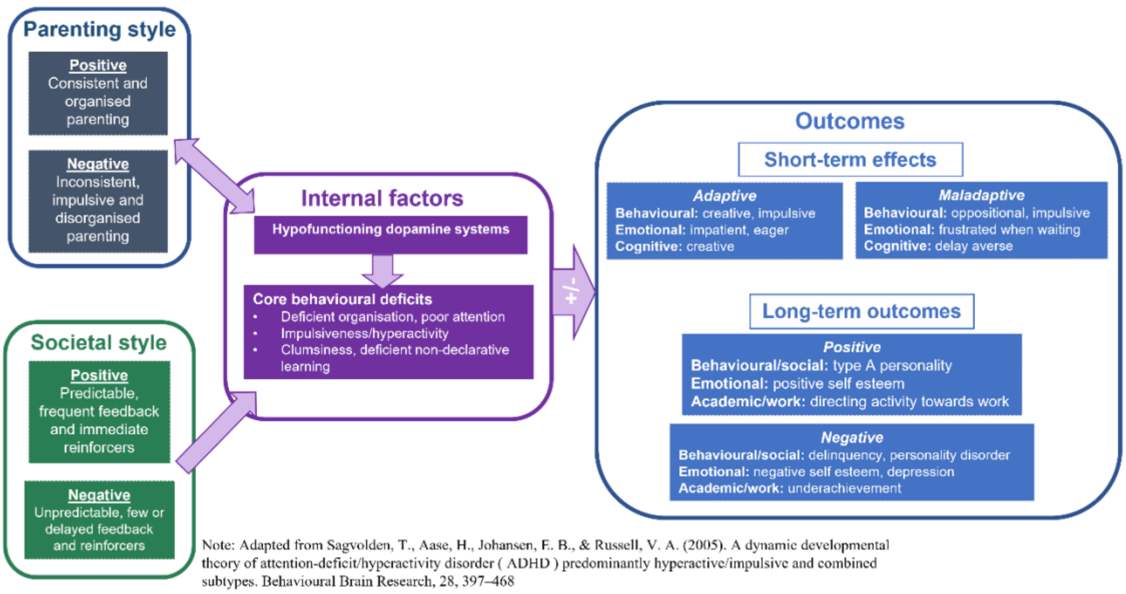
Like Barkley (1997b) and Sonuga-Barke (2004), Sagvolden et al. (2005) also postulated that ADHD is grounded in issues with response inhibition and delay aversion. However, this model's origin is represented as hypo functioning dopamine systems that may account for all the symptoms in the hyperactive/impulsive and combined ADHD subtypes. The dynamic developmental theory (DDT) is based on work with animal models in Behaviourism (Skinner, 1953, 1971), and defines ADHD as arising from two faulty behavioural processes: altered reinforcement of novel behaviour and deficient extinction of reinforced behaviour (Sagvolden et al., 2005).

Figure 6

Sagvolden's Dynamic Developmental Theory model

Figure 6

Sagvolden's Dynamic Developmental Theory model



Based on research with methylphenidate (Grace, 2001), the DDT argues that issues with ADHD arise from naturally occurring abnormally low levels of tonic dopamine transmission or slow stimulus adaptation, leading to naturally elevated phasic dopamine transmission, or rapid stimulus adaptation. It is suggested that phasic dopamine has two subcomponents: a fast component signalling a primary response for engagement with the expectation of reward before confirmation, defined as erroneous "reward prediction", and an intermediate subcomponent involved with behaviours such as movement, reward, punishment, stress and sex (Schultz, 2002). Phasic dopamine is released as a pulse or spike response. Tonic dopamine is located in the extrasynaptic space but is low-concentration and tightly regulated. It is too low in concentration to stimulate receptors, and it is strong enough to exert a continuous down-regulation and modulation of phasic response spikes. (Grace, 2001) Tonic dopamine is thought to be regulated by frontal cortical sensory neurons to the nucleus accumbens via the dorsolateral prefrontal cortex, an area attributed to being responsible for working memory. The DDT suggests that ADHD arises from dysregulation of tonic/phasic dopamine control, causing stunted dopamine phasic responses despite low tonic levels (Sagvolden et al., 2005). Lower levels of existing tonic dopamine in this model, combined with a smaller striatal volume, could also account for deficits in working memory (Castellanos, 2001).

The DDT indicates dopamine hypofunctioning in ADHD impacts three dopaminergic networks responsible for self-regulation: the mesolimbic, the mesocortical, and the nigrostriatal. Impact on the mesolimbic network could result in altered reinforcement and extinction behavioural processes, interfering with establishing behavioural stimulus control and acquisition of verbal instructions to set rule-governed behaviour. This behaviour produces a shorter delay-of-reinforcement gradient, resulting in the delay aversion described by Sonuga-Barke (2004). Because reinforcement and extinction behaviour acquisition processes require tonic and phasic dopamine to be successful, naturally occurring lower tonic dopamine in ADHD will require increased phasic dopamine release to achieve reinforcement. Similarly, normal tonic but reduced phasic dopamine release associated with a reinforcer will result in less efficient reinforcement. This model claims this describes the “motivation” issues seen in ADHD, and therefore reinforcers must be stronger and more salient to control behaviour. Extinction deficits, or inability to stop ongoing behaviour despite lack of reinforcement, accounts for Barkley’s (1997b) response inhibition in this model. Mesocortical network disturbances result in attentional deficiencies that increase behavioural control and direct action toward long-term goals. Deficiencies in the nigrostriatal network are associated with impaired motor control and habit formation through nondeclarative memory, which may be partly responsible for Barkley's (1997b) response inhibition. In other words, reinforcement of behaviour is only successful if the consequences are perceived within a limited time window. Hypofunctioning dopamine systems may impact this time window length in ADHD, leading to limited stimulus control around attention, preferences for short sequences of behaviour leading to motor impulsiveness, and deficient maladaptive behavioural extinction, leading to excessive behaviour or hyperactivity. In this model, executive functions are "untangled" into motor impulsiveness and cognitive impulsiveness due to the slower acquisition of longer sequences of behaviour and difficulty with the extinction of previously reinforced behaviours (Sagvolden et al., 2005).

The DDT hypothesises that the interplay between behaviour and environment at different times of life will generate ADHD heterogeneity. For the person with ADHD, the impact of individual variations in dopamine functioning on learning processes and behaviour will result in developmental delays in identifying connections between situational or instructional demands and behaviour, leading to problems anticipating appropriate situationally relevant behaviours and lack of development of self-directed speech for guiding behaviour. The DDT highlights that ADHD impacts individual and family relationships, particularly when the parents may also have ADHD. While a non-ADHD parent may assist with developing stimulus control in their child by providing frequent and immediate reinforcers, it is unlikely to be achieved by an ADHD parent (Sagvolden et al., 2005). Cultural and social value for behavioural self-control, learning to use time efficiently, and foresee consequences of the behavioural impact on socialising, gaining an education or gaining employment generate challenging expectations for those with ADHD. In Western cultures, permissible unwanted behaviours in childhood are expected to extinguish by adulthood. According to this model, an adult with ADHD will have acquired many maladaptive behaviours that will be difficult to change. Interestingly, the DDT also recognises a successful side of this neurobiology as a positive, creative individual who directs their energy toward work, defined as a type-A personality (Sagvolden et al., 2005).

Nigg et al.'s Multiple Pathway Model

Unlike other ADHD theories, the focus of the Multiple Pathway Model (Nigg, 2017; Nigg et al., 2004; Nigg, Karalunas, et al., 2020; Nigg & Casey, 2005) is less on the aetiology of ADHD and more on clarifying the heterogeneity and different developmental trajectories represented by comorbidities found in ADHD populations (Nigg et al., 2004). To accommodate these differences, this model highlights the integration of cognitive and affective neuroscience through considering components of cognitive control, affect regulation, and their mutual influence on one another in self-regulation and in development (Nigg & Casey, 2005). Maturation leads to neural organisation and increasing hierarchical specialisation and differentiation in cognitive neural systems. Prediction, or learned expectations of temporal and contextual cues, is based on attentional responses from infancy (Saffran et al., 1996). Cognitive control is defined as behavioural regulation, or the ability to adjust behaviour based on these cues and suppress inappropriate behaviours. This ability arises out of four basic circuits identified in neurodevelopment (Amaral, 1986):

- Reflexive, or "where" orienting guided by a parietal–thalamic circuit
- Alerting and vigilance, or "when" orienting, guided by noradrenergic activation of right-lateralized circuitry, including the cerebellar–cortical circuits
- Reinforcement learning and reward response, guided by fronto-limbic circuitry
- Effortful regulation and voluntary planning of behaviour and cognition, which involves frontostriatal circuitry (Nigg & Casey, 2005)

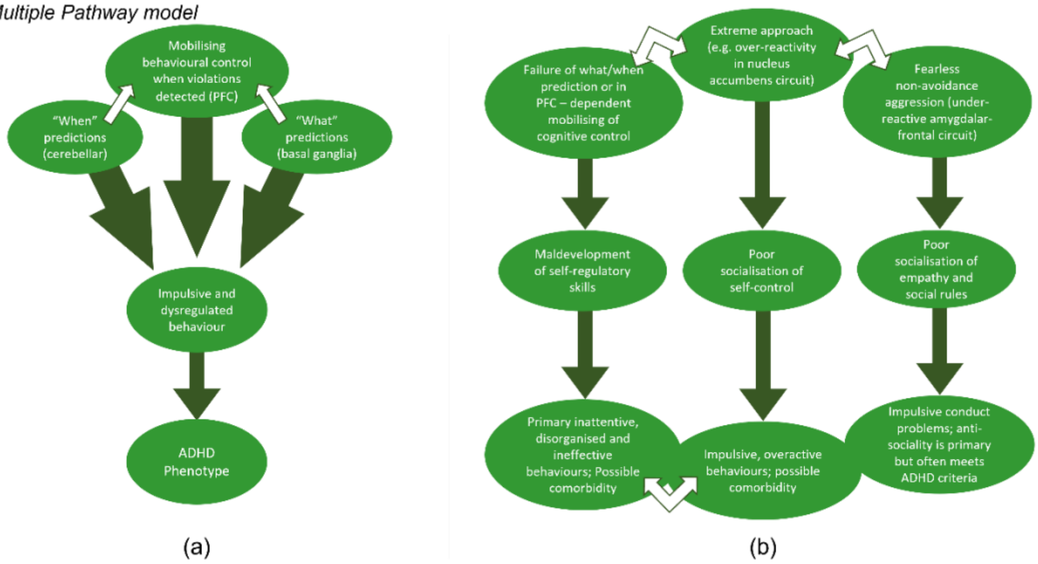
This model links reinforcement and reward and effortful regulation into a third "what" orientation based on mutual reliance on frontostriatal loops and dopaminergic modulation, forming affect-related neural systems that detect events' emotional significance. These circuits facilitate the adjustment of action when predictions of what is being presented are violated. It is the "when" and "what" orientations requiring voluntary or effortful control that this model highlights as challenging to activate efficiently in ADHD, seen as a failure to form accurate predictions resulting in difficulty adjusting behaviour to what is presented *when* something unexpected happens. The actions from these inaccurate predictions account for ADHD behaviours that are continued inappropriately for the context where the outcome/consequences are misjudged, or when action has its effect mispredicted. In other words, breakdowns or disruption in linking the known correct behaviour with the current context leads to inaccurate expectations, resulting in less top-down cognitive control being recruited, affecting planning, maintenance of thoughts and actions over time, and regulation of affect (Nigg & Casey, 2005). Here, the model agrees with Sagvolden (2005) that disruptions in these systems may also lead to inefficiencies in developmental learning and socialisation, interfering with the benefits received from an expected level of parental support or correction and therefore integration and self-regulation.

Figure 7

The Multiple Pathway model

Figure 7

The Multiple Pathway model



Note: Adapted from Nigg, J. T., Goldsmith, H. H., & Sachek, J. (2004). Temperament and attention deficit hyperactivity disorder: The development of a multiple pathway model. Journal of Clinical Child and Adolescent Psychology, 33(1), 42–53; and Nigg, J. T., & Casey, B. J. (2005). An integrative theory of attention-deficit/hyperactivity disorder based on the cognitive and affective neurosciences. Development and Psychopathology, 17(3), 785–806

In highlighting the reciprocal connection between emotions and the recruitment of cognitive control, the core focus is on updating goal states by continual contextual processing of frequency, timing and emotional valance of information which disrupts goal-directed behaviour in ADHD. This model associates the influence of positive emotional valance, an expectation of reward, and negative emotional valance, or non-expectation of reward, with excessive approach motivation and withdrawal/non-approach motivation contextual behaviours. This behaviour is defined as temperament or categories of traits involving affective reactivity and regulation. Thus, inattention-disorganisation can be mapped to effortful control, hyperactivity to activity level, and impulsivity to negative/positive approach (Nigg et al., 2004).

This model suggests there are advantages to temperament parallels with ADHD behaviours: temperament coding would be advantageous in the early stages of development to identify precursors of ADHD and illuminate risk factors or as an outcome moderator. Maturational changes in temperamental traits combined with experience also give rise to personality traits in adulthood, similar to maturational changes in ADHD symptoms (Nigg et al., 2004). Therefore this model argues that temperamental tendencies may lead to ADHD, and ADHD may be identified as a common phenotype clinical outcome of several developmental pathways (Nigg & Casey, 2005)(see (a) in Figure 7). Alternatively, ADHD has multiple identifiable pathways with slightly different phenotypic outcomes (see (b) in Figure 7): prediction breakdowns leading to top-down weakness, arousal regulation and cognitive control, described as “executive functioning” difficulties (Barkley, 1997b); extreme positive approach tendencies leading to problems in reinforcement learning (Sagvolden et al., 2005) with minimal to no executive function deficits; breakdowns in response inhibition, or cognitive control, and affective responding, or a poorly regulated approach system (Sonuga-Barke, 2003, 2004); but also faulty avoidance learning leading to impulsive and anti-social behaviour and psychopathy (Nigg et al., 2004; Nigg & Casey, 2005). Further work on this model has extended to the broader field of psychopathology using network modelling (Borsboom & Cramer, 2013; McNally, 2016) which assumes accumulation or “clusters” of symptoms generates a syndrome rather than a latent disorder or trait (Nigg, Karalunas, et al., 2020; Nigg, Sibley, et al., 2020).

Critical Review of Theories

Issues in ADHD Neurobiology

The cognitive behavioural theory-based conceptualisation of ADHD is prominent in advances in neuroscientific research. In ADHD, differences in structure and function of the brain are presented as evidence of deficits leading to hyperactivity, impulsivity and inattention. These include size differences in the pallidum, thalamus, caudate nucleus, putamen, nucleus accumbens, amygdala, and hippocampus (Hoogman, Buitelaar, et al., 2017); abnormalities within dopaminergic networks, specifically the mesolimbic (Posner et al., 2013; Volkow et al., 2011); differences in cortical maturation rate (Shaw et al., 2007;

Shaw et al., 2006); as well as altered activity in the prefrontal cortex, blood flow to limbic areas via the striatum, and activation of hippocampus, insula and anterior cingulate (Barkley, 2014a). Despite these findings, neuroimaging data remains correlational (Kooij et al., 2019), and recent meta-analysis indicates no significant difference in brain structure between adults with ADHD and controls (Hoogman, Buitelaar, et al., 2017; Wolfers et al., 2019). Besides, there are several persistent concerns and considerations regarding ADHD neurobiology.

Issues with ADHD and EF

Recent research has shown that no single EF deficit is high enough to support executive dysfunction as the cause of all cases (Boonstra et al., 2005; Castellanos et al., 2006; Nigg, Stavro, et al., 2005; Nigg, Willcutt, et al., 2005; Posner et al., 2020; Willcutt et al., 2005) and neuropsychologically identified EF is not associated with deficient emotional self-regulation in ADHD (Surman et al., 2015). Criticism of EF weaknesses highlights that the complexity of neurocognitive processes in executive tasks makes isolating the exact locus of dysfunction difficult using current EF task testing designs (Willcutt et al., 2005). However, Barkley (2012, 2014a) and Brown (Barkley & Brown, 2008; Brown, 2005, 2006, 2009) argue that laboratory-based neuropsychological tests of EF impairments in adults with ADHD are limited in scope due to their focus on single variable isolation. They recommend assessing the ability to perform complex everyday self-managed tasks as a more appropriate way to measure individual executive functioning. Consequently, Barkley's (1997b, 2012) EF model is still promoted as clinically useful for case formulation, treatment planning, and intervention design (Ramsay, 2016, 2020).

Altered brain activity in ADHD

While altered brain activity in ADHD has been noted in neuroimaging research, it has received limited positive attention. In several studies, brain activity in ADHD engaged differently or oppositely to controls. Selective attention tasks showed robust bilateral activity in the ventrolateral prefrontal cortex (BA 45) and insular cortex compared to controls and unilateral activation of caudate, putamen, thalamus, and pulvinar, indicating potential recruitment of a different response pathway (Bush et al., 1999). In switch tasks, adults with ADHD more strongly engaged the right middle temporal gyrus, dorsal anterior cingulate cortex (dACC), precuneus, lingual gyrus, and the left precentral gyrus (supplementary motor area) and insula, demonstrating that those with ADHD display different frontostriatal and parietal activation than controls during the performance of an executive control task (Dibbets et al., 2010). In working memory tasks, a diffuse network of regions was activated rather than right PFC regions, including the parietal, precuneus, and occipital lobe, indicating that individuals used more visual strategies in this aurally presented task suggesting a system more reliant on visual strategies and response to visual stimuli (Fassbender & Schweitzer, 2006). In research on an inhibitory paradigm and delay task, activations were seen in right pre- and post-central gyrii, right inferior parietal lobe and right caudate instead of bilateral frontal areas of the PFC suggesting activation differences may reflect differences in strategies for task performance (Fassbender & Schweitzer, 2006; K. Rubia et al., 2000). When progressive time-on-task activation was examined in a working memory task, increases in activation in the right lenticulate, left parahippocampal gyrus, and cerebellum was shown over time, possibly indicating a reliance on motor regions (Schweitzer et al., 2004). Complex cognitive function tasks showed activation of the right side of the basal ganglia rather than left, leading to speculation of differences in how this region is used to perform tasks (Durston et al., 2003; Shafritz et al., 2004).

It has long been recognised that the dopaminergic reward pathway is altered in ADHD. However, findings also showed a strong positive correlation with the motivational measure of Positive Emotionality and D2/D3 receptor availability in the midbrain in adults, indicating the importance of intrinsically interesting activities in improving motivation (Volkow et al., 2011).

In resting-state connectivity analysis, connections between dorsal (DAN) and ventral (VAN) attentional networks were less segregated functionally in ADHD than controls, with hyper connections with the VAN. Increased coupling with the VAN and the Salience Network (SN) produces an altered saliency attribution mechanism in ADHD. Interestingly, the connection between the Default Mode Network (DMN) and the SN was intact and unaffected (Sidlauskaite et al., 2016). The SN has been identified as crucial in identifying biologically and cognitively relevant endogenous and external stimuli to adaptively guide behaviour between large scale brain networks, with the anterior insula particularly key in salient event detection signalling reward, motivation, and affective saliency (Menon, 2015). More recently, research in altered interaction between large scale networks showed hyperactivation with the DMN during cognitive paradigms leading to excessive spontaneous "mind-wandering" in ADHD (Bozhilova et al., 2018; Posner et al., 2015). While excessive mind-wandering can be impairing, mind-wandering has been positively correlated with creativity tasks such as the generation of novel and useful ideas (Carson et al., 2003; Fink et al., 2012) and better creative output due to a broad attentional focus (Kasof, 1997; Mendelsohn, 1976; Zedelius & Schooler, 2015).

Investigations of stop-signal tasks and stop-signal reaction time indicate that inattentive and hyperactive symptoms represent an entirely different integration of distributed processing in ADHD that recruits resources used in task-directed performance by typically developing individuals (TD). It is hypothesised that this style of processing is not amenable to the reinforcement learning models that appropriately describe neural function in TD (Chevrier & Schachar, 2020). Cordova et al.'s (2020) findings from the comparison of subgroups showed that biological differences exist and are not entirely attributable to a global theme of over-or under-connected functional networks but display a fundamentally different organization attributable to more complex mechanistic interactions across networks.

Heterogeneity

Heterogeneity remains an unresolved problem, leading researchers to infer that causes of ADHD may be distinct but also shared with other conditions as well as TD (Cordova et al., 2020; Feczko et al., 2019; Nigg, Karalunas, et al., 2020; Posner et al., 2020). Heterogeneity in ADHD is demonstrated both aetiologically and phenotypically in multiple dimensions including neurobiological, developmental, psychosocial and emotional/cognitive self-regulation (Luo et al., 2019; Nigg, Sibley, et al., 2020). The polygenic liability of ADHD adds to its complexity, considering the overlap or co-occurrence with other phenotypes and psychiatric disorders (Cross-Disorder Group of the Psychiatric Genomics Consortium, 2013; The Brainstorm Consortium, 2018) and a recent genome-wide associaton study (GWAS) that has identified 12 independent significant associated genetic loci (Demontis et al., 2019). However, affect sizes are small for each individual gene despite multiple gene involvement (Faraone & Larsson, 2019; Luo et al., 2019; Nigg, Sibley, et al., 2020). While heterogeneity is acknowledged in the DSM-5 by specifying three presentations: mostly inattentive, mostly hyperactive, and combined (APA, 2013), some theories account for all these presentations (Brown, 2013; Nigg, Karalunas, et al., 2020; Sergeant, 2005; Sonuga-Barke, 2003) while others characterise them as separate conditions (Barkley, 2014c; Sagvolden et al., 2005). Conceptualisations of ADHD currently recognise the dimensionality of the disorder, yet there is very little research on positive attributes such as hyper-focus, creativity, divergent thinking, curiosity, courage, transcendence, and resilience (Boot, 2017; Boot et al., 2017; Redshaw &

McCormack, 2022; Sedgwick et al., 2018; H. A. White & Shah, 2006, 2011, 2016). Phenomenological qualitative studies of the lived experience of ADHD indicate that interest is associated with meaning and a sense of "flow" (Csikszentmihalyi, 1975), mainly when working with or assisting others (Ek & Isaksson, 2013); that aspects such as persistence and perfectionism can be identified as undervalued resources, and that those with ADHD strive to find a healthy balance and develop strategies (Bjerrum et al., 2017). However, these positive aspects tend to be perceived as "individual strengths" which are encouraged in treatment, rather than unifying positive features of ADHD (Champ et al., 2021).

The ADHD Paradox or Context Variability

Research has also identified that while there is a persistence of core symptoms in ADHD, there is significant variability in context (Brown, 1995, 2014; Hirvikoski et al., 2011). Individuals with ADHD demonstrate consistently good, sustained attention on tasks which are engaging or "interesting" but symptoms increase in situations synonymous with low stimulation or boring activities, often resulting in delay aversion and inattention (Antrop et al., 2000; Boonstra et al., 2005; Hoza et al., 2001; Johansen et al., 2002; Roberts et al., 2014; Wender, 1995; Zentall et al., 1985). However, characterisations of ADHD often define this behaviour as "stimulus seeking" and tend to focus on the inability to engage with non-stimulating tasks. Research also shows a correlation in ADHD with a need for autonomy, defined in this context as a freedom of choice (Dimic & Orlov, 2014; Houghton, 2006; Partridge & Williams, 2008; Young, 2000). Studies show that those with ADHD performed better in working environments where autonomy was supported, sometimes highlighted as entrepreneurship (Boot, 2017; Toner et al., 2006). Young & Bramham (2012) specifically stress that for those with ADHD to succeed, they must define their structures and boundaries. There is little research into the motivational influences of interest and autonomy in ADHD other than as a reward.

Theoretical Influence on Current Treatment Approaches

Traditionally, the primary goal of research on self-regulation in ADHD is the management and reduction of the experience of negative emotions, which are presented as problematic, destabilising, and leading to dysregulation and overwhelm. Therefore, the focus of non-pharmacological interventions have been to improve self-regulation by the cognitive reframing of maladaptive schema, habituation of behavioural management skills via continuous reinforcement, and development of cognitive regulation skills in attention-shifting and positive reappraisal (Philipsen et al., 2010; Ramsay, 2020; Ramsay & Rostain, 2015; Safren et al., 2005; Solanto, 2010; Tuckman, 2009; Young & Bramham, 2012; Zylowska et al., 2008). The reappraisal goal is to identify negative responses early in the emotional experience and consciously alter them to positive perspectives (Gross, 2013). While this skill is helpful in some contexts, such as managing an immediate crisis or when another's safety or emotional stability is of primary concern, such as a child, the process of reappraisal involves avoidance of the experience of emotion in preference to minimising negative affect (Wolgast et al., 2013). However, being cognitively led, reappraisal requires an additional cognitive cost, as described in "effortful coping" (K. Ochsner et al., 2002), implying a high demand of performance for those with ADHD considering effort avoidance (Roberts et al., 2014) and an inability to allocate sufficient cognitive effort are both considered core characterisations of ADHD (Sergeant, 2000). Reappraisal also is shown to be less accessible as a resource when emotional intensity is high (Gross, 2013), and intensity of emotional dysregulation is identified as a core component of impairment in ADHD (Barkley, 2014a; Corbisiero et al., 2013).

Self-Determination Theory: A New Perspective

Extensive research in multiple areas of human functioning has led to the understanding that ADHD presents motivation, engagement, and self-regulation issues. Understanding interest and its role as a motivational factor in ADHD is key to gaining a new perspective on ADHD behaviour. However, motivational research has highlighted interest as a central affective marker of intrinsic motivation (Ryan & Deci, 2017). Self-determination theory (SDT) presents intrinsic motivation as the spontaneous tendency ‘‘to seek out novelty and challenges, extend and exercise one’s capacity, explore, and learn’’(Ryan & Deci, 2000, p. 70). SDT is an empirical, organismic approach to personality development that investigates people’s inherent growth tendencies as a basis for self-motivation and personality (Ryan & Deci, 2000). At the core of SDT is the assumption that human development includes an innate, active tendency toward integration of structures, functions and experiences resulting in greater effectiveness, organisation and unity in functioning (Ryan & Deci, 2017; Ryan, 1993). Defined as organismic integration, SDT describes organisation as both a fundamental biological principle and a perspective reflected in multiple psychological traditions such as Piaget’s (1971, 1981) ideas of organisation expressed as propensities toward assimilation; Freud’s (1923) concept of synthetic function of the ego; White’s (1959, 1963) description of inherent independent ego energy manifesting in intrinsically motivated activities; and Rogers’ (1963) primacy for the tendency toward actualisation as a basic motivational tendency underlying behaviours.

SDT and Self-Regulation

SDT defines the self as a synthetic function of the psyche, reflecting this inherent tendency towards organisation and integration as an active process. Unlike social-cognitive approaches which define self as an object perceived by oneself or another (self-concept), supported by mechanisms for governing action (self-schemas), SDT cites McAdams (1990, 1996, 2013) view of the “self-as-subject” phenomenally experienced both as a centre of experience and the initiator and regulator of volitional behaviour (Ryan & Deci, 2017). This “self-as-process”, or autonomous functioning, is defined in SDT as having the freedom to choose actions that align with the interests, values, and a sense of meaning originating in the internal self-concept. Freedom, in this instance, is not defined as independence from external influences, but a higher-order coordination of component systems into a relative unity and acting from that organised vantage point (Ryan et al., 1997). Autonomy, meaning “self-governing”, is considered central to healthy development as it functions both phenomenologically and structurally to organise integration and regulate actions to integrate new functions, values, narratives, preferences and regulations (Ryan & Deci, 2017). Thus, self-regulation in SDT is synonymous with autonomy and “disturbances in autonomy” are equated to self-regulation disturbances (Ryan et al., 1997).

Traditionally, the exploration of issues with healthy self-regulation focuses on the control and management of behaviour. Instead, SDT’s organismic approach orients questions about motivation and behaviour toward what supports human functioning and flourishing. According to SDT, the quality of an individual’s motivation and vitality depends on what resources they have been able to draw from their exchanges with their environment to maintain, support and enhance their existence or satisfy their needs. While it is clear that organisms have biological deficit needs (Hull, 1943) that, when satisfied, will return an organism to equilibrium, SDT postulates there are also basic psychological needs that do not require deficiencies to motivate action. When satisfied within cultural, interpersonal and developmental contexts, basic psychological needs facilitate growth, integrity and well-being and, when frustrated, generate psychological harms (Ryan & Deci, 2017). SDT identifies three innate basic psychological needs - autonomy, competence and connection, or relatedness - which, when satisfied, allow optimal function and growth. As previously described, autonomy is the feeling of willingness and volition with respect to behaviours. Competence is defined as feeling effective with interaction in social environments or, more precisely, experiencing support and opportunities for the exercise, expansion and expression of capacities and talents. Relatedness is defined as feeling connected and having a sense of belonging, referring to both experiencing others as responsive, and sensitive (Ryan & Deci, 2017). SDT suggests that people can become self-determined, make choices and manage their lives independently when their needs for competence, relatedness, and autonomy are fulfilled (Deci & Ryan, 1985). Acting volitionally to achieve goals and satisfy needs experienced as intentional and thus personally caused is the basis of self-determination. SDT defines self-determination from the phenomenological tradition as a willed action caused "as an initial act of the ego-center itself" (Pfander, 1967 p.20) differentiated from acts caused by external agents. However, this autonomous action could occur even when experiencing external pressures if one agrees to act in that way (Ricoeur, 1966).

As an organismic approach, SDT is concerned with both goal achievement and the nature and motives of goal adoption. SDT highlights that there are process differences for goals that have different origins. The satisfaction of the basic psychological needs will be consistent with the achievement of some goals but not others, and thus "all goals are not created equal" (Ryan et al., 1996). Critically, SDT cites Heider's (1958) and DeCharms' (1968) work on the psychological construct of perceived locus of causality (PLOC) and its impact on motivation: the degree to which autonomy is experienced as a salient sense of personal causation determines the intrinsic nature of the action. Individuals who are intrinsically motivated engage with activities because they are interested in and find them inherently satisfying. Exploratory "seeking" behaviours, experienced as curiosity, interest, sensation seeking and search for meaning, produce a sense of immediate positive feedback on progress when a challenging task at an achievable or optimum level is mastered. This sense of gaining *competence*, or "flow" state (Csikszentmihalyi, 1975), is seen as a process of continually seeking and reducing information gaps in knowledge or problem-solving (Di Domenico & Ryan, 2017). Motivation to engage and regulate activity is heightened in some domains, forestalled or conflicted in others, and some opportunities will amplify or diminish interest, meaning SDT recognises both social contextual and within-person variations in regulatory functioning (Ryan & Deci, 2017).

In light of these potential variations and in contrast to other models of self-regulation, SDT recognises three regulatory styles that are characteristic of human functioning: relatively autonomous and integrated modes, relatively controlled and introjected (non-autonomous) modes, and absence of regulation (and motivation) (Deci & Ryan, 1985; Ryan & Deci, 2017). Integrative regulation represents natural human development to actively internalise and assimilate social norms and regulations for healthy functioning. Independent reproduction of socially and culturally accepted assimilated behaviours, attitudes, and values reflect the process in which extrinsic behaviours become a part of an aspect of an individual's mind and motives. Research indicates that three facilitating factors lead to internalisation: a meaningful rationale, so individuals find value in the activity; acknowledging potential negative feelings; and highlighting choice. A key conclusion from this research was the importance of the relationship between the subject's behaviour and feelings: the more positive the relationship, the more integrated the regulation (Deci et al., 1994). SDT views healthy emotion regulation as including rich access to positive and negative emotions as informational inputs that assist in both the choice and self-guidance of actions. Taking an active interest in emotional responses, expressing them, and using them as a built-in feedback system to provide physiological, cognitive, and motivational signals that inform behaviours and goals to satisfy basic psychological needs is a key part of Integrated Emotional Regulation (IER) (Roth et al., 2019). This system supports an individual to exercise potential, find meaning, connect with others and express vitality – a eudaimonic view of wellness (Ryan et al., 2006).

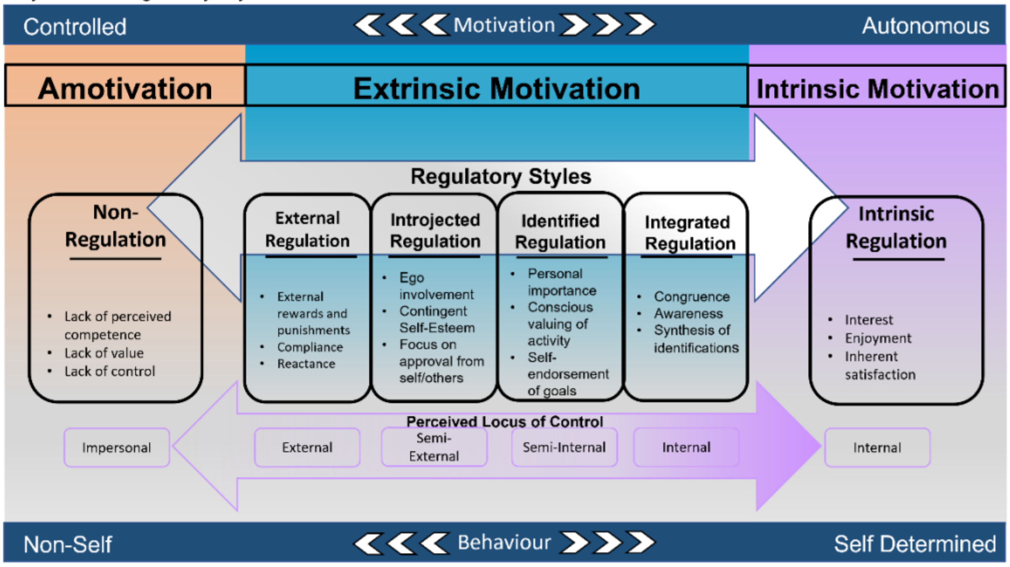
Additionally, SDT outlines that rewards, contingencies, and pressures attached to specific outcomes can be experienced as controlling rather than based on the individual's autonomous choice. The opposite of autonomy in SDT is not dependence but heteronomy, defined as controlled by outside forces (Ryan & Deci, 2017). Behaviours that are introjected or externally motivated to establish internal control over the self are simply responses to the environment rather than internalised and establish an expectancy (implicit or explicit) that the contingency is in effect. When introjected, behaviours are experienced as an internal, controlling force – a sense that one "should" or "must" do the behaviour. Therefore, the behaviours will not be sustained over time because they are dependent on the maintenance of these external or internal pressures and contingencies for reliable occurrence. Controlling regulation results in unstable self-esteem (Kernis & Paradise, 2002; Ryan & Brown, 2013) and suppression of negative emotions impairing the ability to disclose, listen to, or deal with them effectively (Roth et al., 2014).

Figure 8

The Taxonomy of SDT Regulatory Styles

Figure 8

The Taxonomy of SDT Regulatory Styles



Note: Adapted from Ryan, R. M., & Deci, E. L. (1999). Approaching and avoiding self-determination: Comparing cybernetic and organismic paradigms of motivation. In R. S. Wyer Jr. (Ed.), Perspectives on Behavioural Self-Regulation (pp. 193 215)

Absence of regulation, or amotivation, is defined as a state where one is not motivated to behave or behaves in a way not mediated by intentionality. Amotivation potentially results from two sources: lack of perceived competence, or believing that acting will either not achieve the desired outcome or that the behaviour cannot be performed; or perceiving a lack of value or interest in the behaviour. The first is recognised in social cognitive theory (Bandura, 1996), but the second is also recognised in SDT as an absence of interest and utility, leading to a lack of motivation to act (Ryan & Deci, 2017). Emotionally, amotivation can be experienced as dysregulation, where individuals' daily functioning is impacted by their inability to manage negative emotions and consequently feel overwhelmed and therefore engagement with others and the environment is impaired (Roth et al., 2014). SDT highlights that intrinsic motivation only occurs when individuals experience self-determined action, perceived competence and relational responsiveness and security, or *relatedness*. Therefore, autonomy is "fragile", and must be supported for optimal development and expression (Ryan et al., 1997). Not all goals will result in positive consequences for the individual, and individuals may discontinue practice once pressure or controlling elements are removed

(Ryan & Deci, 2008). Therefore, autonomy-supportive environments are critical to integrated self-development (Ryan et al., 2016).

SDT and Neuroscience

Recent research in motivational neuroscience has identified brain structures and neural pathways, establishing a neural basis for motivational states. Neuroscience literature highlights that intrinsic motivation arises from spontaneous satisfaction one experiences while engaged in a task or intrinsic rewards, and this sense of task satisfaction is what makes the experience of engagement with a task enjoyable or interesting. The anterior insula generates these intrinsic satisfactions, and the extent to which an activity is considered interesting is represented by activity in the anterior insular cortex, making it the key structure in intrinsic motivation (Reeve & Lee, 2019b). Engagement with an environmental activity that allows a person to feel volition, effectance and connection also produces need-satisfying spontaneous satisfactions, showing that basic psychological need satisfaction is indicated by anterior insular and striatum activations (Lee & Reeve, 2017; Reeve & Lee, 2019). Studies in dopaminergic function show that task-related feedback is registered even in the absence of external rewards (Tricomi & DePasque, 2016) and that salience related dopaminergic activity drives curiosity and desire for information (DeYoung, 2013). Therefore, SDT proposes that intrinsic motivation is associated with activity in the dopaminergic value system (Di Domenico & Ryan, 2017). The Salience Network (SN), involves the anterior insula, dorsal anterior cingulate cortex (dACC), and subcortical nodes in the amygdala, nucleus accumbens (NAcc), substantia nigra, and ventral tegmental area (VTA) (Menon, 2015). The SN is believed to receive motivationally significant dopaminergic information from several of its main structures and subcortical nodes, which is integrated with sensory input from the environment and viscera for “bottom-up” detection of contextually relevant events in self-regulation. It is suggested a function of the SN is to act as a dynamic hub to modulate activity between two other large scale brain networks that support cognitive functions. The first is the Default Mode Network (DMN), which has major nodes in the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC) and is active during passive resting states and involved in internally focused self-referential cognition, spontaneous cognition and mind wandering (Buckner et al., 2008). The DMN is also associated with introspective attentional orientation related to mentalising and emotional processing (Gusnard et al., 2001) and the maintenance of a sense of self (Gusnard, 2005; Sonuga-Barke & Castellanos, 2007). The second is the Central Executive Network (CEN) which includes the dorsolateral prefrontal cortex (DLPFC) and the posterior parietal cortex (PPC) and is active during cognitively demanding, externally focused tasks and involves working memory and executive functions. Neuroimaging studies support SDT theory that activities involving intrinsic motivation recruit the salience and central executive networks, while suppressing the default mode network, specifically activity within the midbrain, anterior cingulate cortex (ACC) and bilateral insula in response to free-choice (autonomy) cues (Di Domenico & Ryan, 2017).

SDT Aetiology of ADHD

SDT and ADHD

Applying the organismic approach of SDT to our current understanding of ADHD clinical presentation, neurobiological research, and treatment design and outcomes has the potential to offer a new conceptualisation and approach. Recognising that those with ADHD actively seek to improve engagement with their environment to achieve integration and self-actualisation fundamentally alters the ADHD discourse. This perspective also highlights the importance of understanding the task or activity targeted for engagement and its relationship with both ADHD neurocognitive abilities and the individual's regulatory state. Seen from an SDT perspective, ADHD aetiology could be described as neurobiologically altered approaches to processing and task engagement, supported by structures that have been primarily associated with salient event detection and affective functioning. The following presents a positive aetiology of ADHD within a practical framework for treatment design and outcomes.

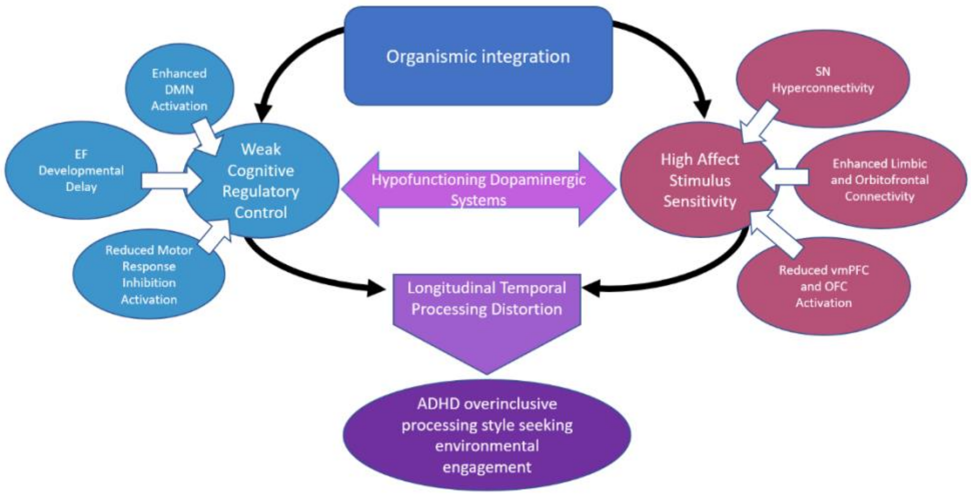
Altered Neural Processing

Research has demonstrated there are neurobiological differences in development, function, and information processing in ADHD. A prolonged developmental trajectory, enhanced connectivity and clustering of regions associated with emotional processing and smaller volumes in areas related to cognitive control networks can lead to less efficient "top-down" management and dominant cognitive self-regulation. However, recent research supports an entirely different integration of distributed processing with different neural representations and subjective experience of task-related stimuli in ADHD (Chevrier & Schachar, 2020).

Figure 9

ADHD Altered Neural Processing model

Figure 9: ADHD Altered Neural Processing model



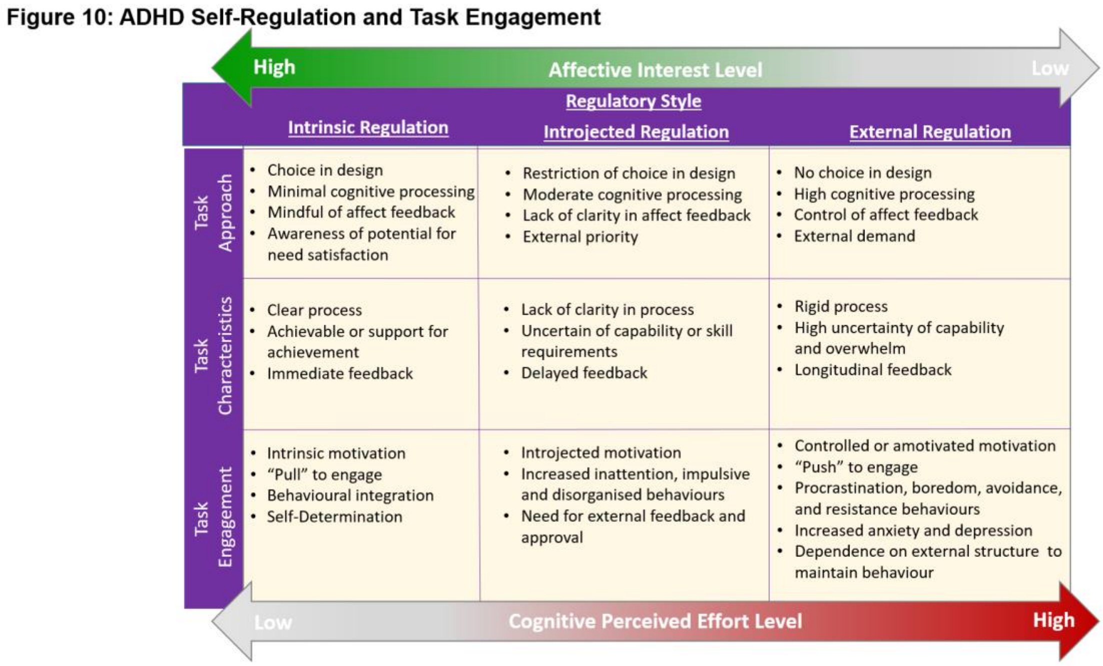
Altered connectivity between brain networks has been indicated in ADHD, specifically altered connectivity between the Central Executive Network (CEN), Salience Network (SN) and the Default Mode Network (DMN) (Castellanos & Proal, 2012; Cortese et al., 2012; Gao et al., 2019). Research indicates that hypofunctioning dopaminergic systems resulting in low tonic/high phasic dopamine transmission in ADHD may increase exploratory seeking behaviours (Di Domenico & Ryan, 2017; Sagvolden et al., 2005). The altered dopaminergic activity also results in semi-suppression of the DMN during cognitive tasks (Fassbender et al., 2009; Tomasi et al., 2009) and hyperconnectivity between the SN and the DMN (Hart et al., 2012, 2013; Sidlauskaite et al., 2016; Viering et al., 2021). Increased connectivity with the SN demonstrates a susceptibility to higher salient stimuli (Götting et al., 2017; Sidlauskaite et al., 2016) and reduced connectivity between the orbitofrontal cortex and ventral striatum results in less cognitive regulatory control (Posner et al., 2013). A high level of sensitivity to affective stimuli and weaker cognitive functionality would indicate that self-regulation is more affect dominant than cognitively dominant within the bi-directional relationship. This sensitivity may also influence the differences in temporal processing associated with ADHD, as research into models of time processing or the "internal clock" highlight the dependence of time awareness on attentional executive control processes (Droit-Volet et al., 2018) and the premotor cortex (Droit-Volet, Monceau, et al., 2020), the influence of dopaminergic activation of cortico-striatal circuits including attention and working memory (Toplak et al., 2006) and the effect of emotion and arousal on the magnitude of time distortions (Droit-Volet, 2018; Droit-Volet et al., 2018; Droit-Volet, El-Azhari, et al., 2020; Vasile, 2015). Research also shows that individuals with ADHD experience cognitive domain-dependent neuro-functional impairments in different neural networks depending on the cognitive context (Dibbets et al., 2010; Hart et al., 2012).

Motivation and Engagement

This neurobiological foundation impacts the effectiveness of the task approach and engagement in multiple dimensions. Distortions in estimating external time longitudinally combined with susceptibility to higher salient stimuli would lead to a wider and more immediate attentional awareness resulting in an overinclusive processing style (Acar & Runco, 2012; Eysenck, 1993, 1994; H. A. White, 2018). This style would suggest a tendency for chaotic cognitions and divergent thinking, an aspect of creative cognition shown to be a potential positive outcome of ADHD particularly in the dimension of idea generation (Cardello & George, 2021; Girard-Joyal & Gauthier, 2021; Steele et al., 2021), although findings are inconsistent and more research is needed (Boot, 2017; Hoogman et al., 2020; Sedgwick et al., 2018; Taylor et al., 2018; H. A. White, 2018; H. A. White & Shah, 2006, 2016). ADHD individuals would also be strongly intrinsically motivated by an interest in seeking environmental engagement and positive feedback from problem-solving (Di Domenico & Ryan, 2017; Sagvolden et al., 2005). Task approaches that are inherently interesting and therefore increase dopaminergic activity will generate positive affective feedback – they will feel easy or more engaging, and positive experiences of competence can lead to a sense of "flow" or hyperfocus (Deci & Ryan, 2000; Di Domenico & Ryan, 2017; Ek & Isaksson, 2013; Sedgwick et al., 2018). However, task approaches requiring dopaminergically supported suppression of the DMN and efficient activation of the CEN will be more challenging for those with ADHD. From an SDT perspective, an individual with ADHD will feel less competent at engaging with these task approaches, as they will require more effort to engage and potentially maintain engagement.

Figure 10

ADHD Self-Regulation and Task Engagement



As we have seen, curiosity and interest are concurrent with dopaminergic release and are key factors in intrinsic motivation (DeYoung, 2013; Gruber et al., 2014; Ryan & Deci, 2017). Therefore, if the challenge is too difficult to feel competent, lacks clarity, or the interest is too low, a natural reaction would be to not engage with these challenging tasks but to initiate seeking behaviours to facilitate engagement with tasks or activities that feel more achievable or interesting. In controlled environments where an individual is unable to autonomously pursue activities of interest, this engagement seeking behaviour could appear as the hallmark ADHD indicators of hyperactivity, impulsivity and inattention.

Psychopathology

SDT states that psychopathology arises from autonomy depriving and thwarting environments (Ryan et al., 2016). Evidence indicates that adults with ADHD have experienced a lifelong history of need frustration (Oram et al., 2020). They find low autonomy environments that are highly structured or controlled challenging, and will experience boredom, are made redundant or change jobs frequently (Boot et al., 2017; Dimic & Orlov, 2014; Houghton, 2006). Inconsistencies in personal management, organisational skills, and underachievement provide negative evidence for competence or efficacy in achieving goals for personal growth (Bokor & Anderson, 2014; Goodman, 2007; Mitchell et al., 2013; Newark & Stieglitz, 2010). Rejection, lack of acceptance or understanding of differences in behaviour creates a significant impact on interpersonal skills and social connections or relatedness (Houghton, 2006; Toner et al., 2006).

Developmentally, and depending on the social-cultural context, an individual with ADHD will encounter more and more task approaches that require DMN suppression and CEN activation, in other words, those that require independent management, cognitive control and behavioural inhibition leading to an increase in symptomatic behaviours and coping mechanisms (Fleming & McMahon, 2012; Fortes et al., 2014; Knouse & Fleming, 2016; Nigg, Sibley, et al., 2020; Ramsay & Rostain, 2008b; Wender, 1995). Lack of understanding of the altered processing in ADHD results in inefficient learning (Chevrier & Schachar, 2020) and dominance of standardised reinforcement models to develop skills, habits, and routine behaviours are experienced as controlling or amotivating. Therefore behaviours often become introjected or remain extrinsically motivated by social or environmental domains and will cease once circumstances alter or change (Roth et al., 2019; Ryan & Deci, 2008).

Occasional successful strategy design and application is often followed by turmoil (Toner et al., 2006) as lack of awareness of neurocognitive and psychological needs leads to an incoherent understanding of the building blocks for success. Many individuals will describe experiences of constant stress or crisis, high anxiety, or a desire to procrastinate or be "under pressure" to complete tasks (Nadeau, 2005; Ramsay et al., 2016; Safren et al., 2004; Wolf et al., 2009). This framework suggests that through salient affect-based responses to either the task or the approach or both depending on context (Posner et al., 2020), the ADHD individual is aware of a lack of interest or challenges with engagement. The internal conflict between natural seeking behaviours, the need to complete the task and lack of skills or understanding to support achievement generates a stress response. Exposure to psychosocial stress is associated with dopaminergic output (Bloomfield et al., 2019; Payer et al., 2017), providing the additional dopaminergic "push" needed for the ADHD individual to suppress the DMN and activate the CEN to utilise the reinforcement model-based skills to engage with the task. With a lack of access to alternative strategies, and because stress generates a dopaminergic response leading to intermittent success, over time, the individual with ADHD becomes unconsciously dependant on anxiety ("flight") or frustration and aggression ("fight") as a motivational coping strategy. Chronic exposure also leads to compensatory down-regulation (Bloomfield et al., 2019; Payer et al., 2017), therefore active use of the stress cycle as a motivational strategy generates long term co-morbid anxiety and depression, which is often the first presentation clinicians will see in undiagnosed ADHD (Bolea-Alamañac et al., 2014; Kooij et al., 2019; Lackschewitz et al., 2008; Nigg, Sibley, et al., 2020; Solanto et al., 2008).

The impacts of altered neural processing on embodied time (Droit-Volet, Monceau, et al., 2020) also have a developmentally negative impact on perceived competence. More affect-dominant self-regulation combined with an altered perception of embodied time may result in reduced sensitivity to longer durations but a higher response to shorter durations, as the experience of time fluctuates according to arousal and affect (Droit-Volet et al., 2013). Many socially presented skills, habits and planning processes are predicated on spontaneous time awareness that evaluates long durations, which rely on efficient cognitive processing and working memory (Droit-Volet, 2018; Droit-Volet et al., 2013). Inefficient cognitive processing in ADHD makes this resource unreliable, leading to over- or under-estimation of embodied time and therefore interfere with cognitive dominant strategies and skill use, impacting time management, planning, prioritisation and estimation (Barkley, 2006; Brown, 2013; Roberts et al., 2014).

Treatment Design and Outcomes

Research has shown that reinforcement models may be inappropriate for learning in ADHD (Chevrier & Schachar, 2020). Therefore, recognising the impact of altered neural processing and using an SDT approach to the aetiology of ADHD would significantly affect treatment design and outcomes. Treatment design would include assessing an individual's regulatory style, contextualising task-based need frustration, and clarifying where supportive behaviours need to become internalised. Identification of variations in regulatory functioning could highlight keys for individual challenges and context-specific treatment application. Therapist characterisation of ADHD as an alternative or neurodiverse processing style requiring an unconventional skill set could support the individual development of self-acceptance and self-esteem by recognising biological and individual strengths and resources.

Psychoeducation on the importance of the relationship between natural seeking tendencies, interest and motivation and the impact of engagement of the stress cycle as a motivational tool would be key to increasing self-awareness. Developing skills to interpret information from emotional responses as feedback to inform behaviours would facilitate awareness of the intention and need satisfaction behind these behaviours concerning the context, increasing a sense of choice and development of autonomous self-regulation. Acknowledging the reduced sensitivity to longer time durations would generate exploration of tools and methods for supportive time management. Understanding the tendency toward natural seeking behaviours and the importance of positive feedback from problem-solving would influence goal selection, strategy development and outcome measures for achievement.

Summary and Future Work

Theoretical perspectives strongly influence the aetiology of symptoms, research focus, and treatment guidance in ADHD. This influence extends beyond academia and mental health decision-making and impacts public perception and the development of the individual's self-concept and identity. The dominant theoretical paradigm of ADHD provided by cognitive behavioural theory presents an aetiology limited to a deficit-focused, motivationally hedonistic perspective that generates treatment outcomes focused on symptom reduction and emotional and behavioural control.. Alternative theoretical approaches are needed that incorporate conceptualisations with outcomes aiming to strengthen positive psychological factors and support growth and well-being.

We have introduced a theoretical framework for ADHD aetiology grounded in self-determination theory to provide an alternative view of the research data and a positive approach to well-being and treatment outcomes. The main propositions from this framework are:

1. That all humans have an inherent growth tendency and thus have a natural inclination to seek engagement with their environment in order to satisfy basic psychological needs for autonomy, a sense of competence, and belonging or relatedness
2. ADHD neurocognitive differences in hypofunctioning dopaminergic systems, efficency of cognitive processes and susceptibility to higher salient and affective stimuli may result in:
    a. Seeking behaviours designed to facilitate environmental engagement and interest, interpreted in some contexts as hyperactivity, impulsivity and inattention
    b. Self-regulation processes that are more affect dominant than cognitive dominant in the bi-directional relationship
    c. Less efficient cognitive control generating under- or over-estimations in embodied time, creating distortions in longitudinal time awareness and a higher sensitivity to short durations, and therefore a wider and more immediate attention (or overinclusive) processing style
3. These differences are observable in task engagement and motivation as:
    a. A tendency toward chaotic but also creative cognitions, including the potential for divergent thinking and idea generation
    b. Active participation in task approaches that are oriented toward problem-solving, are intrinsically interesting and provide positive and more immediate feedback
    c. Negative outcomes if a task approach requires more cognitive effort than feels achievable and autonomous approach design is unsupported, generating feelings of lack of competence

4. Psychopathology arising from a lifetime of need frustration, experiences of social rejection and lack of understanding due to stigma, and environmental and social demands to prioritise task approach processes based on reinforcement models of learning. Attempts to engage a consistently high level of cognitive effort generates a dependency on stress responses ("fight or flight") based on internal conflict to provide a dopaminergic "push" to activate this cognitively dominant skillset, often with inconsistent results further reinforcing a negative self-concept and identity

We propose that viewing ADHD behaviours through an SDT lens provides an opportunity to shift the focus in research, diagnosis and treatment outcomes from deficit identification and symptom control to neurodivergent difference identification and integration. This theoretical shift addresses the challenges in ADHD neurobiological research, heterogeneity, and context variability in the following ways:

- If the motivational drive behind ADHD symptomatic behaviours is an organismic need for engagement and growth, then an awareness and understanding of the origin, or "why", of the behaviour is critical to identifying the need, and challenges with context variability are reframed as issues with engagement
- If self-regulation is more affect than cognitive dominant in ADHD, then developing skills to increase awareness and understanding of emotional responses as informational in relation to behaviour is key to ADHD self-awareness, self-monitoring and self-regulation
- If psychopathology arises not from neurobiological deficits, but altered neuro processing combined with need frustration, then clarity of ADHD altered neuro-functioning process attempts to satisfy basic psychological needs, act via intrinsic motivation, and engage in self-regulation requires further research

- Shifting the focus away from deficit based models of functioning alters the perspective on heterogeneity, providing opportunities to research ADHD aetiology and behaviours in relation to other presentations within a neurodiversity paradigm and investigate the potential benefits of ADHD altered neuro processing
- If goal design, progress, and achievement utilise basic psychological need satisfaction as outcomes, then processes for goal achievement, particularly long term goals, can accommodate ADHD neurobiological time distortion

Using this SDT based framework as a foundation, our following projects focus on understanding potential positive aspects of ADHD, and a pilot of a treatment approach. Recent research highlights the critical nature of lived experience accounts, particularly in neurodivergent populations (Grant & Kara, 2021; Milton & Bracher, 2013; Rosqvist et al., 2020b; Stenning & Rosqvist, 2021). Examining ADHD lived experience through the lens of SDT may provide new insights into the positives offered by ADHD. Following analysis of this research, a treatment approach is designed to include psychoeducation in ADHD altered neuro processing, understanding the relationship between ADHD neurobiology and environmental engagement, and skills development in mindful self-awareness, task identification, and goal design and development. Treatment outcomes would include symptom reduction and quality of life, but critically also include measures for autonomy and self-determination.

Working with a trained therapist in an autonomy supportive manner, we suggest that individuals with ADHD could better understand how they function, differentiate between biological needs and individual needs, and develop an alternative skillset to improve self-regulation, integrate experiences and act volitionally in ways that feel more self-determined resulting in an integrated positive ADHD identity and self-concept.

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