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The effects of emotional lability, mind wandering and sleep quality on ADHD symptom severity in adults with ADHD

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ABSTRACT

Mind wandering, emotional lability and sleep quality are currently mostly independently investigated but are all interlinked and play a major role is adult attention-deficit/ hyperactivity disorder (ADHD). Emotional lability is a core feature of the disorder, excessive mind wandering has recently been linked to symptoms and impairments of ADHD and poor sleep quality is experienced by a clear majority of adults with ADHD. All three phenomena lead to functional impairment in ADHD, however their relationship to each other and to ADHD symptom severity is not well understood. Here we used serial multiple mediation models to examine the influence of mind wandering, sleep quality and emotional lability on ADHD symptom severity. 81 adults diagnosed with ADHD participated in this study. We found that mind wandering and emotional lability predicted ADHD symptom severity and that mind wandering, emotional lability and sleep quality were all linked and significantly contributed to the symptomatology of adult ADHD. Mind wandering was found to lead to emotional lability which in turn lead to ADHD symptom severity; and poor sleep quality was found to exacerbate mind wandering leading to ADHD symptoms. Future research should employ objective on-task measures of mind wandering, sleepiness and emotional lability to investigate the neural basis of these impairing deficits in ADHD.

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1. Introduction

1.1. ADHD and emotional lability

Attention-deficit/hyperactivity disorder (ADHD) is a pervasive neurodevelopmental disorder affecting 5–6% of children and 3–4% of adults [1,2]. In both children and adults ADHD is characterized by age-inappropriate and impairing levels of inattention, hyperactivity and impulsivity [3]. According to DSM-5 measures of emotional lability can be used in a supportive capacity to help establish the diagnosis of adult ADHD. This can include a number of symptoms such as high irritability, changing moods or low frustration threshold [4]. Emotional lability is also a prominent feature of borderline personality disorder and bipolar disorder [4], which are both common comorbidities of ADHD [5,6]. However, it has been argued that emotional lability in adults with ADHD is not related to comorbid conditions, but is a core feature of the disorder [7]. This is supported by multiple lines of evidence: emotional lability is present in adults with ADHD without psychiatric comorbidities [8], it responds well to ADHD medication [9,10] and is related to functional impairment beyond other symptoms of ADHD [11]. Moreover, genetic studies indicate shared genes explain the strong link of ADHD to emotional lability [12].

1.2. ADHD and mind wandering

Mind wandering is an omnipresent life experience, when our mind drifts away from a primary task and focuses on internal, task-unrelated thoughts and images. It has been defined as a shift of attention from the external environment towards inner, self-generated, task-unrelated and stimulus-independent thoughts, decoupled from immediate sensory perceptions [13,14]. It is estimated that up to 50% of our daily lives are spent in a mind wandering state [15,16]. Mind wandering can be spontaneous and unintentional, which is often detrimental to the task at hand and

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have little strategic value to the individual; or deliberate, when it may be related to strategic thinking about future plans [17]. Excessive spontaneous mind wandering has recently been proposed as a candidate mechanism leading to the symptoms and impairments of ADHD, as it correlates strongly with ADHD symptom domains and impairment scores [18–21], and mind wandering is closely associated with default mode network (DMN) activity [22–24] and dysregulation of the DMN is a prominent feature of ADHD [21]. Mind wandering and ADHD symptoms have been examined predominantly in populations of college students not diagnosed with ADHD [25,18,20,26]. These studies found that spontaneous mind wandering is positively associated with ADHD symptom severity [18], both when measured in the laboratory as well as in daily life [20]. Participants with a childhood diagnosis of ADHD reported more task-unrelated thoughts compared with other participants [25].

1.3. ADHD and sleep quality

Poor sleep quality and the resulting sleep deprivation have profound consequences on daily human functioning, negatively affecting cognition and emotion [27]. Lack of good quality sleep disrupts normal wakefulness resulting in inattention [28–30]. Excessive daytime sleepiness due to disrupted sleep is extremely common in the general population [31] as well as in children and adults with ADHD [32,33]. Furthermore, adults with ADHD report higher excessive daytime sleepiness relative to healthy controls [34]. A variety of sleep problems are associated with ADHD [35]. It is estimated that up to 78% of adults with ADHD experience sleep problems [36,37] and report lower sleep quality than neurotypical controls [38–41]. Sleep problems are thought to add to lower quality of life in ADHD, and are also associated with poorer academic performance, obesity, as well as more negative relations with carers [42]. Sleep disorders may also generate ADHD-like symptoms which can make differential diagnosis challenging [43,44]. There is a positive correlation between mind wandering and poor sleep quality or difficulty falling asleep in the general population [45] and a single night of sleep deprivation can increase mind wandering. Poor sleep quality as well as a range of sleep problems has also been linked to difficulties in emotion regulation and negative mood [46–48].

1.4. Default mode network activity

The DMN consists of interconnected cortical regions, including ventromedial prefrontal cortex and posterior cingulate cortex, which are activated (positively correlated) during rest and deactivated (anti-correlated) in response to attentional demands [49]. Individuals with ADHD have disturbed DMN connectivity leading to hyperactivation of DMN during daily activities [50], which is hypothesised to lead to excessive mind wandering [21]. Connectivity in the DMN can also be altered by any sleep-related reduction of consciousness [51], such as sleep deprivation [52–54]. DMN is also one of the crucial brain networks responsible for self-referential processing and emotion regulation [55–57] and failure to downregulate the DMN activity has been linked to depressive ruminations [58]. Finally, mind wandering is well-known to cause transient dysphoric mood [16].

1.5. Impairment

ADHD, mind wandering and poor sleep quality are all associated with increased rates of car accidents while driving [59–62] and together with emotional lability they contribute to poor academic performance [63,11,64,14]. Emotional lability leads to multiple functional impairments 0 [11].

1.6. Aim and hypotheses

In summary, it is striking that ADHD, excessive mind wandering, poor sleep quality and emotional lability bear such a close resemblance in their negative effects on everyday functioning and share a close association with disrupted activity within the DMN. Despite this, these concepts have never been investigated together. Therefore, in the present study we aim to investigate the effect of mind wandering, emotional lability and sleep quality on the severity of symptoms of ADHD in a sample of adults diagnosed with ADHD. Based on the literature reviewed above, we hypothesize that all three variables will significantly exacerbate the symptomatology of ADHD. We further hypothesize that the independent variables will be causally linked: 1) mind wandering will lead to emotional lability [16] which would lead to ADHD symptom severity [9,11,8,7]; and 2) poor sleep quality would lead to emotional lability [46–48] and mind wandering [65,66], which would lead to ADHD symptom severity [7,21].

2. Methods

2.1. Sample

The data presented here is part of a larger study (Oils and Cognitive Effects in Adult ADHD Neurodevelopment, ClinicalTrials.gov Identifier: NCT01750307). In total 81 English-speaking adults with ADHD volunteered to participate in the study (60 male, 51 female, mean age 32.4 years, SD 10 years, mean IQ 110, SD 13). Diagnosis was made according to the DMS-5 criteria [4]. Participants were recruited via South London and Maudsley Adult ADHD Outpatient Services (see Table 1 for detailed characteristics).

2.2. Clinical measures

ADHD symptoms were measured using the Conners' Adult ADHD Rating Scales (CAARS) [68], a self-report 18-item scale assessing the level of inattention and hyperactivity/ impulsivity consistent with the DSM-5 criteria for adult ADHD [4]. Emotional Lability was measured with the Affective Lability Scale (ALS) [69] a self-report 18-item scale sensitive to swift changes in emotion and mood.

Mind wandering was measured with the Mind Excessively Wandering Scale (MEWS) [19], a reliable self-report 12-item questionnaire developed on the basis of ADHD patients' descriptions of their thought processes: capturing thoughts constantly on the go, thoughts flitting from one topic to another and multiple overlapping thoughts at the same time. The MEWS is thought to be especially sensitive in detecting unintentional and uncontrollable mind wandering that is closely related to ADHD [19,17,26]. MEWS has been validated against experience sampling data in daily life (Moukhtarian et al., unpublished data), and was significantly correlated with measures of spontaneous but not deliberate mind

Table 1
Background, clinical and cognitive variables of the study sample.

	Participants with ADHD	
Gender	N=81	44 males (54%)
	Mean	SD
Age (years)	33.5	10.3
IQ	109.4	13.7
ADHD Symptom Severity (CAARS)	65.7	15.7
Emotional Lability (ALS)	17.9	7.1
Mind Wandering (MEWS)	23.6	7.9
Sleep Quality (PSQI)	14.1	6.8

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales.

wandering in a community sample (Mowlem et al., unpublished data).

Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI) [70], a 19-item questionnaire with high validity and reliability in retrospective self-assessment of disturbed sleep quality over the last month, including the ensuing daytime dysfunction [71]. PSQI broadly assess both quantitative (sleep latency, number of awakenings) and qualitative (restlessness, functioning) aspects of sleep and its utility is established in both clinical and non-clinical populations [72]. PSQI covers several indications for sleep disorders using the following seven component scores: 1) subjective sleep quality; 2) sleep latency; 3) sleep duration; 4) habitual sleep efficiency; 5) sleep disturbances; 6) use of sleeping medication; 7) daytime dysfunction [70]. People with ADHD who additionally suffer from sleep problems show difficulties across all these seven components [73].

2.3. Statistical analyses

We conducted serial multiple mediation modelling using ordinary least squares path analysis in PROCESS [74]. For the estimation of the indirect effects of the independent variables on the outcome variable via the intermediary variables we used 95% bias-corrected bootstrap confidence intervals (CI) based on 10,000 bootstrapping samples. A confidence interval was considered statistically significant when it was entirely above or below zero. The two-tailed alpha was set at 0.05 for all analyses.

3. Results

A multiple regression was run to predict ADHD symptom severity from mind wandering, sleep quality and emotional lability. There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin-Watson statistic of 1.970. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. The assumption of normality was met, as assessed by a Q-Q Plot.

The multiple regression model statistically significantly predicted ADHD symptom severity, $F(3, 74) = 86.969$, $p < .001$. R^2 for the overall model was 77.9% with an adjusted R^2 of 77.0%, a large effect size according to Cohen (1988). Mind wandering and emotional lability added statistically significantly to the prediction, $p < .05$. Regression coefficients and standard errors are presented in Table 2.

All study variables were significantly positively correlated, see Table 3.

As mediators in model A (emotional lability and sleep quality) were significantly correlated, $r(78) = 0.377$, $p < 0.001$) as well as in model B (mind wandering and emotional lability), $r(78) = 0.575$, $p < 0.001$ we run a serial multiple mediation models (see Fig. 1).

Table 2
Summary of Multiple Regression Analysis.

Variable	*B*	SE_B	β	Sig.
Intercept	25.464	2.913		0.000
Mind wandering	0.419	0.136	0.212	0.003
Sleep Quality	0.067	0.14	0.029	0.634
Emotional Lability	1.614	0.152	0.73	0.000

Note. *B* = unstandardized regression coefficient; SE_B = Standard error of the coefficient; β = Standardized coefficient.

Table 3
Summary of Correlations.

Variable	Mind Wandering (MEWS)	Sleep Quality (PSQI)	Emotional Lability (ALS)	ADHD Symptom Severity (CAARS)
Mind Wandering (MEWS)		0.389	0.575	0.639
Sleep Quality (PSQI)			0.377	0.387
Emotional Lability (ALS)				0.867

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales. All correlations are statistically significant at the level 0.001, two-tailed.

3.1. Model A

The model (see Table 4) was statistically significant, $R = 0.65$, $R^2 = 0.42$, $F(1,76) = 54.84$, $p < 0.001$. We found a significant direct effect of mind wandering on ADHD symptom severity ($c' = 0.42$, $p = 0.003$). There was a strong association between mind wandering and emotional lability ($a2 = 0.46$, $p < 0.001$) as well as between mind wandering and sleep quality ($a1 = 0.33$, $p = 0.000$). We found a significant effect of emotional lability on ADHD symptom severity ($b2 = 1.61$, $p < 0.001$), but no effect of sleep quality on ADHD symptom severity ($b1 = 0.07$, $p = 0.634$). The effect of mind wandering on ADHD symptom severity was mediated by emotional lability ($Ind3 = 0.74$, 95% CI 0.49–1.04), but not sleep quality ($Ind1 = 0.02$, 95% CI: -0.07 to 0.13). However, the interaction between the mediators also yielded a statistically significant mediatory effect where sleep quality affected emotional lability ($Ind2 = 0.10$, 95% CI 0.01 to 0.25).

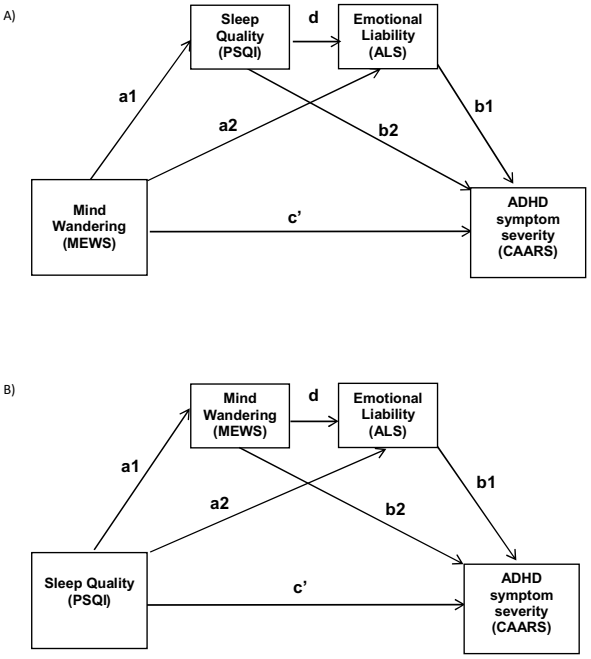
3.2. Model B

The model (see Table 5) was statistically significant, $R = 0.39$, $R^2 = 0.15$, $F(1,76) = 13.38$, $p = 0.001$. There was no statistically significant direct effect of sleep quality on ADHD symptom severity ($c' = 0.07$, $p = 0.634$). There was a strong effect of sleep quality on mind wandering ($a1 = 0.45$, $p < 0.001$), but no significant effect of sleep quality on emotional lability ($a2 = 0.19$, $p = 0.079$). Again, we found a significant effect of mind wandering on ADHD symptom severity ($b1 = 0.42$, $p = 0.003$), as well as emotional lability on ADHD symptom severity ($b2 = 1.61$, $p < 0.001$). As there was no significant direct effect, the influence of sleep quality on ADHD symptom severity was completely mediated by mind wandering ($Ind1 = 0.19$, 95% CI 0.06 to 0.41) and emotional lability ($Ind3 = 0.30$, 95% CI 0.01 to 0.62). The interaction between the mediators was also statistically significant ($Ind2 = 0.34$, 95% CI 0.16 to 0.60).

4. Discussion

We found that mind wandering and emotional lability predicted ADHD symptom severity and that mind wandering, emotional lability and sleep quality are all linked and significantly contribute to the symptomatology of adult ADHD. The mediation models supported both our prior hypotheses. Mind wandering was found to lead to emotional lability which in turn leads to ADHD symptom severity; and poor sleep quality was found to exacerbate mind wandering leading to ADHD symptoms.

Our findings fit well into the previous findings. We confirmed that mind wandering and emotional lability are significantly linked with core deficits in adult ADHD [9,11,8,18,7,19,20,21] and that poor sleep quality may lead to emotional dysregulation [46–48] as well as exacerbate mind wandering [65,66]. We have also confirmed an influential result that mind wandering could lead to emotional lability and negative emotions [16].



Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales.

Fig. 1. A) Serial multiple mediation model of sleep quality and emotional liability on the effect of mind wandering on ADHD symptom severity; B) Serial multiple mediation model of mind wandering and emotional liability on the effect of sleep quality on ADHD symptom severity.
Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales.

Table 4
Results from the serial multiple mediation model of the intermediary effect of sleep quality and emotional lability on the relationship between mind wandering and ADHD symptom severity.

	Mediators: (1) Sleep Quality (PSQI) and (2) Emotional Lability (ALS)			
	Mind Wandering (MEWS) —> ADHD Symptom Severity (CAARS)			
	Coefficient/ Effect	SE	t	p
a1	0.33	0.09	3.68	0.000
a2	0.46	0.09	5.12	0.000
b1	0.07	0.14	0.48	0.634
b2	1.61	0.15	10.65	0.000
d	0.19	0.10	1.78	0.079
c'	0.42	0.14	3.08	0.003
c	1.28	0.17	7.41	0.000
Ind1	0.02	0.05	95% CI: -0.07 to 0.13	
Ind2	0.10	0.06	95% CI: 0.01 to 0.25	
Ind3	0.74	0.14	95% CI: 0.49 to 1.04	
model	$R = 0.65$, $R^2 = 0.42$, $F(1,76) = 54.84$			0.000

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales; CI: 95% Bootstrapping Confidence Intervals.
c': direct effect of the independent variable (Emotional Liability in A or Sleep Quality in B) on the outcome variable (ADHD Symptom Severity);
a: effect of the independent variable on the intermediary variable (Emotional Liability in A or Sleep Quality in. B);
b: effect of the intermediary variable on the outcome variable; c: total effect, which is the sum of the direct and indirect effects;
d: serial effect of mediator 1 (Sleep Quality) on mediator 2 (Emotional Lability);
Ind: indirect effect of the independent variable on the outcome variable via the intermediary variables;
Ind1: MEWS —> PSQI —> CAARS.
Ind2: MEWS —> PSQI —> ALS —> CAARS.
Ind3: MEWS —> ALS —> CAARS.

Table 5
Results from the serial multiple mediation model of the intermediary effect of mind wandering and emotional lability on the relationship between sleep quality and ADHD symptom severity.

	Mediators: (1) Mind Wandering (MEWS) and (2) Emotional Lability (ALS)			
	Sleep Quality (PSQI) —> ADHD Symptom Severity (CAARS)			
	Coefficient/ Effect	SE	t	p
a1	0.45	0.12	3.68	0.000
a2	0.19	0.10	1.78	0.079
b1	0.42	0.14	3.08	0.003
b2	1.61	0.15	10.65	0.000
d	0.46	0.09	5.12	0.000
c'	0.07	0.14	0.48	0.634
c	0.89	0.24	3.66	0.001
Ind1	0.19	0.09	95% CI: 0.06 to 0.41	
Ind2	0.34	0.11	95% CI: 0.16 to 0.60	
Ind3	0.30	0.16	95% CI: 0.01 to 0.62	
model	$R = 0.39$, $R^2 = 0.15$, $F(1,76) = 13.38$			0.001

Note. MEWS: Mind Excessively Wandering Scale; PSQI: Pittsburgh Sleep Quality Index; ALS: Affective Lability Scale; CAARS: Conners' Adult ADHD Rating Scales; CI: 95% Bootstrapping Confidence Intervals.
c': direct effect of the independent variable (Emotional Liability in A or Sleep Quality in B) on the outcome variable (ADHD Symptom Severity);
a: effect of the independent variable on the intermediary variable (Emotional Liability in A or Sleep Quality in. B);
b: effect of the intermediary variable on the outcome variable;
c: total effect, which is the sum of the direct and indirect effects;
d: serial effect of mediator 1 (Sleep Quality) on mediator 2 (Emotional Lability);
Ind: indirect effect of the independent variable on the outcome variable via the intermediary variables;
Ind1: PSQI —> MEWS —> CAARS.
Ind2: PSQI —> MEWS —> ALS —> CAARS.
Ind3: PSQI —> ALS —> CAARS.

4.1. Limitations

It should be noted, that even though we would like to hypothesise that the links between the variables are causal and despite the fact that the mediation model itself encourages a causal interpretation of the links between the variables [74], the cross-sectional nature of our data limits the causal inferences that can be drawn from these analyses [75]. Therefore, we based our model on a specific a priori hypothesis developed based on a theoretical model that arises from empirical observations linking the constructs investigated here [76,77]. To investigate the causal nature of these hypotheses, further studies using a longitudinal design or experimental manipulations will be required.

4.2. Mind wandering and emotional lability

In this study, we have investigated a specific hypothesis that mind wandering leads to emotional lability. This is based on one of the most influential studies in the field, investigating mind wandering in a neurotypical group, where it has been found that mind wandering was the cause, and not a consequence, of negative feelings [16]. However, another prominent study found that negative mood can lead to more mind wandering [78] and today it is generally acknowledged that emotional processes play a major, if not the central, role in generation of mental content during mind wandering [14]. It seems that mind wandering and emotional lability are so closely linked that a two-way process might be a best explanation for the existing data. Mind wandering is a cause of emotional dysregulation when the negative content of the thought, or the intrusive nature of mind wandering itself, leads to higher levels of stress, including emotional distress, which in turn enhances the level of task-unrelated, negatively-valanced thoughts. Such a mechanism seems to be especially plausible in adults with ADHD, as the mind wandering experiences in ADHD are more intrusive and excessive [21], and there is emotional overactivity to stressful events [8]. Mind wandering and emotional lability in adults with ADHD are both an integral part of the disorder [7], and this may be underpinned by abnormal activity in the DMN [79,21]. This reasoning can be additionally supported by the fact that mindfulness-based treatments for adults with ADHD seem to be promising and the preliminary data suggest high efficacy [80]. Mindfulness and meditation practices are known to normalize activity and connectivity in the DMN and lead to decreased mind wandering and improved emotion regulation [81]. Further work is however needed to test the hypotheses arising from our study.

4.3. Sleep, emotional lability and mind wandering

We found a similar bi-directional relationship between sleep quality and mind wandering, which is in line with previous findings in neurotypical subjects [65]. It seems that not only poor sleep quality and the resulting sleep deprivation leads to higher incidence of mind wandering [66], but also a restless wandering mind makes it harder to fall asleep. It should be noted that one of the items on the MEWS scale, which was used to measure mind wandering in our study, reads: “Because my mind is ‘on the go’ at bedtime, I have difficulty falling off to sleep” [19]. Mind wandering and sleepiness are similar in terms of the EEG signal and are both linked to the DMN activity [82]. Moreover, poor sleep quality results in negative affect [65], which is also in line with our findings regarding sleep quality and emotional lability. As discussed above, because mind wandering and emotional lability are so closely linked via negative affect, even when poor sleep quality exacerbates one of the variables, inevitably both of them will be increased [83,45], especially in adults suffering from ADHD.

4.4. Future directions

In summary, this study aimed to link the currently mostly independently investigated concepts of emotional lability, mind wandering, sleep quality and adult ADHD. Future studies should employ experimental on-task measures of mind wandering (experience sampling), sleepiness (event-related potentials, quantitative electroencephalography and polysomnography) and frustration tasks to objectively measure emotional lability; and link them to the activity of the DMN using neuroimaging and experimental designs involving ADHD medication and mindfulness training. Investigating these concepts in diverse samples, across developmental stages and diagnostic categories, holds a big promise in fully uncovering the causal mechanism behind these impairing deficits.

Declaration of interest

Professor Asherson has received funds for consultancy on behalf of King's College London to Shire, Eli-Lilly, and Novartis, regarding the diagnosis and treatment of ADHD; educational/research awards from Shire, Eli-Lilly, Novartis, Vifor Pharma, GW Pharma, and QbTech; speaker at sponsored events for Shire, EliLilly, and Novartis. All funds are used for studies of ADHD. Ruth Cooper has received funding from Vifor Pharma. The other authors report no conflicts of interest.

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