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Review Articles

Psychological Perspectives on Attention Deficit Hyperactivity Disorder in Relation to Reading Disorder and Chinese Children

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Abstract This review paper discusses the application of DSM diagnostic criteria applied to Chinese children with attention deficit hyperactivity disorder (ADHD); the adaptation of extant rating scales for children, teachers and parents and the mechanisms of comorbidity with reading disorder (RD). Partial genetic and cognitive overlaps and the nature of executive functioning in children are examined. Available evidence suggests that constructs of processing speed and spatial and verbal working memory with their measurable tasks show promise in assessing comorbid ADHD and RD. The paper concludes with the suggestion of applying some of the neurophysiological research paradigms used in longitudinal research into RD in prospective studies of the developmental trajectory of ADHD.

Key words Attention deficit hyperactivity disorder; Comorbidity; Reading disorder; Processing speed; Working memory

In this review paper I confine my discussion of the vast and complex literature on attention deficit hyperactivity disorder (ADHD) to several psychological aspects and with reference to reading disorder (RD) and Chinese children. These topics are discussed: (a) DSM-IV-TR diagnostic criteria of ADHD and rating scales for Chinese children; (b) Perception of ADHD by U.S. and Chinese teachers; (c) Mechanisms of comorbidity of ADHD and RD; and (d) Cognitive markers for diagnosis applicable to ADHD and RD in relation to Chinese students. The need to study the developmental trajectory of ADHD and early assessment is emphasised.

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Applying DSM-IV-TR Diagnostic Criteria to Chinese Children

This review paper begins with a quick summary of the consensus diagnosis of ADHD according to DSM-IV-TR.[1] DSM-IV-TR stipulates that individuals with a diagnosis of ADHD must have had their symptoms of severe hyperactivity, impulsiveness, and inattention for at least 6 months, that these symptoms must be developmentally deviant, that the impairment must have developed by 7 years of age, and that from the hyperactivity and impulsivity list six of the nine items must be assessed as inappropriate, and from the inattention list also six of the nine items must be assessed as deviant.[2,3] The type of ADHD diagnosed can be classified as Predominantly Inattentive (ADHD-PI), Predominantly Hyperactive-Impulsive (ADHD-PHI) or Combined (ADHD-C), depending on whether diagnostic criteria are met for inattention, hyperactivity-impulsivity, or both.[2,3] In essence, DSM diagnosis of ADHD describes specific behavioural characteristics of individuals and is

both categorical (all or none) and also dimensional (behaviour falling along a continuum).[4] Barkley sums up his review this way: "The dimensional approach to ADHD seems most consistent with the available evidence, whereas the categorical approach remains one of convenience, parsimony, and tradition".[3]

Rating Scales

Within the DSM diagnostic framework, research into ADHD on Chinese children these past twenty years or so have been in several inter-related directions. One is the attempt at adapting and standardising rating scales for the study and diagnosis of ADHD; the other is to examine comparative patterns of ADHD in the Chinese population, especially in Hong Kong.

Some twenty years ago the Conners' Teacher's Rating Scale[5] was administered by Luk et al. to a representative sample of 914 aged 6 to 12 primary school children in Hong Kong.[6] Luk et al. found a significant sex difference with boys having higher total and subscale scores of hyperactivity, inattention and conduct disorder whereas girls had elevated scores on the subscales of anxiety-tension. The Conners' Scale was subsequently validated by this research team for Chinese children in Hong Kong.[7]

From a larger number of carefully screened 3069 Chinese schoolboys a stratified sample of 611 was examined by Leung et al.[8] in a two-stage epidemiological study involving a number of neuro-developmental measures, parental and teachers interviews on the pre DSM-IV criteria of hyperactivity.[9] These researchers found in their sample a "rather low" prevalence rate of 6.1% of attention deficit disorder with hyperactivity (ADDH) and attributed their findings to two main plausible reasons. One plausible reason was the possible biological vulnerability of Chinese children to hyperactivity and the other was the cultural practice of discipline, conformity, and inhibition of impulses. Leung et al.[8] concluded that ADHD as a diagnosis was associated with over-activity and inattention as well as significant cognitive, academic and neuro-developmental deficits.

From current perspectives the earlier 10-item Conners Scale was shown to assess aggression more than hyperactivity.[10] There is the Conners 3rd Edition for a thorough assessment of ADHD.[11] The Child Behavior Checklist,[12] based on the original Achenbach and Edelbrock Scale,[4] is now regarded as a more rigorously developed and better normed scale for parents and teachers. Recently, Liu et al.[13] adapted the Achenbach's Teacher's Report Form (TRF)[14] and the teacher version of the Child Behavior Checklist[15] for use with Chinese children as the Chinese Version (TRF-CV). Liu et al.[13] administered the TRF-CV to a population sample of 2936 children aged from 6 to 11 years in Shandong Province of China to assess the reliability and concurrent validity of TRF-CV. They obtained satisfactory internal consistency and concurrent validity of the Chinese scale and replicated most of the six syndromes identified in the American samples: Aggressive/Delinquent Bahavior, Withdrawn/Depressed, Somatic Complaints, Attention Problems, Social Problems and Thought Problems.[14,15] Liu et al. also obtained higher prevalence rate of 15.5% of teacher-reported behavioural and emotional problems as compared with some earlier Chinese studies.[13]

More recently, the test-retest reliability and criterion validity of the Chinese versions of Achenbach's Teacher's Report Form (TRF),[14] Child Behavior Checklist (CBCL),[15] and Youth Self-Report (YSR)[16] on community and clinic samples in Hong Kong were studied by Leung et al.[17] These researchers found these Chinese versions of CBCL, TRF and YSR to be reliable and valid with the proviso that CBCL and TRF screened ADHD and external problems better, while YSR screened internalising problems better. They further pointed out the 1991 Achenbach CBCL, TRF and YSR correlated very highly (r=0.97) with the newer versions of CBCL, TRF and YSR in Achenbach and Rescorla[18] but cautioned from their sensitivity and specificity results in signal detection that clinicians should be aware of the score/case attenuation at short test-retest intervals.

Very recent epidemiological and empirically based comparisons of new versions of the Youth Self-Report (105 items and 14 positive quality items) from 24 countries (N=27,206) including Hong Kong, using the same statistical procedures such as Mplus, show that there is strong multinational consistency across these countries in self-reported problems by adolescents.[19] In addition, girls obtained significantly higher scores than boys in internalising type problems, whereas boys obtained significantly higher scores than girls in externalising type problems. Adolescents were found to report significantly more problems than their parents reporting them. In countries and communities such as Japan, Korea and Hong Kong adolescents obtained lower Positive Qualities scores as compared with their counterparts in the U.S., suggesting strong parental and social pressure not to appear to be boastful. The overall multinational comparisons indicate that the YSR is well suited for use in cross-national epidemiological studies.

There are rating scales that are freely available from the internet: the SWAN Rating Scale by Swanson (also

www.ADHD.net)[20] and the Swanson, Nolan, and Pelham (SNAP) Teacher and Parent Rating Scale (www.ADHD.net) of Swanson (1994) and Swanson et al. (2006).[21] The SWAN Scale asks for the rating on a seven-point scale from far below to far above of 30 common behavioural and emotional problems of childhood such as "Organise tasks and activities", "Control temper", "Control anger and resent" and other symptoms. The SNAP-IV contains 40 similar items on a four-point scale (0, "not at all"; 1, "just a little"; 2, "pretty much"; and 3, "very much"). A score above 2.0 is considered severe in the domains of inattention and hyperactivity/impulsivity for ADHD. These rating scales should be adaptable for the Chinese population. When supplemented by psychiatric interviews, questionnaires about psychopathological behaviour and neuropsychological tests, the adapted rating scales should serve as components for an assessment battery for ADHD in Chinese children.

Teachers' Perception of ADHD (U.S. and Chinese Teachers)

In a sample of American children, modest agreement was found between classroom teachers and parents and teachers and therapists in identifying a given child as meeting DSM-III criteria for at least one of the domains of hyperactivity, impulsivity or inattention.[22] In the case of Chinese children there were some recent studies of Chinese teachers' ratings of the diagnostic definitions of ADHD as described in DSM-IV and ICD-10. One hundred and twenty one elementary teachers in Taipei, Taiwan were asked[23] to rate 2 boys and 2 girls each from their homerooms on a 20-item ADHD checklist based on DSM-IV criteria.[9] A principal component analysis of the teachers' ratings of ADHD symptoms found components consistent with DSM-IV diagnostic criteria in showing attention deficit and hyperactivity-impulsivity to represent two main dimensions among Chinese children in Taiwan.

More recently, a 55-item questionnaire based on DSM-IV-TR[1] was used to survey 328 teachers in China and the U.S. (202 teachers from China and 126 teachers from the U.S.) and also 224 college students in these two countries (116 from China and 108 from the U.S.) to examine and compare their perception of ADHD.[24] The researchers noted considerable differences in the perception of ADHD between teachers and college students in China and the U.S. Their results showed that the Chinese groups paid more attention to hyperactivity symptoms whereas their U.S. counterparts focused on both hyperactivity and inattention. The Chinese groups were less inclined toward the use of psycho-stimulant medication and more readily attributed ADHD as a failure of parenting or the children's efforts, as compared with their U.S. peers.

To take just the ranking of the importance of symptoms among the American and Chinese teachers, these were the differential rankings by the American teachers and the Chinese teachers (shown respectively as the first and second numbers in the parentheses): concentration problems (1, 1); difficulty in sustaining attention in tasks or fun activities (2, 3); being easily distracted (3, 2); losing control of oneself (4, 6); and acting without thinking (5, 18.5). Despite some differences, all four groups endorsed symptoms in the DSM-IV(-TR) as the most critical to diagnosis and also the biological causes of ADHD. While this comparative study was carried out with teachers and college students and not with pediatricians or psychologists, it should be noted that teachers, as compared with children and parents, are the optimal informants for ADHD symptoms.[25,26] Factor analyses of teachers' and parents' rating of ADHD symptoms have been shown to be highly correlated and the results typically show two dimensions: inattention-restlessness and impulsivity-hyperactivity.[27]

To summarise the fairly representative though rather selective review so far, the different sets of results were in broad agreement. This is despite the fact that the Leung et al. large-scale study was confined to boys,[8] the Yang et al. study was on the components of teachers' rating of children in Taiwan on DSM-IV symptoms,[23] and the Norvilitis and Fang survey was on the perception of ADHD symptoms by Chinese and U.S. teachers and college students.[24] Note that Liu et al.[13] applied their Chinese Version of Teacher's Report Form based on Achenbach's Teacher's Report Form[14] to a population sample of 2936 children aged 6 to 11 years in Shandong Province in China. They found a prevalence rate of 15.5% of behavioural problems with a 2 to 1 boys/girls ratio. Taken together, the research findings all suggest that DSM-IV criteria with some variations are applicable to the Chinese population.

Comorbidity in relation to Reading Disorder

Comorbidity may represent two manifestations of the same disorder, may reflect different stages of the same disorder, may arise from correlated specific and general risk factors, may represent a distinct nosological condition or may be due to one disorder predisposing to the other.[28,29] The important aspect is to determine the distinctiveness and separateness of the two heterotypic disorders (e.g., ADHD

and RD) from different definitional and diagnostic categories and to test competing claims or hypotheses about underlying mechanisms. Research and clinical literature shows that ADHD co-occurs with other disorders such as conduct disorder (CD), oppositional defiant disorder (ODD) and reading disability (RD); and is associated with educational difficulties and problems in peer and family relationships.[2,3]

Of these co-occurring conditions there are more data on ADHD comorbid with conduct disorder and oppositional defiant disorder.[30,31] Yet RD and ADHD are two of the most common childhood disorders. They co-occur more frequently than expected by chance and are not caused by sampling bias and measurement errors.[28] Each disorder is estimated to occur in about 5% of the population according to DSM-IV-TR. About 25% to 40% of individuals with ADHD also meet the criteria of RD; about 15% to 40% of individuals with RD also meet the criteria of ADHD; and rater bias is not likely to give a sufficient explanation of all cases of comorbidity of RD and ADHD.[32]

One of the early studies to pinpoint deficient neuropsychological function of ADHD boys and comorbid opposition defiant disorder (ODD), conduct disorder (CD) and reading disorder (RD) was carried out by Nigg et al[33] Their 171 aged 6- to 12-year-old boys in the total group were considered separately and jointly by disorders, which were studied as categories and dimensions with proper statistical controls. These researchers found their ADHD clinical group (n=100) to exhibit deficits in effortful neuropsychological tasks, after controlling for comorbid ODD, CD and RD conditions. These effortful neuropsychological tasks required response inhibition and planning as tested with Porteus Maze[34] and the Rey-Osterrieth complex figure,[35] working memory and set shifting.

Shaywitz et al.[36] carried out a multivariate study of a large cohort of 186 children aged 7.5 to 9.5 years classified as children with ADHD, with RD, with both ADHD and RD and unimpaired. The hypothesis tested was that ADHD (parental endorsement of at least 8 items on DSM-III-R), and RD (regression discrepancy definition) represented separate entities co-occurring in the same individuals. The major findings were that ADHD and RD are two distinct disorders, which frequently co-occur and that children with RD and RD/ADHD had main difficulties with the language system and those with ADHD with behavioural disorder.

Kaplan et al. found a total of 116 children with ADHD from a sample of 179 school age children and their families from an original group of 687 families.[37] The overlap of disorders was found to be more common with ADHD than with RD. If the children met the criteria for RD, 51.6% had at least one other disorder. If they met the criteria for ADHD, the chance of having at least one other disorder was 80.4%. ADHD was found to occur alone only rarely and RD was found to occur alone more often. In interpreting these results of overlapping groups we should examine if clinical samples or population-based groups are used, the kinds of tasks studied and if comorbid conditions are treated as dimensions rather than categories with proper statistical controls such as ANCOVA and multiple regression analyses.[33]

Kaplan et al. queried the term comorbidity as signifying "unsubstantiated presumption of independent etiologies", and preferred the term co-occurrence or overlap.[37] The term "atypical brain development" (ABD) was suggested as a useful concept for researchers and educators to account for various manifestations of one underlying impairment to show the interdependence of various disorders found to overlap considerably.[38] The question is: What does atypicality of brain development mean? Is there a threshold or cutoff point on some continua? Does it mean delay in the maturation of the brain, possibly the frontal cortex? Does ABD explain the complex interaction of genetic and environmental influences? The notion of ABD is just too generalised for both research and clinical practices. Diagnosing comorbidity among common groups of developmental disorders such as ADHD, RD and autistic spectrum disorder is viewed as important for nosology and the understanding of psychopathological conditions.[28]

Neurocognitive Basis

From clinical and research perspectives ADHD is a biopsychsocial disorder, whereas RD is a language deficit. Biologically, ADHD affects primarily the prefrontal cortex or the region projecting to the prefrontal cortex,[31,39] or the abnormality in the frontal network that controls attention and motor intentional behaviour.[22] Neuroimaging and lesion studies that provide direct evidence of the validity of tests of executive function show they implicate the prefrontal cortex.[40] Data for RD show the neurobiological basis to be in the temporo-parieto-occipital brain regions.[41] A number of functional imaging studies have found that reading acquisition activates widely distributed areas in the left occipito-temporal and left inferior frontal areas and less of posterior right inferotemporal areas.[42,43] Children with RD and their nonimpaired peers show significant differences

in the recruitment of the left occipo-temporal area in reading.

Recent fMRI data by Shaywitz et al. show children with RD in English differ from nonimpaired readers in that the reading for the RD group was primarily localised to the more posterior and medial regions and not so much to the more anterior and lateral occipito-temporal regions.[44] There were also age related changes in the neural systems in the two reading groups. For the RD group there was an age-related increase in the left posterior medial occipito-temporal region and an age-related decrease in the right superior frontal region; whereas for the nonimpaired group there was an age-related increase in the activation in the left inferior lateral occipito-temporal regions and an age-related decrease in activation in the right middle frontal/ superior region.[44] These results were attributed by Shaywitz et al. to the reliance of the RD group on the memory system which implicates the posterior medial occipito-temporal regions.

The brain's reading network identified for alphabetic language and writing systems as summarised above also applies, in key respects and with partial overlap, to the morphosyllabic Chinese. Chee et al. found involvement of left fusiform gyrus in reading Chinese.[45] Tan et al. also reported the activation of both the posterior and anterior areas in the left hemisphere, more than the right, but they further showed bilateral activation for the occipital and occipital-temporal regions in reading Chinese.[46] Subsequent studies confirmed more bilateral involvement for Chinese reading in occipital and fusiform regions and also more activation in the left middle frontal gyrus (LMFG).[47]

In the case of Chinese children diagnosed with developmental dyslexia recent behavioural studies point to deficits in orthographic processing (intra-character relationship of phonetic and semantic radicals) and rapid naming of symbols.[48,49] The recent discovery from fMRI scans implicates reduced activation of the left middle frontal gyrus in reading impaired readers in Chinese, compared with controls.[50] These results suggest dysfunction of neural circuits responsible for mapping the graphic form to the basic unit of the Chinese syllable and to semantic and phonological processes in visual-orthographic and verbal memory.[50] Available evidence of Chinese reading from imaging studies suggests bilateral occipital and fusiform involvement and the important role of the LMFG in integrating visual-orthographic, phonological and semantic information.[51] These results also raise the need to understand the functions and connections of LMFG to other brain regions, its possible role in spatial and verbal working memory system, and to build a viable neural basis of reading and reading impairment.[50,51]

Linking Biology, Behaviour and Cognition

In examining the comorbidity of ADHD and RD the important questions to ask should include: What are the mechanisms that generate comorbidity? How does comorbidity arise? What is the strength of the co-occurrence?[28] Frith offers a useful three-level conceptual framework to link the "biology (genes and brain) to behaviour via the inferred cognitive level..."[52] This framework conceptualizes the behaviour of the child as influenced by both internal factors and the environment. Symptoms of ADHD and RD may be multiple manifestations of the same neurological dysfunction .The same biological and genetic disposition may create various cognitive and behavioural deficits with accompanying symptom complex. Behaviourally, the double deficits co-occurring would results in more severe clinical symptoms. Comorbidity of ADHD and RD occurs as partial genetic overlap in bivariate heritability (h^2 defined as the ratio of genetic variance to phenotypic variance) found for different traits in monozygotic and dizygotic twins; and as cognitive pleiotropy or multiple cognitive deficits on measures of inhibition for ADHD, and phonology and verbal working memory for RD.[53] These genetic and cognitive overlaps are discussed below.

Partial Genetic Overlap

A recent study by Willcutt et al.[32] of the Colorado Learning Disabilities Research Center (CLDRC) is an excellent example of the linkage of biology (genes) with behaviour and cognition, as discussed by Frith.[52] From the ongoing population-based Colorado twin study Willcutt et al. (2005)[32] directly compared an ADHD group (n=113), a RD group (n=109), both RD and ADHD group (n=64) and neither RD nor ADHD group (n=151) on a battery of the same neuropsychological tasks. First, twin pairs were identified as meeting criteria and one twin member from each pair was selected randomly for the study. Assessment of RD was from school history of reading problems. Assessment of ADHD was from the Disruptive Behavior Rating Scale of Barkley and Murphy[54] to obtain parental consent of the 18 symptoms of DSM-IV ADHD.

The Willcutt et al.[32] results show that double dissociation between RD and ADHD was not complete. Factor analysis shows 5 latent domains: Reading and Language Skills,

Processing Speed, Verbal Working Memory, Set-Shifting, and Response Inhibition-Execution. The last 3 domains suggest executive functions (EFs) disorder. Executive functions refer to "a specific class of self-directed actions by the individual that are being used for self-regulation toward the future".[2] As acknowledged by the authors, their study did not have tasks on planning, delay aversion or motor output. ADHD was associated with significant weakness in response inhibition, while RD on reading and language skills; ADHD was associated with visual-spatial working memory deficit and RD with verbal working memory difficulties. Phoneme awareness difficulty was not present in ADHD, set shifting not associated with either disorder after controlling for FSIQ. Working memory and response inhibition were "less compelling candidates for the common deficit".[32] But both RD and ADHD were associated with deficits in orthographic coding measure, a finding not expected by the researchers. Processing speed was suggested as the most promising candidate common to both RD and ADHD. But Willcutt et al.[32] cautioned that the concept of processing speed is overly broad and weakly defined (see discussion in section on processing speed and Shanahan et al., 2006).[55]

Common Polygenetic Hypothesis

Genetically the most parsimonious model would include "a common risk allele or set of risk alleles at one or more genetic loci that influence a common pathophysiological pathway that increases susceptibility to both RD and ADHD".[32] Furthermore, the phenocopy hypothesis that RD might lead to phenotypical manifestations of inattentive or hyperactive activities in the classroom, rather than as a consequence of ADHD in the absence of RD, is not supported by recent data from bivariate heritability and molecular genetic studies as a primary explanation for comorbidity of RD and ADHD.[32,55-57] The non-random mating hypothesis between those with ADHD and with RD was shown not to contribute significantly to the comorbidity of the two disorders from data on 394 twin participants in a community sample.[58] These researchers also found that the two disorders did not segregate independently, suggesting significant genetic overlap in the comorbidity of the two disorders.

The common polygenetic hypothesis is supported by data from genetic linkage studies in the search for chromosomal regions containing a gene or genes that will increase the risk for both disorders. Linkage analyses use DNA markers to identify areas within the 23 pairs of chromosomes that may include a gene or genes involved in RD or ADHD. There is evidence that the quantitative trait locus (QTL) for RD on chromosome 6p21.3 is also a susceptible locus for ADHD.[57] The comorbidity between ADHD and RD is attributable to shared genetic influences which pleiotropically affect the development of both disorders from bivariate twin analyses.[58,59] The risk alleles identified on chromosome 6 need to be further substantiated from molecular genetic analyses as to whether they may also be present in children not identified as with ADHD or dyslexia and their complex interaction with environmental risk factors.[56,58,59]

According to the common polygenetic hypothesis, RD, ADHD and RD+ADHD all show some common neuropsychological weaknesses, with other genetic and environmental influences affecting particular individuals. Willcutt, Pennington et al.[32] cautioned that even though various studies suggest common genetic influences contributing to comorbidity of ADHD and RD the mechanisms of common genes are not well known. Furthermore, in the ongoing and significant Colorado study of dyslexia in monozygotic (MZ) and dizygotic (DZ) twins, Olson emphasises that in behaviour-genetic analyses there are significant environmental influences as well.[60] These influences include shared family environmental factors such as home and school quality and non-shared environmental influences that make the MZ and DZ twins different from each other. The relative contribution of genetic, shared environmental and non-shared environmental influences depends on the reading skills measures. Similar arguments have been put forward by Pennington in his review of multiple deficit models of developmental disorders including ADHD and RD.[53]

Candidate Gene Approach – DRD4

Some recent studies of the candidate gene approach linked to the dopamine deficit theory of ADHD has focused on the dopamine transporter gene and the dopamine receptor type 4 gene (DRD4) located on chromosome 11 (11p15.5). DRD4 as a candidate gene is chosen because the D4 receptor especially the 7-repeat allele is in a brain region important for motivation, attention, effortful processing and novelty seeking;[21,61] and the variable number of tandem repeats (VNTRs) is in a coding region of the gene.[21] There is evidence from a meta-analysis that ADHD is associated with DRD4.[62] The 7R allele frequencies of DRD4 has been shown to vary across ethnic groups but are well established within ethnic groups from a cross-national group multidisciplinary research program.[63] A recent comprehensive overview of published molecular genetic

studies from 1991 to 2004 on ADHD found evidence for the association between ADHD and these genes: the dopamine D4 and D5 receptors and the dopamine and serotonin transporters; with other promising genes needing replication.[64] These researchers, however, caution that all candidate gene approaches yield relatively low power.

In a clinical sample of 32 Han Chinese children with a confirmed ADHD diagnosis it was shown that none of the children had an increased presence of DRD4-7R allele when genotyped, but there was a significant increase in the prevalence of the 2-repeat (2R) allele in the probands.[65] Acknowledging the shortcoming of the small clinical sample and emphasising the need for replication, these researchers pointed out that the haplotype of the 2R allele in Han Chinese might likely derive from the 7R allele and their results were not inconsistent with the 7R allele found in European children. It is also likely that there are other risk alleles influencing ADHD as a function of DSM-IV subtypes.[63,66]

Summary

To summarise this part of the discussion of the comorbidity of ADHD and RD evidence shows that there are multiple pathways that link the two disorders. Comorbidity may vary according to the precision with which ADHD and RD are diagnosed. There are also age related changes in social and cognitive skills and expectations of individuals. Generally, the ADHD-RD relationship is asymmetrical. Much also depends if the groups studied are clinical samples or community samples. With large-scale epidemiological investigations and rigorous identification criteria the overlap between the disorders is much smaller compared with that from clinical samples. The three-level model of Frith, linking biology, behaviour and cognition provides a useful framework to study ADHD and RD as developmental disorders.[52]

Partial Cognitive Overlap

DSM-IV refers to different cognitive subtypes of ADHD. In essence, the cognitive subtype hypothesis predicts the comorbid group will show different patterns of external correlates than would be expected from the additive combination of the correlates of each disorder when they occur separately.[55,56]

Among other main findings, the important Willcutt et al. population study[32] also supports the hypothesis that ADHD, especially the attention deficit component, is associated with a significant deficit in response inhibition and that both ADHD and RD are associated with working memory difficulties. These researchers also suggested additional weaknesses in executive functions and non-executive functions domains. They further cautioned against pinpointing core neurocognitive deficits in ADHD even though this disorder is associated with significant deficits in several executive function domains.[32] In some contrast there is the argument that deficits in attention in children and adults should be interpreted as deficits in the allocation of attentional resources, and not so much attention per se, which results from an overarching executive function domain of self-control.[67] This interpretation of deficit in resource allocation is also offered by Sergeant et al.,[68] who suggested that ADHD children are deficient at the stage of motor response to information processing; and by Wu et al.[69] who attributed the slower performance of their ADHD children to deficits in the regulation of effort and activation.

Neuropsychological Studies of Executive Function in Children

Executive function is generally thought of as involving intentional activities of persistence, sustained attention, response inhibition, verbal and nonverbal working memory, planning and goal-directed problem solving.[70] In a 13+ years longitudinal study of executive functioning in a large sample "rigorously diagnosed as hyperactive in childhood", compared with a community group at young adulthood, significant differences were found between the groups in inhibition, sustained attention, and ADHD related behaviour such as fidgeting, off-task behaviour captured on videotapes.[70] Further analyses by these researchers suggested that some of the cognitive deficits were a function of conduct disorder and comorbid anxiety.

The validity of the execution function hypothesis as primary deficit of ADHD was examined in a recent meta-analysis of 83 studies (N=3734 with ADHD and 2969 without ADHD) by Willcutt, Doyle, Nigg, Faraone, and Pennington.[40] These researchers suggested that at least four neurocognitive criteria must be met to consider executive function as the primary deficit of ADHD. One criterion is that groups with ADHD must show consistent weaknesses on EF measures and these weaknesses must remain significant after controlling for factors such as age, language, general ability, reading ability and other psychopathological symptoms. The second criterion is that EF weakness must explain a substantial proportion of the variance in ADHD symptoms. The third criterion is that weaknesses in EF must be present in most individuals with

ADHD. The fourth criterion is that weaknesses in ED must be coheritable with ADHD. Using a standardised effect size for the mean difference between the groups with and without ADHD on each measure of EF, these authors found significant differences consistently with the Stop-Signal Reaction Time and Continuous Performance Test omission errors, both being markers of response inhibition. There were also significant differences on the measures of planning (Tower of Hanoi and Porteus Maze). Relation between ADHD and spatial working memory, and, to a lesser extent, verbal working memory, was shown to be "promising". The Wisconsin Card Sorting Test subserving the putative EF construct of set shifting was found to be "more weakly related to ADHD". While acknowledging the construct of EF is not strongly defined and the psychometric properties of EF tasks need to be refined, these researchers found from their detailed meta-analysis that EF weaknesses are significantly associated with ADHD but they may not be the "single necessary and sufficient cause of ADHD in all individuals with the disorder".[40] These authors also emphasised that EF involves multiple neurocognitive processes and these processes need to be compared, one with the other.

The description and external validity of EF tasks also provide a useful grouping of some commonly used tasks under putative EF constructs.[40] The following is the conceptually organised summary of the executive function tasks outlined by these researchers.

Planning. The putative EF construct of planning subsumes the Tower of Hanoi/London Test (following certain rules to move a stack of objects from one position to another in the fewest possible moves)[71-73] Porteus Maze,[34] and Rey-Osterrieth Complex Figure Test.[35,74]

Set shifting. The construct of set shifting is subserved by the Wisconsin Card Sorting Test. This commonly used measure requires the individual to match a series of cards on some stimulus characteristics without being instructed on methods of matching and this shifting to a new rule tests perseverative errors.[75,76] The other marker is the Trail Making Test in which the child connects a series of numbers and letters in ascending order while alternating between letters and numbers.[77]

Vigilance. The construct of vigilance can be tested with the Continuous Performance Test omission errors (ability to respond to a rare target amid many nontargets over a period of time between 5 to 20 minutes).[78] The dependent measures include the number of hits recorded, the mean RT to targets, and the number of incorrect responses to nontargets.

Verbal working memory. This construct is subserved by the Memory Span task where participants are asked to answer a comprehension question from one of the unrelated sentences and recall the last word of each sentence in sequence[79] and Digit Backward.[80]

Spatial working memory. This construct subsumes the search for visual locations to find tokens and "self-ordered pointing" (selection of a different design on each card in a series of cards without selecting the same design more than one).[81]

Response inhibition. The construct of response inhibition is subserved by the Stop-signal Reaction Time Test. The participant is first taught to respond to a signal as a primary stimulus, then told to inhibit responding to the same signal as a secondary stimulus; and the speed of the inhibition process is estimated as mean reaction time.[82-84] The Continuous Performance Test omission errors provide another measure.[85,86]

Another study of three putative executive function domains, using a limited battery of widely administered tests (verbal fluency, Tower of London to subserve the construct of planning, and Self-ordered Pointing to subserve spatial working memory) with a group of 61 Dutch children with "disruptive behaviour disorders" and 38 "normal controls" (mean age of 10.3 years for the total group of 91 children) found the presence of AD/HD accounting for executive function deficits.[87] The results suggested executive function deficit may constitute a risk factor for AD/HD and possibly for other disruptive disorders such as conduct disorder and oppositional defiant disorder. The development of response inhibition may be a prerequisite of the executive function domains.[2,3]

Summary

As noted by Nigg executive inhibition as the core of executive function is still unresolved.[88] One of the reasons is that sensitivity and especially specificity of any single executive function are not sufficiently high to support the claim that EF is causal for all children with ADHD.[89,90] From his review of experimental studies on children, Nigg acknowledged the competing claims between treating ADHD as a disinhibitory disorder under external control and that under motivation and arousal control.[88] He found stronger empirical support for a more broadly conceived executive process and much weaker support for the motivation claim of disruption in signaling of delayed reward; and suggested a hybrid response models as a testable hypothesis.

The general idea is that cognitive activities all depend

on efficient, purposeful inhibitory control as integral to behavioural regulation[2,3,31] and intentional inhibition needs prefrontal mediated executive function.[66] Subtypes of ADHD may further delineate multiple measures of inhibition and of strength of motivational response.[88] It is possible that executive function deficits may not be the primary deficits in ADHD.[66] It is further suggested that only a subtype of ADHD children based on a pattern of symptom clusters may exhibit impairment in executive functioning as well as other neurocognitive deficits; but such a conceptual basis needs criteria to be established for partitioning heterogeneity and the nosology needs to be validated.[2,3,40,88]

Processing Speed and Working Memory in ADHD and RD

Processing Speed and Stop Signal Paradigm

Even though findings of significant genetic overlap may not yield directly neuropsychological deficits common to both ADHD and RD, recent studies, as reviewed above and elsewhere, suggest that ADHD and RD may share in varying degrees two main potential cognitive risk factors.[56] One is processing speed and, to a lesser extent, the other is working memory. Processing speed as a shared cognitive risk factor was tested in an in-depth study of a total of 395 children and adolescents as part of the ongoing research program of the etiologies of learning disabilities, ADHD and related developmental disorders of the Colorado Learning Disabilities Research Center (CLDRC).[55] Twin pairs were identified with at least one of the twins meeting the criteria of DSM-IV ADHD and one of the twins meeting the criteria of RD to create an ADHD only group (n=105), RD only group (n=95), RD + ADHD group (n=51) and a comparison group (n=144). The processing speed measures were: WISC-R Coding Subtest,[80] Trail Making test,[77] Rapid Automatized Naming,[91,92] Stroop test,[93] the Stop Signal task,[82,84] Continuous Performance test of the type by Epstein et al.,[78] and two perceptual tests. The tasks used typically tap the factor of rapid naming of stimuli and the factor of speeded non-linguistic and motor abilities.

The results show that the deficits for the two factors were similar in pattern but varying in magnitude with processing deficit larger in RD than in ADHD. There was significant interaction between the ADHD and RD groups with effect sizes of the processing deficit in the combined groups less than the pure ADHD or RD group, thus suggesting underadditivity. If the effects are independent the processing speed deficits in the combined comorbid group should be equal to or even greater than that of the pure ADHD and RD groups.[55] The finding of underadditivity is based on an ADHD x RD interaction and on the reduction of the correlation between ADHD and RD by partialling out processing speed.[55] This shows that processing speed is a shared cognitive risk factor between ADHD and RD and further supports the multiple deficit models of ADHD and RD.[53,55,90]

In this connection it has been argued that the speeded timing generated from the reaction time of the Stop-signal RT test[82] stems from behavioural inhibition and not so much from cognitive inhibition and that the two kinds of inhibition are theoretically and empirically distinct.[94] Behavioural inhibition is explained as suppressing overt behaviour such as impulse control and delay of gratification, and cognitive inhibition is defined as automatic and intentional suppression of cognitive contents such as control of irrelevant meanings of polysemous words.[94] From these perspectives, the Stop Signal paradigm or the time taken to inhibit a response differs from the processing speed notion.

Pennington and Chhabildas suggested that deficits on the stop-signal processing task were specific to ADHD and not related to comorbidity with reading problems.[66] A recent meta-analysis with careful sampling and task variables of 24 studies of the Stop-Signal paradigm in ADHD and behavioural inhibition finds children with ADHD show slower and more variable reaction times, compared with nonimpaired controls , between the go-signal activation and the stop-signal activation to inhibit their activated motor response when required to do so.[95] Alderson et al. report that these differences in executive motor inhibition have been attributed to slower motor speed, deficient attentional processes, slower cognitive processing and deficient energy resources. These authors also note that their review focus on executive-motor inhibition and differs from the cognitive inhibition discussed by Nigg.[88] Their review finding of larger between-group differences for mean RT might be a function of the number of experimental trials and also the modality of the go-stimulus with more pronounced deficits in visual-spatial processing in children with ADHD.

RAN and Fluency in Reading Disorder

The construct of processing speed in the reading disorder literature can be traced to the early formulation proposed by Denckla and Rudel of "lack of automaticity" as a correlate of reading and its difficulties.[91] The resultant rapid automatised naming (RAN) test and its practical

applications have been substantiated and refined.[92] Various recent behavioural studies have validated the "visual-verbal" responses instantiated by RAN which may be a "biomarker" of what the brain does and needs to do in fluent reading.[96] RAN with its pre-symbolic component (colours and objects) and symbolic components (numbers and letters) is part of efficient and rapid phonological retrieval process; and the underlying process relating RAN performance to alphabetic word reading is a complex one.[92,96] It is also well documented that children with RD perform poorly on RAN-types measures of rapid serial naming,[97] and that RAN-type tasks may be quite independent of phonological processing and may implicate orthographic processing.[98,99]

On reading difficulties in Chinese there is recent evidence that RAN on its own (RAN letters in particular) makes low, though statistically significant, contribution to individual differences in inferential text comprehension in Chinese in a study of component cognitive and linguistic skills in a target group of less competent comprehenders of Chinese compared with reading age and chronological age control groups.[100] These results are in line with the general findings from a meta-analysis by Swanson et al. of the correlation literature on measures of reading, RAN, phonological sensitivity, and related abilities from a large N of 2,257 Caucasian children in 49 independent samples with corrections for sample size, restriction in range, and attenuations.[101] RAN and phonological sensitivity were found to be less important than measures of spelling and word attack skills and also played a less important role in reading comprehension. Thus from the purely reading and reading difficulties points of view it would appear that even with quite disparate writing systems – English and Chinese – there are common and specific findings on the role of RAN.

It should be noted that RAN and its variants are not reading tasks in themselves but are correlates of reading. Almost all RAN and RAN-related studies in the reading and reading disorder literature deal with single word reading in elementary school children. This work was recently extended by Leong and Ho in testing directly the fluency in text reading, and not RAN correlates or general speed, of typical and less competent high school Chinese language and reading comprehenders (mean age of 15 years).[102] The emphasis of this verbal fluency task was on the fluency in reading actual textual materials and not on alpha-numeric symbols as proxy of reading; and speed-accuracy trade-off was minimised by requiring the students to answer ensuing multiple-choice questions correctly. This component of fluency in text reading contributed some variation to language and reading comprehension with the main contribution from the component of lexical knowledge subserved by morphology, correction of characters and words, segmentation of text and writing to dictation. However, it should be noted that oral fluency in text reading goes beyond automaticity, and prosodic reading including proper pauses, suprasegmental stress is an important hallmark of proficient language and text comprehension.

To summarise this part of the discussion studies suggest that slow and variable speed of processing stimulus materials may be a promising endophenotype for further studies in the association of ADHD and RD.[102]

Working Memory

In the literature on reading comprehension and its difficulties, there is evidence of the important role of verbal working memory.[103-105] The storage and manipulation of linguistic materials in memory as assessed by the kind of sentence memory span task used[79] likely draws on the same or similar sorts of strategies in processing text materials. Children with reading disabilities have been shown to have shorter verbal memory span and slower and more variable processing speed.[55,56] A recent study of text comprehension in Chinese by Chinese children found that the less competent comprehenders, compared with their reading comprehension controls and chronological age controls, showed difficulty in storing information and in performing concurrent processing as measured in verbal memory tasks.[100]

In the ADHD literature visual-spatial working memory tasks (e.g., self-ordered pointing task),[81] more than verbal memory tasks (e.g., memory span task),[79] in the working memory component are more indicative as a cognitive marker of the disorder.[32,106] This was further shown in the meta-analysis of executive function tasks by Willcutt et al.[40] As discussed earlier, verbal and spatial working memory was one of the four domains (the other three being response inhibition, set-shifting and planning) of weaknesses consistently found in both clinic-referred and community samples of children with ADHD in the meta-analysis of 83 studies critically reviewed by Willcutt et al.[40] These weaknesses were not explainable by differences in IQ, scholastic achievement and symptoms of other disorders. These researchers again cautioned against EF weaknesses being neither necessary nor sufficient to cause **all** cases of ADHD. EF difficulties are one of the several weaknesses in the complex and heterogeneous neuropsychology of the disorder.[40] The relative weakness in spatial span as compared with verbal span in performing complex tasks

by ADHD children suggests that they may have greater difficulty in maintaining and simultaneously working on visual-spatial information. They may find it relatively easy in a listening comprehension paradigm to understand factual details in narrative texts, though not subtle higher-level listening comprehension.[106] The impairment in spatial span working memory tasks is also thought to suggest the possibility of parietal lobe problems in ADHD children.[107]

In Search of Cognitive Markers in an Assessment Framework

The review of the literature in the preceding sections leads to the question of the putative and valid cognitive markers which might help to screen RD and the multi-faceted dimensions of ADHD. A very tentative framework for assessing developmental RD in Chinese was suggested by the present author.[108-110] In general, this framework should consist of reading of real and pseudo two-character words, spelling of both real and pseudo two-character words, rapid automatised naming of Chinese syllables akin to a tongue twister task and of numerics, speech-sound repetition with control for tones, onset and rime similar to the task used by Leong and Tan,[110] and working memory task.[100] The assessment of orthographic sensitivity should include lexical decision tasks to test the rapid and accurate decision of lexicality of individual characters and the correct compositionality of correct phonetic and semantic radicals inherent in the characters. Morphological sensitivity should examine the relational and productive aspects of words such as the rapid and accurate generation of new words from a constituent component character. The analysis of spelling errors should concentrate on: phonologically based spelling errors such as the use of heterographic homophones; graphemic spelling errors related to the substitution of graphemically similar characters, radical substitutions, addition and deletion of strokes and partial radicals; semantic errors related to synonyms and irrelevant substitutions.

The above sketch covering both reading and spelling should provide a workable and effective framework to assess children with RD in Chinese. An expanded and refined framework including text comprehension and essay writing was recently proposed and tested in a sample of 361 secondary school Chinese students in Hong Kong.[102] This framework was adapted from the "Blueprint of the Reader" of Perfetti.[111-113] Perfetti's modestly titled Blueprint is more than a plan of proposals; it shows a dynamic pattern of a series of processes which can be tested empirically. In essence, each subcomponent is encapsulating and at the same time interactive with feed-forward and feed-back capabilities from both the data-driven and the concept-driven perspectives of language and reading comprehension. The Blueprint has in fact been tested in different writing systems including English, Chinese and Korean and different orthographies using different scripts. Leong and Ho found the adaptation of the Blueprint to be eminently workable for the Chinese language.[102] In particular, lexical knowledge comprising rapid and accurate word identification and word knowledge covering orthographic, phonological, morphological and semantic units explains considerable individual variation in Chinese language and text comprehension and their difficulties. This study is being replicated with a more representative sample of 1164 Chinese secondary students working on the same but more refined tasks.[102]

It is suggested that some of the components and the tasks outlined in the preceding assessment framework for developmental dyslexia in Chinese (e.g., spatial and verbal working memory, RAN-like tasks of processing speed and text fluency in particular) could well constitute a part, albeit a small part, for the assessment of comorbid ADHD and RD. However, future research in this area should further evaluate the psychometric characteristics of the EF tasks such as processing speed and working memory for ADHD and the cognitive and linguistic tasks for RD. Different competing theories for ADHD should be directly compared.[40] For RD a recent study has shown over and above the well accepted phonological deficit theory of dyslexia in alphabetic language and writing systems, visual stress may explain a small proportion of the difficulties of children with dyslexia.[114]

Concluding Remarks

This review attempts to highlight the main psychological functioning of ADHD in relation to RD and Chinese children. Admittedly, the review is selective but aims to be comprehensive in the several areas studied, especially the comorbidity of ADHD and RD and the partial genetic and partial cognitive overlaps. For space and other reasons, many areas are not discussed. As examples, the important topic of subtype differentiation by ratings, observations and cognitive methods is not discussed.[115] Functional imaging studies in understanding dyslexia and reading are referred to only briefly.[116] Consultation-based academic

interventions in enhancing educational functioning in children with ADHD, though of clinical and educational significance, is not covered.[117,118] Clinical trials and treatment strategies (e.g., MTA Cooperative Group, 1999, 2004) are also not within the purview of this review.[119,120] As well, there are other topics worthy of attention, which are alluded to in various sections of the text.

Developmental Trajectory

The developmental trajectory of ADHD and its early assessment as explored by various research teams are important and timely.[121-123] Kalff et al. examined in an eighteen-month follow-up prospective study the neurocognitive performance of 5-6 years old children later diagnosed with ADHD. The results showed that neurocognitive testing of visual-motor ability and several aspects of EF could contribute to the early identification of children found to be at risk for ADHD.[121] However, Marks et al. found that preschoolers at risk for ADHD, compared with matched control children, did not show group differences on relatively novel EF measures of nonverbal working memory, memory for relative time and perceptual-motor inhibition after controlling for nonexecutive abilities.[122] These authors suggested that executive functioning may not be sufficient to account for emerging externalising behaviours of the proband children. Using a fairly large sample size of 160 preschoolers between the ages of 3 and 5 years 6 months to oversample high ADHD scores, Sonuga-Barke et al. asked these children to perform these EF tasks: planning (Tower of London), auditory sequencing working memory and inhibition. Sonuga-Barke et al. found that rudimentary levels of planning, working memory and inhibition exist during the preschool period and can be measured reliably.[123] They suggested that nonexecutive functions of the child such as age and IQ and variance common to EF tasks should be taken into account in evaluating the structure of EF in preschoolers. Their results provide at least partial support for the association between executive functioning and ADHD. In particular, it is in the inhibitory domain that the ADHD children show particular deficit, suggesting inhibitory deficits as possible precursors of later EF problems.

From a different perspective, recent developments for early identification of auditory-system dysfunction in dyslexia and, to a minor extent, in ADHD, focus on the use of event-related potentials (ERPs) which are the time-locked components of the electroencephalographic (EEG) activities and also mismatch negativity (MMN) of ERPs. Molfese and his colleagues at Louisville are among the first to use ERPs to study the neural activities of neurologically intact infants as young as 14 and 16 months while pairing verbal labels with objects and to chart scalp-recorded early-occurring and late-occurring neural changes of matched and mismatched experimental conditions.[124,125] The Louisville team showed from their longitudinal studies of speech perception and reading abilities from birth through eight years of age that children developing nomal language skills are better able to discriminate speech sounds at birth than those who develop poorer language skills; and that ERP measures taken shortly after birth predict with a high degree of accuracy reading abilities at eight years of age.[126] These researchers suggested that the biological processes can be modified through learning and the modifications offer possibilities of developmental changes and the likelihood of gauging the effectiveness of intervention programs for children at risk for dyslexia.

Similar results are obtained in the Jyväskylä Longitudinal Study of Dyslexia headed by Heikki Lyytinen. Lyytinen and his team documented the development of a group of children at risk for familial dyslexia compared with controls from infancy to age seven and in the first grade.[127] The results showed that brain event-related responses including ERPs to categorical speech perception and processing of specific temporal features of the Finnish language (phoneme duration or quantity differences which carry meaning changes) as precursors of dyslexia in Finnish. These researchers also found environmental effects including parent-child symbolic play and language interactions on the predictive power of some core language measures in the highly agglutinative Finnish language.

Very recently, the Jyväskylä team has found groups with RD, attention deficit (AD) and a healthy group of Finnish children aged 8 to 14 years elicited clear mismatch negativity (MMN) but no clear differences between the two clinical groups.[128] The MMN component of ERP, which was first discovered by Näätänen et al., is an automatic neural response to change occurring when an improbable event is presented against a background of predictable events.[129] MMN assesses auditory and sensory memory functions which may be differentially organised in the brain and can serve as an index of learning associated with neural plasticity.[130] The MMN component of ERP develops early and is shown to be robust in children.[130] In the Jyväskylä Longitudinal Study of Dyslexia Lyytinen and his research team have shown group effects of MMN in infants at high genetic risk for dyslexia as compared with control children.[131] Furthermore, this group measured event-related MMN-like

brain responses in six-month-old infants, with and without high risk of familial dyslexia, to consonant sound changes embedded in pseudowords; and found less precise sound representations in terms of change detection of temporal features in the at-risk infants. These researchers suggest that infants at-risk for dyslexia may have a deficiency in the timing and perception of temporal cues in speech and that these deficiencies may result from genetic and environmental factors and their interaction. The MMN paradigm should also be applicable to the study of Chinese children with developmental dyslexia in their waves of responses to features of speech sound such as pitch and duration changes in continuous sounds and deviants; and of Chinese children with ADHD with short duration versions (H. Lyytinen, personal communication, October, 2007).

The studies discussed in this review paper suggest the possibility of identifying neuropsychological markers (endophenotype) reflecting common risk factors for ADHD and RD. The structure and parameters of EF (response inhibition, planning, vigilance, working memory, processing speed) and regulatory control with children need to be further clarified. It is possible that subgroups of behaviourally defined children will have deficits in certain neurocognitive functions contributing to the complex and heterogeneous disorder.[132,133] Different competing neurocognitive models of ADHD and those in relation to RD should be tested directly. In addition, EF tasks combined with ERP, MMN, fMRI should further delineate brain structures and functions underlying ADHD and comorbid disorders.

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