Executive Functioning in Attention-deficit–Hyperactivity Disorder – Crucial or Trivial?

a report by
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Abstract
Impairments in executive function (EF) are presumed to be an important aspect of attention-deficit–hyperactivity disorder (ADHD). However, deficits in more basic functions may have been somewhat underexposed in ADHD research. The prominent questions that arise to what extent are these EF and non-EF deficits related to each other, and can these non-EF deficits account for the EF deficits found in ADHD? Based on statistical grounds, the dissociation between EF and non-EF seems artificial. Moreover, a (large) proportion of EF deficits in ADHD may actually be secondary to non-EF deficits. However, there is also support for the notion that EF is disproportionally affected in ADHD compared with non-EF. Therefore, it is premature to abandon the EF concept in ADHD altogether. In any case, future studies need to take into account baseline control conditions when studying EF in ADHD to validate the centrality of the EF deficit in ADHD.

Key words
Attention-deficit–hyperactivity disorder, executive functioning, bottom-up, top-down, hot and cool executive functioning

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Attention-deficit–Hyperactivity Disorder
Attention-deficit hyperactivity disorder (ADHD) is characterised by a triad of symptoms: inattention, hyperactivity and impulsivity.1 The disorder affects around 3–5% of school-age children, and symptoms often continue into adulthood, although severity lessens to some extent for most patients.2 Much research has been conducted aimed at the causal factors of the disorder. In short, genetic factors contribute more to increasing the risk of developing the disorder than environmental factors. About 75–80% of the variance can be explained by genetic factors,3 with multiple genes of small individual effect together increasing the risk of ADHD. Despite the fact that genetic factors are more important in relation to ADHD, certain environmental risk factors have also been identified as related to ADHD. Epilepsy, brain infections, complications during pregnancy and delivery, and exposure to alcohol, drugs and tobacco as a foetus are all more likely to have occurred in children who develop ADHD.4-6

Causal Models of Attention-deficit–Hyperactivity Disorder (ADHD) – Executive Dysfunctioning as an Important Aspect of ADHD
In recent decades, more has been learned about the neurobiological and neuropsychological aspects of ADHD, which will bring us closer to understanding the causal pathways leading to the disorder. Several causal pathway models have been proposed, combining the findings of biological and (neuro)psychological abnormalities frequently found in ADHD. They all have in common that deficits in executive function (EF) are an important aspect of ADHD. EFs have been defined as “those capacities that enable a person to engage successfully in independent, purposive, self-serving behaviour”7 and are strongly linked to abnormalities in the prefrontal lobes and frontal–subcortical structures found in patients with ADHD.8-9 Inhibition, working memory, planning and set shifting are all regarded as being EFs.

One of the theoretical models with EF as central to ADHD has been formulated by Barkley.10 This model links inhibition to four other EFs that appear to depend on inhibition for their effective execution: working memory, self-regulation of affect–motivation–arousal, internalisation of speech and reconstitution (behavioural analysis and synthesis). Barkley proposes that ADHD is primarily an inhibition deficit associated with secondary impairments in other executive abilities. Sonuga-Barke11 also views deficits in inhibition as central to ADHD, but proposes a dual pathway model, with poor inhibitory control and delay aversion as independent contributing factors that are of equal importance to ADHD. In another model, Zelazo and Mueller, a distinction has been made between ‘cool’ and ‘hot’ EFs.12 In the view of the authors, a ‘cool’ EF is elicited by relatively abstract, de-contextualised problems, whereas a ‘hot’ EF is required for...
It is important to make the distinction between primary and secondary EF deficits for scientific and therapeutic reasons. From a scientific point of view, clarifying the hierarchical origin of executive deficits in patients with ADHD will lead to a better understanding of the nature of the pathology of the disorder. From a therapeutic point of view, the target of intervention may be different when deficits stem from the bottom of the hierarchy (basic encoding and/or motor processes) instead of the top of the hierarchy (executive processes). Therefore, the prominent questions that arise are: to what extent are these EF and non-EF deficits related to each other; and can these non-EF deficits account for the EF deficits found in ADHD?

To What Extent Are Executive Function and Non-executive Function Deficits Related to Each Other?

Several studies have examined the inter-relatedness between EFs and functions of lower order, such as motor functions, in ADHD. Piek et al. investigated several measures of EFs in a school sample of children aged between seven and 15 years. They reported motor performance to be significantly related to several measures of EF, in which poorer motor performance correlated with poorer EF. Similarly, Lively et al. found motor performance to be related to Stroop performance in five- and six-year-old children. The Stroop task is one of the most frequently used tasks to tap into interference control (an EF) and does not require an overt motor response. The correlation between the tasks of motor performance and interference control was therefore not based on an overt motor reaction influencing performance on both tasks, but rather is based on a commonality in neural pathways mediating motor performance and interference control. We found similar findings for a relationship between executive and motor performance when we administered a range of executive tasks and motor tasks to a large group (n=816) of children with ADHD, their non-affected siblings and control children. Five executive tasks were administered, tapping into inhibition, verbal and visuo-spatial working memory, time reproduction and set shifting. Five motor tasks measured motor speed, variability, accuracy and timing aspects of motor output. All tasks correlated with each other, supporting the inter-relatedness between EF and motor functioning. In addition, when performing a principal component analysis on the 10 dependent variables of these tasks, one major component emerged instead of two (an executive and a motor component). This suggested that all tasks related to one underlying construct, and no strict dissociation could be made between EF and motor functioning. Taking the findings of these studies together, it appears that EF and non-EF are closely related. In addition, based on statistical grounds, the dissociation between EF and non-EF seems artificial. This may imply that the concept of EF may need to be redefined. It may be hypothesised that every neural function inherently has an EF aspect and that there is no such thing as a separate EF concept.
to be test-specific. This/these model(s) would have to specify the ‘causal’ relation between EF and non-EF functions. On the basis of some (a) model(s), it could be decided whether partialling out non-EF scores is justified or not. If, for example, non-EF deficits were to some degree secondary to EF deficits (there is presumably no task without any EF involvement), partialling out the former from the latter would remove variance of interest from EF scores.

However, we may be able to indirectly examine whether non-EF deficits account for the EF deficits found in ADHD. Only a few studies have administered non-EF tasks alongside EF tasks, and even fewer have controlled appropriately for non-EF deficits when studying EF in ADHD. For example, Rhodes et al.43 administered several EF and non-EF tasks to medication-naive boys with ADHD and control boys. The group differences for the EF and non-EF measures were comparable in effect size, as was also reported by Boonstra et al.13 in a meta-analysis on adults with ADHD. This suggests that EF impairments are not larger than non-EF impairments, as would be most likely if EF impairments are primarily affected. In addition, several studies support the notion that EF impairments can indeed be accounted for by non-EF deficits. For example, Marks et al.44 administered EF tasks with paired control conditions, allowing for the isolation of discrete EF constructs. The group differences between pre-schoolers at risk of ADHD and normal controls were evident on several measures of EF. However, after accounting for the non-EF abilities, no deficits could be attributed to specific functions targeted by the EF tasks. Because performance on the EF tasks was also not related to objective indices of activity level or ratings of ADHD symptoms, the authors questioned whether “EF deficits and/or frontostrial networks contribute etiologically to early behavioural manifestations of ADHD”. Findings in line with this conclusion were reported by Scheres et al.49 and Piek et al.50 Scheres et al.49 demonstrated that EF deficits in boys with ADHD did not survive correction for non-EF deficits, age and IQ. Piek et al.50 demonstrated that a group of ADHD children without co-morbid motor impairments did not demonstrate EF impairments in the domains of working memory, set shifting, processing speed and goal-directed planning. Only the group of motor-impaired children without ADHD showed EF impairments, suggesting EF impairments to be mainly related to motor impairments and not ADHD in this study. Brandeis et al.51 examined the neuroelectric mapping of inhibitory control in children with attention deficit disorder (ADD) using the Stop task. They reported that impaired orientation of attention precedes and may actually partly determine inhibitory control problems in attention-deficit disorder. We have also tried to examine two EFs (motor inhibition and cognitive flexibility) while controlling for the speed and accuracy of responding on a simple baseline condition requiring only a simple two-choice response.64 Not surprisingly, children with ADHD, as well as their genetically at-risk non-affected siblings, committed more errors in the baseline condition. However, compared with their baseline speed and accuracy of responding, they were not disproportionately slow or inaccurate when demands for motor inhibition or cognitive flexibility were added to the task. Therefore, we did not find evidence for deficits in motor inhibition or cognitive flexibility in children with ADHD or their non-affected siblings.

Do these findings imply that we should abandon the hypothesis of an EF deficit central to ADHD? Not entirely. Even though the majority of findings suggest that a (large) proportion of EF deficits in ADHD may actually be secondary to non-EF deficits, there is also support for the notion that EF is disproportionally affected in ADHD compared with non-EF. For example, Kalff et al.52 demonstrated that five- and six-year-old children at risk of ADHD performed disproportionately more inaccurately and had a more unstable performance than control children on executive motor control tasks under conditions of high-level controlled processing compared to low-level controlled processing. Additional support for the notion that the EF concept is important in ADHD was found in our study, including a large group of ADHD-affected children, their non-affected siblings and controls. We examined to what degree the groups could be discriminated from each other using an aggregated EF component (combining five EF tasks) and an aggregated non-EF/motor component (combining five motor tasks). The EF component was better at discriminating the groups than the motor component,53 suggesting EF to be more strongly related to ADHD than motor performance. In addition, the EF component correlated more strongly with teacher ratings of ADHD than the motor component.53 Thus, some support for a primary EF deficit in ADHD is also present.

**Should We Abandon the Executive Function Concept in Attention-deficit–Hyperactivity Disorder?**

EFs cannot be seen as separate from more basic non-EFs such as motor functions. Strong support exists for the inter-relatedness of these concepts. Therefore, studying EFs without taking into account non-EFs will not provide an accurate picture of the state of affairs. However, can we abandon the EF concept altogether in ADHD? This question may be answered on statistical/empirical grounds and conceptual grounds. On statistical grounds, findings are inconsistent as to whether these non-EF deficits can fully account for the EF deficits in ADHD, in which case the EF problems are merely indirect/secondary deficits. Several studies (strongly) support this notion, but other findings seem to support a direct (pure) EF deficit, as well. The only way of testing this directly is by testing (a) model(s) linking EF and non-EF tests. Such (a) model(s) is/are currently not available and would have to be test-specific. On conceptual grounds, distinguishing between EFs and non-EFs, even though not directly supported by statistical evidence, may still be a useful working model. It may not be true or correct in an absolute sense,54 but that does not invalidate the earlier usefulness of the EF concept in the development of understanding the underlying pathology of ADHD. Thus, both on statistical and conceptual grounds, it is premature to abandon the EF concept in ADHD altogether. However, in any case, future studies need to take into account baseline control conditions when studying EF in ADHD to validate the centrality of the EF deficit in ADHD.

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10. Barkley RA, *Behavioral Inhibition, sustained attention, and...*
Attention-deficit–Hyperactivity Disorder

By the Same Author

Support for an Independent Familial Segregation of Executive and Intelligence Endophenotypes in ADHD Families
Rommelse NN, et al.

Impairments in executive functioning (EF) and intelligence quotient (IQ) are frequently observed in children with attention-deficit–hyperactivity disorder (ADHD). The aim of this paper was twofold: first, to examine whether both domains are viable endophenotypic candidates for ADHD, and second, to investigate whether deficits in both domains tend to co-segregate within families. A large family-based design was used, including 238 ADHD families (545 children) and 147 control families (271 children). Inhibition, visuospatial and verbal working memory and performance and verbal IQ were analysed. Children with ADHD and their affected and non-affected siblings were all impaired on the EF measures and verbal IQ (although unimpaired on performance IQ) and all measures correlated between siblings. Correlations and sibling cross-correlations were not significant between EF and IQ, though they were significant between the measures of one domain. Group differences on EF were not explained by group differences on IQ and vice versa. The discrepancy score between EF and IQ correlated between siblings, indicating that siblings resembled each other in their EF–IQ discrepancy instead of having generalised impairments across both domains. Siblings of probands who had an EF but not an IQ impairment showed a comparable disproportionately lower EF score in relation to IQ score. The opposite pattern was not significant. The results supported the viability of EF and IQ as endophenotypic candidates for ADHD. Most findings support an independent familial segregation of both domains. Within EF, similar familial factors influenced inhibition and working memory. Within IQ, similar familial factors influenced verbal and performance IQ.

By the Same Author

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