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Attention Deficit Hyperactivity Disorder (ADHD)

Diagnosis, Treatment, and Management

Edited by
Marios Adamou

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Attention Deficit Hyperactivity Disorder (ADHD): Diagnosis, Treatment, and Management

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Guest Editor

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Contents

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Article

A Nomogram for Predicting ADHD and ASD in Child and Adolescent Mental Health Services (CAMHS)

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Abstract: Objectives: To enhance the early detection of Attention Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD) by leveraging clinical variables collected at child and adolescent mental health services (CAMHS). **Methods:** This study included children diagnosed with ADHD and/or ASD (n = 857). Three logistic regression models were developed to predict the presence of ADHD, its subtypes, and ASD. The analysis began with univariate logistic regression, followed by a multicollinearity diagnostic. A backward logistic regression selection strategy was then employed to retain variables with $p < 0.05$. Ethical approval was obtained from the local ethics committee. The models' internal validity was evaluated based on their calibration and discriminative abilities. **Results:** The study produced models that are well-calibrated and validated for predicting ADHD (incorporating variables such as physical activity, history of bone fractures, and admissions to pediatric/psychiatric services) and ASD (including disability, gender, special education needs, and Axis V diagnoses, among others). **Conclusions:** Clinical variables can play a significant role in enhancing the early identification of ADHD and ASD.

Keywords: ADHD; ASD; predictive models; nomograms

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1. Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) and autism spectrum disorder (ASD) are two of the most prevalent neurodevelopmental disorders among children [1–3]. Much research has been devoted to exploring the risk and protective factors for ADHD [4–6] and ASD [7,8]. Unfortunately, predicting ADHD and ASD based on available clinical information, especially at an early age, presents significant challenges. The difficulty in early identification of both ADHD and ASD lies in the current reliance on clinical, subjective data for diagnosing mental disorders. This data depends heavily on the observer's perspective and experience, making the process inherently subjective. In other words, the challenge of achieving an accurate diagnosis is compounded by the lack of biomarkers for these mental disorders. Furthermore, complicating matters is the fact that the manifestations of these disorders vary widely among patients [9]. Furthermore, patients with either ADHD or ASD frequently show comorbidities with other mental disorders. These difficulties make finding potential biomarkers or clinical indicators especially important.

For a biomarker to be clinically useful, it must have high sensitivity (>90%) and specificity (>90%) [10]. Moreover, considering the significant genetic component of both disorders, parents may not always accurately convey their children's clinical manifestations. They tend to normalize certain symptoms that they, too, have experienced. Against this backdrop, the integration of new tools to enhance the early detection of ADHD and ASD is exceedingly justified.

Only in recent times have predictive models for ADHD or ASD been introduced. The majority of these models leverage artificial intelligence. For instance, Lee et al. [11] proposed a model for ADHD prediction using negative emotionality, communication abilities, coarse motor skills, social competence, and academic performance as predictors. Tachmazidis et al. [12] used a hybrid machine-learning/expert system approach to develop their ADHD predictive model using items from tests of ADHD, drug and alcohol abuse, and personality, mood and anxiety disorders as inputs. Slobodin et al. [13] also used machine learning to build predictive models from variables of the CPT. Sen et al. [14] used data from magnetic resonance imaging to build their predictive model. Maniruzzaman et al. [15] and Garcia-Argibay et al. [16] performed a variety of machine-learning-based methods using clinical variables as predictors. Only these two last studies, as well as Silverstein et al. [17] and Caye et al. [18], used a regression-based approach for their predictive model. Interestingly, however, Caye et al. [18] used both logistic regressions and machine-learning approaches, and they found that machine learning did not outperform logistic regressions. Regarding ASD, some predictive models have been proposed based on neurobiological markers [14,19,20] or screening tests [21]. However, despite their potential utility, these models—especially those utilizing machine-learning techniques—suffer from a lack of transparency. The variables they incorporate and their respective significance within the models remain obscure. A notable exception to this pattern is the model proposed by Caye et al. [18]; these authors have even created a practical calculator for estimating the risk of ADHD, which is readily accessible.

The primary objective of this study is to identify, from the clinical variables commonly reviewed in patient charts at Child and Adolescent Mental Health Services (CAMHS), those that can more reliably predict a diagnosis of ADHD and ASD. This could facilitate the development of predictive models for ADHD and/or ASD using medical information that is readily available. With these clinical variables, the ultimate aim of this study is to develop a series of nomograms (refer to the Section 2 for a detailed description of nomograms and their application), which could be utilized as a calculator in a manner similar to that developed by Caye et al. [18]. The distinctions between their research and our current study lie in the sample population (they utilized adult samples, whereas we employ data from children and adolescents) and the number and variety of clinical variables examined.

2. Methods

2.1. Participants

Data were gathered from children who attended the Child and Adolescent Mental Health Services (CAMHS) at Hospital Universitario Puerta de Hierro Majadahonda. A retrospective evaluation was conducted on a sample size of n = 857 patients. The study included children diagnosed with ADHD and/or ASD, with the only exclusion criterion being the absence of an ADHD or ASD diagnosis. Information was extracted from the patients' clinical records, and the database was anonymized prior to any analysis. Accordingly, we have incorporated some information about anonymization. We used dissociated databases and followed the standard Ethics permitted by the Ethical Committee of the Hospital Universitario Puerta de Hierro Majadahonda to proceed with the study. The study was approved by the local ethics committee (PI 112_17, 11 September 2017).

2.2. Outcome Variables

The outcomes used in the three logistic models were: primary ADHD, ADHD subtype (only for those patients diagnosed with ADHD), and primary ASD. A single child

psychiatrist clinically performed these diagnoses including the five axes of the Diagnostic and Statistical Manual, Fourth version [22] criteria. Axis I diagnosis was made using the fifth version [9]. Dichotomous medical and clinical variables were coded as "1" if the patient had the disorder or condition and "0" if the patient did not have the disorder. ADHD subtype was coded as "1" if the subtype was Hyperactive or Combined and "0" if the subtype was Inattentive.

2.3. Potential Predictors

The predictor variables are described in Table 1. Data were gathered from children who attended the CAMHS at Hospital Universitario Puerta de Hierro Majadahonda. A retrospective evaluation was conducted on a sample size of n = 857 patients. The study included children diagnosed with ADHD and/or ASD, with the only exclusion criterion being the absence of an ADHD or ASD diagnosis. Information was extracted from the patients' clinical records, and the database was anonymized prior to any analysis.

Table 1. Variables explored in this study.

Variable	Operationalization	Categories	Frequencies or Mean (sd) *
Age	How old (in years) is the patient?	Continuous variable	11.1 (3.9)
Gender	What is the gender of the patient?	Male (0) or Female (1)	Male = 593 Female = 276
Adopted	Was the child adopted?	Yes (1) or No (0)	No = 798 Yes = 52
Family (first grade) psychiatric antecedents	Does the patient have any first-grade relative formally diagnosed with any mental disorder?	Yes (1) or No (0)	No = 332 Yes = 471
Risky pregnancy	Was the patient's gestation a risky pregnancy?	Yes (1) or No (0)	No = 608 Yes = 236
Use of toxic substances by the mother during pregnancy	Did the patient's mother take any toxic substances during pregnancy?	Yes (1) or No (0)	No = 783 Yes = 18
Stress/depression during pregnancy	Did the patient's mother suffer stress or depression during pregnancy?	Yes (1) or No (0)	No = 644 Yes = 192
Preeclampsia during pregnancy	Did the patient's mother suffer preeclampsia during pregnancy?	Yes (1) or No (0)	No = 805 Yes = 23
Comorbidity in Axis I (Clinical Disorders)	Does the patient have a second Axis I diagnosis?	Yes (1) or No (0)	No = 245 Yes = 616
Diagnosis in Axis III	Does the patient have a diagnosis of a disorder included in Axis III (general medical condition)?		No = 59 Yes = 809
Atopy	Did the patient suffer atopy?	Yes (1) or No (0)	No = 485 Yes = 371
History of bone fractures or repetitive injuries evaluated or not at the ER?	Has the patient ever suffered a bone fracture? Has the patient had repetitive injuries evaluated at the ER?	Yes (1) or No (0)	No = 469 Yes = 378
Diagnosis in Axis IV	Does the patient have a diagnosis of a disorder included in Axis IV (psychosocial problems)?	Yes (1) or No (0)	No = 187 Yes = 661

Table 1. *Cont.*

Variable	Operationalization	Categories	Frequencies or Mean (sd) *
Disability	Does the patient suffer any disability?	Yes (1) or No (0)	No = 717 Yes = 140
Urine control (day and evening)	Does the patient control his/her urine?	Yes (1) or No (0)	No = 112 Yes = 713
Fecal control	Does the patient control his/her feces?	Yes (1) or No (0)	No = 162 Yes = 761
Started walking	Age (in months) at which the patient started walking	Continuous	15.76 (8.35)
Special education needs	Does the patient have any special education needs?	Yes (1) or No (0)	No = 716 Yes = 108
Genetics	Any confirmed genetic disease?	Yes (1) or No (0)	No = 801 Yes = 43
Physically active	Does the patient exercise regularly?	Yes (1) or No (0)	No = 259 Yes = 573
Admitted to the psychiatric acute inpatient unit?	Has the patient ever been admitted to the psychiatric acute inpatient unit?	Yes (1) or No (0)	No = 794 Yes = 50
Admitted (hospitalization) in pediatric services	Has the patient ever been hospitalized in pediatric services?	Yes (1) or No (0)	No = 709 Yes = 130
Medical treatment	Is the patient taking any medication regarding a general medical condition?	Yes (1) or No (0)	No = 399 Yes = 461
Axis V score	Which is the global assessment scale? (0–100)	Continuous	68.98 (12.16)

* Please note that summing the frequencies of each variable gives different results due to incomplete clinical records.

2.4. Statistical Analyses

The goal was to construct three logistic regression models to predict ADHD as a primary diagnosis, the ADHD subtype (either inattentive or combined/hyperactive) exclusively in patients diagnosed with ADHD or ASD as a primary diagnosis, respectively. Univariate logistic regression analyses were conducted as an initial step to select variables whose regression coefficients achieved statistical significance and those of clinical importance. Subsequently, a multicollinearity diagnostic among the chosen variables was performed using condition numbers [23] and the Variance Inflation Factor (VIF). Once the variables were selected, we performed a backward logistic regressions selection strategy, removing the variable with the higher p-value in every step, to include in each final model only those variables with $p < 0.05$. For each final model, the internal validation was evaluated based on the calibration and discrimination abilities.

A model is considered calibrated when its predictions of the proportion or number of cases (predicted risk of outcome) align closely with the observed proportion of cases (observed risk of outcome). To evaluate model calibration, linear regressions were performed on the predicted versus observed risk of outcome, with their slopes serving as measures of calibration. The closer this slope is to 1, the better the model's calibration. Additionally, we examined calibration-in-the-large (CITL), which compares the average of all predicted risks to the mean observed risk. This parameter reflects whether predictions are systematically too low (CITL < 0) or too high (CITL > 0), with values near 0 indicating good calibration. Discriminability of a model refers to its ability to accurately classify participants as having or not having the outcome—that is, participants with the outcome are predicted to have it, and vice versa. The C-statistic was used to assess discriminability [24], equivalent to the area under the ROC curve.

Both abilities were assessed using a bootstrap resample approach, through the "bsvalidation" command from STATA [25].

To improve the model interpretation, we developed a nomogram for each one of the models.

All analyses were performed with STATA, version 17.0 (College Station, TX, USA, April 2021) and R, version 4.1.2 (R Development Core Team, Vienna, Austria, November 2021). The R package "rms" [26] was used to estimate the logistic regression models and draw the nomograms, and the R package "multiColl" [27] was used to calculate the condition numbers.

2.5. Graphical Outcomes: Nomograms

A nomogram is a graphical tool used to interpret a pre-calculated model and its outcomes based on a specific set of predictor variable values. In this context, the model in question is a logistic regression model, predicting the likelihood of having ADHD (nomogram 1), a specific ADHD subtype (nomogram 2), or ASD (nomogram 3).

A nomogram features an upper horizontal "Points" line with a points scale. This scale is designed to convert the scores of each variable into a unified metric. Directly beneath this scale, horizontal lines represent each predictor in the model, each with its unique metric based on the potential values of the predictor. To translate a score from its original metric to the unified metric, one must locate the raw score on its respective line and draw a vertical line up to the "Points" line; the intersection point indicates the score in the unified metric. Summing up these scores for all variables yields a total score.

The nomogram's final two lines facilitate the conversion of this total score into a probability. This is done by locating the total score on the "Total points" line and drawing a vertical line down to intersect with the final line, where the estimated probability can be read. To illustrate, consider two hypothetical examples based on a fabricated model predicting ADHD, assuming it is influenced by three variables: Gender, adoption status, and age at first words. These examples demonstrate the application of the nomogram to predict ADHD using this model.

Example 1: For a male patient who was not adopted and began speaking at 15 months, as per the fabricated model, being male contributes 47 points, not being adopted adds 0 points, and starting to speak at 15 months adds 50 points to the total score, summing to 97 points. This total score translates into a 0.17 probability of having ADHD. Accordingly, the fictitious model and its nomogram estimate a 0.17 probability of ADHD for this patient. Figure 1 shows the nomogram of this hypothetical example.

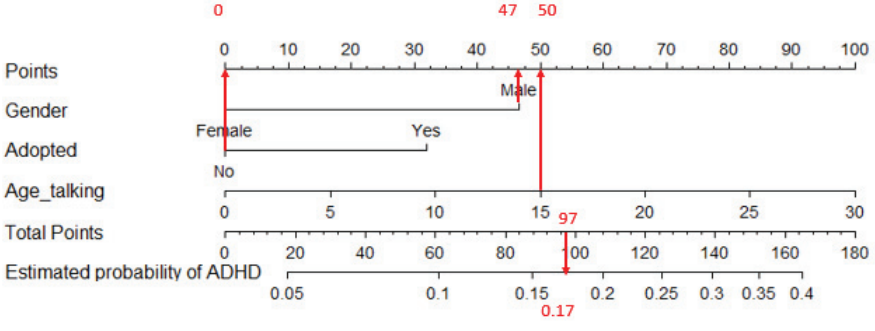

Figure 1. Sample nomogram for applying the hypothetical model to a male patient who was not adopted and began speaking at 15 months. Notice the arrows linking the variable values under "Gender", "Adopted", and "Age_talking" to the upper horizontal line, yielding their respective partial scores (47, 0, and 50). The total score is the sum of these partial scores: 47 + 0 + 50 = 97. This total score is then transformed into a probability using the two bottom horizontal lines. In this scenario, the estimated probability of having ADHD is 0.17.

Figure 2 utilizes the same hypothetical predictive model to estimate the probability of a female patient, who was adopted and began speaking at 20 months, having ADHD. Being female contributes 0 points to the score. Being adopted adds 32 points, and starting to speak at the age of 20 months contributes 67 points. Thus, the total score amounts to 0 + 32 + 67 = 99 points. This total score is subsequently converted into a probability of 0.18 for this patient having ADHD.

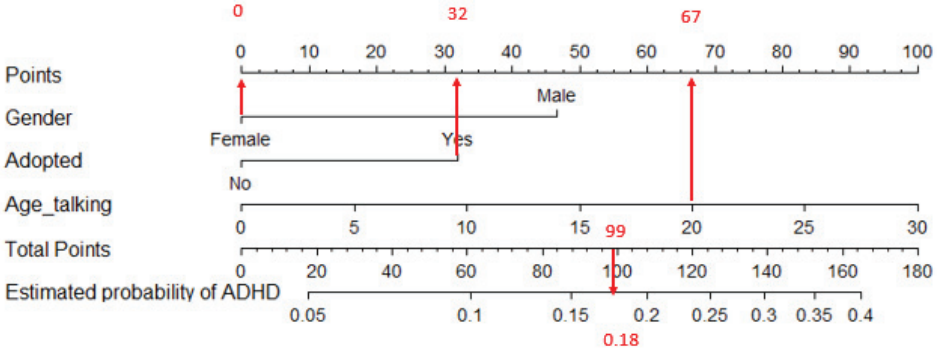

Figure 2. Nomogram associated with applying the made-up model to a female patient who was adopted and started talking at the age of 20 months. Observe the arrows connecting the variable values in "Gender", "Adopted", and "Age_talking" with the upper horizontal line to obtain their respective partial scores (0, 32, and 67). The total score is the sum of the partial scores; 0 + 32 + 67 = 99. This total score is converted into a probability using the two lower horizontal lines. In this case, the estimated probability of having ADHD is 0.18.

It is noteworthy that the predictive power of each variable is reflected in the length of their corresponding lines in the nomogram. Variables with a greater predictive capability will have larger lines than those with a lower predictive capability. The variable weighting is also reflected in the score which a certain variable may give relative to the total amount of points.

3. Results

Table 2 presents the distribution of sociodemographic and clinical variables in the sample. Overall, we developed three logistic models with satisfactory predictive performance. Table 3 displays the models generated for predicting ADHD, its subtypes, and ASD.

Table 2. Sociodemographic variables.

	Total	ADHD (*n* = 599)	No ADHD (*n* = 246)	*p*	Hyperactive/ Combined (*n* = 414)	Inattentive (*n* = 185)	*p*	ASD (*n* = 84)	No ASD (*n* = 84)	*p*
Age	11.1 (3.9)	11.6 (3.5) 3–18	9.8 (4.6) 1.5–22	<0.001	11.1 (3.5)	12.7 (3.0)	<0.001	8.6 (4.4)	11.3 (3.7)	<0.001
Sex (% Female)	31.7%	29.9%	35.4%	0.139	29.6%	39.5%	<0.001	11.9%	33.6%	<0.001
Nationality (% Spanish)	84.9%	85.0%	84.5%	0.9375	86.4%	84.4%	0.599	76.2%	85.8%	0.029

Table 3. Logistic regression model for ADHD, ADHD subtype, and ASD.

Model	Factor	OR (95% CI)	VIF	Condition Number
ADHD (n = 632)	Constant			11.68
	Risky pregnancy (No = 0, Yes = 1)	1.85 (1.14, 3.00)	1.063	
	Age of first words (in months)	0.86 (0.73, 1.02)	1.125	
	Urine control (No = 0, Yes = 1)	0.32 (0.13, 0.88)	1.630	
	Fecal control (No = 0, Yes = 1)	7.14 (2.56, 19.23)	1.623	
	Special educational needs (No = 0, Yes = 1)	0.29 (0.13, 0.63)	1.445	
	Disability (No = 0, Yes = 1)	0.34 (0.18, 0.67)	1.425	
	Physically active (No = 0, Yes = 1)	1.63 (1.05, 2.52)	1.052	
	History of bone fractures (No = 0, Yes = 1)	2.20 (1.44, 3.37)	1.036	
	Medical treatment (No = 0, Yes = 1)	3.33 (2.17, 5.05)	1.065	
	Pediatric admission (No = 0, Yes = 1)	0.44 (0.26, 0.74)	1.023	
	Psychiatric admission (No = 0, Yes = 1)	0.29 (0.12, 0.70)	1.023	
	Comorbidity with Axis I diagnose (No = 0, Yes = 1)	3.70 (2.32, 5.54)	1.070	
ADHD subtype: Hyperactive/Combined (n = 551)	Constant			2.79
	History of bone fractures (No = 0, Yes = 1)	1.66 (1.14, 2.54)	1.020	
	Psychiatric admission (No = 0, Yes = 1)	6.43 (1.36, 28.31)	1.007	
	Sex (Male = 0, Female = 1)	0.60 (0.41, 0.89)	1.058	
	Age (in years)	0.86 (0.81, 0.91)	2.896 *	
ASD (n = 634)	Constant			3.02
	Special educational needs (No = 0, Yes = 1)	2.78 (1.25, 6.20)	1.685	
	History of bone fractures (No = 0, Yes = 1)	0.47 (0.24, 0.93)	1.013	
	Disability (No = 0, Yes = 1)	8.90 (3.91, 20.28)	1.723	
	Sex (Male = 0, Female = 1)	0.21 (0.09, 0.48)	1.026	
	Diagnostic in Axis V (No = 0, Yes = 1)	0.66 (0.50, 0.89)	1.751	

VIF: Variance Inflation Factor. * VIF gives k-1 VIF values, where k is the number of values of a certain variable. In non-dichotomous variables, VIF gives more than one value. In these cases, we report the largest VIF value.

The model for ADHD prediction shows good calibration and discrimination power, and no multicollinearity was detected. The predictive equation was: ADHD = -1.340 + 0.752 × (Physically active) + 0.697 × (History of bone fractures) − 0.034 (Age of first spoken word, in months) − 0.083 × (Disability) − 0.831 × (Pediatric admission) + 0.612 (Risky pregnancy) − 1.079 × (Urine control) + 1.936 × (Fecal control) − 1.243 × (Special education needs) + 1.216 × (Medical treatment) − 1.432 × (Psychiatric admission) + 1.220 (Comorbidity with another Axis I diagnosis). The slope of the calibration plot was 0.863, the CITL was 0.031, and the C-statistic was 0.817.

The model to predict ADHD subtype from patients diagnosed with ADHD did not show multicollinearity. The predictive equation was: Probability of Hyperactive/Combined ADHD = 2.396 + 0.554 × (History of bone fractures) + 1.392 × (Psychiatric admission) + 0.580 × (Male) − 0.150 × (Age in years). The slope of the calibration plot was 0.872, the CITL was 0.004, and the C-statistic was 0.663.

Finally, the model for primary diagnosis of ASD did not show multicollinearity. The predictive equation for ASD was: ASD = -0.286 + 1.124 × (Special education needs) − 1.053 × (History of bone fractures) + 2.330 × (Disability) + 1.299 × (Male) − 0.038 × (Diagnostic in Axis V). The slope of the calibration plot was 0.861, the CITL was 0.008, and the C-statistic was 0.894.

Figures 3–5 show the nomograms of primary ADHD model, ADHD subtype, and ASD, respectively.

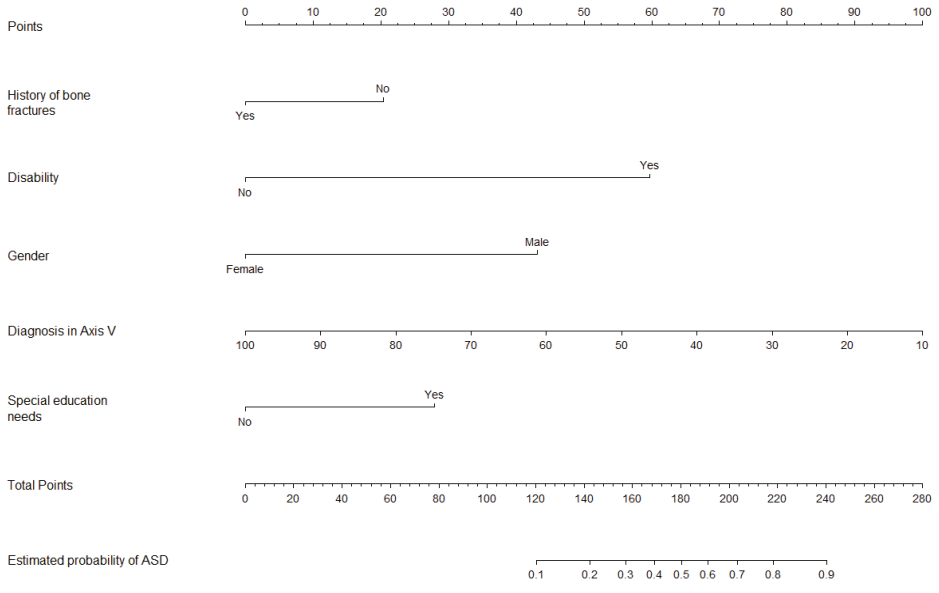

Figure 3. Nomogram for ADHD prediction model.

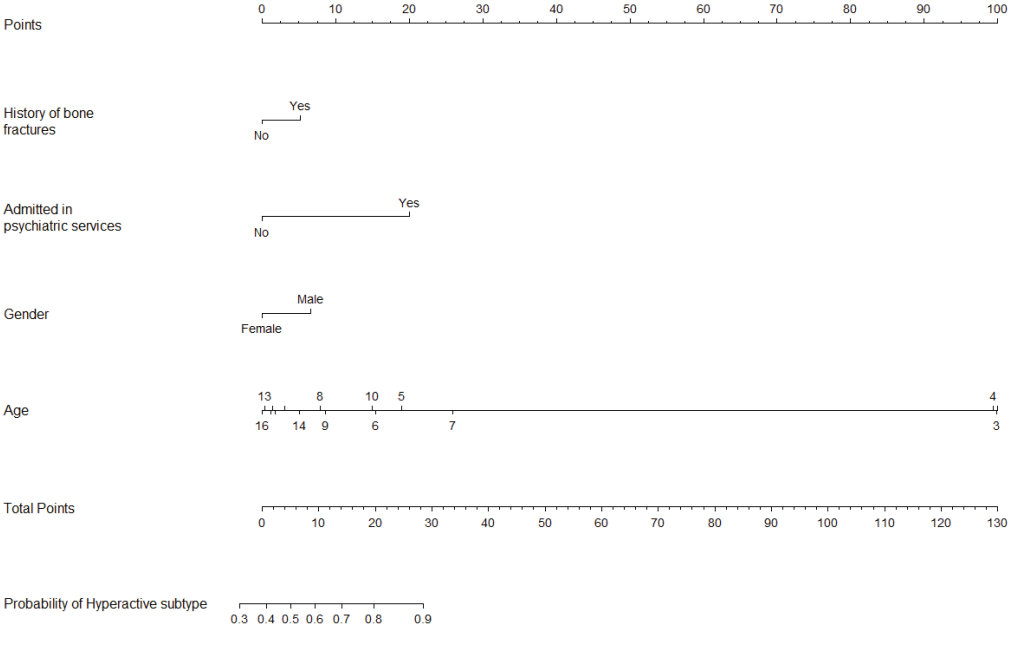

Figure 4. Nomogram for ADHD subtype prediction model.

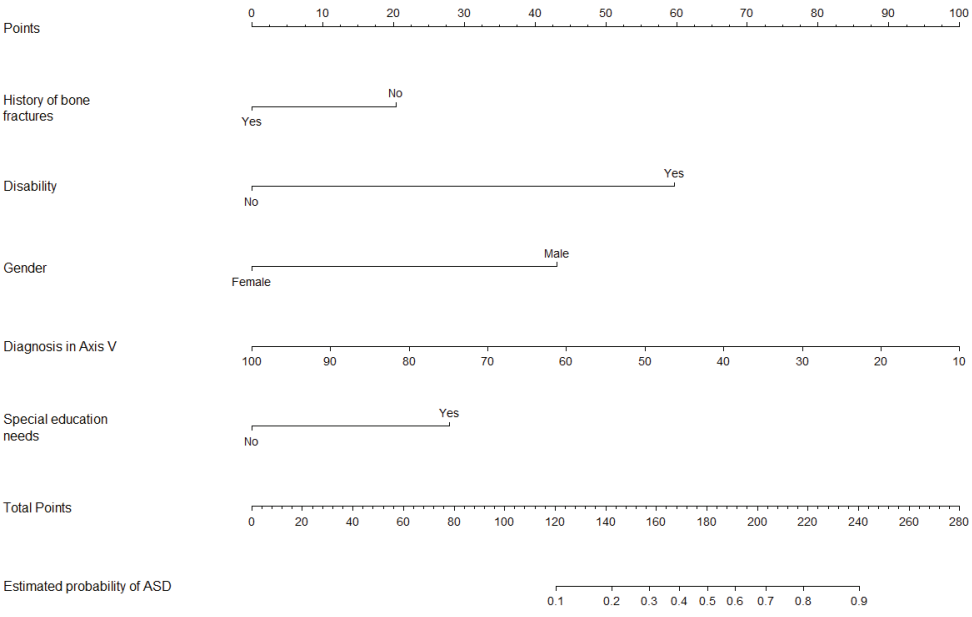

Figure 5. Nomogram for ASD prediction model.

4. Discussion

In this study, we aimed to create predictive models for ADHD and ASD using variables commonly gathered during routine pediatric or psychiatric assessments. We successfully developed models with strong predictive capabilities for a primary diagnosis of either ADHD or ASD. However, the model for predicting ADHD subtypes (either inattentive or hyperactive/combined) did not perform adequately.

The primary objective was to offer clinical practitioners a quick and useful tool for estimating predictions for two of the most prevalent neurodevelopmental disorders. Our methodology is akin to that of Caye et al. [18]. However, they developed their calculator based on data from adult patients, whereas our tool is designed for use in child and adolescent psychiatry services. Moreover, our predictive models incorporate a wide range of variables that, nevertheless, an average practitioner would typically have at their disposal simply by conducting a standard review of their patients' clinical records.

4.1. Predictors of ADHD

Numerous variables were incorporated into the final model for diagnosing ADHD. Initially, a risky pregnancy was reported almost twice as often in children diagnosed with ADHD. Various researchers have highlighted the association between ADHD in offspring and several risk factors during pregnancy, including early pregnancy or pregnancy-induced hypertension [28]. Additionally, we discovered that children with ADHD were three times more likely to experience delays in achieving urinary control, aligning with extensive literature suggesting that enuresis is a predictor of ADHD [29]. For example, in a study assessing the prevalence of ADHD among 86 children with enuresis, the authors found that the likelihood of a child with ADHD experiencing voiding issues after 2 years of follow-up was approximately 3.17 times higher compared to children without ADHD [30]. More challenging to elucidate is the negative association we observed between delayed fecal control and ADHD. Our findings appear to contradict existing evidence suggesting a positive relationship between fecal incontinence and ADHD [29,31,32]. However, our results are similar to those of a study that found an association between enuresis, but not

encopresis, and ADHD [33]. Moreover, these findings could be attributed to the relatively high average age (11.6 ± 3.5) of the patients assessed in this study at the time of their psychiatric consultation. At this age, the prevalence of encopresis is typically low. For instance, in a population-based study involving around 20,000 children in Amsterdam, the prevalence of encopresis was found to be 4.1% among children aged 5 to 6 years, and 1.6% in those aged 11 to 12 years. In our sample, the prevalence of encopresis was 3% in the group with ADHD and 17.8% in the group without ADHD.

Furthermore, two predictors of an ADHD diagnosis were associated with physical activity: (1) increased physical activity, which is indeed a criterion of hyperactivity and, therefore, may be considered a stronger clinical marker of ADHD; and (2) an elevated risk of bone fractures. The prevalence of bone fractures among children and adolescents diagnosed with ADHD, as reported in a recent meta-analysis, was 4.83% (95% CI: 3.07–6.58%) [34]. Furthermore, our finding is in keeping with several studies demonstrating a higher risk of bone fractures among patients diagnosed with ADHD [35–38]. The same studies also present some conflicting data regarding the risk of stress fractures, as the use of methylphenidate has been linked to adverse effects on bone mass.

Lastly, it is unsurprising that the presence of comorbidities in Axis I was predictive of an ADHD diagnosis, given that ADHD often co-occurs with other conditions such as ASD or learning disabilities [39].

4.2. Predictors of ADHD, Hyperactive/Combined Subtype

The model predicting ADHD subtypes included fewer variables and exhibited low predictive capabilities. Nonetheless, certain variables slightly enhanced its predictive power. These findings indicate that female children are more likely to be diagnosed with the Inattentive subtype of ADHD, whereas male children are more often diagnosed with Hyperactive or Combined subtypes, aligning with previous research [40]. Moreover, a history of bone fractures was more closely associated with the ADHD-hyperactive/combined subtype. Surprisingly, much of the research exploring the relationship between ADHD and bone fractures (or the broader concept of traumatic injuries) did not take into account the potential influence of ADHD subtypes. Nonetheless, several authors have noted an elevated risk of accidental injuries among ADHD populations, regardless of subtype [41,42]. On the other hand, at least one study reported that traumatic dental injury is more frequently reported among the hyperactive subtype [43]. Lastly, psychiatric admission also emerged as a predictor for the hyperactive/combined subtype of ADHD. One plausible explanation is that this subtype is often linked to disruptive behavior, which in turn is associated with a higher risk of psychiatric hospitalization [44].

4.3. Predictors of ASD

The model of ASD prediction reflects a bias towards male gender consistent with previous literature [45,46]. However, the most significant factors predicting an ASD diagnosis were disability and special education needs. ASD is highly heterogeneous and often co-occurs with intellectual disabilities. Indeed, the overlap between ASD and intellectual disability has complicated both the diagnosis and research into the genetic factors associated with autism [47,48]. The relationship between autism and special education needs is particularly noteworthy. Indeed, a substantial proportion of children with ASD are enrolled in special education programs [49,50]. Lastly, a history of bone traumas was negatively associated with ASD compared to other psychiatric disorders, such as ADHD. While existing literature indicates that ASD is also linked with an increased risk of trauma, our perspective aligns with the findings of Diguiseppi et al. [51], who showed that the relationship between ASD and trauma was mediated by attention problems. Consequently, the prevalence of bone trauma may assist in distinguishing between children with ASD and those with ADHD.

4.4. Strengths and Limitations

The primary strength of this study lies in the ability to predict the presence of ADHD or ASD using variables that are readily accessible in clinical settings. Additionally, the substantial sample size ensures a degree of representativeness among child and adolescent psychiatric patients. Moreover, employing a practical tool like a nomogram enables clinicians and practitioners to easily implement the models introduced in this study.

However, this study has several limitations. Firstly, all patients were recruited and assessed by a single professional (the principal investigator, HBF), limiting the generalizability of our findings to other CAMHS settings, despite these results aligning with existing literature. Secondly, clinical data utilized the DSM-IV's five axes instead of the DSM-5 classification, reflecting the principal investigator's preference for the DSM-IV's comprehensive multiaxial approach over the DSM-5's. This choice, however, means the study relied on somewhat outdated information regarding ADHD. Future studies should consider using the DSM-5. Thirdly, the study's findings are based on clinical data collection rather than scales, which underscores the study's unique appeal in enabling the early identification of children at risk for ADHD without the need for scales. The clinical variables included were selected based on the principal investigator's routine practice and experience, potentially omitting other relevant variables from the predictive models. Nonetheless, the nomograms provided align closely with scientific literature and can underpin screening diagnoses, particularly in settings where evaluation time is limited.

5. Conclusions

The models introduced in this paper reasonably predict the likelihood of a patient attending CAMHS having ADHD or ASD, based on clinically available variables. In summary, the models for predicting ADHD and ASD incorporate key variables that can aid practitioners in anticipating the occurrence of these disorders. However, further research is needed to improve discrimination between ADHD subtypes, potentially beyond the scope of chart review information.

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Conflicts of Interest: In the last 24 months, H.B.F. has received lecture fees from Takeda, BIAL, laboratorios Rubio, and laboratorios Rovi. He has also been granted with three prizes regarding the development of a serious videogame for treating ADHD (The secret trail of Moon): the Shibuya Prize by Takeda; the first prize of the college of psychologists of Madrid; and a prize to the best innovative health initiative within the healthstart prize (https://www.youtube.com/watch?v=o_j6WBKIpF0&list=PLFM_B3KwjcXObcNBpbL3VBnrbcRTJmOt4&index=5, accessed on 12 August 2022). He is Principal Investigator (PI) of an iPFIS research contract (www.isciii.es, accessed on 12 August 2022; IFI16/00039), co-PI of a MINECO research grant (RTI2018-101857-B-I00), and PI of a research project of the SINCRONIA project, funded by the Start-up Bitsphi; recipient of (1) a FIPSE Grant and (2) an IDIPHIPSA intensification grant; involved in two clinical trials (MENSIA KOALA, NEWROFEED Study; ESKETSUI2002); Co-Founder of Haglaia Solutions. He is also an employee and member of the advisory board of ITA Salud Mental (KORIAN).

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Article

A Female-Specific Treatment Group for ADHD—Description of the Programme and Qualitative Analysis of First Experiences

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Abstract: Background: The diagnostics and treatment of attention-deficit/hyperactivity disorder (ADHD) in women remain insufficient. Fluctuations of reproductive hormones during the premenstrual period, postpartum period, and (peri)menopause are neglected, even though they impact ADHD symptoms and associated mood disorders. Therefore, we created a female-specific treatment group for women with ADHD and premenstrual worsening of ADHD and/or mood symptoms. **Methods**: We describe the group programme and underlying rationale, offering a qualitative analysis of the participants' evaluation. **Results**: The seven bi-weekly sessions foreground the menstrual cycle and address several ADHD-specific topics in relation to this cyclical pattern. Concurrently, women track their menstrual cycle and (fluctuating) ADHD and mood symptoms with an adjusted premenstrual calendar. In total, 18 women (25–47 years) participated in three consecutive groups. We analysed the evaluation of the last group. Participants experienced the group as a safe and welcoming space. Recognition was valued by all. The topics discussed were deemed valuable, and the structure suited them well. Completing the premenstrual calendar augmented the awareness and recognition of individual cyclical symptoms. A lifespan approach increased self-understanding. Participants took their menstrual cycle more seriously, prioritising self-acceptance and self-care. **Conclusions**: Exploring a cyclical approach in a group setting seems to be a positive addition to treatment for female ADHD.

Keywords: attention-deficit/hyperactivity disorder (ADHD); women; menstrual cycle; non-pharmacological treatment; group treatment; sex hormones; premenstrual; female specific therapy; self-awareness; self-acceptance

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1. Introduction

Attention-deficit hyperactivity disorder (ADHD) in women, its characteristics, and its development across the lifespan remain insufficiently studied [1–3]. This is remarkable, taking into account that the sex distribution in adulthood is close to 1:1 [4,5]. As a result, treatment for women with ADHD remains suboptimal [6]. Several differences in the clinical presentation between women and men with ADHD have been described [6,7], but controversy exists [3]. It has been noted that women with ADHD when compared to men with ADHD have more mood [8–10], anxiety, and eating disorders [9], a higher level of emotional symptoms [11], and relational instability [12]. Emotional impulsivity and dysregulation play a substantial role in adults with ADHD [13–16]. For women with ADHD, a lack of emotional control adds greatly to their suffering [17]. For women [18], and women with ADHD especially [19,20], the menstrual cycle probably influences these symptoms.

Furthermore, it remains unknown if there are sex differences in response to treatment [21]. While psychostimulants are the mainstay of ADHD treatment, multi-modal treatment has been shown to improve treatment effects [21,22]. An expert consensus statement noted that the menstrual cycle may impact pharmacotherapeutic response but was unable to offer specific recommendations [23]. Additionally, to our knowledge, non-pharmacological treatment has not been discussed in light of hormonal fluctuations during the reproductive cycle.

Understandably, the cry for female-specific (treatment) approaches in ADHD is becoming louder [2,6,24–28]. Both the research and clinical fields recognise that the treatment of women is inadequate. Research has shown that the impact of sex hormones on mood and cognitive function is significant in women [18,29–39]. This may be more pronounced in women with ADHD [40–42]. Our group previously showed that women with ADHD have a higher prevalence of mood disorders than what is seen in the general population during three major periods of reproductive hormone fluctuation: the premenstrual period, postpartum, and (peri)menopause [20]. In addition, we recently described the benefits of increasing psychostimulant dosage in the premenstrual week for nine women with ADHD and premenstrual worsening of ADHD and/or mood symptoms [42]. In light of these findings, we propose that the impact of hormonal fluctuations can no longer be neglected in (treating) women with ADHD.

We, MdJ, DW and SK, are medical practitioners at a Dutch outpatient clinic (PsyQ) that specialises in treating adult ADHD and co-occurring conditions. In accordance with international guidelines [43], all patients receive a combination of pharmacological and non-pharmacological treatment, which includes psychoeducation and skills training to help them manage their symptoms. In addition, where necessary, we offer more specific emotion regulation, self-image, and schema-focused therapy groups. ADHD has high comorbidity [44,45]. On indication, we offer treatment for co-occurring sleep, depressive, anxiety, and other disorders. In line with the general consensus [23], we have been treating women and men in the same way. Currently, however, we attempt to integrate the influence of sex hormones and hormonal fluctuations into the ADHD treatment we provide [42].

Thus, deploying our professional experience, several theoretical perspectives, and recent scientific advancements, we developed a treatment group specifically for women with ADHD and self-reported premenstrual worsening of ADHD and/or mood symptoms. We foreground the effects of cyclical variations in hormones that influence mental and physical health. In addition, we integrated other relevant and possibly female-specific symptoms. We decided on a *group* programme because of the importance of social difficulties for women with ADHD [10,17]. Like others in the field [23], we recognise the importance of a lifespan approach for women with ADHD. Therefore, the second session addresses ADHD in childhood for girls and the development of symptoms and coping mechanisms over the course of a woman's life. In sessions three, four, five, and six of the programme, respectively, we focus on emotionality, impulsivity, boundaries and safety, and triggers. Stress, its causes and consequences, and adequate management are recurring themes in our group programme.

Here, we present the full programme and underlying rationale in detail and offer a qualitative thematic analysis of the evaluation of our last group. To our knowledge, we are the first to present a therapeutic intervention for ADHD that is specifically structured around the female cyclical pattern.

2. Materials and Methods

We describe our group programme and the qualitative analysis of the first experiences, as offered as part of the treatment at the outpatient clinic for ADHD in adults at PsyQ, The Hague, the Netherlands. This project was carried out in accordance with the Declaration of Helsinki; safety and confidentiality were foregrounded. The Medical Ethics Review Committee of Amsterdam University Medical Centers declared that no further ethical

approval was needed to conduct this study. All participants gave written informed consent after having read an information letter regarding this study.

All women had received a psychiatric assessment at our clinic, where ADHD was diagnosed or confirmed using the DIVA-5 interview [46,47]. A clinical decision was made by the respective individual practitioners to refer women to the group. All women participated in the group in addition to treatment as usual, including pharmacotherapeutic and psychological interventions aimed at minimising complaints of ADHD and co-occurring conditions in accordance with existing treatment guidelines. Women started the group at different phases of their treatment. Inclusion criteria for participation were diagnosis of ADHD, female sex, and (subjective) menstrual cycle-related worsening of ADHD and/or mood symptoms. Mild comorbidity was accepted, and exclusion criteria included severe depression, anxiety or panic disorder hindering group treatment, acute psychotic decompensation, active suicidality, and an inability to be (physically) present for more than 5 out of 7 sessions.

The design of the group and the content and structure of the sessions were based on an integration of professional experience and recent scientific advancements. First, we describe the overarching structure of the group, the session-specific content, and our rationale behind the programme. Second, we offer a qualitative analysis of the evaluation of our last group. We, MdJ and DW, have run the group three times. We refined the programme after evaluating the first and second groups: e.g., including more information about binge eating (episodes) because of the high reported prevalence amongst participants, further adjustments of the PMS calendar to capture the women's experience more accurately, more focus on positive aspects of ADHD to counterbalance the weight of the third session, and an improved session structure.

Data Collection and Analysis

With the consent of the participants, we audio-recorded the evaluation in the final session of the third group. This evaluation was performed in the form of a semi-structured collective interview and was conducted in Dutch. A broad open question about the participants' experience of the group (grand tour question) and a list of relevant topics were prepared in advance. The topics were operationalised further into follow-up questions and relevant themes based on experiences with previous groups and the group programme. MdJ and DW both functioned as moderators, while DW additionally observed and recorded non-verbal communication (e.g., nodding in agreement). Directly after the evaluation, field notes were drafted together. Audio recordings were manually and verbatim transcribed by MdJ and pseudonymised. Non-verbal communication was included in the final transcript. The thematic analysis was carried out in different phases. Together, MdJ and independent researcher MM inductively coded the transcript. Code memos were kept. Iteratively, codes were clustered together until, eventually, a preliminary set of themes was generated. Together with DW, MdJ and MM iteratively refined the preliminary themes. Individually, MdJ, MM, and DW then drew up a figure that best represented the coherence of the identified preliminary themes using individual notes that had been taken. In addition, all researchers revisited the transcript for possible further adjustments. Together, MdJ, MM, and DW then discussed their figures, notes, and observations until a final consensus was reached about the (overarching) themes and their coherence. After the final consensus was reached, themes were translated from Dutch into English by MdJ and DW. Where translations posed a challenge, this was discussed until an agreement was reached. The key themes presented here, with the exception of the overarching themes, are exclusively (translations of) literal words or expressions used by the participants.

3. Results

We firstly describe the group programme, and secondly offer a thematic analysis of the evaluation of the last group.

3.1. The Group Programme

All seven sessions have a similar structure (Figure 1), last two hours, and are conducted every other week. A break of approximately one month, usually between sessions 4 and 5, is included to allow participants to implement what they have learned thus far. During the group, women track their menstrual cycle, their ADHD, mood, and somatic symptoms with an adjusted Premenstrual Dysphoric Disorder (PMDD) calendar: 'PMS calendar' (Appendix A). Thus, women may link any new material presented in the sessions to their own unique experiences.

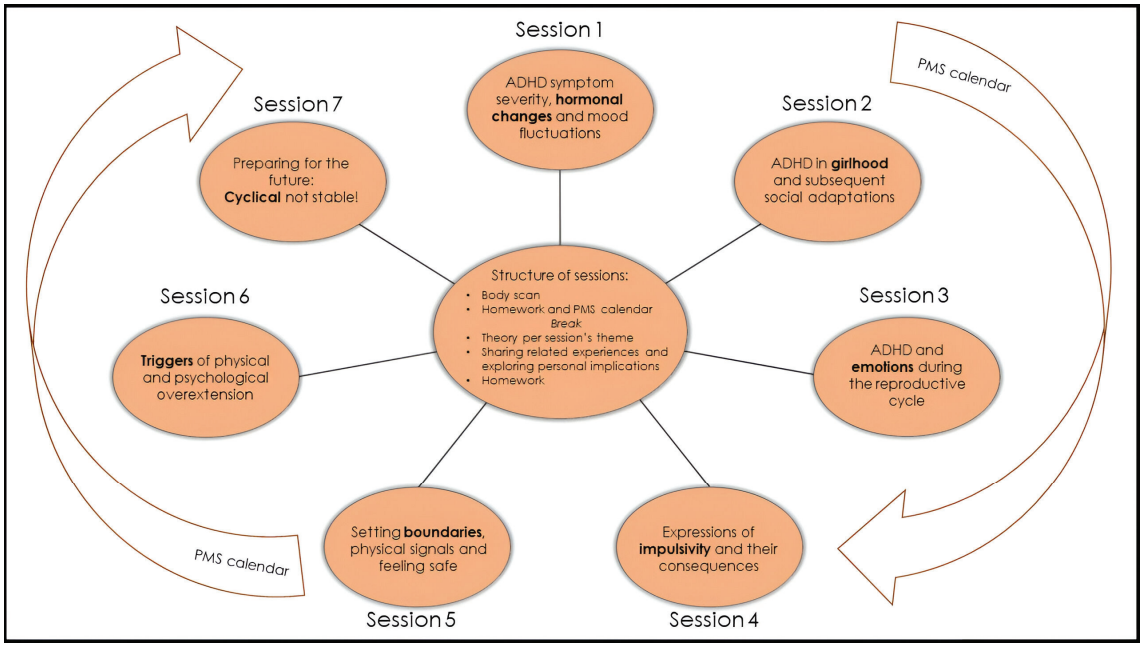

Figure 1. Overview of the female-specific treatment group for ADHD. The programme consists of 7 sessions of two hours that are given every other week, and all have their own focus. The PMS calendar functions as a connecting thread (Appendix A). All sessions have a similar structure. Every session starts with a 5 min body scan meditation. Homework and the PMS calendar are discussed. After a break, the content section consists of a combination of theory and (individual) experiences. Every session ends with the homework assignment for the next session. During the body scan, under verbal instruction from a therapist, participants are encouraged to move attention sequentially via the body, paying attention to present moment sensory experience in each body area without trying to change anything [48]. The PMS calendar was devised and adjusted in collaboration with participants of previous groups. For the duration of the group programme (about 16 weeks), participants use it to track their menstrual cycle, ADHD, mood, and somatic symptoms.

3.1.1. Session 1: The Menstrual Cycle

The structure of the session differs slightly, as it is the first session of the programme.

Start: Introduction of all participants and the professionals running the group (MdJ and DW). Introduction of the programme and its structure and setting ground rules. The group is designed as a safe and non-judgmental space. Amongst others, two rules are: 'come as you are' (e.g., inviting participants to be themselves, obviating the need to fit in socially) and 'do what you need to do to focus' (openness to, e.g., fidgeting, taking medication during the sessions if necessary). Inventory of additional ground rules necessary for all participating individuals to feel safe. Participants answer the following question: 'Why do you want to participate in this group specifically?'.

Content: The impact of sex hormones on mental wellbeing [29,31,32] and brain plasticity [49]. Women with ADHD appear to have increased and more severe hormone-related complaints [20], than women without ADHD [35].

Cycle: PMS calendar is introduced and explained. From now on, this calendar will be filled in by participants between sessions.

Homework: Participants are asked to select and bring a photograph of themselves as a child, where they recognise themselves completely, unadjusted to societal expectations.

3.1.2. Session 2: ADHD in Childhood for Girls

Homework: What was the experience of selecting the photograph like? Share the one chosen and explain why this particular one. What was it like to be that girl? What was the impact of social adaptation? Reflect on current relationship with the little girl in the photograph.

Content: How ADHD symptoms differ in boys and girls [7,50–54], aetiology of ADHD, risk of a missed diagnosis [7,52] or misdiagnosis [55] in girls and women, ADHD in puberty [56,57], ensuing coping strategies such as masking [58] or socialisation [59], and the impact hereof in later life [17,28]. Discussion of behavioural changes around the time of menarche.

Cycle: Address additional questions or problems concerning the implementation of the PMS calendar.

Homework: Full attention paid to the PMS calendar. The next session completes one month of tracking symptoms. Reflect on and discuss any apparent patterns.

3.1.3. Session 3: ADHD and Emotionality

Homework: Share and discuss the implementation of the PMS calendar and discern any patterns emerging.

Content/Cycle: Menstrual cycle and associated hormone fluctuations in more detail. Premenstrual syndrome (PMS) [60] and PMDD [61] in more detail. The interrelationship between fluctuating sex hormones and ADHD (symptoms) [30,62] and the relation between oestrogen and dopamine [63]. Effect of oestrogen on the prefrontal cortex [34]. ADHD is associated with more frequent and severe premenstrual- and postnatal mood symptoms, (peri-)menopausal complaints [20] and dysmenorrhea [64]. Emotional impulsivity and self-(dys)regulation presented as possible core characteristics of ADHD [13]. Reflect on the influence of the menstrual cycle on these symptoms. End with positive sides of ADHD [65].

Homework: Reflect on and present three positive aspects of participants' own ADHD.

3.1.4. Session 4: ADHD and Impulsivity

Homework: Share and discuss personal experiences of positive aspects of ADHD.

Content: Impulsivity can manifest in different ways [15]. In adult ADHD, it is associated with compulsive sexual behaviour, 'sensation seeking,' difficulties in delayed gratification, and emotional dysregulation [16]. Mutually sustainable relationship of impulsivity, restlessness, and stress. Hormonal fluctuations impact impulsive [30,62] and addictive behaviours [66]. ADHD is associated with disordered eating behaviour [67–73]. Eating behaviour fluctuates cyclically [74], and oestrogen influences appetite [75]. Individual experiences with fluctuating impulsivity, possible consequences and sharing of tips and tricks used to alleviate symptoms.

Homework: Plan and execute (at least) three self-care activities. These are novel activities or activities that are rarely experienced but are usually enjoyed.

3.1.5. Session 5: ADHD, Boundaries, and Safety

Homework: Share and discuss self-care activities and the experience of foregrounding these.

Content: Unsafety and feeling unsafe. Sensory hyper- and hyposensitivity in women with ADHD [76], and the spectrum of consequences; any resulting 'sensation seeking'

behaviour can lead to unsafe situations, while too many light/sound/tactile stimuli can produce overstimulation and cause feelings of unsafety. Fluctuating impulsivity and emotional dysregulation in relation to maintaining personal boundaries. Cyclically fluctuating boundaries and the role of interoception [77,78]. Prolonged masking behaviours and negative previous/current social experiences [17,79] as sources of feeling unsafe. Negative consequences of insufficient self-care. The importance of a sense of control or agency for women with ADHD [17]. Individual experiences with unsafety and feeling unsafe in relation to the theory.

Homework: Explore individual boundaries by reflecting on the following questions: (1) Where do you have adequate boundaries? (2) Where do you have inadequate boundaries? (3) When was the last time you transgressed your own boundaries? (4) Which signals does your body give you when you (almost) transgress your boundaries?

3.1.6. Session 6: ADHD and Triggers

Homework: Share and discuss the answers to the questions above. What was the experience of reflecting on them like? How does the menstrual cycle influence the (experienced) boundaries?

Content: Prevalence of delayed circadian rhythm in ADHD [80] and effect of psychostimulants on late sleep [81]. How women with ADHD tackle stress and experience impairment [10] in social functioning and with time perception. Influence of premenstrual hormonal fluctuations on sleep [82], social functioning [83], emotional stress and psychological triggers [84]. Explore sensitivity to (physical/psychological) triggers in relation to the menstrual cycle (e.g., sensory stimuli, experiencing rejection, judgement, and sleep deprivation). Discuss individual experiences with triggers and their shared characteristics.

Homework: Create a plan of how to integrate what was learned in the group, a cyclical plan that considers one's particular wants and needs. Get creative!

3.1.7. Session 7: The Future

Homework: Presentation of the future plans of all participants.

Ending: Evaluation of the group programme.

Following the group, participants have the possibility to discuss and implement their individual plans for the future with their individual therapist.

3.2. Experiences

Six women (29–46 years) commenced the group treatment (Table 1). All completed the programme. Five were present at the final evaluation; the sixth group member was unable to attend but had sent a detailed email describing her experiences and future plans, which we shared during the final session. The recorded evaluation lasted 36 min. We, MdJ and DW, experienced the evaluation as somewhat different from the regular sessions. Especially at the beginning of the evaluation, the participants took great care to take turns speaking. After a lengthy discussion, MdJ and DW concluded that the evaluation nonetheless reflected the typical group dynamic.

All participants had received their ADHD diagnosis in adulthood. The mean time since the ADHD diagnosis was 32 months; the mean time since the commencement of treatment for ADHD at PsyQ was 10 months. At the start of the group, four of the six women used ADHD medication, of which two were on stable doses. At the final meeting, five of the six women were using ADHD medication, of which three were on stable doses (Table 1). During the programme, one participant had started an SSRI. No hormonal contraceptives were used by 4/6 participants. The combined oral contraceptive pill was used by one participant (1/6), as was a hormonal intrauterine device (1/6). For co-occurring conditions, see Box 1.

Table 1. Participant characteristics.

	Mean (Range)
Age *	37.8 years (29–46 years)
Time since ADHD diagnosis	32 months (4 months–10 years)
Time since treatment start **	10 months (2–22 months)
	n^0 (total = 6)
Use of ADHD medication at start *	4
Stable medication *	2
Use of ADHD medication at the end ***	5
Stable medication ***	3

* At the start of the group programme ** Time since the commencement of treatment for ADHD at PsyQ, The Hague *** At the end of the group programme.

Unlike the description of the standard group above, for this particular group, we were forced to cancel the fourth session as a result of dangerous weather conditions. In consultation with the participants, we integrated the fourth into the fifth session.

Box 1. Classifications based on DSM-5.

Main diagnosis: ADHD (67%), ADD (33%)

Co-occurring conditions:
Affective: Depr-recur-mild (17%), PDD (17%), Depr-recur-part-remis (17%)
Anxiety: GAD (33%), UAD (17%)
Trauma: PTSD (17%), UTSD (17%)

Other: DSPD (33%), ASD (17%), CUD (17%)

Somatic: Hypertension (17%), Migraines (17%)

Prevalence of diagnoses in the last group (n = 6). Abbreviations: ADHD: attention-deficit/hyperactivity disorder–combined subtype; ADD: attention-deficit/hyperactivity disorder–inattentive subtype; ASD: autism spectrum disorder; CUD: cannabis use disorder; Depr-recur-part-remis/mild: depressive disorder–recurring–in partial remission/mild; DSPD: delayed sleep phase disorder; GAD: generalised anxiety disorder; PDD: persistent depressive disorder (dysthymia); PTSD: post-traumatic stress disorder; UAD: unspecified anxiety disorder; UTSD: unspecified trauma and stressor-related disorder.

Evaluation

In our qualitative analysis of the final evaluation, we identified six key themes: safety-sharing-welcome; recognition; good fit; eyeopener; take (n) seriously; and empathy. The two overarching themes were understanding and connection (Figure 2).

Participants emphasised that they valued feeling **safe** in the group, at ease and **welcome**. They underlined the importance of **sharing** openly, honestly and with emotion. They shared previous stories and experiences as well as their current experience with the group.

> I knew about the [menstrual] cycle, I have of course covered it in my studies, because I've studied healthcare, but it was never discussed with me in *this* way, really with emotions and stuff like that, and (we) really share it with each other (emphasis in transcript). (I2)

> Last week for instance, I was very emotional, but I was actually welcomed here with open arms by everyone and I could share my story. . . I was not exaggerating, as all of you would actually have the same feelings [if you were in my position], so for me that recognition is great. (I3)

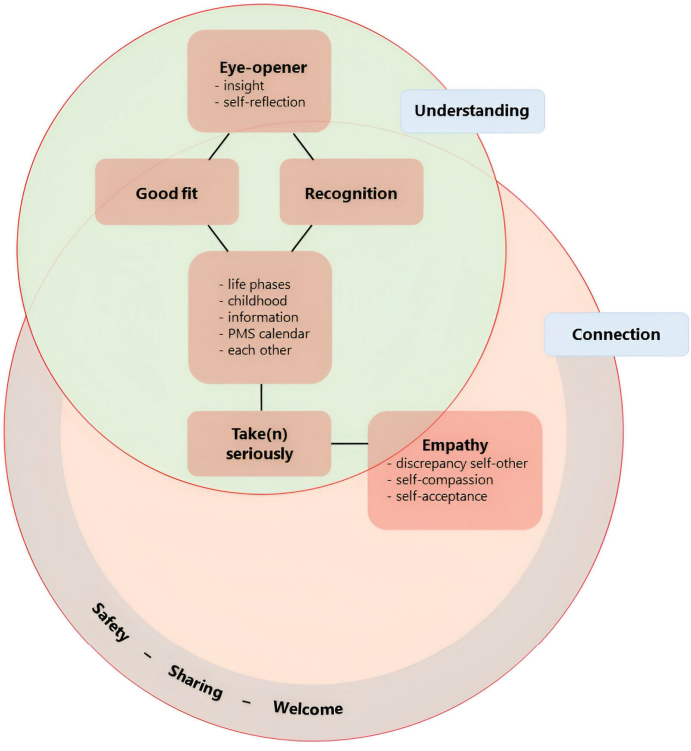

Figure 2. Graphical summary of themes from final evaluation and their interrelationship. Six key themes were identified via our qualitative analysis of the final evaluation: eyeopener, good-fit, recognition, take(n) seriously, empathy, and safety-sharing-welcome. We decided on a compound theme for safety-sharing-welcome as we felt that the separate meanings were similar enough to group but not identical enough to merge. All key themes are literal (translations of) expressions of our participants. The overarching themes, which overlap, are understanding and connection.

The participants mentioned the value of **recognition**. Some valued the group's emphasis on the menstrual cycle, while others considered it a bit too strong. They recognised themselves in the other group members and mentioned that the structure of the topics was a **good fit** for them.

> I appreciated it that for instance . . . sometimes emotions can invade like a kind of fireworks, that others were able to recognise it too, which made me think . . . 'oh, [this is] apparently not something special, because . . . other people experience it too', I liked that a lot too. (I4)

> Recognition is very valuable, just like you already said, because it is something completely different to . . . encounter an Instagram-account online . . . in which you do recognise yourself, but then you just continue scrolling. Here, you are actually sitting around the table [together]. (I5)

Participants mentioned multiple **eye-openers**. Several considered the childhood theme impactful, as it changed their self-regard and made them want to change some things in their lives. They found it insightful to discuss other life phases and address them from the perspective of ADHD and hormones.

> Yes, and that it does not only influence your [menstrual] cycle but also other phases in your life, during puberty and later menopause . . . or after giving birth . . . and that this is once again so connected with ADHD. I also did not know this,

> but it again explains a lot. So if I go back in time . . . why was *I* such a terrible adolescent? . . . [What] was happening in my head? I also like it that we have discussed that. (I3)

The PMS calendar (Appendix A) was considered useful as participants were not aware that all the listed symptoms might relate to their menstrual cycle.

> Yes . . . that there was a ready-made list of everything . . . you could suffer from [premenstrually] and that made you start to think, 'oh, that is apparently something that could be related to my [menstrual] cycle'. (I1)

Premenstrual symptoms were similar between participants but not identical.

> For me that was a real issue, that you struggle to get started . . . I noticed a big difference there . . . as I approached my menstruation. (I1)

> For me it was itchiness. I was not at all aware of this, but now that I know it I think 'oh right, that is something that I am a little extra sensitive to'. (I5)

> For me it was feeling a bit under the weather. Yes, I feel a bit unwell when I have PMS. (I2)

Self-criticism was prevalent, while simultaneously, participants had **empathy** for other group members in similar situations. This contrast provided insight, too. At the final evaluation, participants reported that they **take** themselves and the impact of their menstrual cycle **more seriously**. They give themselves more space in the premenstrual phase, are kinder to themselves, listen more to their own needs and say 'no' more often. Participants mentioned improved self-acceptance. They also noted that they are more aware of possible (future) treatment options and what they might need for themselves. In addition, participants expressed that they have gained confidence in communicating about their menstrual cycle to others and can do so more clearly. These changes were described as an ongoing process.

> [Having] some more clarity for myself, allows me to be more clear with other people. (I5)

There was ambivalence about the time investment required for participation in the group. Some participants expressed difficulties fitting the group in alongside work or other (treatment) appointments. While they had found the experience valuable, they were also relieved to have one thing less to fit into their calendar. Others would have preferred the programme to continue for longer. While time investment was a challenge for some, it also showed them that taking time for themselves is possible, even with busy schedules. Potential improvements to the group were suggested. Participants would have liked more time for reflection during the sessions and suggested additional relevant topics: more practical tips, explicitly addressing the costs of ADHD, and more focus on rest and relaxation. Ultimately, all agreed that a part two of the group would be desirable.

Connection was considered an overarching theme. We understand this as a connection with oneself, with others in the group and their similar experiences, and between experience and theory. It additionally captures the experienced value of recognising the connection between ADHD and/or mood symptoms and hormonal fluctuations during different life phases. *Understanding* also emerged as an overarching theme. Participants emphasised the importance of understanding their experiences, making sense of their past, normalising their difficulties, and developing empathy for themselves and each other.

4. Discussion

We describe here a group programme specifically designed for women with ADHD and self-reported premenstrual worsening of ADHD and/or mood symptoms that was offered as an adjunct to the outpatient adult ADHD treatment at PsyQ, The Hague, the Netherlands. This is the first time, to our knowledge, that a therapeutic intervention specifically tailored to the menstrual cycle in ADHD is described. Also, we present a

thematic qualitative analysis of the final evaluation of our last group, which reflects the participants' experience of the group programme. Participants considered the topics valuable and the programme structure well tailored to them. The group was experienced as a safe and welcoming space. Recognition in each other as well as in the provided theory and PMS calendar (Appendix A) was insightful and valued by all. Discussing ADHD throughout the female lifespan increased self-understanding and resulted in a shift in self-regard. At the final evaluation, participants took their menstrual cycle more seriously, prioritising self-acceptance and self-care in the luteal phase of their cycle. This was described as an ongoing process. There was ambivalence about the time investment required, and some participants found the emphasis on the menstrual cycle a bit too strong. Others valued this approach. The key themes that were identified via thematic qualitative analysis of the final evaluation were eyeopener, good fit, recognition, take(n) seriously, empathy, and safety/sharing/welcome (Figure 2). Additionally, we identified two overarching themes: *understanding* and *connection* (Figure 2).

We developed this female-specific treatment option in response to the dire need expressed by many [1,17,19,23–26,28,41,55,85], including patients. The programme is explicitly a product of combining and integrating our clinical experience with the available scientific evidence. Importantly, we do not claim that our programme design is optimal. We hope to boost the parallel and collaborative development of female-specific therapeutic options for ADHD and emerging sex-specific evidence. The group, consisting of seven sessions, foregrounds the menstrual cycle and addresses several ADHD-related topics in relation to this fluctuating pattern: childhood, emotionality, impulsivity, boundaries and safety, and triggers (Figure 1). During the group, participants track their menstrual cycle and possibly related symptoms with a PMS calendar (Appendix A). We advise that this programme be considered in addition to pharmacological and non-pharmacological treatment as usual and not be used as a substitute.

4.1. Merging Practice and Research

Several differences in the clinical presentation of ADHD in women and men have been described [4,6,7,24], but controversy exists [3]. As previously described, women with ADHD, when compared to men with ADHD, seem to have more mood [8–10], anxiety and eating disorders [9], a higher level of emotional symptoms [11] and relational instability [12]. Social functioning, time perception, and tackling stress also seem more impaired in women with ADHD [10]. The presentation of ADHD in women is described as more complex [11] and no less invalidating [4] than the presentation of ADHD in men. However, women are more often misdiagnosed [23] and diagnosed later [85] than men with ADHD. What is more, female-specific treatment options are scarce. So far, the only female-specific intervention known to us was designed by Gutman et al. [86]. They summarise that women with ADHD struggle with consistency in managing the organisation and stressors of their multiple social roles [86,87]. To target this specific combination of symptoms, they designed an individually tailored intervention for women with (self-reported) ADHD [86]. However, the intervention does not address the menstrual cycle.

During many years of clinical experience, we have come to discern a pattern specific to our female patients. Hormonal fluctuations seem to impact ADHD symptomatology. Available evidence has confirmed this [23,88]. Compared to the general population, women with ADHD are at increased risk of depression and depressive symptoms during periods of ovarian hormone fluctuations [20,41,89,90]. Additionally, during periods of low oestrogen, increased ADHD symptoms [30,41,91,92] and decreased response to psychostimulant medication [25,42,93–95] have been described. Moreover, in the periovulatory phase, increased risk-taking behaviour has been reported [19]. High trait impulsivity is central to ADHD and has also been linked to fluctuations in oestrogen and progesterone during the menstrual cycle [96]. Oestrogen is thought to stimulate dopamine synthesis [62,63] and to have a direct and comparable effect on the prefrontal cortex to that of dopamine [34]. Recently, we published a case series that demonstrates the potential benefits of increased

psychostimulant dosage in the premenstrual phase. We reported relief of worsening ADHD and mood symptoms premenstrually in all nine consecutive cases [42]. But beyond psychopharmacology, multi-modal treatment for (women with) ADHD is optimal to improve treatment outcome [21]. According to Young et al., non-pharmacological treatment for women with ADHD should include a lifespan approach, giving attention to the complex and developmentally changing presentation of ADHD [23]. Additionally, they and others emphasise that treatment plans should be informed by the interaction between ADHD and fluctuating hormones [19,23,25,26,41]. We agree that the interrelationship between fluctuating sex hormones and ADHD (symptoms) must be addressed in *both* pharmacological and non-pharmacological treatment for women with ADHD [30,62]. Therefore, we have developed a female-specific group programme that foregrounds the effect of cyclical variations in hormones and their influence on mental and physical health.

The core of non-pharmacological treatment for ADHD consists of psychoeducation, support, Cognitive Behavioural Therapy, and practical organisational skills [22]. At PsyQ, all patients are offered a combination of pharmacological and non-pharmacological treatment for ADHD. If indicated, additional interventions are provided. Until we started the group, no female-specific treatment options were available.

4.2. A Group Setting

Growing up, girls with ADHD are more likely to have no friends, struggle with social skills and peer interaction, be less popular, and be at greater risk of victimisation [79]. The experience of being a girl with ADHD is covered in the second session of our group programme. Participants considered it an intense but impactful session. Attoe and Climie identified four key themes in their systematic review of the experience of women with an adult diagnosis of ADHD: impacts on social-emotional wellbeing (e.g., low self-esteem, peer relations and emotional control, and coping strategies); difficult relationships; lack of control; and self-acceptance after diagnosis [17]. The group setting, consciously chosen because of the importance of social difficulties for women with ADHD, was valued by the participants as a welcoming and safe space in which they could openly share, even in the presence of strong emotions. Sharing the experience of the group, mutual recognition was greatly appreciated. While the start of the group was stressful for some, participants were impressed by the openness and understanding of other group members. The incorporation of emotions in the group programme offered insight. In adults with ADHD, emotional impulsivity and dysregulation play a substantial role [13–16]. For women [18], and women with ADHD especially [19,20], the menstrual cycle probably influences these symptoms. For women with ADHD, lack of emotional control adds greatly to their suffering [17]. We deal with these topics in detail in our third and fourth sessions. In ADHD, an interaction between alexithymia, emotion-processing dysfunction and social anxiety has been suggested [97]. Clinically, we consider this a large burden that, if left unaddressed, may impact a woman's life immensely. Participants of our group found that intense emotional experiences were normalised somewhat, as others had also experienced and described them. In addition, they noted that an increased understanding of the impact of cyclical fluctuations and actively discussing these in the group helped them communicate more confidently and clearly about their cycle and their fluctuating (emotional) needs.

4.3. Time and Planning

Inconsistency in regard to reaction time can be considered a stable feature of ADHD, where adults have been described as consistently inconsistent, both behaviourally and in their performance on neurocognitive tests [98]. We argue that some women with ADHD, in the reproductive period of their lives, are *fluctuatingly* inconsistent due to their cyclical nature. Thus, in order to help them manage their symptoms adequately, this additional variability needs to be addressed [42]. In the first session of the group, we introduce the importance of the menstrual cycle. In the third session, we discuss in depth the interrelationship between fluctuating sex hormones and ADHD (symptoms) during different life

phases. For the duration of the entire programme, participants track their menstrual cycle and fluctuating ADHD and/or mood symptoms with the PMS calendar (Appendix A). Some women with ADHD feel little control over their lives [17]. Skills training for planning and organising is an essential part of non-pharmacological ADHD treatment [99,100]. We propose that skills training for women with ADHD whose menstrual cycle impacts their mood and cognitive function should explicitly accommodate the menstrual cycle. Thus, 'realistic planning' should not only cater to ADHD-specific needs but also help with self-management during the different phases of the cycle (Table 2). The symptoms were similar between individual participants, although not identical, which emphasises the importance of an individually determined, realistic plan.

Table 2. Realistic planning per menstrual phase.

	Follicular Phase	Periovulatory Phase	Premenstrual Phase
Description	Approximately the first two weeks of the menstrual cycle. From day 1 of menses until ovulation. Term used loosely: from the moment during menstruation when subjective premenstrual symptoms start improving until the periovulatory phase.	The days around ovulation. In our groups, the exact moment of ovulation is unknown. We rely on subjective reports of 'ovulation-like' symptoms. Importantly, some women experience mild 'premenstrual symptoms' directly after ovulation.	This is the period before menstruation commences. This phase is also known as 'week 4′ of the menstrual cycle and is characterised by lower oestrogen and progesterone levels.
Symptoms	More energy and focus	Increased risk-taking behaviour	Worse mood and ADHD symptoms
Plan for	Particularly challenging/boring tasks	Sufficiently stimulating activities	Increased periods of 'down-time'
Examples	Job interviews, house cleaning, buying groceries in bulk for other phases, completing administration, preparing for big deadlines Plan ahead (realistically) Discuss what is needed during premenstrual phase with (life)partners	Engaging in hobbies, such as cleaning out an old wardrobe Socialising Avoid 'dangerous' situations (e.g., clubbing)	Simple and enjoyable tasks that have been 'saved up' Fewer social obligations Avoid big decisions Relaxing activity (e.g., TV series, massage)

Note: the suggested examples and plans are not exhaustive or ideal.

Initially, we were struck by how unaware women were of (the impact of) their own menstrual cycle. However, ADHD is associated with difficulties in time perception [101,102], so it is not surprising that some women with ADHD have a limited overview of the relationship between the increase in symptoms and the phase of their cycle. In addition, they may struggle to adequately recognise their (fluctuating) wants and needs. Consequently, every month, in the premenstrual phase, women with ADHD may be caught off guard by their worsening ADHD and/or mood symptoms [7,30,40,41]. Similarly, they may be repeatedly surprised mid-cycle by the increase in their risk-taking tendencies [19]. Possibly more poignant, if women do not understand the interaction between fluctuating hormones and ADHD symptoms, they will battle to make sense of their fluctuating course. For this reason, we foreground the menstrual cycle in our programme. In our group, participants became aware of the extent and impact of their own fluctuating symptoms by completing the PMS calendar (Appendix A). For many, the changes associated with menstruation are still shrouded by shame and taboo [103]. Participants in our group emphasised the value of openly sharing with others and experiencing recognition. They recognised themselves in the theory and each other. This, similar to their experience with sharing intense emotions, helped normalise their fluctuating struggles. They began to take their difficulties more seriously. Increased understanding of bodily functions and the interconnectedness with ADHD throughout different life phases allowed for shifts in self-regard and self-acceptance. At evaluation, participants noted that they had incorporated their menstrual cycle in their planning more or had a strong intention to do so in the future. Once they had acknowledged their cyclical pattern, they were able to predict periods of

poorer function and adapt their planning in accordance with their cycle. They described their experience as less burdensome.

4.4. Masking the Menstrual Cycle

If a professional fails to address the (impact of the) menstrual cycle or ignores the timing aspect of therapeutic interventions, we pose that treatment remains suboptimal at best. Where the menstrual cycle is ignored, women with ADHD may fail to adhere consistently to treatment plans. In ADHD, repeated failure experiences are commonly described [104], and may result in a negative spiral of poor self-esteem, anxiety and depressive symptoms [105,106]. Women, when compared to men with ADHD, appear to have a more pessimistic self-perception [8]. We argue that appropriately tailored treatment plans will minimise experiences of failure and increase adherence to treatment for women with ADHD. Indeed, participants of our programme found the group topics and structure well-tailored to them. During the evaluation, one participant remarked that she had surprised herself, as she had completed her homework almost every time.

A second possible consequence of ignoring the menstrual cycle in ADHD treatment is that women may feel compelled to mask their difficulties, as they may feel embarrassed or not understand the relevance of their ADHD treatment. From an early age, women with ADHD learn to mask their symptoms [58] and adjust their behaviour to the expected social norms [59]. Masking implies continuous confirmation that one needs to adapt to be accepted and, conversely, one is not good enough as herself. In fact, some researchers suggest a relation between this socialisation and the high prevalence of anxiety and depression in girls and women with ADHD [28,87]. ADHD is strongly associated with internalising problems [107], and women with ADHD have more internalising disorders [4] and a more pessimistic self-perception [8] than men. In the second session, we explore the possible consequences of masking from an early age. One participant from the first group explicitly mentioned that the ground rules 'come as you are' and 'do what you need to do to focus best' were encouraging to minimise masking during the sessions. For the women in our last group, the childhood topic was an 'impactful eye-opener'. In session two, participants share a photograph of their childhood selves, where they recognise themselves completely, unadjusted to societal expectations. Discussing their girlhood and sharing vulnerabilities made them realise they had masked their ADHD symptoms from childhood onwards. This realisation caused a shift in self-regard, stimulated self-compassion, and made them more aware of what they wanted to change in their lives. Simultaneously, in our experience, the emotional exchange of session two helps stimulate a feeling of group cohesion.

4.5. Physically Stressed

Clinically, women with ADHD describe periods when they are more easily overwhelmed, struggle more to maintain an overview, and experience less resilience to stress. Unsurprisingly, these periods often coincide with the premenstrual phase. What is more, in this period, they fail to keep up with obligatory tasks and may have emotional outbursts and/or (severe) depressive or anxious symptoms. This, in turn, augments stress. Stress management was an ongoing topic in our programme. Each session started with a body scan meditation (Figure 1). We included it both as a conscious moment of transition (from work/study/traffic to the group) and as a practice of interoceptive attention. The body scan developed as a part of mindfulness-based stress reduction [108] has been shown to be effective in stress reduction, increased self-compassion, decreased rumination, and medical symptom relief [48]. Between sessions three and four, we introduce positive aspects of ADHD. In session four, we expand on the relation between impulsivity, restlessness and stress and the influence of different phases of the cycle. We also explore ways of harnessing aspects of participants' own ADHD to break this vicious cycle and reduce stress. The homework of exploring self-care activities between sessions four and five is additionally included to practice stress reduction in different phases of the menstrual cycle. In session five, we then elaborate on the importance of adequate self-management for maintaining

or creating (a sense of) safety. Unfortunately, for this particular group, we were forced to amalgamate the fourth session into the fifth. Consequently, there was less focus on rest and relaxation. During the final evaluation, it was suggested that 'rest and relaxation' could have been more strongly highlighted in the programme. This again underlines the importance of stress reduction. Furthermore, stress relief seems especially relevant in light of recent findings that connect ADHD, (chronic) stress, and inflammation [109,110].

4.6. Understanding and Connection

At evaluation, self-compassion was deemed very important by participants. Recognising and understanding behavioural patterns helped participants have a less judgemental attitude towards their own behaviour. In women who have *fluctuatingly* inconsistent symptoms, we consider physical awareness of great importance. Participants in all three groups described premenstrual binge eating episodes and increased emotional eating. ADHD is associated with disordered eating patterns [111]. Emotional dysregulation and negative affectivity may mediate this association [72], while deficits in interoceptive accuracy also contribute [77]. In community samples, emotional eating appears to be related to the low oestrogen/high progesterone state, amongst other associations [112]. In bulimics, binge frequency increases in the mid-luteal/premenstrual phases [113]. With increased insight concerning premenstrual binge eating episodes, participants were more likely to *care for* their periods of craving by buying slightly less unhealthy but still satisfying foods *in advance*. As they understood their cravings better, they were also more self-forgiving if they ate an entire chocolate bar during their premenstrual period. Some found that this change in attitude from 'I must not' to 'I will try not to, but if it happens now and again, that is alright' actually resulted in fewer reported binge eating episodes.

Understanding and *connection*, the overarching themes distilled from the evaluation, emphasise the importance of offering well-tailored, female-specific information. This helps women with ADHD understand their experience so that they can connect different aspects of their life that they did not know were related. In turn, self-regard and self-management improve, which positively impacts stress and stimulates connection. A deepened understanding of hormonal fluctuations may help women communicate more clearly and confidently about their fluctuating symptoms and have a stronger voice when discussing future (hormonal) treatment options with their own therapist or medical practitioner. Finally, in our group, the experience of being valued and recognised in a real-life setting was appreciated by all participants. Where women with ADHD can share common struggles in an environment that is considered safe, the isolation that stems from masking may be successfully breached.

4.7. Clinical Applications

While the initial challenge of organising such a group might seem demanding, we have found several benefits to a group approach. If running the group in its entirety proves unfeasible, we argue that individual implementation of (parts of) this programme may be worthwhile nonetheless. For example, recognition of the relationship between hormonal fluctuations and emotional and cognitive states could be included in the psychological management of women with ADHD. Amongst patients and practitioners alike, there is a great demand for female-specific treatment options for ADHD. While the number of participants in the first three groups is small, some of the participants have gone on to educate those around them directly and/or via social media. In addition, a significant number of our participants were mothers and intended to use the acquired knowledge and skills to educate their (female) children (with ADHD).

4.8. Limitations and Strengths

While this is the first time, to our knowledge, that a group programme for women with ADHD is presented taking the menstrual cycle into account, our project does have some limitations. Firstly, although we describe the group programme in great detail,

we have analysed the evaluation of only one group (the last). The experience of the first two groups is not included in the current presentation. However, they did provide positive feedback and considered the group a valuable addition to treatment as usual. By presenting this group programme, which is subject to continuous development, we hope to inspire others to meet this unmet need and treat women with ADHD as *women*. A second potential limitation is that the final evaluation of the group, which was relatively short, was conducted by MdJ and DW, who also designed and led the group. Although we explicitly emphasised the importance of full openness and honesty, this might have hindered participants from expressing negative feedback. In the evaluation, the participants explicitly denied that they felt constrained, and both positive and negative feedback was shared. Additionally, to ensure the rigour of our qualitative analysis, we used triangulation of researchers, wherein MM, who had no relation with the programme or participants whatsoever, functioned as an independent researcher. We also consider it a limitation that we have so far only completed three groups. However, when reflecting back on the first two groups and our experience with the third, we do feel like the current presentation is an accurate representation. Strikingly, no participants in the third group had a co-occurring diagnosis of PMDD at the start of the programme. After completing the PMS calendar for several months, participants gained insight into their fluctuating symptoms and developed a stronger voice in discussing possible adjustments to their diagnoses and further treatment options with their individual therapists. Finally, while the (subjective) impact of the group was discussed during the evaluation, we did not measure the effect of the group. Nonetheless, we hope to provide a starting point for a female-specific treatment perspective for women with ADHD.

4.9. Future Directions

Firstly, it is important to objectivate the effect of our group programme by including standardised before- and after measurements. Including a longer follow-up may also be helpful. In the future, we will no longer include participants who are at the very beginning of their ADHD treatment. This will ensure optimal group dynamics, less discrepancy between group members, and a better use of group time. We advise other practitioners to adopt this approach, too. The field would benefit from the implementation of our programme by others and the evaluation of their (patients') experiences. Beyond the menstrual cycle, we aim to create similar specific groups for perimenopausal and post-natal women with ADHD, as these are other periods in women's reproductive lives that are characterised by hormonal fluctuations that impact mood and ADHD symptoms. Additionally, it would be interesting to implement a similar group programme for women with other psychiatric conditions, as ADHD is not the only disorder that is associated with cyclically fluctuating symptoms (e.g., autism spectrum disorder [114], schizophrenia [115], and bipolar disorder [116]) [18]. We are examining ways to address the expressed wish of participants for a follow-up group. Finally, we are considering constructive ways of including the (life) partners of group members into the programme.

5. Conclusions

Fluctuating sex hormones appear to influence ADHD symptomatology. Therefore, the menstrual cycle needs to be taken into account in both pharmacological and non-pharmacological treatment for women with ADHD. We have described this first group programme specifically for women with ADHD and self-reported premenstrual worsening of ADHD and/or mood symptoms and qualitatively analysed the final evaluation of our last group. Female-specific psychoeducation combined with a tailored treatment plan may enhance adherence and clinical outcomes for these women. By taking the menstrual cycle into account in ADHD, the clinician avoids reinforcing maladaptive behaviour and/or compounding experiences of failure. Our report will hopefully open the door to improving awareness of the hormonal impact on ADHD (treatment) for women with ADHD and all who treat them.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki. The Medical Ethics Review Committee of Amsterdam University Medical Centers declared that no ethical approval was needed to conduct this study because participants were not subject to procedures or required to follow rules of behaviour outside of their treatment as usual offered at PsyQ, The Hague (No. 2023.0895). The ethics approval date is the 27 December 2023.

Informed Consent Statement: Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement: The datasets presented in this article are not readily available because we are describing clinical findings, and patient privacy will be protected.

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Conflicts of Interest: Dr. M. Michielsen is employed by Antes and PsyQ. The other authors have no conflicts of interest to declare.

Appendix A

PMS Calendar

	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Description
Cycle	Day of cycle																																Dark red = bleeding, light red = possibly bleeding
	Cramps																																
	Tender breasts																																
	Binge eating																																
	Struggling with tasks																																Planned tasks
	Sex drive																																More libido = more colour in square
Body	Muscle/joint pain																																Back, arms
	Acne																																
	Itchiness																																Fidget with skin, hair, stuff
	Feverish(cold)/ unwell																																Coughing, Raynaud (discolouring cold hands and feet)
	Tense muscles																																
	Low energy																																
	Trouble sleeping																																Trouble falling asleep, waking up a lot, nacht terrors (previous night)
	Lack of sleep																																Assessment of sleep quality of previous night
	Headache																																
Mood	Depressed/down																																
	Anxious																																
	Mental chaos/restless																																Excessively task driven, switching tasks, obsessive planning, jumble of thoughts
	Concentration																																More trouble concentrating = more colour in square
	Difficulty task initiation																																More problems = more colour in square
	Impulsive																																More impulsive = more colour in square
	Fluctuating emotions																																
	Easily irritated/angry																																Very irritable, conflict seeking
	Tearful																																
	Self-criticism																																Harsh self judgement
	Overstimulated																																
	Self confidence																																More self confidence = more colour in square
	Numbness																																
	Cheerful/happy																																
	Optimistic																																
	Energetic																																Moments of silliness, friskiness, acting crazy
Stressors	Study/work																																
	Family																																
	Home																																
	Friends																																
	Medication																																New medication, side effects
	Society																																
Notes																																	

Figure A1. PMS calendar.

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Attention Deficit Hyperactivity Disorder: A Risk Factor for Premature Discontinuation of Inpatient Opioid Withdrawal Treatment

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Abstract: Background: Substance use disorders present a tremendous challenge within contemporary healthcare systems. Specifically, in the domain of opioid use disorders (OUDs), several foundational elements are crucial for the efficacious management of afflicted individuals. Regrettably, the premature discontinuation of inpatient opioid withdrawal treatment is a prevalent phenomenon. This study aims to elucidate the prevalence of the premature termination of inpatient opioid withdrawal treatment among patients with comorbid ADHD. **Methods**: We conducted a comprehensive assessment of all participants currently undergoing inpatient opioid withdrawal treatment. Our assessment protocol included the administration of the ADHD Self-Report Scale (ADHD-SR) and the Wender Utah Rating Scale (WURS-k). Additionally, participants who met the thresholds on one or both questionnaires underwent further evaluation using the Diagnostic Interview for ADHD in Adults (DIVA-2.0). **Results**: The prevalence of individuals diagnosed with ADHD within the studied cohort was determined to be 29.3%. Among the subset of participants identified as ADHD-positive, a notable 54.5% prematurely ceased therapy. In contrast, among those identified as ADHD-negative, the premature discontinuation rate was substantially lower at 28.3%. **Conclusions**: In summary, the impact of ADHD as a comorbid condition on the efficacy of inpatient opioid withdrawal treatment has been underscored. By identifying comorbid ADHD early in the treatment process, tailored therapeutic approaches may help to maximize the effectiveness of interventions and may improve patient outcomes. This underscores the importance of proactive screening for ADHD as a psychiatric comorbidity in optimizing the management of individuals undergoing inpatient opioid withdrawal treatment.

Keywords: ADHS; SUD; opioid; addiction; withdrawal treatment

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1. Introduction

Substance use disorders (SUDs) pose significant challenges within contemporary healthcare systems, with opioid use disorders (OUDs) standing out as particularly pressing [1,2]. When discussing OUDs, they predominantly refer to a dependence on diacetylmorphine, commonly known as heroin [3]. Addressing the challenges of treating patients with OUD requires a multifaceted approach, prominently featuring outpatient opioid maintenance therapy for stabilizing individuals struggling with opioid dependency [4]. Historically, opioid maintenance therapy primarily utilized methadone [5]. However, subsequent research has revealed that levomethadone is the active enantiomer in methadone, prompting the widespread adoption of this substance for opioid maintenance therapy due to its reduced side effects [6]. Over time, additional pharmacological agents have been introduced, including buprenorphine, which has emerged as a frequently employed alternative owing to its diminished sedative properties compared to levomethadone [7]. Moreover, certain countries offer opioid maintenance therapy utilizing diacetylmorphine

prescribed by physicians, permitting supervised intravenous self-administration by patients [8]. Despite the array of available substances, ongoing research endeavors continually introduce novel compounds, such as extended-release morphine tablets, aimed at maximizing individualized treatment modalities for affected individuals [9]. However, when opioid consumption persists despite such interventions, the role of inpatient withdrawal treatments becomes pivotal, either mitigating the adverse consequences of sustained use or facilitating complete cessation [10,11]. Yet, transitioning towards abstinence necessitates long-term residential treatment, emphasizing the complexity of managing OUDs [12].

Both physical and psychiatric comorbidities play crucial roles in shaping the trajectory of SUDs [13]. Psychiatric ailments often precipitate self-medication practices, potentially exacerbating primary condition symptoms or instigating additional psychiatric comorbidities, like substance-induced psychosis [14–16]. Furthermore, psychiatric disorders characterized by heightened impulsivity, such as borderline personality disorder (BPD) and attention deficit hyperactivity disorder (ADHD), can impede treatment adherence, hindering efforts to address SUDs effectively [17–19].

The worldwide ADHD prevalence is approximately 2.5% in adults and 3.4% in childhood, rendering it among the most pervasive neurodevelopmental disorders in the pediatric and adolescent populations [20,21]. It is typified by a persistent pattern of inattention and/or hyperactivity/impulsivity leading to functional impairment across various contexts, manifesting behavior that is comparatively more inappropriate or disruptive relative to peers of a similar age [22]. While ADHD symptoms typically manifest in childhood, a considerable proportion of afflicted individuals continue to experience its symptomatology into adolescence and adulthood [23]. As delineated in the Diagnostic and Statistical Manual of Mental Disorders 5 (DSM-5), three primary presentations of ADHD exist [24]. Within adult ADHD cohorts, the combined presentation prevails most prominently (70%), succeeded by the predominantly inattentive presentation (18.3%) and the pre-dominantly hyperactive–impulsive presentation (8.3%) [25]. In patients with OUD, an ADHD prevalence of 20.9% was reported in a recent meta-analysis [13]. There is a global consensus among experts regarding the use of stimulants as the primary therapeutic approach for ADHD, endorsed for both adults and pediatric populations [26]. This consensus is further reflected in the recommendations outlined in the National Institute for Health and Care Excellence (NICE) guidelines [27].

ADHD, in particular, has been associated with a more severe course of substance use, social and mental health impairment, and an increased likelihood of developing SUDs at a younger age [19,28,29]. Recognizing the importance of early diagnosis, experts advocate for initiating the diagnostic process for ADHD among SUD patients promptly when there are neither serious withdrawal symptoms nor serious intoxication [30]. Studies have reported a significant prevalence of ADHD among patients with alcohol and opioid use disorders, underscoring the need to consider therapeutic strategies for both disorders in treatment plans [31].

Notably, patients with comorbid OUD and ADHD undergoing oral opioid maintenance treatment exhibit many psychiatric comorbidities and greater addiction severity [32]. The adherence of individuals with concurrent ADHD and OUD undergoing Oral Opioid Maintenance Therapy is documented to be significantly suboptimal, frequently leading to discontinuations and the subsequent reinstatement of this therapeutic regimen [33–35]. Evidence indicates that pharmacological intervention for childhood ADHD utilizing stimulants may mitigate the risk of the subsequent development of SUDs [36]. However, there is an ongoing debate regarding the optimal management of patients with comorbid SUD and ADHD, due to concerns over the pronounced likelihood of abusing stimulants. This apprehension stems from the potential exacerbation of addictive propensities, particularly in individuals already susceptible to SUDs [30]. Nevertheless, psychopharmacological treatment alone appears insufficient in treating OUDs or ADHD in patients with ADHD actively using substances, highlighting the necessity of multimodal therapies [37]. Indeed, it is evident that no gold standard has been established for the treatment of patients presenting

with an OUD alongside comorbid ADHD. Nonetheless, clinical recommendations advocate for the initiation of ADHD therapy promptly following the stabilization of OUD [38].

A critical question arises regarding the behavior of patients with comorbid ADHD during inpatient opioid withdrawal treatment. The premature discontinuation of treatment is a significant challenge during inpatient withdrawal treatments, often driven by unbearable withdrawal symptoms or strong cravings for opioids [39]. Given the impulsivity associated with ADHD, it is reasonable to hypothesize that patients with comorbid ADHD are more likely to prematurely terminate their inpatient withdrawal treatment [40].

Despite the importance of diagnosing ADHD among patients with SUD, data on whether comorbid ADHD influences the premature termination of inpatient opioid withdrawal treatment are lacking. Thus, the aim of this study is to determine the prevalence of premature therapy discontinuations in inpatient opioid withdrawal treatments among patients with comorbid ADHD.

Objectives: The primary objective of this study is to ascertain the prevalence of ADHD among patients undergoing opioid withdrawal treatment and to investigate the impact of an ADHD diagnosis on the trajectory of opioid withdrawal treatment. Specifically, this study aims to elucidate the disparity in premature discontinuation rates between patients with a confirmed diagnosis of ADHD and those without such a diagnosis.

2. Materials and Methods

2.1. Procedures and Study Design

We conducted a study involving patients with OUD undergoing inpatient opioid withdrawal treatment at the psychiatric department of the university hospital of Bonn. Patient recruitment commenced subsequent to obtaining ethical approval from the local Ethics Committee of the University Clinic of Bonn.

Upon admission for opioid withdrawal treatment, each patient received comprehensive information regarding the objectives and procedures of the study. The inclusion criteria comprised an age of 18 years or older and a confirmed diagnosis of OUD according to the International Statistical Classification of Diseases and Related Health Problems–10 (ICD-10) [41]. The exclusion criteria encompassed the presence of severe withdrawal symptoms persisting throughout the entire treatment duration, thus rendering a diagnosis of ADHD unfeasible. Additionally, conditions resulting in significant cognitive deficits, such as Korsakoff syndrome or acute psychosis, led to exclusion [16,42].

Upon obtaining written informed consent, participants completed the German versions of the self-rating behavior questionnaire for ADHD (ADHD-SR) and the Wender Utah Rating Scale (WURS-k) [43,44]. Subsequently, the Diagnostic Interview for ADHD in Adults (DIVA 2.0) was administered to those meeting the cutoff criteria in one or both questionaries [45]. The ADHD diagnosis adhered to the guidelines outlined by the National Institute for Health and Care Excellence (NICE) [27].

Following this, participants were categorized into two groups based on their ADHD status: ADHD-positive and ADHD-negative. These groups were then longitudinally monitored throughout the withdrawal treatment period to evaluate the impact of ADHD on treatment outcomes. Subsequent to enrollment, the participants underwent a treatment akin to other individuals undergoing opioid withdrawal therapy. The initial dosing aimed to establish a regimen wherein patients remained free of withdrawal symptoms, gradually tapering the dose thereafter until opioid cessation or reaching a threshold that prompted transition to opioid maintenance therapy. Nursing staff closely monitored patients throughout, conducting vital sign assessments at least four times daily to preempt potential complications. Daily ward physician rounds, excluding weekends, and weekly senior physician assessments were standard. Following ADHD diagnosis during the study, deliberation occurred during the ward physician rounds, with a collaborative assessment performed by senior physicians to validate the clinical ADHD diagnosis. In addition, discussions were held regarding participants who exhibited elevated scores on the ADHD-SB and/or WURS-K measures but received a negative diagnosis for ADHD based on the

DIVA-2.0 interview. This inquiry aimed to determine the veracity of these apparent false-negative outcomes or potential inaccuracies in the diagnostic determination provided by the DIVA-2.0 interview.

2.2. Psychometric Inventories

The study utilized the WURS-k as a retrospective questionnaire to assess ADHD symptoms between the ages of 8 to 12, and used the ADHD-SR to evaluate ADHD symptoms in adulthood. The cut-off scores for ADHD-SR and WURS-k were set at 18 out of 66 points and 30 out of 84 points, respectively, yielding a combined sensitivity of 94% and specificity of 56% [46].

For diagnostic purposes, DIVA 2.0 was employed. This clinical interview adhered to the DSM-IV criteria and encompassed inquiries regarding both childhood and adult symptoms of ADHD. DIVA 2.0 comprised nine questions each for inattentive symptoms and hyperactivity/impulsivity, with concrete examples provided to facilitate symptom identification. Additionally, the interview assessed the impact of ADHD symptoms on various domains of functioning. The diagnosis of ADHD required the presence of at least six symptoms in one cluster, with symptom onset before the age of seven [45]. DIVA 2.0 showed sufficient validity among SUD patients with comorbid ADHD [47]. The DIVA 2.0 interviews, typically lasting 30 to 90 min, were conducted by a single interviewer (N.G.).

Recruitment and diagnosis occurred between June 2022 and August 2023. The DIVA 2.0 interviews were scheduled subsequently. Statistical analysis was performed using IBM SPSS Version 29.0.2.0 (20).

3. Results

3.1. Clinical and Sociodemographic Characteristics of the Participants

The study included 75 participants in total, of which 68% were male with a mean age of 45.52 $\pm$ 8.71 years. In total, 86.7% of the participants were treated with outpatient opioid maintenance therapy before applying to the inpatient opioid withdrawal treatment. Among them, 56% were treated with levomethadone, 8% with buprenorphine, 6.7% with methadone, and 16% with intravenous diacetylmorphine. According to the DIVA 2.0 interviews, 29.3% fulfilled the diagnostic criteria for childhood ADHD and 25.3% for persisting adult ADHD. In 96%, ADHD had not been diagnosed before participating in this study. In total, 36% prematurely ceased inpatient opioid withdrawal treatment.

When looking at the group of participants who prematurely terminated the inpatient opioid withdrawal treatment, 74.1% were male and the mean age was 42.48 $\pm$ 10.08 years. In total, 81.5% of these participants were treated with outpatient opioid maintenance therapy before applying to the inpatient opioid withdrawal treatment. Among them, 48.1% were treated with levomethadone, 14.8% with buprenorphine, 7.4% with methadone, and 11.1% with intravenous diacetylmorphine. According to the DIVA 2.0 interviews, 44.4% fulfilled the diagnostic criteria for childhood ADHD and 37% for persisting adult ADHD.

Looking at the two groups based on their ADHD status:

ADHD-positive: 72.7% were male with a mean age of 42.5 $\pm$ 8.9 years. In total, 90.9% of these participants were treated with outpatient opioid maintenance therapy before applying to the inpatient opioid withdrawal treatment. Among them, 54.5% were treated with levomethadone, 22.7% with buprenorphine, 9.1% with methadone, and 4.5% with intravenous diacetylmorphine. According to the DIVA 2.0 interviews, 86.4% fulfilled the diagnostic criteria for persisting adult ADHD. In total, 54.5% prematurely ceased inpatient opioid withdrawal treatment.

ADHD-negative: 34% were female and the mean age was 46.77 $\pm$ 8.4 years. In total, 84.9% of the participants were treated with outpatient opioid maintenance therapy before applying to the inpatient opioid withdrawal treatment. Among them, 56.6% were treated with levomethadone, 1.9% with buprenorphine, 5.7% with methadone, and 20.8% with intravenous diacetylmorphine. In total, 28.3% prematurely ceased inpatient opioid withdrawal treatment. It should be noted here that four participants who met the cut-off

criteria of the questionnaires discontinued treatment prior to the DIVA 2.0 interview. For diagnostic certainty, we classified these participants as ADHD-negative.

In summary, it is evident that the attrition rate is elevated among individuals with ADHD. Specifically, over fifty percent (54.5%) of patients presenting with comorbid ADHD prematurely terminate inpatient opioid withdrawal treatment, contrasting with a 28.3% discontinuation rate among ADHD-negative counterparts. Additionally, a noteworthy trend emerges wherein buprenorphine emerges as a relatively favored substitution in opioid maintenance therapy within the ADHD-positive cohort, whereas intravenous diamorphine employment remains comparably infrequent.

3.2. ADHD-SR, WURS-k, and DIVA 2.0

Overall, 38.7% met the cut-off criteria for ADHD in WURS-k and 54.7% met it in ADHD-SR, while 34.66% met the cut-off criteria for ADHD in both. Of the 40 DIVA 2.0 interviews, 55% confirmed the presence of an ADHD diagnosis, with the combined presentation being the most prevalent.

Looking at the group of participants who prematurely terminated the inpatient opioid withdrawal treatment, 48.1% met the cut-off criteria for ADHD in WURS-k and 63% met it in ADHD-SR, while 44.4% met the cut-off criteria for ADHD in both. Of the 14 DIVA 2.0 interviews, 85.71% confirmed the presence of an ADHD diagnosis, with the combined presentation being the most prevalent.

Looking at the two groups based on their ADHD status:

ADHD-positive: 77.3% met the cut-off criteria in WURS-k, 90.9% met it in ADHD-SR, and 68.18% met the cut-off criteria in both.

ADHD-negative: 22.6% met the cut-off criteria in WURS-k, 39.6% met it in ADHD-SR, and 20.75% met the cut-off criteria of both inventories.

The WURS-k and ADHD-SR appeared to be very useful diagnostic tools in this study, with a 45% false positive result rate and simple and low-threshold usability [44]. According to the standards of the international and German guidelines, ADHD diagnosis must be confirmed as a clinical diagnosis [30,48]. A structured diagnostic interview, like the DIVA 2.0 Interview, can aid diagnostic assessment and has been very useful in our research setting [45,47]. The combined presentation was the most prevalent (68.42%), followed by the predominantly hyperactive–impulsive presentation (15.78%) and the predominantly inattentive presentation (15.78%), in our OUD populations with comorbid ADHD in adulthood.

4. Discussion

The findings of this study underscore the significant impact of comorbid ADHD on the premature discontinuation of inpatient opioid withdrawal treatment. Our results reveal a striking prevalence of ADHD within the cohort of inpatients with OUD undergoing treatment, with 29.3% of participants diagnosed with ADHD. Notably, among those identified as ADHD-positive, over half (54.5%) prematurely ceased therapy, compared to a substantially lower premature discontinuation rate of 28.3% among ADHD-negative individuals. These findings highlight the pronounced vulnerability of individuals with comorbid ADHD to the premature termination of inpatient opioid withdrawal treatment.

Furthermore, it prompts inquiry into whether patients with ADHD exhibit a propensity to terminate treatment due to inherent symptomatology, such as impulsivity, or if they indeed encounter greater difficulty in coping with the withdrawal symptoms inherent to treatment. Additionally, an underlying factor may involve patients with ADHD facing inherent disadvantages during opioid withdrawal treatments, as the therapeutic team may encounter challenges in accommodating the unique needs of this patient population within the treatment milieu.

Our findings emphasize the critical need for systematic screening for ADHD among individuals undergoing opioid withdrawal therapy. The early identification of comorbid ADHD holds the potential to guide tailored therapeutic approaches, enhancing treatment

efficacy and improving patient outcomes [30]. By addressing ADHD alongside opioid use disorder, healthcare providers can mitigate the risk of premature treatment discontinuation and optimize the effectiveness of interventions.

Moreover, our results underscore the importance of considering psychiatric comorbidities in addiction treatment settings [13]. The high prevalence of ADHD among individuals with opioid use disorder emphasizes the need for integrated treatment strategies that address both substance use and underlying psychiatric conditions [37]. A failure to address comorbid ADHD may compromise treatment outcomes and exacerbate the challenges associated with managing opioid-related disorders.

Our study contributes to the existing literature by elucidating the relationship between comorbid ADHD and treatment outcomes in the context of opioid withdrawal therapy. While previous research has highlighted the impact of psychiatric comorbidities on addiction treatment, our findings provide specific insights into the role of ADHD in premature treatment discontinuation. By addressing this gap in the literature, this study enhances our understanding of the complex interplay between psychiatric disorders and substance use disorders, informing future research and clinical practice.

Building upon the findings of this study, future research should explore the potential mechanisms underlying the association between comorbid ADHD and premature treatment discontinuation. Longitudinal studies are needed to examine the trajectory of ADHD symptoms during opioid withdrawal treatment and their impact on treatment outcomes over time. Additionally, investigations into the effectiveness of tailored therapeutic approaches for individuals with comorbid ADHD and opioid use disorder are warranted. By elucidating these mechanisms and interventions, future research can inform the development of targeted interventions to improve treatment outcomes for this vulnerable population.

Ultimately, the question as to whether patients with ADHD exhibit a pervasive trend towards low compliance arises, as this predisposes them to premature treatment cessation, non-adherence, or suboptimal therapeutic outcomes [49]. In psychiatric treatment paradigms, robust adherence assumes paramount importance, given the rapid deterioration of conditions resulting from medication noncompliance. This is particularly evident in schizophrenia, where noncompliance is frequently encountered, prompting an examination of whether individuals with comorbid schizophrenia and ADHD also demonstrate proclivity towards premature treatment discontinuation [50]. Similarly, affective disorders necessitate meticulous medication adherence to forestall disease exacerbation. The compliance behaviors of patients presenting with ADHD and comorbid affective disorders warrant investigation [51]. Moreover, within somatic disease contexts, adherence to treatment regimens assumes heightened significance, given the potential dire consequences of noncompliance, such as missed medication doses. Hence, the adherence patterns of individuals contending with comorbid ADHD and HIV infection, or those facing life-threatening cancer diagnoses alongside ADHD, merit scrutiny to ascertain these individuals' ability to adhere to therapeutic protocols effectively [52].

Limitations: It is important to acknowledge the several limitations of our study. Firstly, the sample size may limit the generalizability of our findings to broader populations of individuals undergoing opioid withdrawal treatment. It is pertinent to acknowledge that the limited participant pool was influenced by the arduous nature of participant recruitment. Identifying suitable candidates for the study proved to be a formidable task, largely due to the intrinsic characteristics of opioid withdrawal treatment. Patients often presented in a highly intoxicated state upon admission, with subsequent occurrences of pronounced withdrawal symptoms during the course of treatment. These circumstances posed substantial challenges to enrollment, as the diagnostic evaluation of ADHD in such contexts was deemed impractical. Furthermore, prospective participants frequently exhibited a lack of interest in study involvement, focusing primarily on opioid withdrawal treatment or demonstrating a general apathy towards research participation. Additionally, our study relied on self-report measures for assessing ADHD symptoms, which may

introduce bias or in-accuracies. In the intricate interplay of ADHD and SUD co-occurrence, individuals and clinicians alike encounter considerable difficulty in disentangling symptom attribution to either disorder. Within the clinical milieu of ADHD assessment, external collateral information assumes critical significance. However, within the SUD population, obtaining such data poses a formidable challenge. This predicament arises from disrupted familial connections and limited social networks, where associations primarily revolve around peers also grappling with SUD. Furthermore, the retrospective nature of the WURS-k may pose challenges in accurately capturing childhood ADHD symptoms. The attribution of childhood memories already poses a challenge for individuals with ADHD. For those enduring SUD over an extended period, this difficulty is compounded by the frequent phenomenon of memory retrieval failure. Future research should aim to address these limitations through larger sample sizes, objective measures of ADHD symptoms, and longitudinal study designs.

5. Conclusions

In conclusion, our study highlights the significant impact of comorbid ADHD on the premature discontinuation of inpatient opioid withdrawal treatment. By identifying ADHD as a risk factor for treatment non-adherence, our findings underscore the importance of systematic screening and integrated treatment approaches in addiction care settings. Moving forward, addressing comorbid psychiatric conditions such as ADHD alongside substance use disorders is essential for optimizing treatment efficacy and improving patient outcomes in addiction treatment settings. Future research endeavors should delve into elucidating the underlying factors contributing to treatment discontinuation in patients with and without ADHD undergoing opioid withdrawal therapy. Moreover, there is a pressing need to design studies aimed at evaluating interventions geared towards preventing the premature cessation of opioid withdrawal treatment. Furthermore, it is imperative that forthcoming investigations probe whether ADHD serves as a potential risk factor for treatment discontinuation across diverse therapeutic modalities. The potential avenues for inquiry may encompass critical interventions such as antiretroviral therapy for individuals afflicted with HIV infection or multimodal therapeutic approaches for cancer patients.

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What Is the Link between Attention-Deficit/Hyperactivity Disorder (ADHD) and Dyslipidemia in Adults? A German Retrospective Cohort Study

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Abstract: Background: Alterations in the serum lipid profile have been suspected in many psychiatric disorders, such as schizophrenia and depression. However, studies on lipid status in attention-deficit/hyperactivity disorder (ADHD) are sparse and inconsistent. **Methods:** Using the nationwide, population-based IQVIA Disease Analyzer database, this retrospective cohort study included 5367 outpatients from general practices in Germany aged ≥18 years with a documented first diagnosis of ADHD between January 2005 and December 2021 and 26,835 propensity score-matched individuals without ADHD. Study outcomes were the first diagnosis of lipid metabolism disorders as a function of ADHD within up to 10 years of the index date. The cumulative 10-year incidence was analyzed using Kaplan–Meier curves and compared using the log-rank test. In addition, univariate Cox regression analyses were performed. **Results:** In the regression analysis, there was no significant association between ADHD and subsequent lipid metabolism disorders in the total population (HR: 0.94; 95% CI: 0.83–1.08), among women (HR: 1.04; 95% CI: 0.84–1.28), and among men (HR: 0.89; 95% CI: 0.74–1.06). In addition, no significant association was observed in the disease-stratified analyses. **Conclusions:** The findings of this study indicate that ADHD does not exert an influence on lipid metabolism. However, further investigation is warranted, particularly with respect to pharmacological interventions.

Keywords: attention-deficit/hyperactivity disorder; adult ADHD; lipid metabolism disorder; lipid profile; epidemiology; Germany

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1. Purpose

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common mental disorders in childhood and adolescence, often persisting into adulthood and is associated with functional deficits and significant health and economic problems. The global prevalence in childhood and adolescence is approximately 5%, with no significant international differences [1–4], and is reported to be 2.5% in adulthood [5]. According to the diagnostic criteria of the World Health Organization's (WHO) ICD-10 classification system, a diagnosis of ADHD requires a persistent pattern of inattention, impulsivity, and hyperactivity that interferes with functioning or development. Typically, ADHD symptoms are present to an extent that is inappropriate for the person's age and developmental stage, occur in a variety of situations, and cause significant distress and/or limitations in family, social, school, or work life. The pathogenesis of ADHD appears to be complex and not well understood. A number of interacting factors are thought to play a role in its development. In particular,

genetic predisposition and pre-, peri-, and early postnatal environmental exposures that affect the structural and functional development of the brain are thought to be important factors [6–9]. ADHD is rarely diagnosed as an isolated disorder. Rather, up to 85% of ADHD patients have an additional comorbid mental disorder [10], and 60% of cases have multiple comorbidities [11,12].

The co-occurring disorders vary with age in the following ways: in early childhood, the focus is on social behavior disorders but also on learning and achievement disorders, especially reading and spelling difficulties, autism spectrum disorders, and developmental coordination disorders; in early adolescence, the focus is on anxiety disorders, depression, and tic disorders. In young adulthood and later adolescence, substance abuse, affective disorders, and personality disorders dominate [11,13,14]. For all comorbid disorders, it is important to distinguish whether the condition is a true comorbidity, a consequence of ADHD, or a subtype of ADHD. However, only a few studies have examined the prevalence of comorbid disorders in adulthood by age and gender.

The treatment of ADHD requires a multimodal therapeutic approach that aims to reduce the immediate symptoms, treat comorbidities, improve social integration, e.g., in school, work, and family, and improve quality of life [15]. In addition to psychoeducation, behavioral therapy, and pharmacological therapy as established pillars of treatment, treatment options such as diets or substitution therapies are being discussed as alternatives and supportive measures [11,16]. Several studies have investigated omega-3 supplementation and suggested a clinically relevant change in lipid status in ADHD, although convincing empirical evidence is still lacking [17,18].

Lipid alterations have been implicated in other psychiatric disorders such as schizophrenia and depression. In ADHD, however, studies on lipid status and changes in serum lipids are sparse and inconsistent [19–22]. In the absence of comparable previous data, the present retrospective cohort study aims to compare the lipid profile of adult patients with ADHD to adult patients without ADHD using the representative nationwide, population-based IQVIA Disease Analyzer database.

2. Methods

2.1. Database

This retrospective cohort study was based on routine data from the Disease Analyzer database (IQVIA, Frankfurt, Germany), which contains drug prescriptions, diagnoses, and basic medical and demographic data of outpatients obtained directly and anonymously from the computer systems of general practitioners and specialists [23]. The database includes approximately 3000 office-based physicians in Germany. The panel of practices included in the Disease Analyzer database has previously been shown to be representative of general and specialist practices in Germany [23]. Finally, this database has already been used in a previous study focusing on lipid metabolism disorders [24].

2.2. Study Population

This study included adult patients ($\geq$18 years) with a first documented diagnosis of ADHD (ICD-10: F90.0) in 1284 general practices in Germany between January 2005 and December 2021 (index date; Figure 1). Only patients with an observation period of at least 12 months prior to the index date were included in order to have access to co-diagnoses documented within 12 months prior to the index date. Patients with a diagnosis of lipid metabolism disorders (ICD-10: E78) before or on the index date were excluded.

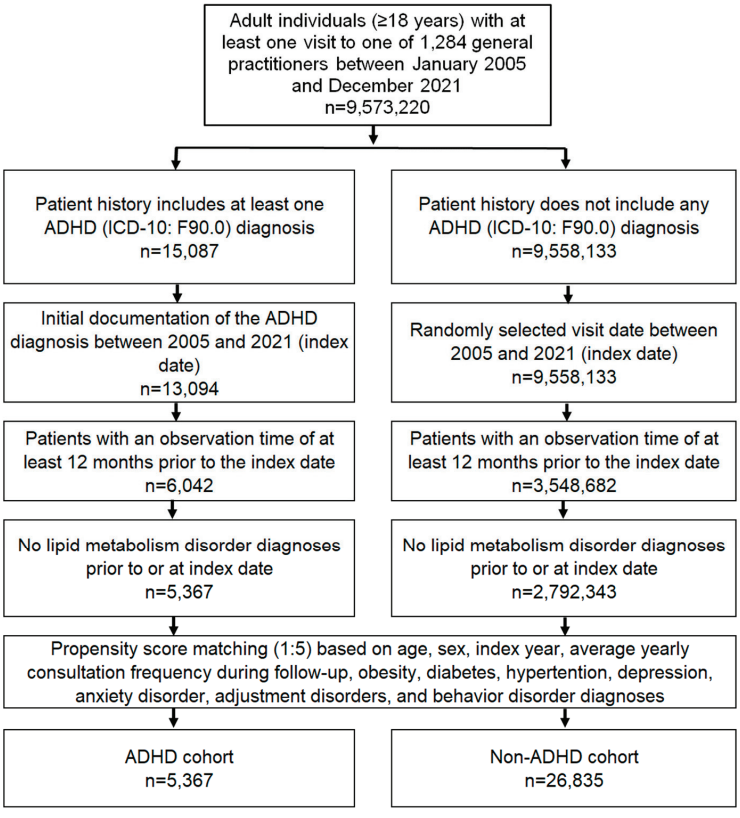

Figure 1. Selection of study patients.

After applying similar inclusion criteria, individuals without ADHD were matched to patients with ADHD using nearest neighbor propensity score matching (1:5) based on age, sex, index year, average annual visit frequency during follow-up, and co-diagnoses of obesity (ICD-10: E66), diabetes mellitus (ICD-10: E10–E14), and hypertension (ICD-10: I10), depression (ICD-10: F32, F33), anxiety disorders (ICD-10: F41), reaction to severe stress and adjustment disorders (ICD-10: F43), and disorders of adult personality and behavior (ICD-10: F60–F69) documented within 12 months before or on the index date. For the non-ADHD cohort, the index date was a randomly selected visit between January 2005 and December 2021 (Figure 1).

2.3. Study Outcomes

The outcomes of this study were as follows: total first diagnoses of lipid metabolism disorders (ICD-10: E78) and pure hypercholesterolemia (ICD-10: E78.0); pure hypertriglyceridemia (ICD-10: E78.1); mixed hyperlipidemia (ICD-10: E78.2); and hyperlipidemia, unspecified (ICD-10: E78.5) in the 10 years after the index date as a function of ADHD. Other disorders of lipid metabolism (i.e., hyperchylomicronemia, lipoprotein deficiency, and disorders of bile acid and cholesterol metabolism) were very rarely documented and could not be analyzed separately.

2.4. Statistical Analyses

Differences in sample characteristics and diagnosis prevalence between the ADHD and non-ADHD cohorts were compared using the Wilcoxon signed-rank test for continuous variables, the McNemar test for categorical variables with two categories, and the

Stuart–Maxwell test for categorical variables with more than two categories. These tests are considered appropriate for paired variables.

The 10-year cumulative incidence of lipid metabolism disorders in total and in defined lipid metabolism disorder types was further examined using Kaplan–Meier curves, and these curves were compared using the log-rank test. Finally, univariable Cox regression analysis was performed to assess the association between ADHD and lipid metabolism disorders. These models were performed separately for female and male subjects. In addition, prescription of ADHD-related medications (methylphenidate, atomoxetine, dexamphetamine, lisdexamfetamine, and guanfacine) was included in the model to evaluate the association between ADHD therapy and lipid metabolism disorders in patients with ADHD only. Results of the Cox regression model are presented as hazard ratios (HRs) and 95% confidence intervals (CIs). A p-value of <0.01 was considered statistically significant due to multiple comparisons. Analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC, USA).

3. Results

3.1. Basic Characteristics of the Study Sample

The present study included 5367 individuals with and 26,835 without ADHD. The basic characteristics of study patients are displayed in Table 1. Median age was 29 (interquartile range (IQR): 18) years; 63.3% were male. Patients visited physicians in median five times per year during the follow-up. Predefined comorbidities were not frequent (7.0% with obesity, 4.1% with hypertension, and 3.6% with diabetes). Moreover, 1073 (20.0%) of ADHD patients received at least one prescription of relevant drug during the study period.

Table 1. Baseline characteristics of the study sample (after 1:5 propensity score matching).

Variable	Proportion among Patients with ADHD (N, %) N = 5367	Proportion among Patients without ADHD (N, %) N = 26,835	p-Value
Age (Median, IQR)	29 (18)	29 (18)	0.516
Age 18–20	1037 (19.3)	4995 (18.6)	0.636
Age 21–30	1902 (35.4)	9592 (35.7)	
Age 31–40	1112 (20.7)	5642 (21.0)	
Age 41–50	758 (14.1)	3705 (13.8)	
Age >50	558 (10.4)	2901 (10.8)	
Female	1966 (36.7)	9840 (36.7)	1.000
Male	3399 (63.3)	16,995 (63.3)	
Number of physician visits per year during the follow-up (Median, IQR)	5 (7)	5 (7)	0.942
Obesity	374 (7.0)	1756 (6.5)	0.253
Diabetes	195 (3.6)	965 (3.6)	0.894
Hypertension	594 (11.1)	2811 (10.5)	0.198
Depression	2038 (38.0)	10,287 (38.3)	0.619
Anxiety disorders	824 (15.4)	4132 (15.4)	0.934
Reaction to severe stress and adjustment disorders	1086 (20.2)	5414 (20.2)	0.921
Disorders of adult personality and behavior	613 (11.4)	3005 (11.2)	0.541

Proportions of patients in N, % given, unless otherwise indicated. SD: standard deviation. IQR: interquartile range.

3.2. Cumulative Incidence of Lipid Metabolism Disorders among Patients with and without ADHD

After up to ten years of follow-up, 12.2% of ADHD patients and 12.4% of non-ADHD patients were diagnosed with lipid metabolism disorders ($p = 0.398$, Figure 2a). There were 14.3% of women with ADHD and 12.8% of women without ADHD ($p = 0.716$), as well as 11.0% vs. 12.5% of men ($p = 0.175$), with a diagnosis of lipid metabolism disorders.

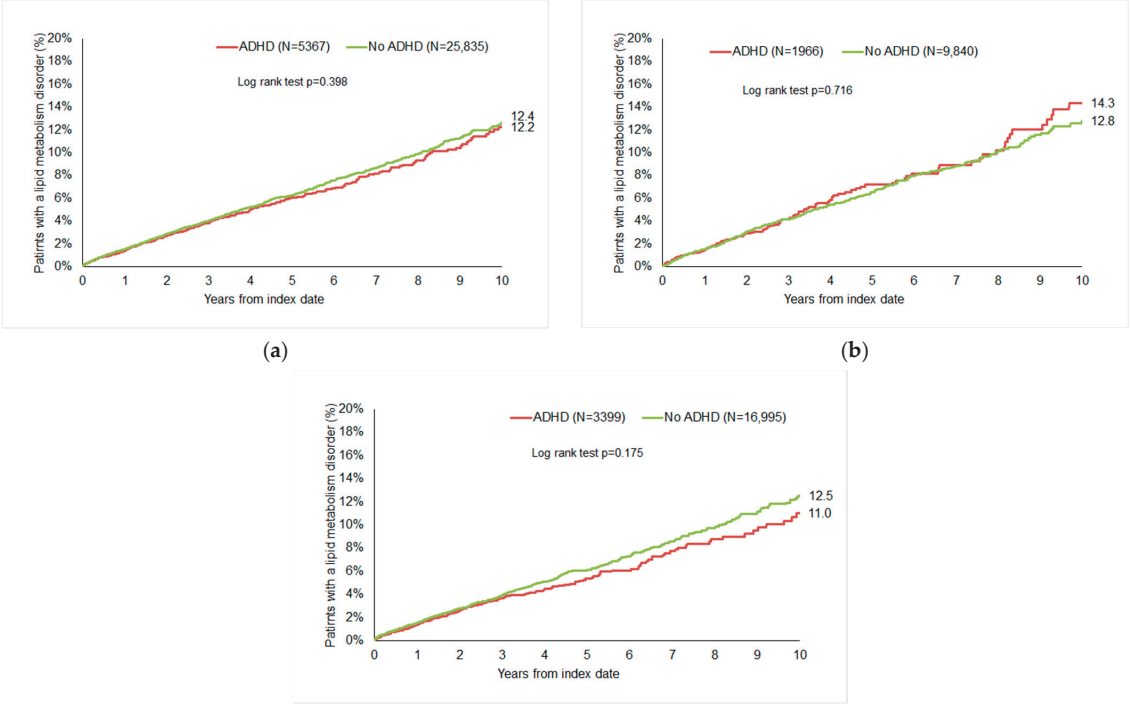

Figure 2. Cumulative 10-year incidence of lipid metabolism disorders in patients with and without ADHD. (**a**) All patients; (**b**) women; and (**c**) men.

3.3. Association of ADHD with Lipid Metabolism Disorders Diagnoses

In the regression analysis, there was no significant association between ADHD and subsequent lipid metabolism disorders in the total population (HR: 0.94; 95% CI: 0.83–1.08), among women (HR: 1.04; 95% CI: 0.84–1.28), and among men (HR: 0.89; 95% CI: 0.74–1.06). In the disease-stratified analyses, no significant associations were observed either (Table 2).

Table 2. Association between ADHD and subsequent lipid metabolism disorders in patients followed in general practices in Germany (univariable Cox regression models).

	All Patients		Women		Men	
Outcome Diagnosis	**HR (95% CI)**	***p*-Value**	**HR (95% CI)**	***p*-Value**	**HR (95% CI)**	***p*-Value**
Lipid metabolism disorders (total)	0.94 (0.83–1.08)	0.398	1.04 (0.84–1.28)	0.713	0.89 (0.74–1.06)	0.175
Pure hypercholesterolemia	1.00 (0.83–1.21)	0.976	1.18 (0.90–1.55)	0.221	0.87 (0.66–1.14)	0.313

Table 2. *Cont.*

	All Patients		Women		Men	
Outcome Diagnosis	**HR (95% CI)**	***p*-Value**	**HR (95% CI)**	***p*-Value**	**HR (95% CI)**	***p*-Value**
Pure hyperglyceridemia	1.00 (0.65–1.56)	0.995	0.50 (0.15–1.67)	0.262	1.14 (0.71–1.84)	0.582
Mixed hyperlipidemia	1.16 (0.73–1.84)	0.544	1.43 (0.64–3.20)	0.386	1.05 (0.59–1.86)	0.870
Hyperlipidemia, unspecified	0.89 (0.69–1.16)	0.386	1.03 (0.68–1.56)	0.882	0.81 (0.58–1.14)	0.234

3.4. Role of ADHD Therapy

In an additional regression model, no association was seen between ADHD therapy and subsequent lipid metabolism disorders in the total population (HR: 0.82; 95% 0.60–1.13), women (HR: 0.57; 95% 0.33–1.01), and men (HR: 1.01; 95% 0.69–1.49). Also, in disease-stratified analyses, no significant associations were observed.

4. Discussion

In this retrospective cohort study, a large cohort of 5367 adult outpatients with ADHD was analyzed for lipid metabolism disorders using the representative database. Data from adults aged 18 years and older with ADHD were compared with a cohort of propensity score-matched individuals without ADHD.

Overall, the findings of this study revealed no significant association between ADHD and lipid metabolism disorders in the overall study population, which included both female and male patients. Additionally, this study found no evidence of a link between ADHD and specific lipid metabolism disorders, such as pure hypercholesterolemia, pure hyperglyceridemia, and mixed hyperlipidemia. Furthermore, an additional regression model indicated that ADHD medication treatment was not associated with subsequent lipid disorders.

There is a growing interest in the role of lipids in the development and maintenance of psychiatric disorders [25–28]. For example, studies have implicated lipid metabolism in depression [26], Alzheimer's disease [27], and schizophrenia [28]. Niemann–Pick type C disease, an autosomal recessive lysosomal storage disorder, is a severe form of impaired cholesterol metabolism caused by a mutation, usually in the NPC-1 gene (Niemann–Pick type C1 gene). In this disorder, defective intracellular cholesterol transport mechanisms lead to cholesterol accumulation, resulting in severe cognitive impairment and reduced life expectancy [29]. Against this background, a post hoc analysis published in 2019 by Pinho et al. compared serum levels of total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides in patients with ADHD and controls without ADHD using data from the nationwide population-based German Health Interview and Examination Survey for Children and Adolescents (KiGGS) of the Robert Koch Institute (RKI). Using multivariate and univariate models, the authors showed small but statistically significant associations between total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides in children with ADHD compared with controls. However, serum triglyceride concentrations were higher and serum LDL concentrations were lower in ADHD patients [19]. These findings contrast with a 2018 study by Avcil et al., in which 32 boys with ADHD were compared with a control group of 29 healthy subjects for their lipid profile. They concluded that the average levels of triglycerides (TGs), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were significantly lower in the ADHD group than in the control group [20]. On the other hand, Ugur et al. reported higher cholesterol and LDL levels in a total sample of 88 children aged 8 to 12 years with ADHD compared to 88 healthy children. Despite controlling for age, gender, and body mass index (BMI), the authors found that total cholesterol and LDL levels were significantly higher in the ADHD group

than in the healthy control group, whereas TG and HDL cholesterol levels were similar in both groups [21]. In contrast, in a small study of nine boys with ADHD compared with 11 controls, Irmisch et al. found significantly higher serum HDL concentrations [22]. These very heterogeneous and partly contradictory results underline the importance of further research in this area, not only with regard to a possible explanation of the pathogenesis but also with regard to a possible alteration of the lipid profile with child development, as well as possible treatment options and prevention approaches. Interestingly, several studies have investigated the effect of fatty acid supplements on ADHD. In a meta-analysis of nine different studies, Hawkey and Nigg showed that all 586 children with ADHD had low blood levels of omega-3 fatty acids and that supplementation could slightly improve symptoms [18]. In contrast, Agostoni et al. found only a weakly significant effect that was mostly limited to one dimension, either hyperactivity or inattention [30]. However, studies are heterogeneous, as different fatty acids were substituted or administered in addition to medication, so that effects cannot always be clearly attributed to fatty acid supplementation [30]. Based on this, the German S3 Guideline on ADHD does not yet recommend substitution, and there is a need for further research in this area [31]. Additionally, further research is needed to better understand the role of fatty acids in ADHD. Despite the absence of an association between lipid metabolism disorders and ADHD in our study, an intriguing yet under-researched hypothesis regarding an underlying pathophysiological mechanism between other psychiatric disorders and lipid metabolism disorders is being discussed. This hypothesis, known as the membrane hypothesis, postulates that alterations in the composition and structure of cell membranes may play a role in the pathogenesis of psychiatric disorders [32]. In this context, animal studies have shown that the membrane properties of the cell, such as fluidity, viscosity, and functionality, are strongly dependent on the lipid composition [32]. In addition, it has been shown that a reduced cholesterol content in neuronal membranes can lead to a reduced number of serotonin receptors and reduced impulse control [32]. Alterations in the lipid composition of neuronal membranes may play an important role in the neuronal transmission of stimuli and thus in the pathogenesis of disturbed neuronal control circuits in ADHD. Interestingly, Dietschy et al. have shown that central and peripheral cholesterol metabolism appear to be separate, as the blood–brain barrier itself is impermeable to cholesterol [33]. The hypothesis of cholesterol transfer across the blood–brain barrier was also refuted by Castellanos et al. in animal experiments [34], and it is suggested that most cholesterol in the central nervous system (CNS) is synthesized de novo intracerebrally [35,36]. In contrast, Meijer et al. found differences in methylation of the cholesterol signaling genes APOB (apolipoprotein B gene) and LPAR5 (lysophosphatidic acid receptor 5 gene) in blood samples from individuals with a persistent or remitting ADHD diagnosis, although conclusions about central nervous mechanisms should be treated with caution [37]. In conclusion, basic research findings are not yet sufficient to be translated into clinical practice. The need for further research in this area is therefore even greater in order to develop a new therapeutic approach in the future or to take preventive measures at an early stage of diagnosis.

Although our study did not find an association between medication for ADHD and subsequent lipid metabolism disorders, other studies in this area have suggested that many psychotropic medications may even have a beneficial effect on the lipid profile in blood plasma and its metabolism. In a small study of 42 patients with an average age of 16 years who were treated for ADHD in adolescent psychiatric facilities between 2003 and 2007, Charach et al. investigated the influence of the piperidine derivative methylphenidate on the plasma lipid profile of patients diagnosed with ADHD. Blood samples were analyzed for total cholesterol, LDL-C, HDL-C, triglycerides, apolipoprotein A, apolipoprotein B, and lipoprotein (a) (Lp(a)) before the start of treatment and after 3 months of continuous treatment. The results showed that methylphenidate improved the lipid profile by significantly lowering total cholesterol, triglycerides, LDL-C, and Lp(a) [38]. Again, further studies, especially in a large cohort of ADHD patients, are needed to clarify these findings.

Finally, the present study is limited by several unavoidable aspects, mainly related to the study design and methodology, that have already been described in detail in the past [39]. First, all diagnoses were coded with ICD-10 codes, which may lead to misclassification or undercoding of certain diagnoses. Additionally, due to the relatively small number of ADHD cases, 1:5 matching was used for analysis. Although age and sex are included in the analyses, information on patients' lifestyle (e.g., dietary habits and physical activity) and other socio-demographic characteristics such as occupation, social class, and income are missing. Furthermore, clinical parameters, in particular blood test results, questionnaire results, and clinical symptoms, were documented only for a small part of patients. Although we also examined the influence of ADHD medication on the occurrence of lipid metabolism disorders, we have no information on other concomitant medications that may have influenced lipid and lipoprotein metabolism. Further studies are required to elucidate the extent to which statin therapy, in particular, which is often employed to treat hyperlipidemia, especially hypercholesterolemia, can influence the occurrence of ADHD.

The Disease Analyzer database is lacking in data pertaining to socioeconomic status, including patients' education and income, and lifestyle-related risk factors, such as smoking, alcohol consumption, and physical activity. Consequently, these variables could not be included in this study. Moreover, the database is deficient in data pertaining to mortality quality that would be suitable for the purposes of this study. The specific type of ADHD was not available, as this information has not been documented by general practitioners. A further limitation is the absence of data on the duration of ADHD. The initial ADHD diagnosis by a general practitioner was considered the index data in this study. Nevertheless, it is possible that some patients may have been diagnosed with ADHD during childhood and that the cohort profile may differ between incident and prevalent ADHD patients. This may also be a confounding factor in the relationship between ADHD and lipid metabolism disorders.

Finally, our study does not allow causal attribution, only associations. However, it must be emphasized that our study is one of the few to examine the association between lipid alterations in patients with ADHD, especially in adulthood. Finally, the IQVIA Disease Analyzer database used for the analyses in this study is representative of the general population and has been extensively published [40–42] and shown to be valid [23].

5. Conclusions

Overall, our study adds to the literature and provides some evidence that ADHD is not associated with disorders of lipid metabolism. However, the heterogeneous and partly contradictory results make it clear how important further research in this area is, not only with regard to a possible explanation of the pathogenesis but also with regard to a possible change in lipid levels with individual development as well as possible treatment options and prevention approaches.

Author Contributions: S.K. and K.K. designed the study. K.K. performed statistical analyses and generated figures and tables. S.K. and K.K. wrote the manuscript. M.K. and A.K. made corrections to the manuscript and provided intellectual input. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The database used includes only anonymized data in compliance with the regulations of the applicable data protection laws. German law allows the use of anonymous electronic medical records for research purposes under certain conditions. According to this legislation, it is not necessary to obtain informed consent from patients or approval from a medical ethics committee for this type of observational study that contains no directly identifiable data.

Informed Consent Statement: Patient data were analyzed in aggregated form without the inclusion of individual health data. Individual informed consent was therefore not obtained.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors have no relevant financial or non-financial interests to disclose.

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Systematic Review

Systematic Review of Executive Function Stimulation Methods in the ADHD Population

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Abstract: Background/Objectives: Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by elevated motor activity, impulsivity, and attention deficit. Approximately 5% of the population suffers from this disorder. Among the key explanations of ADHD, executive functions play an important role in understanding the symptomatology present in this disorder and in determining the main treatment strategies for affected patients. We present a systematic review that seeks to identify the treatment methods developed to support executive functions in individuals with ADHD. **Methods:** Articles were analyzed in the SCOPUS, PUBMED, and Science Direct databases. Initially, 739 articles were found. After applying inclusion and exclusion criteria, 30 articles remained and were included in the data extraction process. **Results:** Among the primary treatments identified, 14 studies propose psychological training for executive functions, 9 studies recommend medication, 5 studies suggest digital interventions, and 1 study advocates for sports as beneficial for executive functions. **Conclusions:** The data are discussed around the need to develop new proposals to enhance the executive functions of individuals with ADHD, thereby improving their performance in educational, personal, social, and family activities impacted by this disorder.

Keywords: attention deficit hyperactivity disorder; executive functions; treatment

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1. Introduction

ADHD is a neurodevelopmental disorder characterized by persistent patterns of inattention, hyperactivity, and impulsivity. These symptoms often manifest in childhood and can persist into adolescence and adulthood [1]. The global prevalence of ADHD ranges from 5.9% to 7.1% in children and 1.2% to 7.3% in adults, indicating its significant impact across different age groups [2,3].

However, prevalence rates of ADHD can vary based on ethnic differences. Contrary to previous beliefs, recent studies contradict the notion that the prevalence of ADHD is lower in certain ethnic groups. For instance, while it was once thought that Black children and adolescents had lower rates of ADHD compared to their White counterparts, research has shown that the prevalence rates between these groups do not significantly differ [4]. Moreover, Asian and Latino children and adolescents tend to present lower prevalence rates of ADHD than both their Black and White counterparts. These differences may be influenced by factors such as access to healthcare, socioeconomic status, and cultural attitudes toward mental health [5].

ADHD is a disorder of multifactorial origin, with the following most commonly described causal factors in the literature: genetic predispositions, gestational and perinatal factors, and environmental influences [2]. Changes in brain structure and function are

observed in individuals with ADHD, affecting mechanisms such as neurogenesis and synaptogenesis, which, in turn, disrupt attention and impulse control, core functions regulated by the central nervous system [3]. The etiology of ADHD is diverse, with interactions between genetic and environmental factors contributing to the heterogeneous manifestation of the disorder among individuals and subsequently influencing their response to interventions [6].

This disagreement on the causes can contribute to a clash in treatment processes, which, in turn, impacts both academic and familial spheres. In the academic realm, for instance, children with ADHD may struggle to concentrate, follow instructions, and complete tasks, thereby affecting their academic performance and self-esteem [7]. Within the family, the lack of understanding about the nature of the disorder can generate stress and frustration, increasing tensions at home. This situation will affect the support networks available to a child with ADHD in their close environment since the specific needs of this population require collaborative efforts [8].

Individuals diagnosed with ADHD can encounter several challenges in their daily lives across various domains. In childhood and adolescence, ADHD can significantly impact academic achievement, social interactions, and overall well-being. Symptoms of ADHD, such as inattention and hyperactivity, often persist into adolescence, leading to difficulties in peer relationships, academic performance, and behavioral challenges. An estimated 72% of adolescents with ADHD present with sleep problems [9,10]. This affects their daytime functioning and exacerbates symptoms of inattention and hyperactivity. Moreover, untreated ADHD in adolescence increases susceptibility to risky behaviors, substance misuse, and mental health issues, including depression [11–13].

In adulthood, individuals with ADHD can face occupational challenges, educational impairments, financial difficulties, and family instability [14]. They are less likely to graduate from high school and college, have lower job stability, and demonstrate impaired job performance. ADHD also contributes to higher rates of substance abuse, mental health disorders, and financial stress, leading to increased reliance on public aid and decreased income [15,16].

Moreover, individuals with ADHD often experience comorbid conditions, such as anxiety disorders, significantly higher than the general population [17]. Anxiety symptom severity is associated with lower social skills and higher social problems in young people with ADHD, exacerbating existing social difficulties. Additionally, challenges with emotional regulation are common among individuals with ADHD, characterized by difficulties in managing and expressing emotions effectively. Studies indicate that adults with ADHD exhibit lower emotional regulation scores compared to controls, utilizing non-adaptive emotion regulation strategies such as self-blame and rumination. Emotional dysregulation is associated with greater socio-functional impairment, impacting relationships, stress management, and coping abilities. Addressing comorbid conditions and emotional regulation challenges is crucial for comprehensive support and intervention to mitigate the impact of ADHD [18,19].

One of the most widely accepted theories explaining the essential cause of ADHD symptomatology states that children, adolescents, or adults with this disorder present an immature executive function development [20]. Executive functions are a set of high-level mental abilities that help us plan, organize, and control behavior to achieve goals [21]. There is no specific number of executive functions and there are proposals that consider them as a single factor or multiple skills that interact to achieve behavioral regulation [22]. Different authors propose that there are different executive functions: inhibitory control, working memory, planning, verification, decision-making, emotional regulation, and cognitive flexibility [23–25].

In ADHD, the main executive function that is thought to be affected is inhibitory control. This impairment generates a domino effect, causing difficulties with working memory capacity, internal language regulating behavior, reconstitution of new behaviors, regulation of emotion, and arousal and motivation [26]. This alteration of the executive

functions is what causes ADHD to present as a lack of regulation of behavior and cognition. This generates problems affecting individuals diagnosed with this disorder in different spheres, such as the educational, family, personal, social, work, and others [27–29].

The need to work on executive functions in ADHD is a crucial aspect of the management of this neurodevelopmental disorder. Over the years, various strategies have been explored to address these functions, which play a fundamental role in the regulation of behavior, attention, planning, and decision-making in individuals with ADHD. Among the most common interventions is the use of stimulant medications such as psychostimulants, which have been shown to improve attention and reduce hyperactive and impulsive symptoms in many patients. However, while these medications may be effective for some individuals, they are not a definitive solution as they do not directly address executive function deficits [30].

Another important approach is cognitive behavioral therapy (CBT), which focuses on identifying and changing dysfunctional patterns of thinking and behavior. CBT can be beneficial in improving skills such as self-regulation, problem-solving, and organization, which are directly related to executive functions. In addition, neuropsychological therapy, which focuses on rehabilitating specific areas of cognitive functioning, shows great potential for the treatment of ADHD. Through activities designed to improve working memory, cognitive flexibility, and inhibitory control, we seek to strengthen executive functions and improve overall functioning [31].

However, despite advances in these approaches, there is still no clear consensus on what is the best strategy for addressing impaired executive functions in ADHD. Research has shown mixed results leaving as a consequence many unanswered questions. Therefore, it is crucial to conduct a systematic review that integrates the most recent findings and evaluates the relative effectiveness of various interventions that address executive functions in people with ADHD.

This review could help inform clinical practice and guide the development of more effective and personalized future research that addresses the specific needs of each individual with ADHD. In addition, it would highlight the importance of further research in this field to improve the quality of life and functioning of individuals affected by this disorder.

2. Materials and Methods

The scope of this research focuses on analyzing systematic reviews by applying the PRISMA method [32]. The first stage involved identifying the research question and proceeding with data collection. Initially, a total of N = 739 articles were obtained. In the second stage, duplicate articles (N = 285) were identified and excluded. In the third stage, the remaining articles were assessed according to the inclusion criteria (human participation, treatment to improve executive functions, people diagnosed with ADHD, and articles in English and Spanish) and exclusion criteria (languages other than Spanish and English, systematic reviews, books or theses, paid access, or articles that proposed interventions not aimed at improving executive functions in ADHD), resulting in the exclusion of N = 406 articles. Consequently, in the fourth stage, a selection of N = 32 articles was made and used in this research. In the fifth stage, the statistical analysis is presented. Finally, in the sixth stage, the summary collation and dissemination of the results are carried out through the application of the analytical framework (Figure 1).

To achieve our research objective, we used the following databases: SCOPUS, Science Direct, and PUBMED using the keywords: executive functions, ADHD, treatment, and intervention, with the respective Boolean terms (OR, AND). During the research process, three reviewers supervised: titles, abstracts, and full texts considering the inclusion and exclusion criteria, thus accepting, or rejecting the discrepancies found in the papers. Consequently, each independent article was combined into a single file, thus adopting the results of the three reviewers by extracting the files with different results. The extraction table included data such as authors, research design, year of publication, the sample size used, type of intervention, intervention time, country of application, tests applied to assess

executive functions, and results, among others. This investigation has been registered in the PROSPERO platform under the number 557,233. This information is presented in Appendix A.

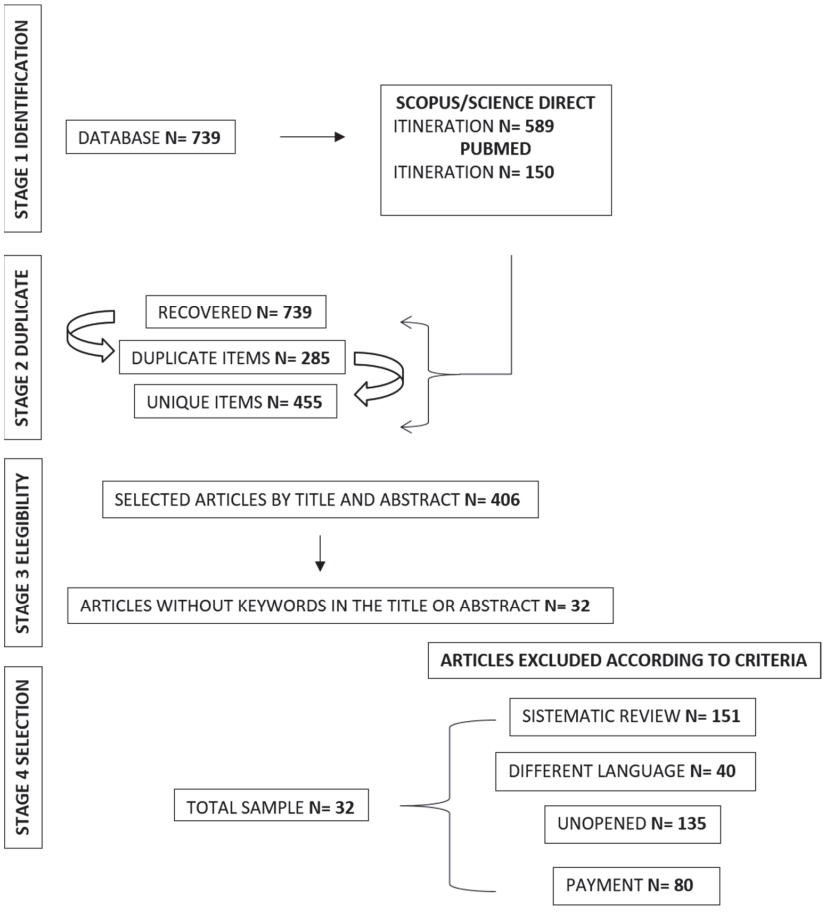

Figure 1. Flowchart of the systematic review conducted.

3. Results

The process to obtain the results involved a series of meticulous steps that allowed for a comprehensive analysis and understanding of the data. Firstly, dynamic tables were used to organize the data in a structured manner. These tables provide a dynamic view of the items for each variable, facilitating the identification of patterns and key relationships among the data. Subsequently, specific ranges were generated to perform detailed and segmented tabulations of the results. These ranges enabled us to group similar data and establish relevant categories for deeper analysis. Once the data were organized and analyzed, the results were visualized through charts. These charts were designed to visually represent the trends and relationships identified in the data, thus facilitating their interpretation.

Furthermore, key statistical measures, such as mean and standard deviation, were calculated for both subjects with ADHD for adults and children participating in the study. These measures provided us with a deeper understanding of the central tendency and dispersion of the data, enriching our analysis and conclusions. In summary, the process of

obtaining results was a combination of descriptive and visual data analysis techniques that allowed us to explore and understand our research findings in depth.

3.1. Research Design

Feasibility studies, preliminary studies, and randomized controlled trials (RCTs) were the main research designs we encountered. RCTs stood out as the most prevalent. Check out Figure 2 to see their prominence.

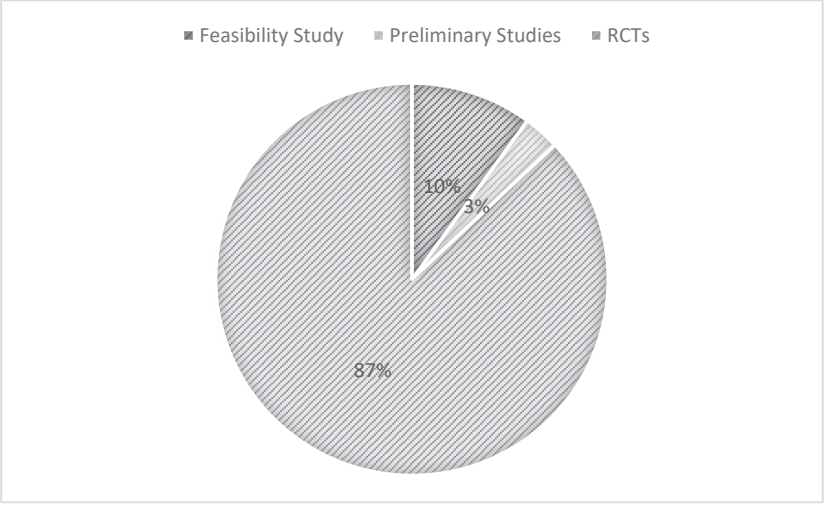

Figure 2. Research designs of the articles reviewed.

3.2. Research Countries

China leads with 7 studies, followed by the United States with 5 and Norway with 4, among other countries. Discover this distribution of studies in Figure 3.

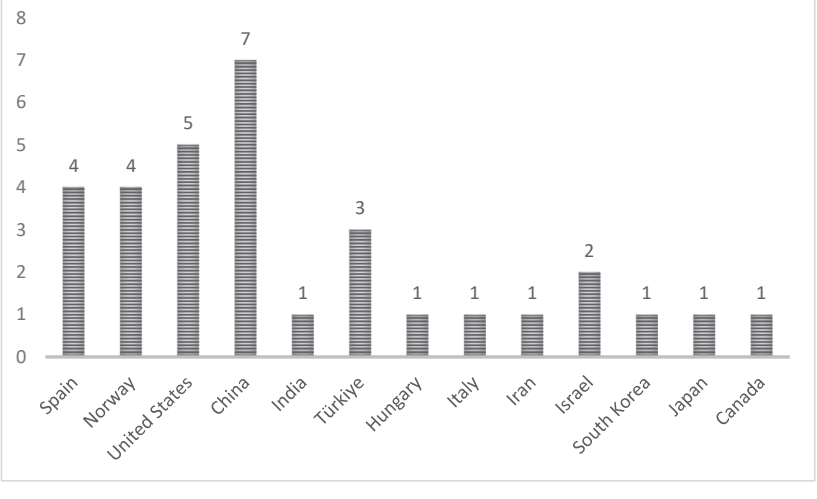

Figure 3. Research in countries.

3.3. Participants Stage

In terms of the life stage of individuals who underwent treatment, there were 21 studies involving children, followed by 7 studies in adults. Additionally, 2 studies encompassed adolescents and a combination of children and adolescents. These data are presented in Figure 4.

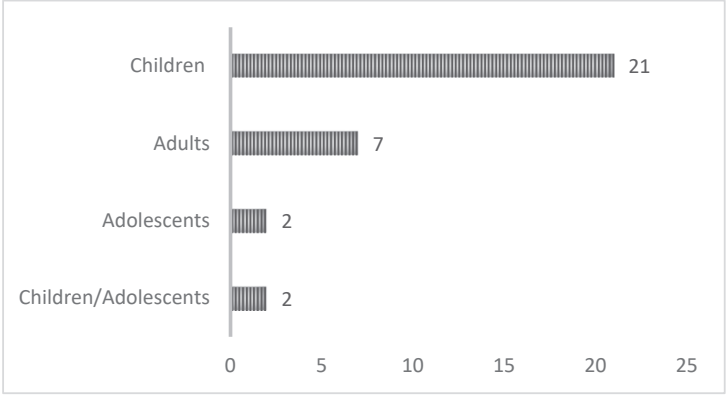

Figure 4. Subjects' stage.

3.4. Treatment Implemented

In the articles, various treatments were implemented to improve executive functions in individuals diagnosed with ADHD. The primary treatments included methylphenidate and mindfulness, followed by transcranial anodal direct current stimulation and viloxazine, among others. Psychological treatments were predominantly used, featured in 14 studies, followed by medication in 9 studies. Conversely, treatments such as polyamines and sports received the lowest number of studies. This distribution is visualized in Figure 5.

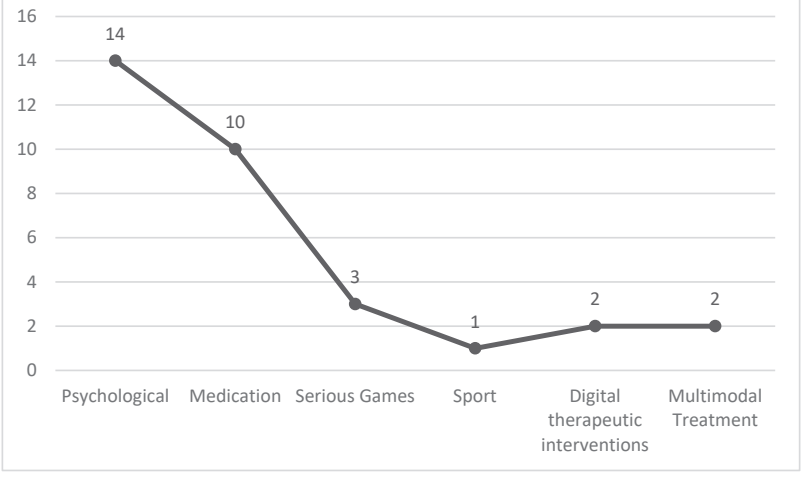

Figure 5. Treatment Type.

3.5. Test Administered in Previous Research

In the articles, various tests were administered, with the BRIEF used in 6 studies and the Stroop test used in 3 studies. These tests were used to identify the presence of ADHD

and assess executive functions. Explore Figure 6 to visualize the distribution of these tests across the studies.

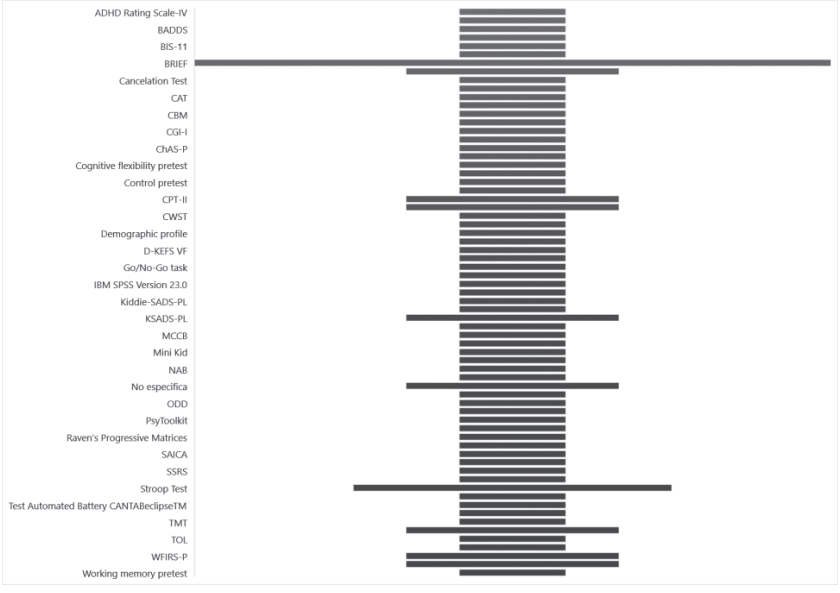

Figure 6. Test implemented.

3.6. Intervention Time

There were four ranges used to identify the intervention duration of treatments in days. The range of 0–182 days included 21 studies, followed by 183–365 days and 731 days or more, each with 4 studies, and finally, 549–730 days with 1 study. Explore Figure 7 to visualize the distribution of treatment durations across the studies.

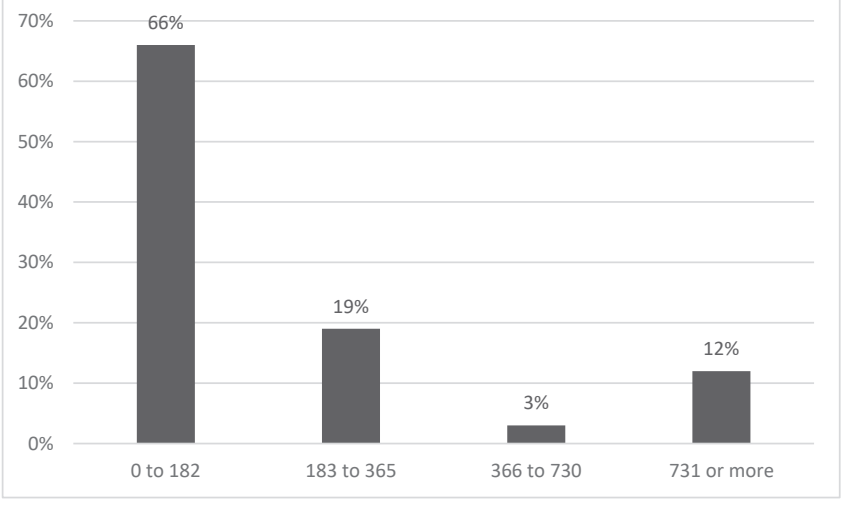

Figure 7. Implemented time in days.

3.7. Improved Executive Functions

In the analysis of the results, there was evidence of improvement in executive functions, although not uniformly across all aspects. Notably, working memory demonstrated the highest score in 15 studies, followed by inhibition in 12 studies, and cognitive flexibility in 5 studies. However, processing speed and sustained attention showed the lowest scores, each with only 1 study. To identify the efficacy of the treatment received with executive functions, a significant association was found between improving executive functioning and the type of psychological treatment ($x^2 = 11.82$, $p = 0.03$). Explore these findings further in Figure 8.

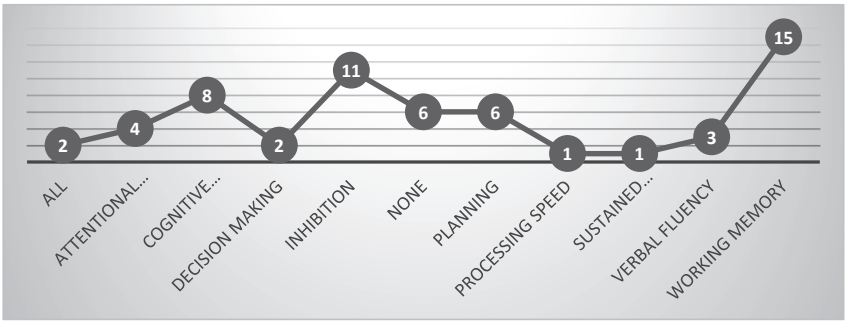

Figure 8. Improvement of executive functions.

4. Discussion

ADHD is a neurodevelopmental disorder that affects the normal development of children, adolescents, and adults. It is one of the most prevalent mental health problems. For this reason, it is vital to continue the dialogue on this matter and its treatment processes, which currently lack consensus on proposals or results [33,34].

Within the context of this article, the research based on a quantitative systematic review of treatment methods for executive functions in the ADHD population is presented. The importance of research on executive functions lies in the central role played by skills, such as inhibitory control, working memory, emotional regulation, cognitive flexibility, and planning in understanding the problems with the regulation of behavior and cognition that occur in this disorder [20,26].

The research began with 739 articles, and after analyzing the inclusion and exclusion criteria, 32 studies were included, allowing for the planned analyses to be carried out. The main results identified that randomized controlled trials were the most frequently performed research design. Regarding the temporality of studies, it was found that the last 5 years represent the highest scientific production in this line of research. Regarding the location of the research, it was found that the largest number of studies were conducted in Europe. As for the developmental level at which most studies were carried out, it was during childhood. The most frequently used treatment to support executive functions in ADHD was psychological interventions. The executive functions that benefit most from the identified treatments are working memory, inhibition, and cognitive flexibility. This study contributes to the understanding of ADHD by confirming the importance of executive functions when conducting interventions with individuals with this disorder. As previously mentioned, the roles of functions such as inhibitory control, working memory, and cognitive flexibility are crucial for individuals with ADHD to improve their behavioral regulation skills.

The findings of this systematic review underscore the breadth of research exploring interventions for ADHD, with particular emphasis on supporting executive functions, which tend to be affected by this neurodevelopmental disorder. Notably, both psychological interventions and pharmacotherapy have received substantial attention. For clinicians

and healthcare providers navigating treatment options for individuals with ADHD, a thorough consideration of the available evidence must be conducted. Moreover, tailoring interventions to suit the developmental stage of the patient is essential to ensure the benefits seen in the patient's quality of life. Furthermore, the combination of interventions, such as medication and psychological therapies, needs careful examination to ensure efficacy is grounded in empirical evidence.

Beyond treatment modalities, the cultural context emerges as a pivotal factor influencing intervention success. While existing research predominantly emanates from North America, Europe, and Asia, it is imperative to acknowledge and address the diversity of cultural backgrounds among individuals seeking treatment worldwide. Adapting interventions to local contexts is crucial for their applicability and efficacy [35–37]. This adaptation process necessitates not only clinical adjustments but also rigorous research to elucidate the specific cultural nuances that impact treatment engagement and effectiveness [38–41]. As such, bridging the gap between research and practice entails a comprehensive understanding of the multifaceted influences shaping the experiences of individuals with ADHD across diverse cultural landscapes.

Future research motivates us to develop our own intervention for executive functions in the ADHD population. Our interest lies in technological aspects that may be useful, especially for children and adolescents with the disorder. Finally, it is essential to continue studying executive functions, as these high-level mental abilities are not only affected in ADHD but also in other pathologies that affect human mental and behavioral activity and their pharmacological, non-pharmacological, and multimodal treatments [41–51].

The main limitation of this research lies in the lack of access to all the published articles, as several documents required payment to download. Another aspect is the language delimitation, as we only worked with studies published in English and Spanish; however, in future studies, we will review works published in other languages to cover the largest number of works on ADHD.

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

Appendix A

Table A1. Information Extraction Table.

Title	Country	Authors	Sample Size Used	Subjects with ADHD	Stage	Treatment Used	Type of Treatment	Test Implemented	Intervention Time/Days	Which Executive Functions are Improvement
Clinical and cognitive correlates of childhood attention-deficit/hyperactivity disorder in first-episode psychosis: a controlled study	Spain	Sánchez-Gistau et al. [52]	133	68	Children	Emotional stabilizers Antidepressants Antipsychotics	Medication	MCCB TMT-A NAB	1641	All
Dialectical behavioral therapy-based group treatment versus treatment as usual for adults with attention-deficit hyperactivity disorder: a multicenter randomized controlled trial	Norway	Halmøy et al. [53]	121	121	Adults	Mindfulness Dbt-bgt	Psychological	BRIEF DERS	98	All
Device-based movement behaviors, executive function, and academic skills among African-American children with ADHD and disruptive behavior disorders	United States	Santiago et al. [54]	42	23	Children	Af vigorosa	Psychological	BRIEF CBM AWMA-short version	7	None
Differential long-term medication impact on executive function and delay aversion in ADHD	Spain	Rubio and Hernández [55]	58	26	Children	Mph Atx	Psychological	K-BIT test Test automated battery cantabeclipsetm	273	Working memory Decision making Inhibition Planning Cognitive flexibility Verbal fluency
Effect of game-based high-intensity interval training program on the executive function of children with ADHD: protocol of a randomized controlled trial	China	Sun et al. [56]	42	42	Children	Gamehiit Games	Serious games	CWST CBTT Octamon fNIRS system TLT	60	Working memory Inhibition Planning Sustained attention Cognitive flexibility
Transcranial direct current stimulation as an effective treatment compared to video games on executive functions in children with attention deficit hyperactivity disorder	India	Makkar et al. [57]	61	61	Children	Tdcs along with video game Video game only	Serious games	TMT-A Raven progressive matrices	30	Working memory Cognitive flexibility Inhibition Verbal fluency
Effectiveness of online mindfulness-based intervention (imbi) on inattention, hyperactivity-impulsivity, and executive functioning in college emerging adults with attention-deficit/hyperactivity disorder: a study protocol	China	Pheh, et al. [58]	108	54	Adults	Mindfulness	Psychological	ASRS ADEXI	56	None
Effects of combing group executive functioning and online parent training on school-aged children with ADHD: a randomized controlled trial	China	Chu et al. [59]	145	145	Children	Gef-opt	Psychological	SNAP-IV BRIEF Go/no-go task WFIRS-P	30	Inhibition Planning Working memory

Table A1. *Cont.*

Title	Country	Authors	Sample Size Used	Subjects with ADHD	Stage	Treatment Used	Type of Treatment	Test Implemented	Intervention Time/Days	Which Executive Functions are Improvement
Effects of methylphenidate on executive functioning in children and adolescents with ADHD after long-term use: a randomized, placebo-controlled discontinuation study	Norway	Rosenau et al. [60]	94	94	Children and adoles-cents	Methylphenidate	Medication	Neuropsychological assessment	49	Working memory
Effects of agmatine, glutamate, arginine, and nitric oxide on executive functions in children with attention deficit hyperactivity disorder	Türkiye	Sarl et al. [61]	35	35	Children	Elisa	Medication	Stroop test TMT	365	None
Efficacy of cognitive behavioral therapy in medicated adults with attention-deficit/hyperactivity disorder in multiple dimensions: a randomized controlled trial	China	Pan et al. [62]	98	98	Adults	Methylphenidate	Medication	Cantab Regarding executive function	84	Inhibition
An empirical examination of executive functioning, ADHD associated behaviors, and functional impairments in adults with persistent ADHD, remittentADHD, and without ADHD	Spain	Roselió et al. [63]	61	61	Adults	Image	Psychological	CAARS BRIEF BRI MI WFIRS-P	1460	Inhibition Working memory Planning
Executive function and attention performance in children with ADHD: effects of medication and comparison with typically developing children	Hungary	Miklós et al. [64]	168	50	Children	Medication	Medication	Kitap testing Mini kid	730	Attentional control Inhibition
Executive function measured by brief in adolescents diagnosed and treated for ADHD: problem profiles and agreement between informants	Norway	Andersen et al. [65]	100	100	Adolescents	Tcc	Psychological	Kiddie-sads-pl Ksads-pl	1095	Working memory Planning
Executive function outcome of treatment with viloxazine extended-release capsules in children and adolescents with attention-deficit/hyperactivity disorder: a post-hoc analysis of four randomized clinical trials	United States	Faraone et al. [66]	1154	605	Children and adoles-cents	Viloxazine	Medication	Cgi-s Mmrm	56	All
Iamhero: preliminary findings of an experimental study to evaluate the statistical significance of an intervention for ADHD conducted through the use of serious games in virtual reality	Italy	Schena et al. [67]	60	60	Children	Iamhero	Serious games	Wisc-iv Bia Tol	42	Planning Attentional control Decision making
Feasibility, acceptability, and effectiveness of a new cognitive-behavioral intervention for college students with ADHD	United States	Solanto et al. [68]	19	19	Adolescents	Transcranial anodal direct current stimulation	Psychological	Home exercise	84	Working memory Cognitive flexibility

Table A1. *Cont.*

Title	Country	Authors	Sample Size Used	Subjects with ADHD	Stage	Treatment Used	Type of Treatment	Test Implemented	Intervention Time/Days	Which Executive Functions are Improvement
Improved executive function in adults diagnosed with attention-deficit/hyperactivity disorder as measured by the brown attention-deficit disorder scale following treatment with shp465 mixed amphetamine salts extended-release: post hoc analyses from 2 randomized, placebo-controlled studies	United States	Brown et al. [69]	673	673	Adults	Shp465 mas	Medication	Badds	42	Attentional control
Impacts of soccer on executive function in boys with ADHD	China	Chen [70]	968	968	Children	Soccer practice intervention	Sport	Control pretest Working memory pretest Cognitive flexibility pretest	42	Cognitive flexibility Inhibition
Influence of methylphenidate on long-term neuropsychological and everyday executive functioning after traumatic brain injury in children with secondary attention problems	United States	Leblond et al. [71]	26	26	Children	Methylphenidate	Medication	BRIEF CPT-II D-KEFS VF WISC-IV	168	Processing speed Attentional control
Mindfulness training for children with ADHD and their parents: a randomized control trial	Spain	Valero et al. [72]	30	30	Children	My mind program	Psychological	CONNERS WISC-IV NEPSY-II	168	Cognitive flexibility Working memory
Osmotic release oral system-methylphenidate hydrochloride (oros-mph) versus atomoxetine on executive function improvement and clinical effectiveness in ADHD: a randomized controlled trial	Türkiye	Torun et al. [73]	135	95	Children	Oros-mph	Medication	KSADS-PL CTRS Stroop test Cancelation test	126	None
Perceptual-motor skills reconstruction program improves executive functions in children with attention-deficit/hyperactivity disorder	Iran	Kouhbanani and Rothenberger [74]	50	50	Children	The perceptual-motor skills reconstruction program	Psychological	Demographic profile Clinical interview Conner's parent rating scale-revised Delis-Kaplan executive function system	168	Cognitive flexibility Inhibition Verbal fluency Working memory
Parental occupation executive training (poet): an efficient innovative intervention for young children with attention deficit hyperactive disorder	Israel	Frisch et al. [75]	72	72	Children	Copm	Psychological	CPRS CTRS CHAS-P	84	Inhibition Working memory

Table A1. *Cont.*

Title	Country	Authors	Sample Size Used	Subjects with ADHD	Stage	Treatment Used	Type of Treatment	Test Implemented	Intervention Time/Days	Which Executive Functions are Improvement
The potential effectiveness of digital therapeutics specialized in executive functions as an adjunctive treatment for clinical symptoms of attention-deficit/hyperactivity disorder: a feasibility study	South Korea	Sun et al. [76]	30	27	Children	Nurow	Digital therapeutic interven-tions	CAT PSYTOOLKIT CBCL	28	None
Predictors and moderators of treatment outcome in cognitive training for children with ADHD	Norway	van der donk et al. [77]	98	98	Children	Cwmt Pac	Psychological	LDS ODD	25	Working memory
Randomized control study of the effects of executive function training on peer difficulties of children with attention-deficit/hyperactivity disorder c subtype	China	Lan et al. [78]	96	96	Children	Geft Sst	Psychological	SAICA CPT-II WCST Adhd rating scale-iv Raven's progressive matrices	84	Working memory Cognitive flexibility
Response inhibition and interference control in adult attention deficit hyperactivity disorder	Türkiye	Çelik et al. [79]	85	42	Adults	Neuropsychological	Psychological	Stroop test Bis-11 Ibm spss version 23.0 Sst	1095	Inhibition
Scaffolding the attention-deficit/hyperactivity disorder brain using transcranial direct current and random noise stimulation: a randomized controlled trial	Israel	Berger et al. [80]	19	19	Children	Transcranial electrical stimulation Computerized of training	Digital therapeutic interven-tions	TDCS DLPFC	365	Working memory
Safety and efficacy of guanfacine extended-release in adults with attention deficit/hyperactivity disorder: an open-label, long-term, phase 3 extension study	Japan	Iwanami et al. [81]	150	150	Adults	Grx	Medication	CAARS CGI-I BRIEF	350	Working memory
Randomized controlled study on the effect of multimodal therapy and drug therapy on children with attention deficit hyperactivity disorder	China	Qian et al. [82]	61	61	Children	Medicine and Psychological treatment	Multimodal Treatment	SNAP STROOP WCST	360	Working Memory Inhibition
Moderating role of individual and familial characteristics in the improvement of organizational skills ADHD Youths' participation in the TRANSITION project	Canada	Girars-Lapointe et al. [83]	70	70	Children	Medicine and Psychological treatment	Multimodal Treatment	DISC-IV Conners WISC-IV	270	Planning Working Memory Organization

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Attention-Deficit Hyperactivity Disorder Symptoms in Adults Diagnosed with Multiple Sclerosis: Prevalence and Correlates

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Abstract: Background: The relationship between adult ADHD symptoms in People with Multiple Sclerosis (PwMS) is understudied. This study aimed to answer two questions: are PwMS more likely to experience higher ADHD symptoms versus healthy subjects? And what are the correlates of severe ADHD symptoms in PwMS? **Methods**: This study followed a cross-sectional design with predefined inclusion criteria. The Adult ADHD Self-Report Scale-V1.1 (ASRS) was used to assess the ADHD symptoms severity. **Results**: Data were analyzed from 171 PwMS and 200 controls. Regression analysis revealed that PwMS were at a significantly (B = 3.05, t = 2.24, 95% CI = 0.37–5.73, $p = 0.02$) higher risk to report higher ADHD scores versus controls. In addition, PwMS with relapses in the last 6 months and PwMS reporting smartphone addiction were at a significantly higher risk for severe ADHD (B = 7.19, t = 269, 95% CI = 1.91–12.48, $p = 0.008$) and (B = 9.18, t = 3.47, 95% CI = 3.97–14.41, $p = 0.001$), respectively. In conclusion, diagnosis with MS in our study was identified as a risk for higher ADHD symptoms. **Conclusions**: Further research is required to establish this relationship, and holistic medical and psychological interventions are required to improve the cognitive status of PwMS.

Keywords: ADHD; multiple sclerosis; risk

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1. Introduction

Attention-deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that features hyperactivity, lack of attention, high impulsiveness, and cognitive dysfunction; taken all together, these symptoms affect the daily functioning of the affected patients, who are mainly children [1]. Unstable relationships, poor achievement at work or school, low self-esteem, and other issues can result from ADHD [2]. Even though ADHD is frequently linked to childhood, it can still exist in adults and cause particular difficulties and impairments in social, professional, and academic settings [3], as well as a markedly higher chance of developing numerous medical disorders, or worsening their severity [4]. Although ADHD is a childhood disorder affecting approximately 5% of children worldwide [5], ADHD continues in adulthood with a prevalence rate reaching up to 3% of the adult population [5,6]. The cross-talk between neuropsychiatric disorders and autoimmune diseases has been established; however, the exact association between ADHD and multiple sclerosis is poorly studied and results are still inconclusive [7]. Multiple sclerosis is an autoimmune progressive and disabling disease affecting young adults [8]. Accumulating

evidence underscored the poor cognitive status among People with Multiple Sclerosis (PwMS). For example, one study that recruited about 200 PwMS reported a prevalence of cognitive dysfunction to be 34% [9]. Furthermore, other reports estimated that up to 65% of PwMS could experience cognitive dysfunctions and other debilitating symptoms including memory, attention, and information processing speed. This could be related to changes in the white matter lesions and other unknown disease-related conditions [10]. Although cognition has been studied in PwMS, adult ADHD symptoms in PwMS are still poorly studied. The symptomatology of ADHD covers several aspects including cognitive deficits. Therefore, the study of ADHD symptoms in PwMS could provide more holistic insight into the other cognitive-related symptoms experienced by PwMS.

One study that compared 72 PwMS with healthy peers showed that PwMS reported a higher rate of ADHD symptoms—36% compared to 4%—in the control group according to the Adult Attention Deficit/Hyperactivity Disorder Self-Report Scale (ASRS) [11]. In the same study, ADHD symptoms were related to the mental health burden, namely anxiety and depression. According to our knowledge, very few studies have examined whether PwMS could be at higher risk for severe ADHD symptoms, and very few studies identified potential risk factors for severe ADHD symptoms in PwMS. Therefore, the present study sought to (1) investigate whether PwMS are at higher risk for severe ADHD versus healthy controls and (2) identify the correlates of severe ADHD among PwMS.

2. Materials and Methods

2.1. Study Design and Settings

We employed a cross-sectional design with predetermined inclusion criteria. PwMS were recruited from the MS unit located in Al Bashir Hospital-Jordan. All the potential PwMS were approached upon their frequent visit to the unit where the study objective and protocol were fully explained before enrollment. The control group was randomly recruited from healthy individuals visiting the hospital with their family members to provide them assistance. A link leading to the study questionnaire was sent to all the willing participants, who were asked to fill out the written consent form electronically before enrollment. The sample size was informed by previous studies. All the participants had the right to exit from the study at any time. The study obtained ethical approval from the Yarmouk University IRB Committee (692).

2.2. Inclusion Criteria

PwMS with a diagnosis of RRMS based on the 2017 McDonald criteria [12] and receiving disease-modifying therapy for at least one year were recruited for this study.

2.3. Exclusion Criteria

PwMS diagnosed with other types of MS, those not adhering to their disease-modifying therapy for at least one year, and those newly diagnosed as PwMS were excluded from the study.

2.4. Study Instrument

A well-designed study instrument has been created to cover the demographical and clinical information of the study population. The demographics covered were sex, age, marital status, employment status, and smoking status. The clinical information for PwMS covered the disease duration, the disease-modifying therapy received, and the history of relapse(s) in the last six months. In addition, the addiction to smartphones for PwMS was assessed using the Smartphone Addiction Scale. This Arabic-translated validated and reliable scale (Cronbach alpha = 0.94) [13] comprises 10 questions, each one rated against a 6-point Likert scale with responses that range from 1 for "strongly disagree" up to 6 for "strongly agree". The scale generates a score between 0 and 60 with a cut-off score of 39 and above to identify addiction to smartphones [14,15].

2.5. Outcome Measure

ADHD Symptoms

The Arabic version of the Adult ADHD Self-Report Scale-V1.1 (ASRS) was employed to evaluate the ADHD symptoms. The scale shows excellent internal consistency with a Cronbach alpha of 0.94 [16]. This scale consists of 18 items aligned with the diagnostic criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM) and generates a maximum score of 72, with a higher score indicating a higher severity of ADHD [17–19].

2.6. Data Analysis

Before the data analysis step, all the participants with incomplete data were excluded to improve the data quality and to minimize any potential bias.

The categorical variables of the demographics of the enrolled participants and the clinical information of the PwMS were described using frequencies and percentages. The continuous variables (age and ADHD scores) were described through mean ± standard deviation. The variables between the two groups were compared using the Chi-square analysis for the categorical variables and the independent t-student test for the continuous variables. To investigate whether diagnosis with MS could be a risk factor for higher ADHD scores, a univariate linear regression analysis was performed with ADHD as the dependent variable. To identify the correlates for severe ADHD symptoms in PwMS, a univariate linear regression analysis was carried out to identify potential confounders showing $p < 0.1$, and then these factors were used to feed the multivariable linear regression model built using the backward step-wise approach. Confidence intervals were set at 95% and significance at $p < 0.05$. Data were analyzed using SPSS software version 21.

3. Results

3.1. Study Sample Features

Data analysis comprised a cohort of 371 participants, of which 171 were PwMS and 200 were demographically matched controls. In regards to the PwMS group, 125 (73.1%) were females, 103 (60.2%) were married, 107 (62.6%) were unemployed, 92 (53.8%) were non-smokers, 30 (17%) reported relapses for the past 6 months, 98 (57.3%) had been diagnosed with RRMS for less than 5 years, 32 (18.6%) reported addiction to smartphones, 90 (52.6%) were on fingolimod, 47 (27.5%) on interferons, and 34 (19.9%) on dimethyl fumarate (Table 1).

3.2. PwMS and Risk for ADHD Severity

The mean score of ADHD was compared between the two groups through the independent t-test. The PwMS reported a significantly higher score (Mean ± SD) (30.94 ± 13.85) compared to (27.89 ± 12.42) in the control group, (t (369) = −2.23, $p = 0.02$). Moreover, according to the linear regression univariate model for ADHD as the dependent variable, PwMS were at a significantly higher risk for higher ADHD scores (B = 3.05, t = 2.24, 95% CI = 0.37–5.73, $p = 0.02$), as shown in Table 1.

Table 1. The demographics, clinical information, and ADHD scores of the two study groups.

Factor		Controls (n = 200)	PwMS (n = 171)	*p*-Value
Age (M ± SD)		37.19 ± 16.6	37.85 ± 9.83	0.67
ADHD Score (M ± SD)		27.89 ± 12.42	30.94±13.85	0.02 *
Sex	Males	65 (32.5%)	46 (26.9%)	0.25
	Females	135 (67.5%)	125 (73.1%)	
Marital Status	Single	86 (43%)	68 (39.8%)	0.59
	Married	114 (57%)	103 (60.2%)	

Table 1. *Cont.*

Factor		Controls (n = 200)	PwMS (n = 171)	*p*-Value
Employment	Unemployed	125 (62.5%)	107 (62.6%)	0.99
	Employed	75 (37.5%)	64 (37.4%)	
Smoking Status	Non-smoker	125 (62.5%)	92 (53.8%)	0.10
	Smoker	75 (37.5%)	79 (46.2%)	
MS Relapses during the last 6 Months	No	N/A	141 (82.5%)	
	Yes	N/A	30 (17.5%)	
MS Duration	For less than 5 years	N/A	98 (57.3%)	
	For 5 years or more	N/A	73 (42.7%)	
Addiction to Smartphones	No	N/A	140 (81.4%)	
	Yes	N/A	32 (18.6%)	
Fingolimod		N/A	90 (52.6%)	
Dimethyl fumarate		N/A	34 (19.9%)	
Interferons		N/A	47 (27.5%)	

The independent t-student test was performed to compare means of the continuous variables "age" and "ADHD" scores. The other categorical variables were compared using Chi-square analysis. ADHD: attention-deficit hyperactivity disorder according to the ASRS scale; MS: multiple sclerosis, N/A: not applicable M: mean, SD: standard deviation, * $p < 0.05$.

3.3. Correlates of ADHD Symptoms in PwMS

To investigate which factors were independently associated with higher ADHD scores in the PwMS group, an initial univariate linear regression analysis was carried out followed by a multivariable linear regression model. This revealed that PwMS with "Relapses in the last 6 months" and PwMS reporting "Smartphone addiction" were at a significantly higher risk for severe ADHD (B = 7.19, t = 269, 95% CI = 1.91–12.48, $p = 0.008$) and (B = 9.18, t = 3.47, 95% CI = 3.97–14.41, $p = 0.001$), respectively, as shown in Table 2.

Table 2. The association between PwMS covariates and ADHD severity using univariate and multivariable linear regression models for ADHD (dependent variable) according to the ASRS scale.

Factor	Univariate Analysis				Multivariable Analysis			
	B	t	95% CI	*p*	B	t	95% CI	*p*
Increasing age	0.05	0.54	−0.15–0.27	0.54	---	---	---	---
Female	1.95	0.81	−2.77–6.67	0.42	---	---	---	---
Married	1.28	0.59	−3.01–5.36	0.55	---	---	---	---
Employed	−3.26	−149	−7.57–1.04	0.14	---	---	---	---
Smoker	−0.54	−0.25	−4.74–6.67	0.80	---	---	---	---
MS duration	1.91	0.89	−2.32–6.14	0.38	---	---	---	---
Relapses in the last 6 months	6.29	2.29	0.86–11.72	0.02 *	7.19	2.69	1.91–12.48	0.008 *
Smartphone addiction	8.49	3.17	3.20–13.79	0.002 *	9.18	3.47	3.97–14.41	0.001 *
Fingolimod	−0.17	−0.08	−4.37–4.03	0.94	---	---	---	---
Dimethyl fumarate	−0.23	−0.08	−5.49–5.02	0.93	---	---	---	---
Interferons	0.39	0.16	−4.30–5.09	0.87	---	---	---	---

MS: multiple sclerosis, B: beta coefficient, t: t value, CI: confidence interval, * $p < 0.05$, $r^2 = 0.095$.

4. Discussion

The present study had two objectives: first, to examine whether PwMS are at higher risk for severe ADHD versus healthy controls, and second, to identify the correlates of severe ADHD among PwMS. Our findings reported that PwMS are at higher risk, i.e., three-fold higher risk to report severe ADHDH symptoms versus their healthy peers. Also, we report that PwMS who had previous relapses and who reported addiction to smartphone use were at higher risk for severe ADHD symptoms.

Our findings identified MS as a significant correlate for severe ADHD symptoms. In the present study, all PwMS were diagnosed with RRMS. The previous literature identified higher ADHD rates in MS types; for example, almost 45% of PwMS with RRMS type suffered ADHD [20]. Although this study identified a significant association between PwMS and ADHD symptoms, the author reinforces that this preliminary research does not claim a causal relationship between PwMS and ADHD symptoms.

Although the exact mechanism underlying this comorbidity is yet to be clarified, this could be attributed to the neurological changes seen in the grey and white matter of PwMS, the distribution of the cortical and the juxtacortical lesions, ventricles enlargement, and corpus callosum atrophy, which are all thought to correlate to cognitive dysfunction [21–23]. This could explain that, in our study, PwMS who reported one or more relapses were at higher risk for severe ADHD; this suggests that ADHD symptoms could deteriorate with the disease course. This is supported by a study that confirmed that three out of four PwMS who reported poor cognition at baseline continued to suffer from cognition deterioration [24]. Findings from the current study revealed that PwMS participants who had previous relapses and who reported addiction to smartphone use were at higher risk for severe ADHD symptoms, which is consistent with the existing literature. A recent systematic review made use of recent empirical data to show the relationship between adult health outcomes and smartphone addiction. Results have consistently shown an association between smartphone addiction and symptoms of both physical and mental health, such as anxiety, depression, musculoskeletal pain, and insomnia [25]. Factors such as personality features, impulsivity, and mental health issues are implicated [26,27].

ADHD, in particular, in the present study has been connected to internet and smartphone addiction, and this finding has been confirmed in several previous studies [14,28,29]. Numerous studies examining the relationship between ADHD and addiction indicate that the disorder appears to be associated with behavioral addictions [30,31]. There is strong evidence that problematic internet use addiction is linked to cognitive deficits in working memory, motor inhibitory control, attention-focused inhibition, and decision-making, as shown by a recent meta-analysis [32].

Although little research has been found to relate ADHD and smartphone use, we suggest that because PwMS are young compared to other neurological disorders, these subjects are highly and easily attracted to the continuously updating technologies presented via smartphones. The prevalence of addiction to smartphones, according to the published studies, could reach up to 26% in young populations depending on the scale and the cut-off points used [33]. The relationship between addiction to smartphones and ADHD symptoms is believed to be bi-directional, multifactorial, and complicated. For instance, individuals with problems in assurance-seeking and avoidance behaviors are prone to be addicted to their smartphones [34]; in addition, people reporting impulsivity, focusing problems, and lack of new stimuli as ADHD symptoms could be more vulnerable to smartphone addiction [35]. On the other hand, excessive smartphone use can aggravate symptoms of ADHD by lowering attention span, raising impulsivity, and interfering with daily schedules [36]. Furthermore, the overuse of smartphones reinforces the feeling of controlling the target, as well as the freedom of self-expression on social media platforms that yields rewarding feelings for people with ADHD [37,38]. In addition, many studies found that addiction to smartphones/internet in subjects with ADHD symptoms was tightly related to depression and anxiety symptoms [39].

This pioneering study provides a significant contribution to the little existing literature about ADHD symptoms in PwMS. Altogether, the novelty, the validated ADHD and smartphone addiction scales, and the robust analysis of data are strengths of this study. Conversely, this study has some limitations. For instance, the ADHD status was not monitored at baseline, i.e., at the moment of diagnosis with MS; in addition, the smartphone addiction variable was only examined in PwMS and not for the whole cohort. Furthermore, the nature of the data collected from the scales could lead to possible bias, which was managed by excluding incomplete questionnaires and using validated and reliable scales. In addition, the study design and settings did not allow for the accurate and definitive ADHD diagnosis among PwMS due to social, cultural, and other related personal barriers such as stigma to mental health in developing countries such as Jordan.

5. Conclusions

This study concludes that PwMS reported higher ADHD symptoms severity compared to the healthy group. PwMS with relapses and smartphone addiction were at higher risk for ADHD. Although these findings could not be recognized as confirmatory, these findings underscore the importance of implementing more thorough, large-scale, and follow-up studies to further reveal the association between MS, smartphone addiction, and ADHD symptoms in adults. Furthermore, the findings of this study open new avenues for clinicians to provide comprehensive medical and psychological care to prevent the deterioration of these disabling symptoms in this fragile population. More in-depth studies are required to fully unravel the association between MS and ADHD.

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Push–Pull Mechanism of Attention and Emotion in Children with Attention Deficit Hyperactivity Disorder

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Abstract: Background/Objectives: While deficits in executive attention and alerting systems in children with attention deficit hyperactivity disorder (ADHD) are well-documented, findings regarding orienting attention in ADHD have been inconsistent. The current study investigated the mechanism of attentional orienting in children with ADHD by examining their attentional bias towards threatening stimuli. Furthermore, we explored the modulating role of anxiety levels in ADHD on this attentional bias. **Methods**: In Experiment 1, 20 children with ADHD and 26 typically developing children (TDC) performed a continuous performance task that included task-irrelevant distractions consisting of angry faces and neutral places. In Experiment 2, 21 children with ADHD and 25 TDC performed the same task, but with angry and neutral faces as distractors. To measure children's anxiety levels, the State-Trait Anxiety Inventory was administered before each experiment. **Results**: In Experiment 1, results revealed no attentional bias effects in children with ADHD, whereas TDC exhibited attentional capture effects by both types of distractors. However, in Experiment 2, ADHD children demonstrated an attentional bias towards angry faces, which revealed a significant positive correlation with their trait anxiety levels ($r = 0.61$, $p < 0.05$). Further analyses combining all ADHD children showed that trait anxiety levels in Experiment 2 were significantly higher than those in Experiment 1. Finally, a significant positive correlation was found between anxiety levels and attentional bias towards angry faces in all ADHD children ($r = 0.36$, $p < 0.01$). **Conclusions**: Children with ADHD exhibited atypical attentional-orienting effects to threats, and their levels of trait anxiety appeared to modulate such attentional-orienting mechanisms.

Keywords: attention deficit hyperactivity disorder; attentional orienting; attentional bias; trait anxiety; anxiety levels

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1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by symptoms of inattention, hyperactivity, and impulsivity [1]. Prevalence studies suggest that approximately 10% of children in the general population are diagnosed with ADHD, with higher rates observed in boys compared to girls [2,3]. Central to ADHD is a deficit in attentional functions, which play a crucial role in efficiently selecting relevant information in one's surroundings to achieve current goals [4].

Posner delineated three core attentional networks: alerting, orienting, and executive control networks [5,6]. The alerting network maintains vigilance, the orienting network facilitates rapid shifting of attention, and the executive control network governs selective attention and conflict resolution [5]. While deficits in executive control and alerting networks have been consistently reported in children with ADHD [7,8], the status of the orienting network remains less clear [9].

Specifically, some studies demonstrated intact functions of orienting in children with ADHD [7,8,10]. However, other studies reported abnormal functions of attentional-orienting mechanisms in children with ADHD. For instance, McDonald and colleagues [11] found that children with ADHD showed difficulty disengaging attention from an invalidly

cued location, suggesting deficits in attentional disengagement. Additionally, Ortega and colleagues [12] reported slower response times and lower accuracy in children with ADHD compared to typically developing children (TDC) when valid cues were provided before the target appearance, along with abnormal event-related potential (ERP) components associated with attentional orienting in ADHD. These discrepancies underscore the need for further investigation into attentional-orienting functions in ADHD, especially considering its implications for cognitive and behavioral outcomes.

In addition to the major deficits in attentional functions, ADHD is also associated with deficits in socio-emotional functions, including difficulties in recognizing negative facial emotions [13–15]. Faces play a critical role in social interactions, and the ability to process facial expressions develops during late childhood and early adolescence [16]. Notably, faces can involuntarily capture attention, leading to attentional biases, particularly toward threatening facial stimuli [17,18].

Previous research on attentional bias has predominantly focused on attentional bias towards threatening stimuli in neurotypical individuals and those with anxiety disorders [19–21]. For example, Kim et al. [21] found that individuals with social anxiety disorder exhibited heightened attentional bias towards angry faces at both behavioral and neural levels. Moreover, a recent study investigated the influence of anxiety levels on attentional bias in neurotypical adults and adolescents, revealing that while the onset of abrupt distractors automatically captured attention in adults irrespective of distractor type, only angry face distractors affected reaction times in adolescents [22]. Additionally, this study demonstrated a positive correlation between levels of state anxiety and attentional capture in adults but not adolescents, suggesting the significance of anxiety levels in attentional bias towards emotional stimuli, particularly in developing populations.

However, research specifically addressing attentional bias towards facial stimuli in children with ADHD is scarce and often overlooks an individual's anxiety levels [23,24]. However, about 25–30% of children with ADHD are accompanied by anxiety symptoms [25]. High levels of anxiety have been reported to exacerbate symptoms of ADHD and impair emotional interference control, leading to difficulties in handling emotional stimuli [26,27]. Particularly, ADHD children with high trait anxiety are susceptible to external stimuli due to prevalent inattentive symptoms, resulting in deficits in sustained attention [28,29]. Thus, investigating the relationship between attentional bias toward threatening stimuli and anxiety levels in children with ADHD is crucial.

Thus, the present study aimed to address this gap by investigating attentional bias towards emotional facial stimuli in children with ADHD and its relationship with anxiety levels, comparing them with TD children. By employing the paradigm introduced by Parks et al. [18], this study examined attentional bias patterns in response to emotional facial stimuli in children with ADHD. Building upon the design of a previous study [18], our research comprised two experiments. In Experiment 1, we utilized angry faces or non-emotional place images as distractors to explore potential attentional capture and holding effects in both TD and ADHD children, modulated by their anxiety levels. In Experiment 2, we employed both angry or neutral faces as distractors to investigate whether children with ADHD would demonstrate attentional capture or holding effects toward task-irrelevant facial stimuli within the context of all facial distractors. Additionally, we examined the effects of anxiety levels on attentional bias effects toward faces in both TD and ADHD children. In two experiments, we investigated whether children with ADHD exhibit atypical attentional-orienting functions, specifically by lacking attentional capture effects towards threatening stimuli. Additionally, we examined whether these atypical orienting functions in ADHD are modulated by anxiety levels. Our research questions and hypotheses are as follows:

Research Questions:

1. Do children with ADHD exhibit atypical attentional-orienting functions, indicated by a lack of attentional capture effects towards threatening stimuli?

2. Are the atypical orienting functions in children with ADHD modulated by their anxiety levels?

Hypotheses:

Hypothesis 1. *Children with ADHD will display deficits in attentional bias towards emotional facial stimuli compared to TDC.*

Hypothesis 2. *Higher levels of trait anxiety in children with ADHD will be positively associated with an attentional bias towards threatening stimuli.*

2. Experiment 1

2.1. Materials and Methods

2.1.1. Participants

Twenty children with ADHD (aged 11–15 years, 16 boys, 4 girls) and 26 age-matched typically developing children (TDC; aged 11–15 years, 16 boys, 10 girls) were recruited for this experiment (Table 1). Children with ADHD were diagnosed according to DSM-5 criteria (19 inattentive types and 1 combined type) and were recruited from child mental health and treatment centers in Seoul, Gyeonggi-do, and Chungcheongnam-do in Republic of Korea. Typically, developing children (TDC) were recruited from public schools in Seoul and Gyeonggi-do, Republic of Korea. Parent reports were used to screen for neurodevelopmental or psychiatric conditions in TDC, and none reported any current or past psychiatric conditions. All participants were right-handed, had full-scale IQs (FSIQ) above 80, and had normal or corrected-to-normal vision. Ethical approval for the study protocols and procedures was obtained from the university's internal review board.

Table 1. Participants' characteristics included in Experiment 1.

Group	Sex		Age	State Anxiety	Trait Anxiety
	Boy (%)	Girl (%)	M (SD)	M (SD)	M (SD)
ADHD (N = 20)	16 (80)	4 (20)	13.17 (1.27)	39.45 (8.37)	40.90 (9.32)
TDC (N = 26)	16 (62)	10 (38)	13.37 (1.51)	35.88 (7.53)	39.00 (7.71)

2.1.2. Continuous Performance Task (CPT)

The attention task was created using Presentation version 18.1 (Neurobehavioral Systems) and displayed on a 14-inch monitor with an AMD quad-core laptop. The task replicated the design used by Parks et al. [18], a modified version of the Continuous Performance Task (CPT) developed by Kim and Hopfinger [4] to study attention mechanisms based on stimulus characteristics. As in the previous study [18,22], we chose face and place stimuli as distractors in Experiment 1. Specifically, facial stimuli were selected from the Korean Facial Expressions of Emotion (KOFEE) [30], consisting of eight angry face stimuli (4 females and 4 males). Angry face stimuli were chosen as distractors because they can evoke a sense of threat in participants. To serve as control stimuli with neutral emotional value, eight-place stimuli were also selected as distractors. These place stimuli were chosen from the stimulus set used in Parks et al. [18]. All stimuli were converted to grayscale images.

To perform the task, participants were instructed to fixate on a central point while distractors (either an angry face or a place with a visual angle of 8°37 × 8°37) appeared for 4 s in the center of the screen. The target stimulus, a red "T" (5°88 × 5°88), appeared at the upper right of the screen, overlapping with a black cross. Participants were instructed to respond as quickly and accurately as possible to the direction of the red "T" while ignoring the distractors.

In this task, participants were required to maintain fixation on the central point and disregard the distractor stimuli while responding to the direction of the red "T" (the target).

If the target stimulus appeared vertically or horizontally (0°, 90°, 180°, 270°), participants pressed the left mouse button with their right hand. If the target stimulus appeared diagonally (45°, 135°, 225°, 315°), participants pressed the right mouse button with their right hand.

The task involved two types of conditions: distractor type and time condition. The distractor type had two levels: angry face and place. The time condition included five levels: T1, T2, T3, T4, and TBaseline (TB), representing the target presentation timing. T1 indicated the target presented concurrently with the distractor for 1000 ms, T2 indicated the target presented 1000 ms after T1, T3 indicated the target presented 1000 ms after T2, and T4 indicated the target presented 1000 ms after T3. TB represented trials where only the target was presented without distractors and was randomly presented within four conditions lasting 3000 to 6000 ms.

In accordance with the methodology outlined by Parks et al. [18], attentional capture was defined as the slow reaction time to the target at T1, while attentional holding referred to the slow response time to the target from T2 to T4. A visual representation of the task is depicted in Figure 1.

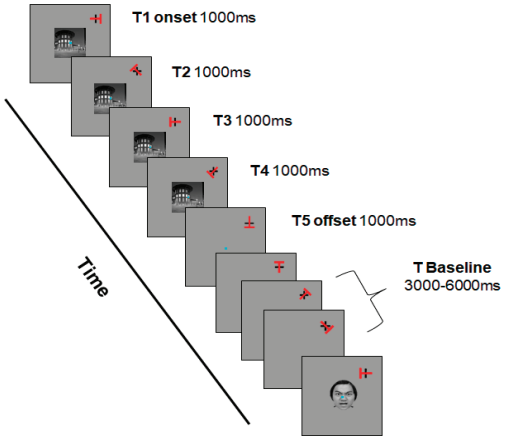

Figure 1. The attention task paradigm of Experiment 1.

Before performing the main CPT, all participants engaged in a passive viewing task designed to expose them to the stimuli used in the primary task, thereby controlling possible attentional capture effects by novel stimuli. This task involved the random presentation of 16 face and place stimuli, each shown twice for 2000 ms, lasting approximately 2 min. Subsequently, to familiarize participants with the task procedure, a practice session was conducted using the same task format, lasting approximately 1 min and 10 s. The main task comprised four blocks, with each block consisting of 204 trials, resulting in a total of 816 trials and lasting approximately 16 min and 20 s. The entire experimental session lasted approximately 20 min.

2.1.3. State-Trait Anxiety Inventory: STAI-X I, II

The State-Trait Anxiety Inventory (STAI-X I, II) [31] was utilized in this study to assess levels of state anxiety and trait anxiety. Each anxiety scale comprised 20 items, rated on a scale from 1 to 4. The state anxiety scale included questions such as "How do you feel at this moment?" while the trait anxiety scale included questions like "How do you generally feel in your daily life?" Scores ranged from 20 to 80, with higher scores indicating higher levels of state and trait anxiety. The reliability and validity of the Korean translation of the STAI-X have been reported to be sufficient (test-retest reliability: $r = 0.69$ for the STAI-X

I and $r = 0.75$ for the STAI-X II; Cronbach's alpha = 0.88 for the STAI-X I and Cronbach's alpha = 0.83 for the STAI-X II) [32].

2.1.4. Procedures

The tasks were conducted in a quiet environment free from noise distractions. Prior to the experiment, all participants and caregivers provided informed consent, and participants completed the STAI-X I and II questionnaires. Participants then received detailed instructions and explanations regarding the experiment and commenced the task once it was confirmed that they thoroughly understood the instructions. Participants completed the task while seated approximately 60 cm away from the monitor. Upon completion of the task, participants who met the requirements received a 5-dollar gift certificate as compensation. The total duration of the experiment was approximately 40 min, which included 5 min for completing the consent forms, 15 min for completing the STAI-X I, II questionnaire, and 20 min for completing the attention task.

2.1.5. Statistical Analysis

All the data in this study were analyzed using SPSS version 21.0. Reaction times (RTs) less than 150 ms and greater than 1150 ms in the attention task were excluded from the analysis based on previous research [4,18,21,22]. The exclusion was necessary because an RT of 150 ms is too fast for attention to be properly directed in the current task paradigm [4,18]. Furthermore, the target in the current task changed its direction every 1000 ms; thus, it is unclear which trial corresponds to an RT of greater than 1150 ms [4,18,21,22]. For both accuracy and RTs, individuals with mean data 3 standard deviations away from the group average were determined as outliers and excluded from the final analyses. Initial screening analyses revealed that no child in our study met this criterion for being an outlier.

First, descriptive statistics were computed to determine the mean age, state anxiety, trait anxiety levels, and mean RTs for the target. Subsequently, repeated measures ANOVAs were conducted with factors including distractor type (angry face, place), time order (T1, T2, T3, T4, TB), and group (ADHD, TDC). In this context, T1 represented performance on the target presented simultaneously with the distractor, T2 indicated the target following T1, T3 indicated the target following T2, and T4 indicated the target following T3. Partial eta squared (η^2) was used to measure the effect size (small effect size: 0.01; medium effect size: 0.06; large effect size: 0.14) [33,34]. For significant interaction effects, post hoc analyses utilized paired *t*-tests with the Benjamini–Hochberg correction [35] to compare RTs of time order concerning the type of distractors relative to TB. Finally, Pearson correlation analysis was conducted to examine the relationship between the distractor effects and the levels of state and trait anxiety.

2.2. Results

First, a three-way mixed ANOVA ($2 \times 5 \times 2$) was conducted to explore attentional bias effects based on distractor type (angry face, place), time order (T1, T2, T3, T4, TB), and group (ADHD, TDC) (Table 2, Figure 2). The analysis revealed a significant main effect of time order ($F(2.98, 131.10) = 18.67$, $p < 0.001$, $\eta^2 = 0.30$) and a significant interaction effect between time order and group ($F(2.98, 131.10) = 9.20$, $p < 0.001$, $\eta^2 = 0.17$). Post hoc paired *t*-tests with Benjamini–Hochberg correction [35] were conducted to elucidate the attentional bias across time orders within each group.

The results indicated differential attentional bias effects between ADHD and TD groups across time orders for each distractor type. Specifically, the ADHD group did not exhibit a significant attentional capture effect, regardless of distractor type (all *p*s > 0.05). In contrast, TD children exhibited attentional capture effects for both angry face and place distractors (angry face T1: $t(25) = 6.65$, $p < 0.001$; place T1: $t(25) = 6.33$, $p < 0.001$), with no attentional holding effect for angry face (all *p*s > 0.05). However, a significant attentional holding effect was observed for place distractors at T2 ($t(25) = 2.62$, $p < 0.05$) in the TD group.

Subsequently, correlation analyses were conducted to examine the relationships between anxiety levels and attentional bias effects within each group. Specifically, correlations were assessed between the distraction effects of angry face or place stimuli and state-trait anxiety scores for both groups. The results indicated no statistically significant correlation between distraction effects caused by either an angry face or place and state or trait anxiety levels in either TD or ADHD children.

Table 2. An ANOVA table in Experiment 1.

	F	*p*	η^2
Distractor	$F(1, 44) = 2.41$	0.13	0.05
Time order	$F(2.98, 131.10) = 18.67$	<0.001	0.30
Group	$F(1, 44) = 1.84$	0.18	0.04
Distractor × Group	$F(1, 44) = 0.51$	0.48	0.01
Time order × Group	$F(2.98, 131.10) = 9.20$	<0.001	0.17
Distractor × Time order	$F(4, 176) = 0.786$	0.54	0.02
Distractor × Time order × Group	$F(3.51, 154.46) = 2.18$	0.083	0.05

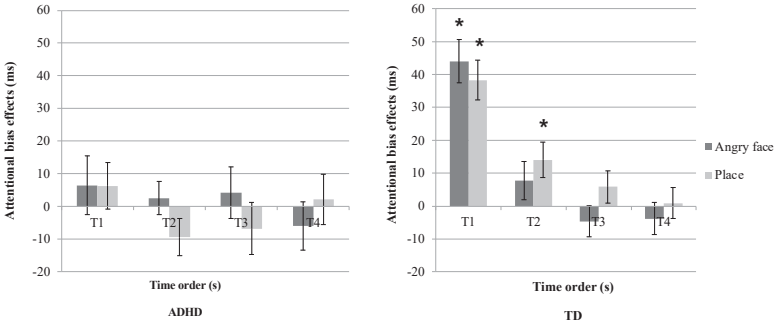

Figure 2. Attentional bias effect on the distractor type and time order in Experiment 1 (* indicates a significant effect with $p < 0.05$).

3. Experiment 2

3.1. Materials and Methods

3.1.1. Participants

A total of 21 children aged 11 to 15 diagnosed with ADHD (17 boys and 4 girls), based on DSM-5 criteria, were recruited from child mental health facilities and treatment centers located in Seoul, Gyeonggi-do, and Chungcheongnam-do, Republic of Korea. Among the subtypes of ADHD, 12 were classified as inattentive, and 9 were classified as combined. Additionally, 25 age-matched TD children (16 boys and 9 girls) were recruited from general schools in Seoul and Gyeonngi-do, Republic of Korea. One TD boy was excluded from the final analysis due to RTs exceeding three standard deviations from the mean. Demographic information for the participants included in the final analysis is presented in Table 3. All participants had normal or corrected-to-normal vision and were right-handed. The study procedures were approved by the Ethics Committee of the University.

Table 3. Participants' characteristics included in Experiment 2.

Group	Sex		Age	State Anxiety	Trait Anxiety
	Boy (%)	Girl (%)	M (SD)	M (SD)	M (SD)
ADHD (N = 21)	17 (81)	4 (19)	12.64 (1.29)	38.14 (7.84)	49.14 (9.54)
TDC (N = 25)	16 (64)	9 (36)	12.64 (1.07)	35.24 (5.39)	41.48 (9.14)

3.1.2. Tasks and Procedures

The Continuous Performance Task (CPT) was conducted using the same computer setup as in Experiment 1. Experiment 2 utilized the same CPT as Experiment 1 with one modification: instead of non-emotional place images, Experiment 2 included non-emotional neutral face stimuli along with angry face stimuli (Figure 3). Each set of face stimuli consisted of 4 women and 4 men, totaling 16 face stimuli. Apart from the types of distractors, all procedures, anxiety questionnaires, and statistical analyses remained identical to those in Experiment 1.

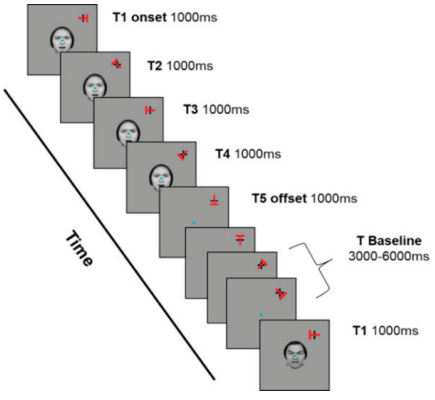

Figure 3. The attention task paradigm of Experiment 2.

3.2. Results

A three-way mixed ANOVA (2 (Group: ADHD/TDC) × 2 (distractor type: angry/neutral face) × 5 (time order: T1, T2, T3, T4, TB) conducted on the RT data in the CPT revealed a trend-level significance for the main effect of distractor type ($F(1, 44) = 3.91$, $p = 0.054$, $\eta^2 = 0.08$), indicating a potential difference in attentional bias between angry and neutral face stimuli (Table 4). Moreover, a significant main effect of time order was observed ($F(2.97, 130.85) = 11.83$, $p < 0.001$, $\eta^2 = 0.21$), suggesting variations in RTs across different time points. However, no significant interaction effect was found. Post hoc paired *t*-tests with Benjamini–Hochberg correction were conducted to explore the main effects of distractor type and time order (Figure 4).

Results indicated that ADHD children and TD children demonstrated differing patterns depending on the distractor type and time order. Specifically, ADHD children exhibited a significant attentional capture effect when the distractor was an angry face (T1; $t(20) = 2.85$, $p < 0.05$), whereas no significant attentional capture effect was observed with neutral face stimuli. Conversely, TD children demonstrated attentional capture effects for both angry and neutral face stimuli (T1; angry face: $t(24) = 7.22$, $p < 0.001$, neutral face: $t(24) = 4.95$, $p < 0.001$). In both groups, no significant attentional holding effects were observed for either distractor type (all *p*s > 0.5).

Table 4. An ANOVA table in Experiment 2.

	F	*p*	η^2
Distractor	$F(1, 44) = 3.91$	0.05	0.08
Time order	$F(2.97, 130.85) = 11.83$	<0.001	0.21
Group	$F(1, 44) = 0.13$	0.72	0.003
Distractor × Group	$F(1, 44) = 0.97$	0.33	0.02
Time order × Group	$F(4, 176) = 0.997$	0.41	0.02
Distractor × Time order	$F(2.81, 123.63) = 0.75$	0.56	0.02
Distractor × Time order × Group	$F(2.81, 123.63) = 0.38$	0.77	0.01

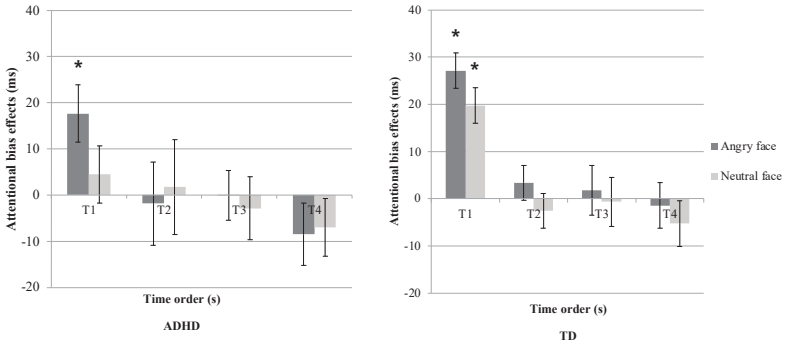

Figure 4. Attentional bias effect on the distractor type and time order in Experiment 2. (* indicates a significant effect with $p < 0.05$).

Correlation analyses were subsequently performed to examine the relationships between attentional bias scores and anxiety levels within each group. The results indicated a significant positive correlation between distraction effects induced by angry face stimuli and trait anxiety levels in ADHD children (r = 0.61, $p < 0.05$), suggesting that higher trait anxiety levels were associated with greater attentional capture effects by angry face stimuli in this group (Figure 5). However, no statistically significant correlations were found between state-trait anxiety levels and distraction effects in the TD group.

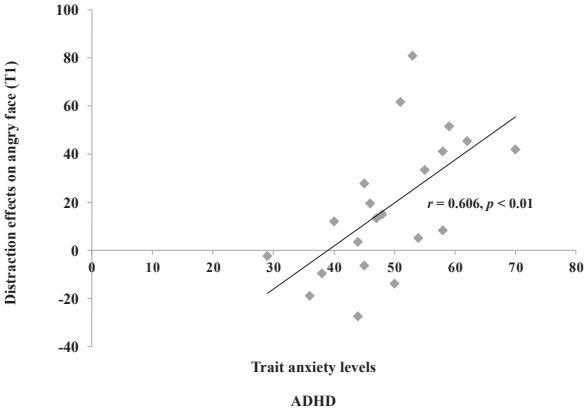

Figure 5. Correlation between trait anxiety and distraction effects on angry face in ADHD children in Experiment 2.

Of particular note, we observed a statistically significant correlation between trait anxiety levels and attentional capture scores solely in children with ADHD in Experiment 2. To thoroughly elucidate the disparity between the findings of the two experiments, we conducted an independent *t*-test to examine whether there was a difference in state and/or trait anxiety levels among ADHD children across the two experiments. The results revealed no significant disparity in state anxiety levels between the two experiments, whereas a significant difference was found in trait anxiety levels ($t(39) = -2.80$, $p < 0.01$). Specifically, the trait anxiety levels of ADHD children in Experiment 2 were significantly higher than those in Experiment 1. Furthermore, a statistically significant correlation was observed between attentional capture effects by angry face distractors and trait anxiety levels among all ADHD children across Experiments 1 and 2 ($r = 0.361$, $p < 0.01$; Figure 6).

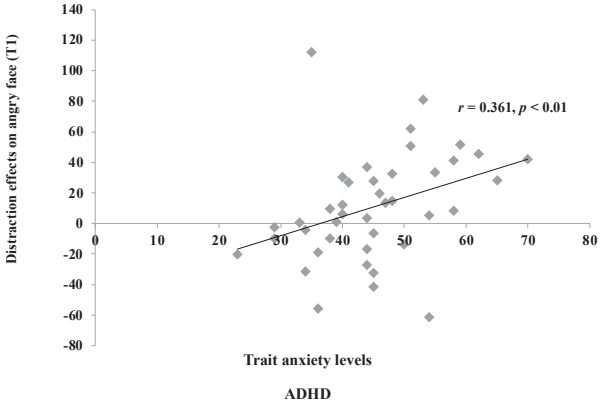

Figure 6. Correlation between trait anxiety and distraction effects on the angry face in all ADHD children.

Overall, our findings collectively suggest that ADHD children exhibit distinct attentional bias patterns compared to their TD counterparts, particularly in response to emotional facial stimuli. Additionally, our results indicate that trait anxiety may exert a differential influence on attentional processes in individuals with ADHD.

4. Discussion

Our study aimed to explore attentional bias patterns towards emotional facial stimuli in children with ADHD and TD. The findings from Experiment 1, which utilized angry face and place stimuli as distractors, indicated that ADHD children did not demonstrate significant attentional capture or attentional holding effects for either angry face or place stimuli. Conversely, TD children exhibited a significant attentional capture effect for both distractors, along with an attentional holding effect for place stimuli at T2.

In Experiment 2, which involved angry and neutral face stimuli as distractors, we found a significant attentional capture effect only for angry face distractors in children with ADHD. TD children, however, showed an attentional capture effect for all distractors but no attentional holding effect for any distractors. These findings in TD children are consistent with previous studies using the same task paradigm, where attentional capture effects but not holding effects were reported when all the distractors were from the same category (e.g., face) both in TD children [22] and in neurotypical adults [18,21]. Therefore, our findings suggest that children with ADHD exhibit atypical attentional bias patterns, characterized by reduced attentional capture effects by face distractors, with the exception of face stimuli displaying angry expressions.

Interestingly, children with ADHD in our study only exhibited attentional capture effects in response to angry face distractors in Experiment 2, while they did not display significant attentional bias effects towards neutral faces, neutral places, or angry face distractors in Experiment 1. These results prompt inquiries regarding the influence of anxiety levels on attentional orientation processes in children with ADHD. Our correlation analyses revealed that while no statistically significant correlation was found between distraction effects caused by angry face stimuli and trait anxiety levels in ADHD children in Experiment 1, a significant positive correlation was observed in Experiment 2. Conversely, no statistically significant correlations were found between distraction effects on angry or neutral face stimuli and state or trait anxiety levels in TD children across both experiments.

Subsequent analyses comparing anxiety levels in ADHD children between Experiment 1 and 2 revealed significantly higher anxiety levels in ADHD children in Experiment 2 than those in Experiment 1. Finally, correlation analyses including all ADHD children in our study also showed a significant positive correlation between trait anxiety levels and attentional bias scores to angry face distractors.

Overall, our findings suggest that anxiety levels in ADHD children, rather than attentional functions per se, play a crucial role in attentional orienting to emotional face stimuli. In other words, our findings indicate atypical attentional-orienting functions in children with ADHD, with anxiety levels modulating attentional-orienting functions toward angry face distractors.

In both experiments, TD children exhibited an initial attentional capture effect for all distractors, consistent with previous studies demonstrating such responses to sudden emergent stimuli [4,18,21,22]. However, unlike previous findings [18], our study revealed that TD children displayed attentional capture and holding effects for place stimuli rather than face stimuli when the context of distractors was inconsistent (e.g., place and face). These discrepancies from prior research may be attributed to the type of place stimuli employed in our study. Specifically, the place stimuli we utilized reflected foreign cultures, potentially differing culturally from places in Republic of Korea. Since human cultural contexts can influence cognitive and attentional functions [36], participants in our study may have exhibited different attentional patterns compared to those in previous studies. Thus, future research should consider modifying place stimuli to align with the cultural context.

In contrast, children with ADHD did not demonstrate attentional capture or attentional holding effects for either angry face or place stimuli in Experiment 1. This finding is consistent with previous research indicating deficits in covert orienting attention in individuals with ADHD [11,12,37]. Parks et al. [18] reported that unconscious attentional capture occurred irrespective of stimulus type when stimuli suddenly appeared in a typically developing population. However, given the attentional-orienting difficulties observed in ADHD children, their pattern of attentional capture effects may differ from that of TD children. Thus, ADHD children did not exhibit attentional capture for either angry face or place stimuli.

However, Experiment 2 yielded contrasting results, with ADHD children showing an initial attentional bias effect towards angry face distractors. This finding deviates from previous studies [23,24], which reported no attentional bias towards negative emotional stimuli in ADHD children. This discrepancy may be explained by differences in anxiety levels among children with ADHD. Although the same angry face stimuli were used in both experiments, varying anxiety levels were observed among ADHD children in Experiments 1 and 2. Specifically, significant differences in trait anxiety levels were evident, with ADHD children exhibiting higher trait anxiety scores in Experiment 2 compared to those in Experiment 1. Moreover, all ADHD children across both experiments demonstrated a statistically significant correlation between trait anxiety levels and distraction effects caused by angry face stimuli. These findings suggest that attentional bias towards negative facial stimuli in ADHD children may be affected by their anxiety levels.

In previous studies [23,24], where anxiety levels were not measured in ADHD children, no attentional bias towards negative facial stimuli was observed. Specifically, the face-dot probe task used in previous research presented a cue to the target stimuli by presenting a probe, which appeared at the same or opposite site after the face stimuli [24]. Therefore, attentional bias effects may not be consistently reported because facial emotional stimuli and target stimuli are related to each other. However, our study presented task-irrelevant distractors, allowing us to confirm the impact of facial emotions on attention as completely unrelated distractors. Additionally, the previous study did not compare ADHD children with TD children [24]. Another previous study using an eye-tracking paradigm did not consider cover attention, which is attention without eye movements [23]. In contrast, our study was able to measure covert attention by orienting attention without eye movements.

Furthermore, our examination of anxiety levels revealed that ADHD children with high trait anxiety may exhibit an attentional bias towards negative facial emotions. This is consistent with studies examining attentional bias for threats among individuals with high trait anxiety or social anxiety [19–21,26,27,38]. Specifically, individuals with higher anxiety levels are more likely to allocate attention to stimuli with negative emotions than

those without emotions [19,20,38]. Additionally, high levels of trait anxiety are associated with susceptibility to threat-related emotional stimuli [26,27].

Overall, the results from Experiments 1 and 2 suggest that ADHD children exhibit deficits in orienting attention, thereby failing to appropriately allocate attention to stimuli. Consequently, ADHD children may lack early attentional capture not only for angry and neutral facial stimuli but also for place stimuli. Furthermore, the observed attentional bias towards angry face distractors in ADHD children with high anxiety levels suggests that psychological characteristics, such as anxiety, may prompt attentional allocation to threatening facial stimuli rather than compensating for orienting attention deficits [20,38].

In TD children, a greater attentional capture effect was noted for angry face distractors compared to neutral face distractors, given their sensitivity to salient threatening cues in the environment [39]. Specifically, angry face stimuli may evoke heightened sensitivity among TDC, as they serve as social cues directly communicating threats in the environment [40–42]. Furthermore, no statistically significant correlations were found between distraction effects on angry face stimuli and state/trait anxiety levels in TDC. These findings align with previous studies [22,43] that reported no relationship between distraction effects on negative emotional stimuli and anxiety levels. Thus, the initial attentional bias toward negative face distractors in TDC appears to be a developmental characteristic sensitive to threatening stimuli rather than anxiety levels.

Several limitations of our study are worth mentioning. Firstly, there was an imbalance in the gender ratio among participants, with more boys than girls in both groups. Although the gender ratio was statistically insignificant between the ADHD and the TD groups in both experiments, the proportion of girls was slightly lower in the ADHD group than in the TD group. This gender bias in recruitment aligns with the higher prevalence of ADHD among boys compared to girls [2]. While the reasons for the imbalanced prevalence rates between genders in ADHD are still unclear, recent research has discussed differences in parent perceptions of ADHD behaviors in girls and the necessity of assessing additional behavioral and emotional problems in girls [44]. Although recent studies have indicated no significant gender differences in the cognitive functioning of children with ADHD [45,46], achieving gender balance in future studies can be beneficial for a comprehensive understanding of ADHD. Second, the potential impact of cultural differences on the stimuli in Experiment 1 should be considered. As discussed earlier, cultural contexts can influence cognitive and attentional functions [36], and our use of pictures of foreign places as distractors might have contributed to the different attentional patterns observed in our study compared to previous research. Future studies should consider modifying place stimuli to better align with the cultural context of the participants, ensuring that the stimuli are culturally relevant and recognizable. This adjustment could provide a more accurate assessment of attentional biases and reduce potential confounding effects related to cultural differences. Third, our study identified a significant positive correlation between trait anxiety levels and attentional bias towards threatening facial stimuli in children with ADHD. To further elucidate the relationship between attentional bias and varying anxiety levels, future research should differentiate between children with ADHD who exhibit high anxiety levels and those with low anxiety levels. Additionally, incorporating a variety of anxiety scales to measure levels of anxiety in participants would be valuable. Lastly, our study did not control for eye movements and employed adult face stimuli as distractors. Future studies could utilize eye-tracking technology to more accurately investigate the attentional bias patterns toward emotional stimuli in children with ADHD. Considering that individuals are more accurate in perceiving face stimuli of their own age group [47], employing child face stimuli for child participants could enhance the precision of measuring attentional mechanisms.

Despite these limitations, our study is significant as the first to investigate attentional bias towards emotional face stimuli over time in children with ADHD, revealing that orienting attentional deficits in ADHD are modulated by their anxiety levels. Ultimately, our findings suggest that anxiety may affect attentional orienting in children with ADHD. Moreover, our findings indicate that children with ADHD may struggle to allocate attention

not only to emotional face stimuli but also to place stimuli, likely due to difficulties in orienting attention. While previous research has predominantly focused on improving executive and vigilance attention in the treatment and evaluation of ADHD [7,8], our results highlight the importance of addressing deficits in orienting attentional mechanisms in interventions for children with ADHD. Specifically, our results suggest that interventions for children with ADHD should incorporate strategies to manage anxiety, as anxiety levels appear to influence attentional orienting. By addressing anxiety, it may be possible to improve the orienting attention of children with ADHD, thereby enhancing their ability to process both emotional and neutral stimuli effectively. Furthermore, developing specific attention assessment tools that include measures of orienting attention could lead to more targeted and effective treatment plans. These tools could help identify children who are particularly affected by anxiety-related attentional biases, allowing for personalized intervention strategies that address both attentional and emotional regulation needs.

While our research provides novel evidence of attentional-orienting mechanisms in children with ADHD and the modulation effects of an individual's anxiety levels on the orienting function, it will be worthwhile to explore whether such effects are also found in adults with ADHD. Additionally, future research could enhance our understanding of individuals with ADHD by utilizing various emotional stimuli, such as happy faces/scenes, or unpleasant stimuli, such as disgusting faces/scenes. Finally, future research could employ a broader range of anxiety measures, such as assessments of social anxiety or general anxiety, to elucidate the effects of anxiety on attentional orienting in individuals with ADHD in greater detail.

Author Contributions: Conceptualization, S.-Y.K.; methodology, S.-Y.K. and J.-H.S.; software, S.-Y.K.; validation, S.-Y.K.; formal analysis, S.-Y.K. and J.-H.S.; investigation, J.-H.S.; resources, S.-Y.K.; data curation, S.-Y.K. and J.-H.S.; writing—original draft preparation, J.-H.S.; writing—review and editing, S.-Y.K.; visualization, S.-Y.K.; supervision, S.-Y.K.; project administration, S.-Y.K.; funding acquisition, S.-Y.K. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Duksung Women's University (protocol code 2021-001-003-A and approved on 30 January 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Individual data are protected and thus are not shareable.

Conflicts of Interest: The authors declare no conflicts of interest.

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Neurodevelopmental Impairments in Adult Psychosomatic Patients

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Abstract: Background/Objectives: Neuropsychological, neurodevelopmental, or minimal cerebral dysfunctions (MCD) can be found in many patients with mental disorders. They can be masked by other symptoms, impair the course of the illness, and impair work and social participation. Despite a long history of research, there is still a lack of data on the spectrum, prevalence, and consequences of these dysfunctions in patients with chronic illness. In this study, we compared patients with and without a history of neurocognitive problems in childhood for present neuropsychological dysfunctions. **Methods**: A convenience sample of 1453 psychosomatic inpatients completed the MCD scale, assessing neurodevelopmental issues in childhood and current neuropsychological dysfunctions. Additional assessments were the Attention Deficit Hyperactivity Self Rating Scale (ADHS-SB) and the Symptom Checklist 90 (SCL-90). **Results**: Significant early neurodevelopmental problems were reported by 8.87% of the patients. This group also reported a significantly higher rate of MCD symptoms and general psychosomatic symptoms (SCL-90) as compared with other patients. **Conclusions**: There is a notable prevalence of neuropsychological dysfunctions in psychosomatic patients in general, and especially in those with early neurodevelopmental problems. To adequately address specific potentially participation-relevant impairments, a broader diagnostic approach is necessary, including exploration of MCD history and present neuropsychological dysfunctions.

Keywords: minimal cerebral dysfunction; partial performance disorders; capacity impairments; neurodevelopmental problems; neuropsychological dysfunctions

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1. Introduction

Neuropsychological dysfunctions can be found in many mental disorders. These are deficits in memory, attention, executive functions, and perception [1–3] with a wide range of variations between and within specific disorder categories [4]. For patients with schizophrenia spectrum disorders deficits in motor function, working memory, executive functions, and processing speed have been reported [5]. Patients with addictive disorders often show deficits in executive control, working memory, and decision-making [6]. Affective disorders come along with deficits in executive functions and verbal memory [7]. In anxiety patients, impairments in executive functions, verbal memory, short-term memory, and attention deficits have been found [8,9]. Patients with schizotypal personality disorder have deficits in working memory [10,11]. In borderline patients, attention deficits and emotional processing deficits are commonly found [12].

Neuropsychological or minimal cerebral dysfunctions (MCD) are found in almost all cases of attention deficit hyperactivity disorder (ADHD) and autism spectrum disorders [13–17]. These disorders do not only exhibit the core symptoms like attention deficits and hyperactivity or social withdrawal but also a broad spectrum of additional neuropsychological performance deficits as can already be taken from established ADHD scales,

which all list many additional dysfunctions [18,19]. Such problems are not found in all patients with respective diagnoses but are only facultative symptoms and impairments. MCDs nevertheless have a negative impact on the course of illness, the suffering of patients, and most importantly their participation in life.

The causes of MCDs can be manyfold and can often not be identified in individual patients [20–22]. There is some agreement that they often stem from minor organic brain damage or structural peculiarities of the brain. Another term for these problems, therefore, has been minimal brain damage (MBD) [23], because the spectrum of symptoms resembles the dementia syndrome, like deficits in memory and learning, emotional control, activity and drive, executive functions, and formal thought disorders. There is evidence that genetic factors [24], brain injury during pregnancy and birth [23,25,26], traumatic brain injury in childhood [27], and meningitis [28] can lead to (neuro)psychological developmental disorders which in many cases persist into adulthood [29]. Similarly, primordial symptomatology also shows associations with neuropsychological impairments in childhood and adulthood. This could be shown, among others, for infantile enuresis [30], nail biting [31], dyslexia [32], math problems [33], motor impairments [34], and hyperarousal [35]. The assumption that deficits simply disappear in adulthood is considered highly unlikely [36]. Irrespective of the causation of MCDs, there is evidence that early cerebral damage and neuropsychological impairment can predict mental disorders such as schizophrenia [37], anxiety disorders [38], depression [39], or personality disorders [40]. Studies have suggested that neuropsychological dysfunctions are more reliable predictors of stress, functioning, and treatment outcomes than disorder-related symptoms [41–44]. Furthermore, several investigations indicate that cognitive remediation therapy (CRT) can significantly improve neuropsychological deficits and have a meaningful impact on patients' functioning across different diagnostic groups, independent of the primary diagnosis [45–47].

The literature strikingly underscores that neurodevelopmental disorders (NDDs) and other mental illnesses are frequently associated. Additionally, it indicates that neuropsychological impairments often serve as better predictors of illness progression and treatment outcomes compared to disorder-specific symptoms. However, few studies systematically investigate the full spectrum of neurodevelopmental problems in childhood and their related neuropsychological impairments and psychiatric symptom patterns in adulthood.

The diversity and clinical significance of neurodevelopmental impairments have often been obscured in both scientific and clinical contexts by a predominant focus on conditions such as ADHD. This narrow focus has concentrated interest on a limited set of symptoms, leaving many aspects underexplored. Moreover, many studies tend to investigate only isolated and specific neurodevelopmental disorders.

In this context, a broader term, such as "complex neuropsychological dysfunctions" or "minimal cerebral dysfunctions (MCD)", may be more appropriate to encompass the full range of issues. Given the variety of comorbidities, MCD requires distinct attention beyond primary diagnoses. As neurodevelopmental deficits are long-term issues that typically emerge in early childhood or even during pregnancy, early reports of related problems are crucial for recognition and diagnosis. An important research and clinical question is the extent to which such early reports are associated with MCD in later life. Data on this issue could enhance our understanding of the problem and assist in identifying patients at risk.

In the present study, we investigated a convenience sample of German patients at a psychosomatic hospital who were suffering from various psychosomatic disorders. We examined the frequency of reports of neurodevelopmental problems in childhood, their relationship with persistent neuropsychological dysfunctions in adulthood, and analyzed their correlates. The overarching goal was to explore the extent to which neurodevelopmental problems in childhood are associated with "complex neuropsychological dysfunctions" or "minimal cerebral dysfunctions (MCD)" in adulthood and to identify how affected patients may differ from other patients with mental illness across various characteristics.

2. Materials and Methods

2.1. Sample

A total of 1453 German participants were treated at a psychosomatic hospital because of various mental disorders. The routine intake assessment was in part computer based, so that the resulting data could be used for scientific analyses. The data collection took place over a two-year period, during which all patients completed the questionnaires used in this study as part of routine diagnostics after admission. Clinical diagnoses were made by the treating physicians in reference to ICD-10 criteria. Work-related information was explored by social workers according to a standardized interview checklist. Patients had a mean age of 49.14 years (SD = 9.28), with the majority being female (65.17%). The primary clinical diagnoses, as determined by their therapists, included depression (39.26%), anxiety or stress-related disorders (34.69%), personality disorders (13.93%), developmental disorders (4.84%), and schizophrenia spectrum disorders (1.49%). Additionally, 20.68% of patients presented with at least one comorbid condition.

2.2. Instruments

2.2.1. The MCD Checklist

The MCD checklist is a validated screening instrument, which asks for concrete, circumscribed, and observable neurodevelopmental problems in childhood and at present. Thereby, two dimensions are explored: (1) the history of neuropsychological phenomena, and (2) present symptoms.

(1) The history part of the MCD checklist asks whether concrete phenomena of minor organic brain damages had happened (6 items, e.g., "I have already had a serious accident involving the head (e.g., unconsciousness)."), and "primordial symptoms" (13 items, e.g., "I know that I had problems with learning to walk.") [19,48,49]. This part of the scale starts with the introductory statement: "If I think about my childhood, then I know or have been told. . ." which is followed by items like "that there were problems during my birth". This is answered by "not true", "may be true", "possibly true", "true", "definitely true". If participants indicate in the history part, that at least six severe or very severe problems (rating 3 or 4) have existed, then they can be classified as persons with developmental problems (DP) [48,50].

(2) The second part of the MCD checklist explores 51 present neuropsychological dysfunctions, i.e., "orientation" (3 items, e.g., "In large or winding buildings or department stores, I have no sense of where to get out."), "memory" (5 items, e.g., "I have problems recognizing faces."), "cognition" (7 items, e.g., "Grammar or a lot of complicated subordinate clauses get me off track."), "vegetative lability" (7 items, e.g., "Noise always quickly becomes too much for me."), "emotionality"(8 items, e.g., "I quickly get into different emotional states."), "motor skills" (7 items, e.g., "When it comes to dancing, I'm rather clumsy."), "attention" (6 items, e.g., "Careless mistakes happen to me quickly."), and "activity"(6 items, e.g., "I am constantly active and on the move."). Each item is rated on a Likert scale from "0 = not true at all" to "4 = very severe". An item was considered to be clinically relevant, when the symptom severity was rated with "3 = severe" and "4 = very severe", to exclude minor and irrelevant complaints. In clinical practice, therapists are advised to look at the spectrum of reported complaints and then make a specific examination of the problem.

A validation of the MCD checklist was carried out with a large sample of German patients (N = 1346) from a psychosomatic clinic [48,50]. The results demonstrated strong psychometric properties, with the scale showing satisfactory internal consistency, as indicated by a Cronbach's alpha of 0.811 [48]. For scientific use of the MCD checklist a sum scores for all items or separately for both dimensions (history, present symptoms) can be calculated to get an idea of the overall symptom load [50]. In sum, the MCD checklist catches a broad spectrum of "neuropsychological and minimal cerebral dysfunctions",

which are (or have been in history) concrete and observable, and which are present in adulthood and come along with relevant impairments [19,48,49].

2.2.2. ADHS-SB (Attention Deficit Hyperactivity Self Rating)

The ADHS-SB is a self-report questionnaire to assess ADHD symptoms in adults, with the subscales "inattention" and "hyperactivity-impulsivity" [51,52]. It is an adaptation of the Wender ADHD scale and based on the definitions in ICD-10 and DSM-IV. The items of the ADHS-SB are answered on a Likert scale from "0 = not true at all" to "3 = severe". Based on the recommendation only items with a rating of at least "2 = moderate" or higher have been considered in our study [52]. Following the authors, the cut-off for ADHD was set at 18, which allows an ADHD diagnosis with a sensitivity of 65% and a specificity of 92% [52].

2.2.3. SCL-90-R

The SCL-90 is a self-rating scale with 90 items, to assess general psychological distress [53]. There are nine subscales like aggressiveness/hostility, anxiety, depressiveness, paranoid thinking, phobic anxiety, psychoticism, somatization, insecurity in social situations, and compulsivity. Ratings are made on a five-point Likert-scale ranging from "0 = not at all" to "4 = very strong". The global severity index (GSI) represents the average over all items.

2.3. Design and Statistics

All patients routinely filled in the above-described scales at the point of admission to the hospital. They were then divided into those with developmental problems (DP group) and without developmental problems (comparison group) according to the MCD checklist history section (Table 1). The cut-off was 6 positive history items out of 19. Warnke, based on the validation sample, proposed a cut-off of at least positive 4 history items for classification into the MCD group. However, considering the distribution of response frequencies observed in the validation study, we opted for a more conservative cut-off value of 6 positive history items to enhance specificity. The rating of severity had to be at least 3 or 4 to exclude minor or unclear memories.

Table 1. Self-reported developmental disorders and primordial problems (DP) in childhood.

MCD Checklist: History	Total Sample (N = 1453)	DP Group (N = 129)	Comparison Group (N = 1324)	Significance of Difference between DP Group and Comparison Group
Minor organic brain damages				
Somatic stress of the mother during pregnancy	10.32%	36.43%	7.78%	$\chi^2 = 104.26$ $p < 0.001$
Mental stress of the mother during pregnancy	11.70%	45.73%	8.38%	$\chi^2 = 158.75$ $p < 0.001$
Difficult birth	17.48%	53.48%	13.97%	$\chi^2 = 127.24$ $p < 0.001$
Meningitis	3.03%	4.65%	2.87%	$\chi^2 = 1.2698$ $p = 0.2704$
Traumatic brain injury	14.04%	40.31%	11.48%	$\chi^2 = 80.953$ $p < 0.001$
Failure to thrive	8.33%	31.01%	6.12%	$\chi^2 = 95.39$ $p < 0.001$
Primordial symptoms in childhood				
Delayed motor development	3.23%	15.50%	2.04%	$\chi^2 = 68.084$ $p < 0.001$
Delayed language development	4.54%	17.83%	3.25%	$\chi^2 = 57.642$ $p < 0.001$
Bedwetting	6.81%	30.23%	4.53%	$\chi^2 = 122.29$ $p < 0.001$

Table 1. *Cont.*

MCD Checklist: History	Total Sample (*N* = 1453)	DP Group (*N* = 129)	Comparison Group (*N* = 1324)	Significance of Difference between DP Group and Comparison Group
Thumb-sucking	22.16%	64.34%	18.05%	$\chi^2 = 146.01$ $p < 0.001$
Tics	2.27%	8.53%	1.66%	$\chi^2 = 24.962$ $p < 0.001$
Hyperarousal	15.97%	65.11%	11.17%	$\chi^2 = 254.88$ $p < 0.001$
Hyperactivity	12.73%	51.94%	8.91%	$\chi^2 = 195.84$ $p < 0.001$
Distractibility	16.17%	72.09%	10.73%	$\chi^2 = 326.52$ $p < 0.001$
Dyslexia	12.60%	44.19%	9.52%	$\chi^2 = 128.35$ $p < 0.001$
Dyscalculia	10.81%	44.19%	7.55%	$\chi^2 = 163.68$ $p < 0.001$
Learning or memory disorder	9.15%	47.29%	5.44%	$\chi^2 = 247.56$ $p < 0.001$
Motor deficits	11.01%	32.56%	8.91%	$\chi^2 = 67.07$ $p < 0.001$
Social outsider	12.87%	40.31%	10.20%	$\chi^2 = 95.06$ $p < 0.001$
Mean history symptoms				
Total Anamnese (19 items)	Mean = 2.05 MD = 1.00 (SD = 2.30)	Mean = 7.46 MD = 7.00 (SD = 1.62)	Mean = 1.53 MD = 1.00 (SD = 1.55)	U = 0 $p < 0.001$
Early brain damages (6 items)	Mean = 0.65 MD = 0.00 (SD = 0.96)	Mean = 2.12 MD = 2.00 (SD = 1.34)	Mean = 0.51 MD = 0.00 (SD = 0.78)	U = 26,444 $p < 0.001$
Primordial symptoms (13 items)	Mean = 1.40 MD = 1.00 (SD = 1.80)	Mean = 5.34 MD = 5.00 (SD = 1.76)	Mean = 1.02 MD = 1.00 (SD = 1.26)	U = 4926.5 $p < 0.001$

The resulting two groups of patients were compared regarding their present MCD symptomatology, their clinical diagnoses, and other correlates. Depending on the data type relative frequencies, mean values, median, and standard deviation were compared. To assess significant differences between the two groups, chi-square tests were applied for categorical variables, while Mann–Whitney U tests were conducted for continuous variables. Data analysis was performed using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

We took data from 1453 unselected patients from the hospital files. Clinical diagnoses, as given by their therapists, were depression in 39.26% of patients, anxiety, or stress disorders in 34.69%, personality disorders in 13.93%, developmental disorders in 4.84%, and schizophrenia spectrum disorders in 1.49%, with 20.68% having at least one comorbid disorder. Criteria for developmental disorders according to our criteria (DP group) were fulfilled by 8.87% of patients.

Table 1 shows the frequencies of self-reported developmental and primordial problems in childhood according to the MCD checklist. It also reports if there are significant differences in the occurrence of these problems between the DP group and the comparison group. DP patients reported birth problems in 53%, maternal mental stress during pregnancy in 46%, traumatic brain injury in 40%, failures to thrive in 31%, and distractibility (72.09%), hyperarousal (65.11%), thumb-sucking (64.34%), and hyperactivity (51.94%), learning problems (47%), dyslexia (44%), dyscalculia (44%), social problems (40%), and motor deficits (33%). In the control group, these rates were significantly and clinically relevant lower. The scope of the burdens of symptoms and differences between the DP group and controls can also be taken from the means of developmental problems.

As shown in Table 2, differences in symptom burden between the DP group and the comparison group were found across all domains of the MCD scale. But there were nevertheless also many MCD symptoms reported by the control patients. In the orientation domain, most common among DP patients were orientation problems (37.98% in DP group vs. 22.23% in the comparison group) and number reversal (20.93% vs. 3.70%). Regarding memory most frequent were word finding difficulties (50.38% vs. 23.94%) and general memory difficulties (42.63% vs. 19.03%). Cognitive and speech problems were preferably stumbling over words (52.71% vs. 22.28%) and prolixity (41.86% vs. 17.60%). Problems in vegetative regulation were noise intolerance (62.02% vs. 42.44%), tiredness (47.29% vs. 27.49%), and exhaustion (44.96% vs. 20.54%). Common emotion regulation problems were difficulties in calming down (55.81% vs. 31.95%), affect incontinence (55.04% vs. 48.87%), lack of serenity (51.94% vs. 31.95%), and affective lability (51.94% vs. 31.34%). In the motor domain, there were problems with handwriting (37.98% vs. 14.35%), dancing (35.66% vs. 21.83%), and neurological soft signs (34.88% vs. 16.62%). Regarding attention distractibility (54.26% vs. 17.67%), slip errors (58.14% vs. 21.75%), and mental leaps (51,94% vs. 24.92%) were most frequent. Activity and drive impairments were difficulties standing in line (48.84% vs. 20.85%), sit restlessness (40.31% vs. 16.77%), and hyperactivity (31.78% vs. 19.94%).

Table 2. Self-reported severe and very severe present MCD symptoms in patients with (DP group) and without (comparison group) developmental problems.

MCD Checklist: Present Neuropsychological Dysfunctions	Total Sample (N = 1453)	DP Group (N = 129)	Comparison Group (N = 1324)	Significance of Difference between DP Group and Comparison Group
Orientation				
Orientation in a foreign apartment	2.96%	6.98%	2.57%	$\chi^2 = 7.9559$ $p < 0.05$
Orientation problems in the forest	21.27%	34.88%	19.94%	$\chi^2 = 15.678$ $p < 0.01$
Orientation problems in foreign cities	23.54%	37.98%	22.13%	$\chi^2 = 16.418$ $p < 0.001$
Orientation problems in foreign builidings	16.72%	31.78%	15.26%	$\chi^2 = 23.051$ $p < 0.001$
Number reversal	5.23%	20.93%	3.70%	$\chi^2 = 70.393$ $p < 0.001$
Memory				
Recognize faces	9.08%	20.93%	7.93%	$\chi^2 = 24.051$ $p < 0.001$
Remember names	27.80%	48.06%	25.83%	$\chi^2 = 28.941$ $p < 0.001$
Remember numbers	15.62%	34.88%	13.75%	$\chi^2 = 39.841$ $p < 0.001$
Word finding difficulties	26.29%	50.38%	23.94%	$\chi^2 = 42.421$ $p < 0.001$
Memory difficulties	21.13%	42.63%	19.03%	$\chi^2 = 39.295$ $p < 0.001$
Cognition				
Word confusion	12.53%	31.00%	10.73%	$\chi^2 = 44.134$ $p < 0.001$
Stumble over words	24.98%	52.71%	22.28%	$\chi^2 = 58.087$ $p < 0.001$
Grammar problems	12.94%	40.31%	10.27%	$\chi^2 = 94.155$ $p < 0.001$
Social awkwardness	20.23%	48.06%	17.52%	$\chi^2 = 67.925$ $p < 0.001$
Word fluency	17.62%	37.21%	15.71%	$\chi^2 = 37.433$ $p < 0.001$
Prolixity	19.75%	41.86%	17.60%	$\chi^2 = 43.654$ $p < 0.001$
Stuttering	17.07%	40.31%	14.80%	$\chi^2 = 54.026$ $p < 0.001$

Table 2. *Cont.*

MCD Checklist: Present Neuropsychological Dysfunctions	Total Sample (N = 1453)	DP Group (N = 129)	Comparison Group (N = 1324)	Significance of Difference between DP Group and Comparison Group
Vegetative lability				
Tiredness	29.25%	47.29%	27.49%	$\chi^2 = 22.256$ $p < 0.001$
Noise tolerance	44.18%	62.02%	42.44%	$\chi^2 = 18.251$ $p < 0.001$
Vitality	22.57%	36.43%	21.22%	$\chi^2 = 15.56$ $p < 0.001$
Exhaustion	22.71%	44.96%	20.54%	$\chi^2 = 39.925$ $p < 0.001$
Hyperexcitability	18.58%	37.21%	16.77%	$\chi^2 = 32.467$ $p < 0.001$
Headache	20.44%	24.81%	20.02%	$\chi^2 = 1.6592$ $p = 0.2074$
Hypersensitivity	23.26%	33.33%	22.28%	$\chi^2 = 8.0438$ $p < 0.01$
Emotions				
Quick temper	30.28%	49.61%	28.40%	$\chi^2 = 25.056$ $p < 0.001$
Lack of serenity	33.72%	51.94%	31.95%	$\chi^2 = 21.014$ $p < 0.001$
Affective lability	33.17%	51.94%	31.34%	$\chi^2 = 22.487$ $p < 0.001$
Affect incontinence	49.42%	55.04%	48.87%	$\chi^2 = 1.7912$ $p = 0.2059$
Undiplomatic behavior	11.22%	22.48%	10.12%	$\chi^2 = 18.03$ $p < 0.001$
Difficulties calming down	34.07%	55.81%	31.95%	$\chi^2 = 29.806$ $p < 0.001$
Affective instability	26.02%	39.53%	24.70%	$\chi^2 = 13.444$ $p < 0.01$
Aggressiveness	14.32%	24.03%	13.37%	$\chi^2 = 10.895$ $p < 0.01$
Motor Skills				
Handwriting	16.45%	37.98%	14.35%	$\chi^2 = 47.775$ $p < 0.001$
Fine motor skills (drying glasses)	4.68%	11.63%	4.00%	$\chi^2 = 15.32$ $p < 0.01$
Fine motor skills (steady hand)	12.66%	27.13%	11.25%	$\chi^2 = 26.795$ $p < 0.001$
Irregular gait	8.12%	24.81%	6.50%	$\chi^2 = 52.819$ $p < 0.001$
Motoric suppleness	12.66%	27.91%	11.18%	$\chi^2 = 29.743$ $p < 0.001$
Dancing	23.06%	35.66%	21.83%	$\chi^2 = 12.676$ $p < 0.001$
Neurological Soft Signs	18.24%	34.88%	16.62%	$\chi^2 = 26.305$ $p < 0.001$
Attention				
Distractibility	20.92%	54.26%	17.67%	$\chi^2 = 95.12$ $p < 0.001$
Slip errors	24.98%	58.14%	21.75%	$\chi^2 = 83.044$ $p < 0.001$
Mental leaps	27.32%	51.94%	24.92%	$\chi^2 = 43.197$ $p < 0.001$
Impatience in listening	20.72%	40.31%	18.81%	$\chi^2 = 33.093$ $p < 0.001$
Misplacing things	19.89%	37.21%	18.20%	$\chi^2 = 26.651$ $p < 0.001$
Patience	15.83%	30.24%	14.42%	$\chi^2 = 22.043$ $p < 0.001$

Table 2. *Cont.*

MCD Checklist: Present Neuropsychological Dysfunctions	Total Sample (*N* = 1453)	DP Group (*N* = 129)	Comparison Group (*N* = 1324)	Significance of Difference between DP Group and Comparison Group
Activity and drive				
Urge to move	16.59%	28.68%	15.41%	$\chi^2 = 14.971$ $p < 0.001$
Sit restlessness	18.86%	40.31%	16.77%	$\chi^2 = 42.579$ $p < 0.001$
Increased activity level	20.99%	31.78%	19.94%	$\chi^2 = 9.9415$ $p < 0.001$
Difficulties standing in line	23.33%	48.84%	20.85%	$\chi^2 = 51.488$ $p < 0.001$
Impulsiveness in conversation	10.94%	23.26%	9.74%	$\chi^2 = 22.024$ $p < 0.001$
Annoying others	10.74%	20.16%	9.82%	$\chi^2 = 13.104$ $p < 0.001$
Mean MCD symptoms				
MCD symptoms without anamnesis (51 items)	Mean= 10.35 MD = 8.00 (SD = 9.27)	Mean = 19.22 MD = 18.00 (SD = 11.10)	Mean = 9.48 MD = 7.00 (SD = 8.60)	U = 40,390 $p < 0.001$
Orientation (5 items)	Mean = 0.70 MD = 0.00 (SD = 1.18)	Mean = 1.33 MD = 1.00 (SD = 1.58)	Mean = 0.64 MD = 0.00 (SD = 1.12)	U = 64,364 $p < 0.001$
Memory (5 items)	Mean = 0.99 MD = 0.00 (SD = 1.31)	Mean = 1.97 MD = 2.00 (SD = 1.60)	Mean = 0.90 MD = 0.00 (SD = 1.24)	U = 50,698 $p < 0.001$
Cognition (7 items)	Mean = 1.25 MD = 0.00 (SD = 1.95)	Mean = 2.92 MD = 2.00 (SD = 2.47)	Mean = 1.09 MD = 0.00 (SD = 1.82)	U = 46,143 $p < 0.001$
Vegetative lability (7 items)	Mean = 1.81 MD = 1.00 (SD = 1.71)	Mean = 2.86 MD = 3.00 (SD = 1.87)	Mean = 1.71 MD = 1.00 (SD = 1.67)	U = 54,674 $p < 0.001$
Emotions (8 items)	Mean = 2.32 MD = 2.00 (SD = 2.31)	Mean = 3.50 MD = 3.00 (SD = 2.49)	Mean = 2.21 MD = 1.00 (SD = 2.26)	U = 59,242 $p < 0.001$
Motor skills (7 items)	Mean = 0.96 MD = 0.00 (SD = 1.36)	Mean = 2.00 MD = 1.00 (SD = 1.90)	Mean = 0.86 MD = 0.00 (SD = 1.24)	U = 53,688 $p < 0.001$
Attention (6 items)	Mean = 1.30 MD = 0.00 (SD = 1.77)	Mean = 2.72 MD = 3.00 (SD = 2.17)	Mean = 1.16 MD = 0.00 (SD = 1.66)	U = 48,874 $p < 0.001$
Activity and drive (6 items)	Mean = 1.01 MD = 0.00 (SD = 1.49)	Mean = 1.93 MD = 1.00 (SD = 1.87)	Mean = 0.93 MD = 0.00 (SD = 1.41)	U = 56,912 $p < 0.001$

Furthermore, we calculated sum scores reflecting the number of severe problems (severity 3/4) per patient. The second part of Table 2 presents the mean values derived from these sum scores for the respective groups. The differences between groups were mostly significant and clinically relevant.

Patients with a striking neuropsychological history (DP group) were more frequently diagnosed with personality disorders (ICD-10 F6) at a rate of 20.00%, developmental disorders (ICD-10 F8) at 17.60%, and disorders with onset in childhood and adolescence (ICD-10 F8) at 2.40%, compared to the comparison group, as shown in Table 3.

Table 4 shows sociodemographic data for the DP group and the comparison group. There are significant differences which suggest that DP patients are globally more burdened as seen by the GSI score (mean = 1.62 vs. mean = 1.14), are more often single, less often married, have a lower education and more often no vocational qualification. Regarding age, no significant differences were found between the groups.

Table 3. Distribution of clinical diagnosis in patients with (DP group) and without (comparison group) developmental problems.

ICD-10 Primary Diagnoses	DP Group (*N* = 129)	Comparison Group (*N* = 1324)	Significance of Difference between DP Group and Comparison Group
Diagnostic categories			
F1: Mental and behavioral problems due to psychotropic substances	0.00%	2.79%	$\chi^2 = 3.583$ $p = 0.05947$
F2: Schizophrenic disorders	2.40%	1.40%	$\chi^2 = 0.77696$ $p = 0.4308$
F3: Affective disorders	27.20%	40.51%	$\chi^2 = 8.4199$ $p < 0.05$
F4: Anxiety and adjustment disorders	28.00%	34.35%	$\chi^2 = 2.042$ $p = 0.1729$
F5: Behavioral dysfunctions associated with somatic problems	2.40%	2.55%	$\chi^2 = 0.0099532$ $p = 1.00$
F6: Personality disorders	20.00%	13.31%	$\chi^2 = 4.2286$ $p < 0.05$
F7: Intelligence disorders	0.00%	0.90%	$\chi^2 = 1.1392$ $p = 0.4158$
F8: Developmental disorders	17.60%	3.53%	$\chi^2 = 48.667$ $p < 0.001$
F9: Behavioral and emotional disorders beginning in childhood or youth	2.40%	0.66%	$\chi^2 = 4.2345$ $p = 0.07696$
One or more comorbid disorders			
Yes	32.56%	22.72%	$\chi^2 = 19.822$ $p < 0.01$
No	67.44%	77.28%	

Table 4. Sociodemographic data of patients with (DP group) and without (comparison group) developmental problems.

		Total Sample (*N* = 1453)	DP Group (*N* = 129)	Comparison Group (*N* = 1324)	Significance of Difference between DP Group and Comparison Group
GSI-Score		Mean = 1.19 (SD = 0.66)	Mean = 1.62 (SD = 0.75)	Mean = 1.14 (SD = 0.64)	U = 53,004 $p < 0.001$
ADHD (ADHS-SB)					$\chi^2 = 64.25$ $p < 0.001$
	Yes	14.59%	38.76%	12.24%	
	No	85.41%	61.24%	87.76%	
Age		Mean = 49.14 (SD = 9.28)	Mean = 47.26 (SD= 10.01)	Mean = 49.32 (SD = 9.19)	U = 81,780 $p = 0.03911$
Sex					$\chi^2 = 6.9056$ $p < 0.01$
	Male	34.83%	45.73%	33.76%	
	Female	65.17%	54.26%	66.24%	
Relationship status					$\chi^2 = 19.885$ $p < 0.01$
	Single	22.00%	36.43%	20.59%	
	Married	55.03%	39.53%	56.54%	
	Divorced	19.59%	20.16%	19.53%	
	Widowed	2.90%	3.10%	2.88%	
	Other	0.48%	0.78%	0.45%	
Education					$\chi^2 = 30.079$ $p < 0.001$
	No school degreee	0.90%	4.65%	0.53%	
	Basic education	12.41%	19.38%	11.73%	
	Secondary education degree	56.76%	51.94%	57.23%	
	High school	29.17%	23.26%	29.75%	
	Other	0.76%	0.78%	0.76%	
Vocational qualification					$\chi^2 = 18.227$ $p < 0.001$
	Apprenticeship	71.31%	73.64%	71.08%	
	Master	3.86%	0.78%	4.16%	
	University degree	19.03%	13.18%	19.61%	
	No degree	4.62%	10.85%	4.01%	
	Other	1.17%	1.55%	1.14%	

4. Discussion

This study has five major results. The first result is that approximately one in ten psychosomatic patients reports neurodevelopmental and primordial problems in childhood. There are events which are known to be risk factors for brain impairment like maternal somatic but also psychological stress during pregnancy [54,55], difficult birth [56], traumatic brain injury [57] and brain infections [58]. Such factors do not in all cases result in brain damage but can have a negative impact on the brain structure of the child. This can occur globally or regionally, and accordingly have different neuropsychological consequences. In some cases, the growing brain can compensate such defects. In others, they will persist or at least lead to changes in the further brain development. Considering these many options, it becomes evident that there must be a great heterogeneity of such problems regarding their type and severity. The question is whether the rate of approximately ten percent is plausible. It can be compared with other clear cut brain defects. In the general population, there are approximately 1% of severe mental handicaps [59]. Different disorders are associated with mental impairment and clearly related to early childhood or prenatal brain damage. These include cerebral palsy, the prevalence of which is estimated at 2/1000 live births [60], or epilepsy, with an estimated prevalence of almost 1% [61]. There are prevalence rates up to 11% of distinct neuropsychological abnormalities in children, like legasthenia, dyscalculia, attention deficit problems and many others [62]. Given that we did not investigate a sample of the general population but psychosomatic patients, the observed rate is quite plausible. In summary, the data show that neurodevelopmental problems should receive proper attention when taking patient history [63]. This seems to be especially true for ADHD patients. Patients in the DP group report ADHD symptoms significantly more often on the ADHD-SB scale. The results suggest that ADHD-specific symptoms may play a role in patients with neurodevelopmental problems, but not necessarily [49]. However, even in the control group, one in ten patients is conspicuous on the ADHD-SB scale. Methodological weaknesses due to the use of self-report questionnaires should be discussed at this point. It is possible that individual primordial symptoms are not remembered retrospectively or were not considered in the MCD questionnaire.

The second important result of our study shows why it is important to ask for neurodevelopmental and primordial problems in childhood. They are significant predictors of current minimal cerebral dysfunctions. Our findings support results from many other studies which show that (neuro)psychological developmental disorders in childhood correspond to MCDs in adulthood and do not simply disappear in the further course of development [15,36,64,65]. When comparing DP patients with other psychosomatic patients, who also suffer from relevant mental disorders, nevertheless significant and relevant differences can be observed.

The third important result of our study is, that it gives an idea of the manifoldness of possible MCDs, and supports similar finding from other authors [1–3]. They cover the full spectrum of organic brain disorders and dementia syndromes. This includes problems with orientation, memory, thinking, vegetative regulation, mood control, motor skills, attention, drive, and activity. Though in much lower rates, all symptoms are also reported by control patients. This may be explained by basic problems with self-rating scales, as individual persons may misunderstand individual items or tend to complain about everything. It may also be because such symptoms can be part of other mental disorders, which is true for mood regulation or autonomic stability, for example. The conclusion is that MCD cannot be diagnosed by looking at single symptoms or by counting symptoms but needs a prototypical diagnostic approach [66].

The fourth important result of this study is that MCDs affect patients with different clinical diagnoses. In our sample, patients with various clinical diagnoses have reported neurodevelopmental problems in childhood and symptoms of MCD in adulthood. This was particularly evident for personality disorder, disorders of psychological development, and behavioral and emotional disorders. This aligns with previous research highlighting the presence of neuropsychological deficits in developmental disorders [67], ADHD [16,18,19],

and personality disorders [11]. These findings emphasize the cross-diagnosis relevance of the MCD concept in adult psychiatry.

The fifth important result is that our data confirm, that MCD has a direct impact on daily life and participation of affected persons. MCD patients show significantly lower education levels, occupational development, and family integration.

In psychotherapy, it may happen that these social problems are recognized and interpreted as causes of the present symptoms. Our data recommend changing this view and understand the symptoms as cause of social problems. Furthermore, MCD problems should be understood as mental handicap, because they are chronic, rest over the lifetime (history and present symptoms), and come along with impairment in fulfilling daily duties. In some cases, cognitive remediation therapy (CRT) may help patients to restore patients' functioning [45–47]. In most cases, training and psychotherapy will not be able to change the core of the problem. Instead, treatment must focus on compensation, for example following the SOC- model (selection, optimization, compensation) under a rehabilitative perspective [68]. This means first to make a precise diagnosis of strengths and deficits. This speaks for the importance of a specific assessment of MCDs. The next step is to focus on the strength and even optimize these by training. Deficits which must be endured need compensatory strategies including the adaptation of the environment in the sense of person–environment fit.

Limitations

When interpreting our results, methodological limitations must be considered. First, it should be noted that the ADHD questionnaire and the MCD checklist are self-rated. There is a potential for bias. It cannot be ruled out that the data are biased, for example, due to a fundamentally increased tendency of patients to complain or because primordial symptoms are no longer remembered (e.g., pregnancy difficulties of the mother). However, the MCD checklist asks for very concrete circumscribed phenomena which can be observed by the person himself and by others, and which are regularly well known and reportable (people know whether they have problems with orientation, or calculation). We have not performed additional objective assessments of selected neuropsychological phenomena. However, there is a broad variety of phenomena, and it would not be possible to assess all problems which are collected in the MCD checklist. Further clinical observations of reported present neuropsychological problems, and performance in selected neuropsychological tests, would add to the structured exploration in future studies. Furthermore, only psychosomatic inpatients were studied here. Results may be different in other clinical populations. Clinical diagnoses were made by therapists, so their validity can be questioned. Due to economic reasons in clinical basic routine diagnostic, we only have basic information on the functional level and participation restrictions in daily life. Further explorations of capacity impairments based on the International Classification of Functioning, Disability, and Health (ICF) would be useful [69].

5. Conclusions

Neuropsychological dysfunctions are common in psychosomatic patients. Patients with self-reported neurodevelopmental problems in their medical history show a significantly higher MCD symptom burden than comparison patients. MCD can be observed across all diagnostic groups, but patients with personality disorder, disorders of psychological development, behavioral and emotional disorders, and schizophrenia spectrum disorders tend to experience higher burdens. The inadequate consideration of MCD symptoms and mild neuropsychological impairments poses a significant issue in the clinical setting, as this patient group exhibits more severe impairments compared to other individuals with mental illness. Therefore, further research is necessary to investigate the prevalence of MCD symptoms in different populations and explore potential treatment approaches. Further research studies should also investigate whether diffuse MCD symptomatology can be objectified by neuropsychological testing and derive specific therapeutic

and compensatory interventions. Therapy manuals for the treatment of neuropsychological dysfunctions are needed. Specific symptom- and function-related interventions in MCD patients might be more effective than global, disorder-related therapies.

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Informed Consent Statement: Data are from a large routine dataset. Therefore, other data analysis and publications with different research questions are carried out based on this dataset. The department management and the hospital management approved the use of the data and post hoc analyses for scientific purposes. Since the data are fully anonymized, subsequent use for research purposes without the consent of the patients is also possible in accordance with the GDPR.

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Article

A New Objective Diagnostic Tool for Attention-Deficit Hyper-Activity Disorder (ADHD): Development of the Distractor-Embedded Auditory Continuous Performance Test

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Abstract: Background/Objectives: Attention-Deficit Hyperactivity Disorder (ADHD) is a prevalent neurodevelopmental disorder characterized by inattention, hyperactivity, and impulsivity. Traditional diagnostic methods, which depend on subjective assessments, often lack precision. This study evaluates the validity and reliability of a newly developed diagnostic tool, the Distractor-Embedded Auditory Continuous Performance Test (da-CPT), which integrates auditory stimuli with distractors to enhance the clinical utility of ADHD diagnosis. **Methods**: The study included 160 children aged 6–12 years, comprising 80 with a confirmed ADHD diagnosis and 80 controls. All participants completed the da-CPT, a web-based tool designed to assess inattention, hyperactivity, impulsivity, and timing via an auditory-based task. To validate the da-CPT, participants also completed the Conners' Parent Rating Scale—Revised Short Form (CPRS-R) and either the MOXO or IVA-2 tests. Data were analyzed using ROC curves and statistical correlations to assess sensitivity, specificity, and overall diagnostic accuracy. **Results**: The da-CPT demonstrated high diagnostic accuracy, with a sensitivity of 91.25% and specificity of 83.75%. ROC analysis indicated that the inattention index had the highest discriminatory power (AUC = 0.881), followed by timing, impulsivity, and hyperactivity (all $p < 0.01$). Furthermore, the da-CPT scores were strongly correlated with ADHD severity ($p < 0.01$). **Conclusions**: This study confirms that the da-CPT is a valid and reliable tool for diagnosing ADHD in children aged 6–12. By incorporating auditory stimuli and distractors, the tool offers a more ecologically valid assessment of ADHD symptoms in clinical settings, improving diagnostic precision and utility.

Keywords: Attention-Deficit/Hyperactivity Disorder (ADHD); Continuous Performance Test; diagnostic tools; auditory stimuli; distractors; Child Psychiatry

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a neuropsychiatric disorder that begins in childhood and is characterized by symptoms of inattention, hyperactivity, and impulsivity that are inappropriate for the person's age [1]. In recent epidemiological studies, the prevalence of ADHD was reported to be 5.9–7.1% in the world [2], while it was shown to be 12.4% in Turkey [3]. ADHD has a considerable and widespread impact, not only on childhood development but also on adulthood, leading to serious consequences. ADHD individuals commonly encounter difficulties in academic achievement, social interactions,

and, later, occupational functioning. These challenges can result in various secondary problems, including lowered self-esteem, interpersonal conflicts, and increased susceptibility to substance abuse [4]. The enduring nature of ADHD's impact on an individual's life trajectory underscores the critical need for accurate and reliable diagnostic methods. Due to the diverse etiology and behavioral manifestations of ADHD, there is no unique test for diagnosis available. The most widely accepted approach for diagnosing involves utilizing the DSM-5 criteria for clinical evaluations, which usually entails gathering data from various sources, such as parents and teachers, conducting a clinical interview with the child to obtain their perspective, making observations, and utilizing neuropsychological tests [5]. Although traditional approaches are essential, they have limited predictive validity, are based on subjective assessments, and are susceptible to biases from clinicians and informants [6]. Subjectivity in diagnosis may result in inconsistencies and potential risks of overdiagnosis or underdiagnosis, especially for groups like girls [7–9]. To address these challenges, it is recommended that incorporating objective assessment tools like continuous performance tests (CPT) in clinical investigations on ADHD could enhance diagnostic sensitivity [10].

The CPT is a computer program characterized by the rapid presentation of a series of visual and/or auditory stimuli (typically numbers, letters, sequences of numbers/letters, or geometric shapes) over a period [11]. Participants are asked to respond when a specific target appears but not to respond to non-targets. While the response to non-target stimuli is called "commission error", the absence of a response to target stimuli is called "omission error" [12]. Typically, CPT measures selective attention, sustained attention, and impulsivity, which are the main symptoms of ADHD. The participant's omission errors measure selective attention, commission errors measure impulsivity, and sustained attention is measured by performance during the test, including response time and reaction time variability [5]. CPTs have been used in many studies to distinguish between ADHD and non-ADHD groups, and in most of these studies, it has been shown that the CPT performance of ADHD groups is worse [13–15]. Several studies have examined factors influencing CPT performance. These studies have found that performance is influenced by external factors such as time of day, gender, and presence of noise, as well as intrinsic factors like task parameters and distractor inclusion [16–18]. For instance, various parameters derived from visual target stimulus-based CPTs are associated with selective attention, impulsivity-hyperactivity, sustained attention, and vigilance. However, Ogundele et al. (2011) state that it is not clear whether CPT's auditory or visual tasks evaluate the same deficits in ADHD [19]. In a recent study, it was found that inattention was partially independent of the sensory modality, response inhibition (hyperactivity/impulsivity) was modality-specific (visual or auditory target stimulus), and children with ADHD performed lower in the auditory modality [14]. In another study, when discriminant functions were evaluated separately for visual and auditory CPT variables, it was shown that specificity for the auditory task was higher than the visual one. The findings suggest that auditory stimulus is more effective than visual stimulus in differentiating individuals with ADHD from those without the disorder [15]. Therefore, in recent years, interest has shifted from CPTs based on classical visual stimuli to CPTs in which auditory stimuli are the main target. This shift is supported by the idea that auditory stimuli can more accurately simulate attention-demanding tasks in real-life settings, such as classrooms, thus providing greater ecological validity [20,21].

Ecological validity in neuropsychological tests refers to the extent to which the test results accurately reflect real-world outcomes. Individuals with ADHD encounter real-life environments with different distractions, such as visual, auditory, and mixed stimuli. Distractors often impact attention levels. Different distractor characteristics can affect individual performance in cognitive tasks [22]. As with traditional CPTs, neurocognitive tasks used to evaluate patients with ADHD are generally free of distracting stimuli. Therefore, it is assumed that traditional CPTs have low ecological validity, which may explain the weak relationship between CPT performance and behavioral measures measuring attention deficit and hyperactivity [23]. In parallel with this assumption, CPT paradigms containing

auditory and visual distractors have been reported to be more reliable and sensitive for the diagnosis of ADHD in children and adolescents than traditional CPTs that do not contain distractors [12].

Contrary to this assumption, it has been suggested recently that individuals with ADHD benefit from distractors and that their cognitive functions can be improved with appropriate stimulation [24]. In a recent study, it was stated that the VR-RVP performance of ADHD and control groups did not differ significantly under conditions with and without distractors [23]. Although distractors are considered to increase ecological validity in ADHD diagnosis, they appear to have a complex effect on CPT performance [25]. Therefore, new studies are needed to develop the most appropriate CPT paradigm using distractors. For example, although it has been suggested in current studies [13–15] that auditory target stimulus-based CPTs are more sensitive than visual target stimulus-based CPTs for the diagnosis of ADHD, the effect of distractors on auditory target stimulus-based CPT performance is unknown.

Upon comprehensive evaluation of all the findings, it was determined that there is a necessity to develop an objective tool that assists in diagnosing ADHD while also amending the shortcomings of existing CPTs. To address this requirement within the clinical setting, we have recently developed a novel distractor-embedded auditory continuous performance test (da-CPT). This tool aims to overcome the limitations of existing CPTs by integrating auditory stimuli with a variety of distractors to enhance its ecological validity and clinical utility. The primary aim of this study is to evaluate the validity and reliability of da-CPT in diagnosing ADHD in children aged 6–12 years diagnosed with ADHD through a semi-structured diagnostic interview. The secondary objective is to assess the clinical utility of da-CPT in differentiating between individuals with ADHD and those without the disorder and determine the accuracy of da-CPT's variable distributions and the proposed diagnostic threshold for ADHD in terms of sensitivity and specificity.

This study represents a significant advancement in the field of ADHD diagnostics, offering a more accurate and reliable approach to clinical assessment through the use of a highly ecologically valid testing paradigm. The main contributions of this study are as follows:

- Development and validation of the da-CPT, a novel tool that integrates auditory stimuli with distractors to enhance ecological validity.
- Demonstration of the da-CPT's effectiveness in providing a more accurate real-world assessment of ADHD symptoms, particularly in environments with auditory distractions.
- Comparison of the da-CPT's performance with established tools like MOXO d-CPT [26] and IVA-2 [27], highlighting its high diagnostic accuracy.
- Provision of evidence with high corelation WISC-R test supporting the da-CPT's clinical utility as a reliable and objective diagnostic tool for ADHD in children.

2. Materials and Methods

The da-CPT has a novel approach by incorporating both auditory and visual distractors across its various stages to simulate real-world environments, thus enhancing the ecological validity of the test. This section outlines the participant selection process, the structure of the da-CPT, the technological infrastructure, the scoring method, and the statistical analyses used in the study.

2.1. Participants

The study's participants were recruited from the Child and Adolescent Psychiatry outpatient clinic at Gazi University Faculty of Medicine during the period spanning from November 2019 to June 2022. The study included two groups: an ADHD group and a control group. Participants needed to have an IQ of 85 or higher, as measured by the Wechsler Intelligence Scale for Children-Revised (WISC-R) [28]. This criterion was implemented for both the ADHD and control groups to reduce the influence of cognitive impairment on da-CPT performance. The recruitment of participants with typical cognitive function ($IQ \leq 85$) ensured that the da-CPT results specifically indicated ADHD-related

attentional deficits, excluding the influence of broader cognitive dysfunction. The ADHD group comprised children between the ages of 6 and 12 who had been diagnosed with ADHD according to the DSM-5 criteria, utilizing the Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version-DSM-5 Turkish Adaptation (K-SADS-PL-DSM-5-T). The exclusion criteria encompassed the presence of comorbid psychiatric disorders, neurological or metabolic diseases, use of any psychoactive drug one month before the application, and having a total IQ score below 85 in the WISC-R test. The control group consisted of children who were of comparable age and sociodemographic features. These children were seeking help at the clinic for non-psychiatric concerns, such as difficulties in family relationships or school adjustment. The inclusion criteria for this study involved individuals who did not have any psychiatric diagnosis after undergoing the K-SADS-PL-DSM-5-T evaluation [29]. The exclusion criteria for this group were the same as those for the ADHD group. Informed consent was obtained from all participants and their parents.

2.2. Distractor-Embedded Auditory Continuous Performance Test (da-CPT)

The Distractor-Embedded Auditory Continuous Performance Test (da-CPT) is a novel, web-based assessment tool. The da-CPT evaluates auditory attention and sustaining attention, response inhibition, hyperactivity, and timing, which are the clinical symptoms of ADHD. The present test encompasses 16 min and is composed of eight distinct sections. At the core of da-CPT lies the auditory-based task, wherein participants are required to promptly press the 'space' key upon hearing the target auditory stimulus. The meow of the cat, which serves as the target stimulus, is presented at the beginning of the test, and the participant is instructed to press the "space" key on the keyboard only once as soon as the target stimulus is heard. In addition, they are instructed not to respond to non-target stimuli, thereby facilitating the assessment of selective attention and impulsivity. The failure to respond to the target stimulus is regarded as an omission error, which provides insight into the attention profile. Response time variability, which encompasses the duration between the target stimulus and the subsequent response and any fluctuations in response time throughout the testing period, measures the timing profile. The act of responding to a non-target stimulus is classified as a commission error. This type of error is indicative of an impulsivity profile, which is a measure of response inhibition. The analysis of excessive or inappropriate responses, such as multiple vital presses or pressing keys other than the 'space' key, is conducted to evaluate the hyperactivity profile. In addition, the test includes both visual (such as images of animals) and auditory distractors (such as ring tones or a baby crying), along with target and non-target stimuli. The addition of distractors serves the purpose of generating real-life situations, thus improving the ecological validity of the test. In this study, the validity and reliability of the da-CPT performance profile in the diagnosis of ADHD were evaluated. The structure of da-CPT, its technological infrastructure, including the rationale behind its design, the types of stimuli used, and its innovative features that distinguish it from other continuous performance tests are detailed in Appendix A.

2.2.1. MOXO Continuous Performance Test (MOXO-CPT)

The MOXO-CPT, developed by Neuro-Tech Solutions Ltd., is a standardized neuropsychological test administered via computer that employs a visual target paradigm [25,26]. The MOXO-CPT distinguishes itself from other CPTs by including additional distractor stimuli designed to simulate real-world distractions. This test has been validated as a reliable and valid tool for assessing ADHD symptoms in children aged 7 to 12 years [26]. In this study, the MOXO-CPT's performance profile was utilized as a comparative measure to validate the da-CPT's effectiveness in screening for ADHD symptoms.

2.2.2. Integrated Visual and Auditory Continuous Performance Test, Version 2 (IVA-2)

The IVA-2 is a widely recognized X-type CPT that integrates both auditory and visual stimuli to assess attentional capacities [27]. The IVA-2, which typically takes 15 min to complete, is a valid and reliable tool for aiding in the diagnosis of ADHD and assessing symptom severity in individuals aged 6 years and above. In this study, the IVA-2 served as an additional comparative tool to evaluate the da-CPT's diagnostic validity and reliability.

2.2.3. Wechsler Intelligence Scale for Children-Revised (WISC-R)

The Wechsler Intelligence Scale for Children-Revised (WISC-R) is a well-established tool for measuring children's cognitive abilities [28]. It assesses both verbal and performance IQ, providing a comprehensive measure of cognitive functioning. The WISC-R has been validated and standardized in the Turkish population, ensuring its reliability and applicability within this study. The WISC-R was employed to determine the IQ levels of all participants, ensuring that any observed differences in da-CPT performance were not confounded by variations in cognitive ability.

2.2.4. Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version-DSM-5-Turkish Version (K-SADS-PL-DSM-5-T)

The K-SADS-PL-DSM-5-T is a semi-structured diagnostic interview designed to evaluate both current and past psychiatric disorders in children and adolescents [29]. This tool integrates information from multiple sources, including the child, parents, and clinical observations, to produce a comprehensive diagnostic assessment. It has been adapted and validated for use in Turkish populations, aligning with the DSM-5 diagnostic criteria. In this study, the K-SADS-PL-DSM-5-T was used to confirm the psychiatric diagnoses of all participants.

2.2.5. Conners' Parent Rating Scale-Revised Short Form (CPRS-R:S)

The CPRS-R:S is a widely used tool for assessing the severity of ADHD symptoms and monitoring treatment efficacy over time [30]. It consists of 27 items, each rated on a 4-point Likert scale ranging from 0 (not at all) to 3 (very frequently). The scale has been translated into Turkish, and its validity and reliability in the Turkish population have been confirmed. In this study, the CPRS-R:S was utilized to assess the severity of ADHD symptoms and to evaluate the accuracy and consistency of the da-CPT in identifying these symptoms.

2.3. Procedure

After the purpose and method of the research were verbally explained, the parents of the participants who agreed to participate in the study were given the CPRS–R: S. Sociodemographic data such as age, gender, and class of both the ADHD group and the control group were recorded on the forms prepared for this study. The ADHD diagnosis was established by an experienced child and adolescent psychiatrist in accordance with DSM-5 criteria, utilizing the K-SADS-PL-DSM-5-T. The same screening procedure was conducted for the control group, and none fulfilled the criteria for ADHD. Moreover, the K-SADS-PL-DSM-5-T were administered to ascertain whether participants fulfilled the diagnostic criteria for psychiatric disorders, which would serve as an exclusion criterion. None of the participants exhibited any psychiatric disorders as delineated in the exclusion criteria based on the K-SADS-PL-DSM-5-T assessment. In the case group, WISC-R was applied to children aged 6–12 years who did not have any additional psychiatric disorders other than ADHD, according to the DSM-5 diagnostic criteria, and after a semi-structured psychiatric interview with the K-SADS-PL-DSM-5-T. In the control group, WISC-R was applied to children who did not have any psychiatric diagnosis after a semi-structured psychiatric interview with DSM-5 diagnostic criteria and the K-SADS-PL- DSM-5-T. After the WISC-R application, da-CPT was applied under expert supervision to the participants who received an IQ score of 85 and above. Participants who underwent da-CPT were randomly administered MOXO CPT or IVA-2 within 3–7 days, at the same time, room, and

computer as da-CPT, under the same expert supervision. The ethics committee's approval of this study was obtained from the Gazi University Faculty of Medicine Ethics Committee (Decision No. 38, 2018).

2.4. Statistical Analysis

Statistical analyses were performed to evaluate the diagnostic accuracy and reliability of the da-CPT in identifying ADHD-related symptoms, ensuring the study's objectives were rigorously met. Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 24.0 and Python. Descriptive statistics, including means, standard deviations, and percentages, were calculated for demographic variables. Sensitivity, specificity, false positive and negative rates, and predictive values of the da-CPT were determined using standard formulas. Additionally, the general accuracy rate and Youden index were calculated to assess the test's diagnostic value.

Receiver Operating Characteristic (ROC) analysis was used to determine the normative values of the da-CPT, with the area under the ROC curve (AUC) serving as the measure of diagnostic accuracy. Higher AUC values indicate better diagnostic performance, interpreted as follows: 0.90–1.00 (excellent), 0.80–0.90 (good), 0.70–0.80 (moderate), 0.60–0.70 (poor), and 0.50–0.60 (fail) [31]. Independent samples *t*-tests compared da-CPT variable scores between the ADHD and control groups, while Pearson correlation analysis examined relationships between the ADHD index and da-CPT variables. The chi-square test was used to compare qualitative variables, with statistical significance set at a p-value of less than 0.05. The power analysis was calculated using the G*Power 3.1.9.7 software. It was determined that at least 64 participants per group would be required to detect a difference with an effect size of 0.5, 80% power, and an alpha error of 0.05. The test development process generally recommends [32] at least 10 participants per step. To further strengthen the study, we included 80 participants in each group (ADHD and control), exceeding the minimum requirement, with similar gender ratios, mean ages, and socioeconomic levels in each group.

3. Results

This section presents a comprehensive evaluation of the da-CPT's effectiveness in diagnosing ADHD in children aged 6–12 years. The analysis includes demographic comparisons between the ADHD and control groups, assessments of diagnostic accuracy through sensitivity and specificity metrics, and ROC curve analyses to evaluate overall performance. Additionally, correlations between da-CPT sub-index scores and ADHD severity, as measured by the Conners' Parent Rating Scale—Revised Short Form (CPRS-R:S), are examined. Comparative analyses with established tools like the MOXO-CPT and IVA-2 are also included to validate the robustness and reliability of the da-CPT in clinical settings.

3.1. Participant Demographics

The demographic characteristics of the participants, including age, gender, and IQ scores, were compared between the ADHD and control groups to ensure no significant differences that could confound the results. As shown in Table 1, statistical analyses, including *t*-tests and chi-square tests, confirmed that the groups were well-matched on these variables, with no significant differences in age or gender distribution, thereby supporting the validity of subsequent cognitive and behavioral comparisons.

Table 1. Demographic Characteristics of ADHD and Control Groups.

Characteristic	ADHD Group (n = 80)	Control Group (n = 80)	*p*-Value
Age (months)	111.08 ± 21.55	112.06 ± 21.03	0.821 [1]
Gender			0.282 [2]
Boys (%)	62 (77.5%)	56 (70.0%)	
Girls (%)	18 (22.5%)	24 (30.0%)	

[1] Independent sample *t*-test, [2] Pearson Chi-square test.

3.2. Diagnostic Accuracy of da-CPT

The diagnostic accuracy of the da-CPT in identifying ADHD was evaluated by calculating key metrics such as sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). These metrics offer a comprehensive understanding of the test's ability to correctly identify ADHD cases (true positives) and exclude non-ADHD cases (true negatives). To further validate its effectiveness, the da-CPT's performance was compared with established tools like the MOXO-CPT and IVA-2. The evaluation was conducted by analyzing key metrics, including sensitivity, specificity, and the Youden Index, which provide insight into each test's ability to correctly identify ADHD cases and exclude non-ADHD cases. As shown in Table 2, the da-CPT demonstrated high sensitivity and specificity, confirming its reliability as a diagnostic tool for ADHD and highlighting its effectiveness when integrated with other cognitive assessment tools.

Table 2. Diagnostic Accuracy Metrics for da-CPT, MOXO-CPT, and IVA-2.

	da-CPT (n = 160)	MOXO (n = 87)	IVA-2 (n = 73)
Sensitivity	91.25% (CI: 82.80–96.41%)	86.05% (CI: 72.07–94.70%)	86.11% (CI: 70.50–95.33%)
Specificity	83.75% (CI: 73.82–91.05%)	84.09% (CI: 69.93–93.36%)	86.49% (CI: 71.23–95.46%)
Youden Index	0.75	0.71	0.73

CI: confidence interval.

As shown in Table 3, the diagnostic accuracy metrics, including sensitivity, specificity, and AUC values, demonstrate that the da-CPT outperforms the MOXO-CPT and IVA-2 in correctly identifying ADHD cases. The area under the curve (AUC) values indicate the effectiveness of these tools in distinguishing between ADHD and control groups. This is further illustrated in Figure 1, where the ROC curves highlight the higher diagnostic performance of the da-CPT, with a higher AUC, indicating its greater effectiveness in distinguishing between ADHD and control groups.

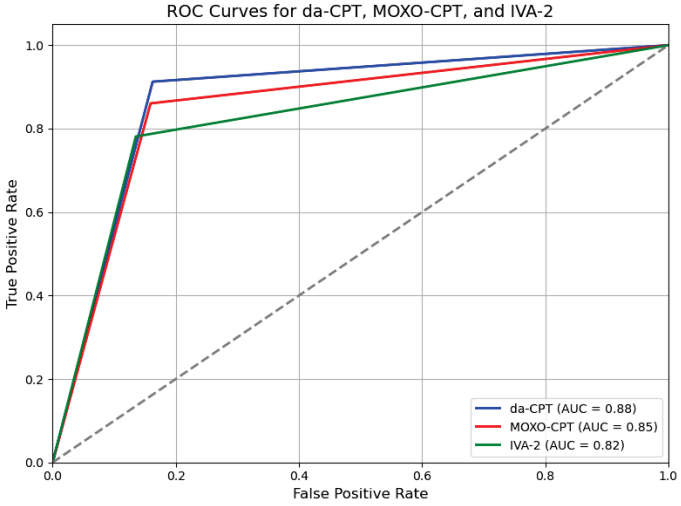

Figure 1. ROC Curves for da-CPT, MOXO-CPT, and IVA-2.

Table 3. ROC Analysis for da-CPT, MOXO-CPT, and IVA-2 in Determining ADHD.

Test	AUC (95% CI)	Cut-Off Scores	*p*-Value	Sensitivity (%)	Specificity (%)
da-CPT Inattention	0.881 (0.824–0.938)	72.6	0.001	87.5	83.5
da-CPT Timing	0.812 (0.743–0.881)	47.89	0.001	80.0	72.5
da-CPT Impulsivity	0.760 (0.685–0.836)	9.84	0.001	72.5	71.2
da-CPT Hyperactivity	0.742 (0.662–0.822)	9.50	0.001	70.0	67.2
MOXO-CPT	0.850 (0.790–0.910)	50.75	0.002	82.0	78.0
IVA-2	0.820 (0.760–0.880)	48.5	0.002	80.0	75.0

3.3. Correlation Between da-CPT Sub-Indices and ADHD Severity

To further assess the clinical utility of the da-CPT, we analyzed the correlations between its sub-indices (inattention, timing, impulsivity, and hyperactivity) and ADHD severity as measured by the Conners' Parent Rating Scale—Revised Short Form (CPRS-R:S). Table 4 presents the correlation matrix between da-CPT sub-index scores and CPRS-R:S ADHD index scores reveals significant relationships between these variables. ADHD severity, as measured by the CPRS-R:S, was found to be negatively correlated with the inattention and timing sub-indices, and positively correlated with the impulsivity and hyperactivity sub-indices. These findings suggest that higher ADHD severity is associated with lower performance on attention and timing tasks, and greater impulsivity and hyperactivity as measured by the da-CPT. Additionally, Figure 2 visually represents these relationships through scatter plots, highlighting the linear trends between da-CPT scores and CPRS-R:S ratings.

Table 4. Correlation between da-CPT Sub-Indices and ADHD Severity (CPRS-R:S Scores).

Variables	ADHD Index Score	Inattention	Timing	Impulsivity	Hyperactivity
ADHD Index Score	1				
Inattention	−0.494 **	1			
Timing	−0.474 **	0.805 **	1		
Impulsivity	0.285 **	−0.350 **	−0.329 **	1	
Hyperactivity	0.271 **	−0.314 **	−0.213 **	0.535 **	1

** $p < 0.01$.

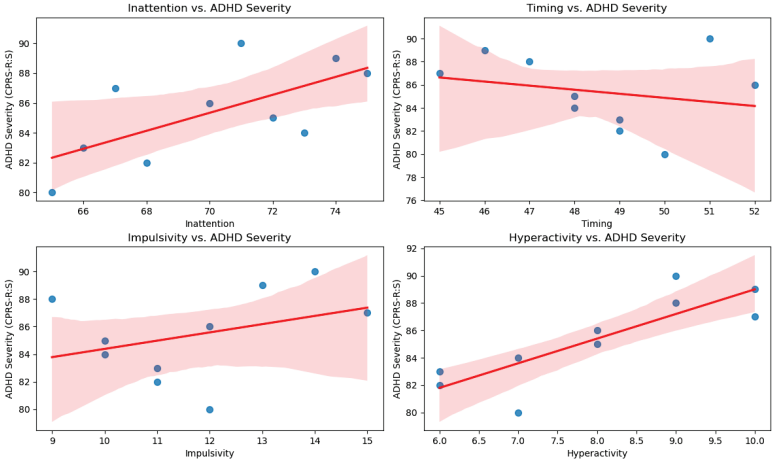

Figure 2. Scatter plots showing the linear relationships between da-CPT sub-index scores (Inattention, Timing, Impulsivity, Hyperactivity) and ADHD severity as measured by CPRS-R:S.

In addition to the correlation analysis, the comparison of da-CPT sub-index scores between the ADHD and control groups also revealed significant differences, as shown in

Table 5. The ADHD group had lower mean scores in inattention and timing but higher scores in impulsivity and hyperactivity compared to the control group. between ADHD and non-ADHD populations. These findings underscore the diagnostic utility of the da-CPT in distinguishing between ADHD and non-ADHD populations.

Table 5. Comparison of ADHD and Control Groups by scores of sub-index of the da-CPT.

Variable	Groups	N	Mean	SD	t	*p* *
da-CPT Inattention	ADHD	80	58.12	14.06	−8.84	<0.001
	Control	80	75.73	10.94		
da-CPT Timing	ADHD	80	35.01	13.23	−7.90	<0.001
	Control	80	50.32	11.19		
da-CPT Impulsivity	ADHD	80	15.22	8.70	6.21	<0.001
	Control	80	8.57	3.99		
da-CPT Hyperactivity	ADHD	80	21.46	17.24	6.10	<0.001
	Control	80	8.53	7.90		

SD: standard deviation, *: Independent sample *t*-test.

4. Discussion

This study evaluated the diagnostic accuracy of the da-CPT for ADHD in children and adolescents aged 6–12 years. We determined the sensitivity, specificity, Youden Index (YI) values, and separate cut-off values for the four subscales. The analysis of these values indicates that the da-CPT has strong discriminant validity, sensitivity, and specificity in diagnosing ADHD in this age group. This highlights its potential as a valuable assistive tool in diagnosing ADHD in children and adolescents.While these results emphasize its potential as a valuable tool in clinical settings for assessing ADHD symptoms, the study should be considered as an initial exploration.

The da-CPT exhibited strong diagnostic accuracy, with a sensitivity of 91.25% (95% CI: 82.80–96.41%) and a specificity of 83.75% (95% CI: 73.82–91.05%). The results were supported by comparing the performance of da-CPT with established tools such as IVA-2 CPT and MOXO CPT, which demonstrated similar levels of sensitivity and specificity. The positive predictive value (PPV) of 84.9%, which exceeds the recommended threshold of 80%, suggests the da-CPT may be useful in combination with other diagnostic measures, including clinical interviews and behavioral rating scales, in providing a more comprehensive assessment of ADHD symptoms. The high PPV of da-CPT suggests that it is a reliable screening tool for providing the diagnosis of ADHD which can be considered an acceptable option in clinical practice [33]. However, it is important to note that, while these results are encouraging, the da-CPT should be regarded as a screening or complementary tool rather than a standalone diagnostic tool.

The da-CPT's primary innovation lies in its incorporation of both auditory and visual distractors, thereby improving ecological validity and providing a more thorough evaluation of ADHD symptoms in real-world settings. The da-CPT, in contrast to MOXO-CPT, focuses on auditory stimuli, which has been suggested to be more effective in evaluating ADHD-related inattention in practical settings, including classrooms. Furthermore, a significant improvement of the da-CPT over the IVA-2 is its set incorporation of auditory and visual distractors, enhancing its ecological validity and practical relevance in real-world contexts. Another innovation is that the da-CPT incorporates a correction factor for hyperactivity, enabling clinicians to account for excessive key presses, thus enhancing the precision of attention and timing scores. Despite da-CPT's strengths in assessing auditory based attention, its visual component is less developed than visual stimuli based tools such as MOXO and the IVA-2, which integrates both modalities more evenly. The da-CPT prioritizes auditory stimuli in conjunction with auditory and visual distractors, providing a distinct advantage in evaluating auditory-based attentional control, especially in contexts where auditory tasks are common, an aspect that is often overlooked in other assessment tools.

CPTs are increasingly valued for their objective insights into ADHD symptoms, aiding clinical understanding and parental comprehension of their children's condition, and alongside clinical evaluations and rating scales, are becoming favored methods for diagnosing and managing ADHD [5,34]. Due to the increasing popularity of using CPTs in the assessment of ADHD, recent systematic reviews primarily examine the psychometric properties of CPTs [35–37]. The sensitivity and specificity of commonly utilized CPTs in the diagnosis of ADHD vary widely, ranging from 30% to 90% and 23% to 100%. Our study's findings align with this range and support the utility of the da-CPT in capturing ADHD, though it is important to contextualize these results within its pilot nature, especially given the lack of comorbidities in our sample. This project developed the first distractor-embedded auditory continuous performance test. Therefore, the sensitivity and selectivity values were compared with those of other frequently employed CPT paradigms. The comparison of its sensitivity and specificity values with other CPT paradigms validates its performance, but further research is needed to fully establish its effectiveness. The obtained results provide a valuable framework for future studies on auditory-focused CPTs that include distractors.

This study utilized ROC analyses to determine the discrimination power of the subindexes of da-CPT in distinguishing between children with ADHD and the control group. Discriminative validity is often regarded as acceptable when the Area Under the Curve (AUC) values fall within the range of 0.7 to 0.8, regarded as good when between 0.8 and 0.9, and excellent when beyond 0.9 [31]. Findings indicated that da-CPT's attention and timing sub-indexes had good discrimination power, while hyperactivity and impulsivity sub-indexes were moderately acceptable. These results are consistent with a recent meta-analysis on ROC analyses of commonly used CPTs [37]. This meta-analysis revealed that the disparities between individuals with ADHD and control groups were more noticeable in terms of omission errors rather than commission errors. In the aforementioned analyses, it is worth mentioning that the AUC values for impulsivity/commission measures in commonly used CPTs were found to be below the acceptable threshold of 0.7 [37].

On the other hand, the sub-indexes of hyperactivity and impulsivity of da-CPT showed higher values, 0.74 and 0.76, respectively, indicating greater discrimination power. Previous research suggests that individuals with ADHD exhibit modality-specific effects (auditory or visual) on commission errors related to impulsivity [14]. Incorporating an auditory target stimulus in the da-CPT paradigm likely enhanced its discriminatory capabilities compared to conventional CPTs. The utilization of both auditory and visual distractors may contribute to the acceptable level of discrimination power exhibited by all subindexes of da-CPT. This is supported by studies indicating that environmental distractors improve the discriminative ability of visual modality CPT [25,38]. The findings of this study emphasize the potential of auditory modalities and the inclusion of distractors in improving the discriminative ability of CPTs for aiding in diagnosing ADHD. However, future studies with larger sample sizes and different age groups are needed to confirm the findings and fully assess the effectiveness of da-CPT for aiding in diagnosing ADHD. This study showed a significant negative correlation between parents' assessments of ADHD severity and the attention and timing sub-indexes of da-CPT, along with a strong positive correlation in the impulsivity and hyperactivity sub-indexes. The results suggest that da-CPT has considerable promise as a complementary tool for assessing the severity of ADHD symptoms. Furthermore, this could provide helpful details for treatment and planning intervention strategies.

The extent to which CPTs accurately represent the clinical symptom cluster of ADHD remains ambiguous [39]. Previous studies have demonstrated a modest correlation between visual modality CPTs and rating scales completed by parents or teachers [40–42]. However, CPTs with an auditory modality exhibit a more substantial alignment, indicating a more reliable concurrence. According to Lehman et al. (2006), children with ADHD exhibited auditory CPT performances more consistent with teacher rating scales, indicating that they were better at detecting attention problems [20]. Another study utilizing an auditory CPT found a strong correlation between CPT performance and scores on the teacher rating scale measuring impulsivity and attention deficit [43]. The findings mentioned above indicate

that the modality of CPTs plays a crucial role in reflecting the clinical symptoms of ADHD. Our findings support the growing understanding that auditory-based CPTs more accurately represent ADHD symptoms.

While this study provides promising insights into the use of the da-CPT in ADHD diagnostics, it is important to view these findings as preliminary. Upon analyzing the study's strengths and its potential impact on clinical practice, the results suggest that the da-CPT could contribute to enhancing our comprehension of ADHD diagnostics, but further research is necessary to confirm its reliability and generalizability. The determination of sensitivity and specificity in typical CPTs typically depends on a threshold that is frequently arbitrary and may not fully distinguish between cases and non-cases [34]. One notable strength of this study lies in its use of ROC analyses to calculate the AUC, which effectively addresses the limitations associated with typical CPTs. The da-CPT is highly adaptable to diverse linguistic and educational backgrounds, making it useful in global contexts, even in resource-limited areas. The simplicity of utilizing da-CPT, which does not require literacy skills, makes it a favorable choice for large-scale studies. The use of universally recognizable stimuli, like cats' vocalizations, indicates its potential as a global primary care screening tool. This is especially advantageous for mid to low-income countries where limited access to treatment and screening tools is often due to high costs. When looking ahead to potential utilizes da-CPT stands out as a promising screening tool for ADHD in preschool-aged children, especially since current tools are frequently inadequate. Further investigation through larger-scale studies is necessary to explore da-CPT's practical usefulness and effectiveness, particularly in diverse clinical settings and among ADHD children with comorbidities.

This study has limitations despite providing insights into the utility of da-CPT for ADHD diagnosis. A significant limitation of the study is the small sample size. Furthermore, this study excluded children with psychiatric comorbidities and IQs below 85 to focus on isolating ADHD-specific attentional deficits. While this approach provided a clear view of ADHD-related cognitive performance, it limits the generalizability of the findings to the broader ADHD population, where comorbidities are common. As such, this study represents a preliminary or pilot test of the tool's efficacy in a more narrowly defined ADHD population. Given the high occurrence of comorbidities in ADHD, particularly those associated with attentional problems [44], future studies need to include a broader range of psychiatric profiles. Additionally, the cross-sectional design of this study limits our understanding of the long-term effectiveness and reliability of da-CPT outcomes. Furthermore, the study's focus on participants aged 6–12 years may restrict the generalizability of the findings across different ages of ADHD. One limitation of the da-CPT is its inability to replicate real-world distance perception. The tool uses natural sounds and professionally created visual distractors, but the two-dimensional screen and consistently equal volume of sounds might not accurately reproduce different levels of depth and distance experienced by children in their everyday lives. The future versions of the da-CPT and other tools contributing to ecological validity might benefit from including spatial audio and, potentially, three-dimensional visual component. Lastly, technological requirements, like internet access and digital devices, may limit da-CPT's accessibility in resource-constrained environments, impacting its global utilization. It is essential to acknowledge the limitations to understand this research in the larger context of aiding in ADHD diagnosis and to guide future studies that aim to achieve a more thorough comprehension of the disorder.

5. Conclusions

This study has demonstrated that the Distractor-embedded Auditory Continuous Performance Test (da-CPT) is a highly effective complementary diagnostic tool for identifying ADHD in children aged 6–12 years. The da-CPT exhibited strong diagnostic accuracy, with a sensitivity of 91.25% and a specificity of 83.75%. These metrics highlight the tool's potential reliability and utility in clinical settings. The ROC analyses further underscored the effectiveness of the da-CPT, revealing that the attention and timing sub-indices had

particularly high discrimination power, as indicated by their AUC values. The impulsivity and hyperactivity sub-indices also performed well, with AUC values of 0.74 and 0.76, respectively, demonstrating the da-CPT's ability to differentiate between ADHD and control groups across a broad spectrum of symptoms. Moreover, the significant correlations between the da-CPT sub-indices and ADHD severity suggest that this complementary tool is valuable not only for diagnosis but also for assessing the severity of ADHD symptoms. These findings support the use of da-CPT as a complementary tool for both the identification and management of ADHD. Due to its excellent sensitivity, specificity, and discrimination power, along with the incorporation of innovative technology da-CPT presents itself as an up-and-coming complementary tool in ADHD diagnosis. Moreover, it indicates a significant step towards a more thorough and accurate assessment of attentional processes in children and adolescents. The findings from this research provide a solid basis for future investigations aimed at advancing and improving da-CPT.

Author Contributions: Conceptualization, E.İ., A.Ö. and M.S.; Methodology, A.Ö., M.S., B.K. and H.K.; Software, M.S., B.K. and H.K.; Validation, M.C., A.Ö., E.G. and E.G.S.; Formal Analysis, A.U.D.; Investigation, A.Ö., M.C. and E.G.; Resources, E.İ.; Data Curation, A.U.D.; Writing—Original Draft Preparation, M.S. and A.Ö.; Writing—Review & Editing, M.S., A.Ö. and H.K.; Visualization, M.S.; Supervision, E.İ.; Project Administration, E.İ. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Gazi University Faculty of Medicine Ethics Committee (Decision No. 38, 24 September 2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data supporting the reported results are not publicly available due to patient privacy and confidentiality concerns. Therefore, we are unable to share the data generated or analyzed during this study.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ADHD	Attention-Deficit/Hyperactivity Disorder
AUC	Area Under the Curve
CI	Confidence Interval
CPRS-R:S	Conners' Parent Rating Scale—Revised Short Form
CPT	Continuous Performance Test
da-CPT	Distractor-embedded Auditory Continuous Performance Test
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, 5th Edition
K-SADS-PL-DSM-5-T	Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version, DSM-5-Turkish Version
MOXO-CPT	MOXO Continuous Performance Test
PPV	Positive Predictive Value
ROC	Receiver Operating Characteristic
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
WISC-R	Wechsler Intelligence Scale for Children-Revised
YI	Youden Index

Appendix A

The (da-CPT is a novel, web-based diagnostic tool specifically designed to evaluate the core clinical symptoms of Attention Deficit Hyperactivity Disorder (ADHD), including inattention, response inhibition, hyperactivity, and timing. By integrating auditory and visual distractions into a controlled testing environment, the da-CPT assesses selective attention and impulsivity through omission errors (failure to respond to the target stimulus) and commission errors (responding to non-target stimuli), respectively. Additionally, it measures timing by tracking response time variability, defined as the interval between the presentation of the target stimulus and the participant's response, as well as fluctuations in response time throughout the test. To enhance ecological validity and simulate real-world scenarios, the test incorporates a variety of visual (e.g., images of animals) and auditory (e.g., ringing tones, a baby crying) distractors, providing a comprehensive and robust assessment of ADHD symptoms [45–47]. The visual distractors used in the ADHD-da-CPT tool were designed by professional cartoon artists, ensuring uniformity in theme and visual style throughout the test. The visual elements, including animal figures, were created using consistent visual fonts and graphic features, specifically focusing on maintaining uniformity in movement capabilities and skeletal structures. This design approach minimizes potential perceptual discrepancies that could otherwise arise from inconsistent visual stimuli.

This section details the da-CPT's structure, technological infrastructure, including the rationale behind its design, the types of stimuli used, and the innovative features that distinguish it from other continuous performance tests.

Appendix A.1. Technological Infrastructure

The da-CPT was developed using advanced web technologies to ensure a user-friendly and efficient platform. The frontend, built with HTML5 and Bootstrap, offers a responsive design adaptable to various devices, while PHP and MySQL securely handle data storage and interactions. Real-time data exchange is facilitated by AJAX, supporting smooth test operations and immediate report generation. The interface simplifies patient registration and test scheduling, providing real-time feedback and data visualization for clinical decision-making.

Appendix A.2. Participant Registration and Demo

The process begins with the registration of the participant by a clinician, such as a child psychologist or psychiatrist. The clinician inputs basic demographic details and assigns a unique identifier to the participant by system. Prior to the main test, the clinician explains the test's objectives, outlining what the participant should focus on and what to ignore. This session is crucial for ensuring that children aged 6–12 years with ADHD understand the tasks and can engage effectively during the test.

Participants are then introduced to a brief demo session lasting approximately 1.5 min. This demo simulates key elements of the main test, such as the target sound (the sound of a cat meowing) and various non-target and distractor stimuli. The demo explains what the participant should do when hearing the target sound and how to avoid reacting to distractors. Before start the main test screen opens, participants are instructed to "press the spacebar once and only once each time when hear the target sound, while ignoring non-target stimuli!" both verbally and in writing on the application screen. This preparatory phase includes both auditory and visual cues to familiarize the participant with the testing environment. If the clinician deems the participant sufficiently familiar with the test, they may choose to skip this demo.

Appendix A.3. Main Test Structure

The main test is composed of eight stages, each increasing in complexity and incorporating various distractors. After a countdown timer, the test automatically begins, with no further interaction from the clinician required. The stages are designed to assess dif-

ferent cognitive functions related to ADHD, including attention, timing, impulsivity, and hyperactivity. The test measures several key variables through participant interactions:

- **Correct Attention Responses**: The participant is expected to press the space key on the keyboard as soon as they hear the target sound (e.g., the cat meowing). Correct responses are recorded when the participant presses the key while the target sound is active or immediately afterward in the designated blank interval.
- **Timing**: Timing is assessed by evaluating the precision of the participant's response, particularly how quickly they react to the target stimulus and maintain consistent reaction times throughout the test. The first key press while the target sound is in progress is used to calculate the timing. Moreover, da-CPT measures response time variability, which includes fluctuations in reaction time between stages. This is a very important measure for the estimation of periods of inattention, under conditions with auditory and visual distractors. In this respect, the test gives a sensitive measure of the lapses in attention so commonly seen in people with ADHD, thus ensuring that periods of inattention and/or delayed responses will be featured in the final outcome of the test.
- **Impulsivity**: Impulsivity is measured by recording instances where the participant presses the key in response to non-target sounds (e.g., the duck quacking or donkey braying).
- **Hyperactivity**: Hyperactivity is calculated based on repeated or inappropriate key presses, particularly when the participant reacts to the same target or non-target stimulus multiple times.

The process of identifying Attention, Timing, Impulsivity and Hyperactivity behaviors is shown in Figure A1.

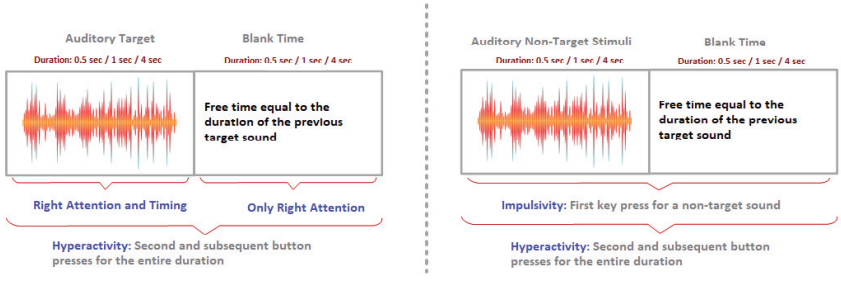

Figure A1. Detection of attention, timing, impulsivity and hyperactivity behaviors.

Adjusting for Hyperactivity: A significant innovation in the da-CPT is the correction for hyperactivity's impact on attention and timing scores. In previous CPT paradigms, hyperactive behavior could lead to inflated scores in attention and timing due to excessive key presses. To address this, the da-CPT incorporates a correction factor that adjusts attention and timing scores if the hyperactivity ratio exceeds two times the sum of attention and timing scores. This correction factor, optimally set at 0.25 times the hyperactivity ratio, ensures that the test results more accurately reflect the participant's true cognitive abilities. Additionally, the system provides the clinician with the option to modify this correction factor based on individual test results, enhancing the test's flexibility and accuracy.

Auditory Target and Non-Target Stimuli: Target, non-target and distraction sounds consist of professionally recorded natural sounds. The primary target stimulus is the sound of a cat meowing, presented at varying intervals of 0.5, 1, and 4 s. This variability challenges the participant's ability to sustain attention and respond accurately. In contrast, non-target sounds include other animal noises, such as duck quacking, donkey braying, horse neighing, and wolf howling. These non-target sounds serve to test the participant's impulsivity by tempting them to react to irrelevant stimuli.

Auditory and Visual Distractors: To simulate real-world distractions, the test includes both auditory and visual distractors. Auditory distractors consist of environmental noises like phones ringing, babies crying, car and motorcycle engines, and general crowd sounds. These sounds are strategically placed between the target and non-target stimuli to challenge the participant's ability to maintain focus amidst distractions. The visual distractors were created by professional designers and graphic designers working in cartoon production as animated cartoons in harmony with the animals with target or distractor sounds. For example, when the cat meowing (target sound) occurs, the screen may display a cat or other animal walking or running. In addition, non-target or distractor sounds might be accompanied by animations of ducks waddling, wolves howling at the moon, or horses galloping across the screen. These animations are designed to be visually engaging, yet challenging, as they test the participant's ability to prioritize auditory over visual stimuli. This alignment or misalignment between sound and image plays a crucial role in measuring sensory attention, particularly auditory focus, which is a key aspect of ADHD assessment.

Appendix A.4. Stages and Stimuli

The da-CPT is designed to last 16 min and consists of eight equally timed stages, starting with basic tasks and progressively increasing in complexity, incorporating both auditory and visual distractors. Each stage evaluates different aspects of attention, timing, impulsivity, and hyperactivity by varying the type and number of stimuli presented. This progression allows the da-CPT to systematically assess cognitive functions under increasingly challenging conditions. By carefully combining auditory and visual stimuli, the test accurately measures a participant's ability to focus and filter out irrelevant information, providing a robust assessment of ADHD-related symptoms. Figure A2 details each stage, including the specific target, non-target, and distractor stimuli used to simulate real-world conditions and enhance diagnostic accuracy.

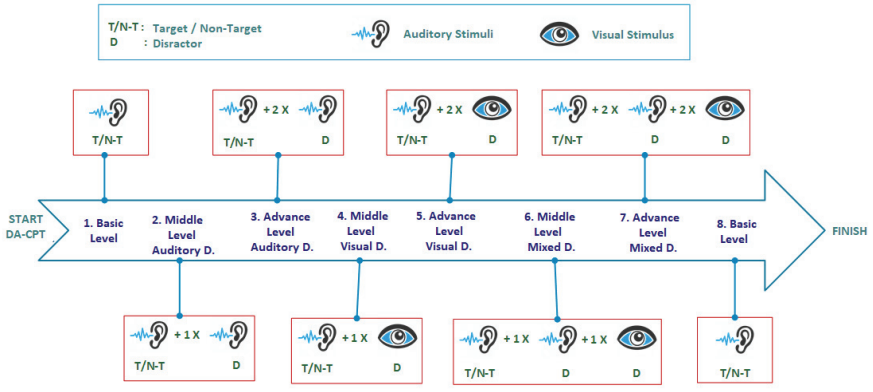

Figure A2. Stages of the Distractor-Embedded Auditory Continuous Performance Test.

- **Stage 1:** Target and non-target sounds only—Participants are introduced to the target sound (cat meow) and non-target sounds (e.g., other animal sounds) without any distractors.
- **Stage 2:** Auditory distractors added—Target and non-target sounds are presented along with auditory distractors (e.g., phone ringing, baby crying, crowd noise, motorcycle/car sounds).
- **Stage 3:** Two auditory distractors—Participants hear two auditory distractors simultaneously with target and non-target sounds. For example, combination of a cat meowing (target), a phone ringing (distractor-1) and a baby crying (distractor-2), with the blank screen.

- **Stage 4:** Visual distractors introduced—A visual distractor (e.g., animated animal) is added alongside the target and non-target sounds.
- **Stage 5:** Two visual distractors—Two visual distractors (e.g., cat chasing mouse, eagle flying above a howling wolf) are added, increasing visual complexity.
- **Stage 6:** Mixed auditory and visual distractors—One auditory and one visual distractor are combined with target and non-target sounds.
- **Stage 7:** Multiple auditory and visual distractors—Two auditory and two visual distractors are presented together with target and non-target sounds.
- **Stage 8:** Return to basic level—Only target and non-target sounds are presented again without any distractors, to assess performance consistency.

Appendix A.5. Reporting and Analysis

Upon completion of the test, the system generates a detailed report that is accessible through a clinician interface. This report includes both raw scores and adjusted scores for attention, timing, impulsivity, and hyperactivity, presented in graphical and tabular formats. The clinician can review these results in the context of the participant's performance, allowing for a more informed diagnostic process. The da-CPT's architecture is distinguished by its emphasis on ecological validity and its innovative approach to handling hyperactivity. By simulating real-world distractions and correcting for hyperactivity's impact on other cognitive measures, the da-CPT provides a more accurate and reliable assessment tool for diagnosing ADHD in children aged 6–12 years. Furthermore, the strategic integration of both congruent and incongruent visual and auditory stimuli enhances the test's ability to differentiate between visual and sensory attention, offering a comprehensive evaluation of the participant's cognitive functions.

Appendix A.6. Public Demo Access for Researchers and the Public

To promote transparency and encourage broader research use, we have developed an open-access demo platform for the da-CPT. The demo can be accessed and used freely for research purposes only and cannot be used for commercial purposes through the following link: https://mehmetsevri.github.io/nadacpt.html (accessed on 23 October 2024).

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The Creative Awareness Theory: A Grounded Theory Study of Inherent Self-Regulation in Attention Deficit Hyperactivity Disorder

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Abstract: Objectives: The aim of this study was to determine why and how adults with attention deficit hyperactivity disorder (ADHD) experience variable impairment and identify the processes and strategies adults with ADHD use to develop positive self-regulation skills. **Methods:** A mixed cohort of 11 participants (6 female and 5 male) from a university, an adult ADHD clinic and an ADHD support group in the UK were interviewed online between September 2021 and February 2022. Data were collected and analysed simultaneously, inspired by a constructivist grounded theory methodology. **Results:** Participants described a "polar awareness of difference" from others in terms of engagement and ADHD characteristics, and a "polar awareness of consciousness" experienced as the states of *chaotic attention* and *hyperfocus*, both of which impact core perceptions of self. Using an infinity paradigm, the results demonstrate unskilled attempts to self-regulate within and between these states using *self-absorption* or *self-transcendence* strategies, including their inherent challenges and energetic cost. Our results further indicate that at the centre of this dynamic paradigm, *creative awareness* strategies exist, which exemplify polarity awareness and the regulation of that awareness supported by an authentic inner compass (AIC). **Conclusions:** This paper presents the empirical foundation for the ADHD Creative Awareness Theory (CAT)—a new theory for understanding the experience of ADHD consciousness and environmental engagement. Practical implications are explored, and recommendations include use of the CAT as a framework for understanding and development of inherent self-regulation skills for adults with ADHD.

Keywords: adult ADHD; neurodevelopmental disorders; self-regulation; grounded theory; self-determination theory; positive aspects; positive attributes; creative adjustment

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1. Introduction

The impact of cognitive behavioural theory on both research and treatment design for ADHD has resulted in a singular deficit perspective of the theoretical origins of ADHD [1]. This perspective is limiting in terms of positive outcomes for treatment and perpetuates a focus on symptom reduction and maladaptive behaviours. While ADHD is primarily viewed as a neurobiological disorder, the possibility that ADHD may confer advantages to the individual is widely debated [2–11]. The characterisation proposed by cognitive behavioural-based theoretical models highlights that the executive function (EF) deficits and impairments of ADHD are such that it should be considered a chronic mental disorder with no cure, and treatments should specifically focus on pharmacological support, reducing stigma and building self-protective attitudes of resilience, self-esteem, and self-efficacy [4,12–17]. This is supported by psychoeducation to develop a perception of internal

"resources" that can assist with daily coping and dealing with impairments, goal achievement and developing perceived self-efficacy [18–21]. Resources are defined as individual characteristics which strongly engage a patient's motivation and are important for self-esteem, such as goals, values and possibilities. These can be mobilised for a process of change in therapy known as "resource activation" [22]. In ADHD, these are identified as personal competence, strengths and aptitudes that may have been stifled or sacrificed due to impairments, which are important in developing strategies for symptom control [23–25].

Academic research using the cognitive behavioural theoretical characterisation of ADHD has supported only the concept of "individual strengths" and has stated that no study has conveyed any universal strengths or advantages associated with the neurobiology of ADHD beyond that of control groups [12,17,26–29], despite a large growing body of anecdotal work regarding positive aspects of ADHD [2,5,30–37]. While resource activation is undoubtedly useful to the development of the self-esteem of the individual, recent research suggests there may be more universal positive attributes that accompany the neurobiology of ADHD including hyperfocus, curiosity, energy, courage, flexibility, humanity, resilience, entrepreneurship, transcendence, divergent thinking, and creativity [6,8,11,38–48]. Research on strengths and resources of ADHD has previously been based primarily on qualitative and phenomenological methodologies [8,24,30,47,49] and thematic analysis [50], with the exception of quantitative research on measures of creativity and divergent thinking [11,38–41,51]. Three grounded theory studies were identified; however, all three studies were based on the cognitive behavioural characterisation of ADHD, and the focus was the experience of late diagnosis [25], the advantages of late diagnosis [52] and quality of life with ADHD [53]. There is a paucity of research in this area in general, and in particular from a perspective not based in cognitive behavioural theory.

Self-determination theory (SDT) has been suggested as an alternative theoretical perspective through which to understand the origins, motivations and behaviours associated with ADHD [54]. Viewing ADHD behaviours through a different theoretical lens provides an opportunity to explore not only the origins of those behaviours but also other assumptions associated with its characterisation [1]. The focus of this study was to identify universal selective strengths that support individuals with ADHD to manage the variability of their impairment. The aim of the study was to generate a theory, grounded in data, that explains (a) why and how individuals with ADHD experience variable impairment; (b) the impact of variable impairment for those with ADHD; and (c) processes and strategies used by those with ADHD to resolve their main concerns regarding the impact and consequences of the variable impairment of ADHD.

2. Materials & Methods

2.1. Study Design and Data Collection Tools

2.1.1. Method

Philosophical Framework

This study has adopted a pragmatic approach in line with the philosophical framework of this thesis. Research on phenomena concerning the experience of ADHD has theoretical implications, and grounded theory is presented as a methodology that is ideal for an area where not much research or theorising has been carried out before [55]. This project employed a constructivist approach [56] which combines features of the Glaser and Strauss [57] methodology, including the constant comparative method, and the Strauss and Corbin [58] methodology, including abductive reasoning; this project was guided by Flick's [55] systematic phases of grounded theory: initial, conceptual–theoretical, confirmatory–selective, and reflective. A constructivist approach recognises the subjectivity and researcher involvement and interpretation of data in theory construction [56]. This was thought to be an important element to monitor during the research process due to the researcher's own personal experience of ADHD.

Methodological Approach

Grounded theory methodology is a dynamic process which includes successive iterations of theoretical sampling. This requires the researcher to adopt an intuitive stance at the beginning of the research, which was considered essential by Glaser to allow the theoretical structure of the issue being studied to emerge [59]. This study followed a systemisation of the intuition process inherent in grounded theory as presented by Flick [55]. He outlines several phases in the grounded theory research process, which are described herein.

2.1.2. Initial Phase

Because data collection methods flow from the research question rather than driving it [56], flexibility in data collection methods throughout the research is encouraged, giving grounded theory a more ethnographic approach than some traditional qualitative methods. Sensitising concepts, or initial ideas, interests and questions to pursue can guide researchers to places at which to start inquiry [56]. This study used memos, which is a key recommended data collection method begun during this phase; memos document the experience of the research process including coding ideas, reflections, diagramming of concepts, and reviews in order to advance abstract levels of theorising [55,60,61]. Initial sampling of data was untangled, or segmented, into single words or short sequences of words to generate units of meaning defined as concepts or 'codes'. The constant comparative method, or comparing data to data, was selected for this study to direct coding categorisation, and the process followed constructivist methodology, wherein this coding is emergent and conducted line by line.

2.1.3. Conceptual–Theoretical Phase

This phase saw initial sampling become theoretical sampling, where cases, groups or materials are sampled according to their relevance to the developing theory. Two types of coding in constructivist methodology occur in this phase, focused and theoretical, where the most significant or frequent codes that make the most analytical sense are identified. These were assessed for relevance and potential to become conceptual categories, and relationships between categories were also identified. This phase also saw an analysis shift from inductive logic to abductive reasoning. Constructivist theory highlights the importance of this shift, as abductive reasoning aims to account for surprises, anomalies, or puzzles in the collected data, which may take the researcher into unanticipated directions or theoretical realms [56]. Awareness of this particular aspect of the constructivist approach proved key in facilitating a significant shift in the analysis process in this study. This progressed iteratively into theoretical coding or conceptualising how codes relate to each other and integrate to form a theory. Charmaz [56] uses Glaser's [62] ambiguity regarding codes both as classifiable and emergent from the research as a tension between the data and inspirational sources of existing concepts and theories to add precision and clarity to the analysis. In this study, this provided a flexibility between establishing static codes and remaining responsive to new concepts arising from the data. This phase also included sorting and diagramming memos according to the developing theory, which were used to elaborate upon and refine categories to guide theoretical sampling and coding toward integration.

2.1.4. Confirmatory–Selective Phase

As categories became increasingly abstract and demonstrated more theoretical connections, the coding process became more selective to confirm the centrality of categories and their relevance to the developing theory. The focus of this phase in this study involved dynamically shifting between categories, with further sampling used as a strategy for identifying variation and gaps among categories.

2.1.5. Reflexive Phase

When new data provide neither new properties for a category nor further insights into the theory, it may be that theoretical saturation has been reached [55,56,62]. In this study, theoretical saturation was identified by clarity in links between the relationships and concepts developed in the research process. Theoretical sorting of memos provided a basis for creating, refining, and organising theoretical links for writing.

2.2. Data Collection and Analysis

Unlike other qualitative methods, grounded theory approaches recommend that the inquiry shapes the data collection [56,57]. This process of finding and generating data that is "rich", or detailed, focused, and full, provides solid material for substantive analysis. For this project, data were provided from intensive interviews and memos or field notes by the researcher.

2.2.1. Intensive Interviews

A key difference in constructivist grounded theory is its approach to interviews. Charmaz's [56] style, called intensive interviewing, is defined as "a gently guided one-sided conversation that explores participants' perspective on their personal experience with the research topic" (p. 56). Intensive interviewing uses a similar attitude to grounded theory in the approach of the researcher; it is open-ended but directed, shaped but emergent, and paced yet unrestricted [56]. The intensive interviewing approach can elicit a dialectic exchange of responses and discourses from the participant, highlighting not only concerns and reflections, but also identities and social connections. This provides the researcher with a chance to enter the participant's implicit world of meaning, facilitating insight through emergent connection and sharing of human experience. Questions are shaped using open questioning and a Rogerian [63] non-directive client-centred approach including participants' own language to encourage further expression and detail. Participant language and meaning is key in constructivist grounded theory, alerting the researcher to the impact of the co-creation of data and the influence of their role in the process. The key characteristics of intensive interviewing are as follows:

- Selection of participants who have first-hand experience;
- In-depth exploration of participants' experience and situations;
- Objective of obtaining detailed responses;
- Emphasis on understanding participants' perspective, meanings, and experience;
- Practice of following up on unanticipated areas of inquiry, hints, and implicit views and accounts of actions [56].

2.2.2. Memos or Field Notes

Memo writing is an essential part of the grounded theory research practice. While the style and structure of memo writing is left up to the individual researcher, it is seen as an essential practice in conceptualising the data for analysis [55]. Memos provide a record of the researcher perspective and the research process and assist in the review and identification of gaps that need investigation [56]. Ideally, memo writing will also bring transparency to the research process, acting as a research diary that is begun from the initial stages. Therefore, this project will include memo writing as additional data for analysis.

2.2.3. NVivo

Grounded theory has some significant methodological differences in its approaches due to varying epistemological views. This can cause confusion for researchers and lead to some quality control issues in research [64]. Therefore, the ability to present a transparent account of the research process is recommended [64,65]. The use of a computer-assisted qualitative data analysis software program (CAQDAS) can not only enhance the data handling and analysis process but also increase the effectiveness of the process of learning from the data if the software is effectively utilised for the project [65–67]. NVivo has been

demonstrated to support and facilitate the iterative process that is core to grounded theory and to provide the process transparency that is recommended to enhance study validity [64]. Therefore, this project will use NVivo 20 (Lumivero, Oxford, UK) from the initial phase to coordinate, organise, and manage all data as well as utilise the program for conceptual and theoretical development.

2.2.4. Ethics and Permissions

Ethical approval was sought from the University of Huddersfield School of Human and Health Sciences—School Research Ethics and Integrity Committee (SREIC) and a regional NHS Research Ethics Committee, since participants were recruited from an NHS trust, universities, and the community. All sessions with participants were held in adherence with the Ethical Framework for Good Practice set by the UK Council for Psychotherapy (UKCP) [68].

The ethical implications for this study were considered in the following contexts.

2.2.5. Pre-Study Preparation

A critical element of this research is the exploration and representation of the lived experience of adults with ADHD, and the applicability, efficacy, and accessibility of the results. Therefore, a patient participation group was organised in pre-study preparation before recruitment. A small group of 5–6 adults with ADHD who expressed strong interest in the research reviewed and refined recruitment materials including the patient information sheet, consent form and interview guide.

2.2.6. Data Protection and Data Storage

The researcher is expected to comply with and update their knowledge of the requirements of the General Data Protection Regulation (GDPR), the NHS Confidentiality Code of Practice, the Computer Misuse Act (covering information security), and all Local Trust Policies with regard to the collection, storage, processing and disclosure of personal information and also to uphold the core principles of data confidentiality both in letter and in spirit. All participant case records were held in accordance with the Data Protection Act [69]. To protect the identity of individual participants, all personally identifiable data (PID) were anonymised and will not be released. Information on confidentiality policy and anonymisation of PID was included in the consent form. Records were kept both in electronic (consent forms, agreements) and hard copy form (memos, process analysis). If electronic access was unavailable, participants were sent hard copies which were scanned electronically, and the originals were destroyed. The participants' home addresses (including postcodes) and telephone numbers were kept on a secure database and spreadsheet on NHS/university computers in compliance with the Data Protection Act [69]. Data held in the NVivo database were anonymised and only accessible by password-protected researcher login. All manual records were kept in a locked cabinet accessible by the researcher only. In accordance with the Data Protection Act [69], personal data will not be retained for longer than is necessary. All participant personal data, transcripts, recordings, memos, and process notes will be retained in order to obtain permission for the study results to be published, in accordance with ethical approval.

2.2.7. Sampling and Participants

Traditional sampling in quantitative research aims to identify a 'primary selection' of cases who possess the optimum knowledge or experience about an issue and the skills to communicate about it effectively. This then becomes a basis for further sampling and generalisation to a wider population [70,71]. As we have seen, the sampling process is quite different for grounded theory research, where simultaneous sampling and coding create an initial category set. In-keeping with the focus on selecting cases which may provide new insights for developing theory, it was considered important to gather data from cases with a comparatively wide range of experience including age, gender, geographical

location, and how recently diagnosis was received. Participants were recruited from three different participation groups: NHS patients from the Adult ADHD Clinic at the South West Yorkshire Partnership NHS Foundation Trust; university students at the University of Huddersfield and the University of Cambridge; and an ADHD Support Group for adults with ADHD. Inclusion and exclusion criteria were as follows.

2.2.8. Inclusion Criteria

- Confirmed diagnosis of ADHD;
- Age 18 or older;
- Access to computer or smartphone with an internet connection.

2.2.9. Exclusion Criteria

- Comorbid diagnosis (e.g., autism, bi-polar, intellectual disabilities, learning difficulties, traumatic brain injury, psychosis or Tourette's);
- Substance abuse disorders;
- Other mental health disorders (e.g., PTSD, oppositional defiant disorder);
- Personality disorders.

In total, 13 participants (6 female-presenting and 7 male-presenting between the ages of 20 and 52) participated in the interviews. Participants were screened by the researcher for exclusion criteria through initial email contact and live at the online interview stage. Two participants in the initial phase (2 and 5) were identified as having comorbid diagnoses at interview and had to be excluded from the study. Of the remaining 11 participants, one was Hispanic American, one South American, and the remaining 9 were White British. One participant received a diagnosis in childhood, and 10 received a diagnosis in adulthood, between the years of 2011 and 2021. Subgroups of diagnosis were also divided, with 7 participants identifying as inattentive type and 4 identifying as combined type (See Table 1).

Table 1. Participant characteristics.

Patient ID	Age	Gender	Race	Year of Diagnosis	Subgroup
1	38	Female	White British	2020	Combined
3	21	Female	White British	2018	Combined
4	35	Male	White British	2011	Inattentive
6	20	Female	White British	2021	Combined
7	24	Male	White British	2009	Inattentive
8	20	Male	Hispanic American	2021	Inattentive
9	52	Female	White British	2019	Inattentive
10	28	Male	White British	2021	Inattentive
11	50	Male	South American	2016	Inattentive
12	42	Female	White British	2016	Inattentive
13	36	Female	White British	2013	Combined

Sites involved in the project made information available to their respective populations but did not engage with active recruitment (e.g., post fliers or information regarding the study in groups or newsletters). Patient information sheets and letters of consent were provided to participants who contacted the researcher directly with an interest in participating in the study. An interview guide was generated as part of the research approval process and as an example to show potential participants. Due to COVID-19 pandemic restrictions on face-to-face contact, all interactions with potential participants

were conducted online through NHS-approved e-signature platforms, as agreed by the HRA and MHRA [72].

2.3. Procedure

Intensive interviews were conducted online between September 2021 and February 2022. Participants received an email invitation to an initial interview to discuss participation in the study. Participants were offered a 60–90 min online semi-structured interview with the researcher to explore their experience of living with ADHD. In addition, all interview participants were entered into a draw for a £50 Amazon gift voucher. Consent forms were completed live during the session via a shared document file to provide the opportunity to ask questions.

2.4. Data Analysis

Each interview was transcribed and uploaded into NVivo for line-by-line coding alongside the video to ensure clarity. This generated several initial themes, which were consistent across interviews. Analysis of the data was an iterative process using the constant comparative method, moving between the transcripts, writing memos, diagramming codes to develop themes, linking themes together, and arriving at core concepts. A theoretical model was identified at the cessation of the 7th interview, and a further 4 interviews were completed to confirm the model. The initial phase produced 70 codes from all 7 interviews, which were grouped into 5 themes. Review of these themes in the conceptual–theoretical phase led to the emergence of surprising core themes, which resulted in reviewing the transcripts to code to new emergent themes. This generated 38 codes, leading to a final 7 core themes and 35 subthemes in the confirmatory–selective phase, and the process was repeated until no further themes emerged and saturation was reached in the reflexive phase.

3. Results

The theory emerging from this process is termed the ADHD Creative Awareness Theory (CAT). The ADHD CAT uses a self-determination theory (SDT) [73]-based framework as the primary theoretical perspective for characterising ADHD motivation and behaviour [54]. Using the example of an infinity paradigm, the ADHD CAT describes the polar nature of ADHD self-awareness and identifies the strategies and processes ADHD individuals are engaging in to successfully self-regulate their experiences. The theory identifies two distinct areas of polar awareness, challenges involved in the management of these states, and the skills and resources that contribute to positive self-regulation. A data sample for each theme is presented here, and a more complete sample is available [74].

3.1. Polar Awareness of Difference

3.1.1. Environmental Engagement

Previous research confirms that individuals with ADHD are aware of a difference between themselves and others. However, this has been reported as a sense of feeling "different" or socially unaccepted due to difference in or comparison of capability [8,23,24,75]. SDT highlights the principle of organismic integration, or an active process of seeking engagement with the environment, as a fundamental component of internalisation and development of the self-concept [73,76]. Participants described a long-standing and ongoing awareness of different experiences of the process of engagement with the environment from others. They describe their natural approaches to engagement as confusing to others, leading to stigma, misunderstanding and negative responses to behaviours. Additionally, participants described experiencing a greater amount of effort to successfully engage with their environment in ways similar to others or meet social standards as compared to others, which often resulted in frustration, exhaustion and feelings of resentment.

Participant 3: "I think that the first difference would probably be the way I will react to certain things or the way my body clock runs... But I think that there is a stigma of that whole situation, if you get up late and go to bed late, that inherently is lazy. Even if

you're up for the same amount of time as someone that will get up earlier and go to bed early and I think that potentially caused some clashes and understanding with my family. And also my reactions to things will be very different to them. Certain things that might seem quite trivial to my family are often more amplified in my emotional reactivity about the situation".

Participant 6: "Everyone does this to some degree, but it feels like it's harder for me... I try and remember that it is in some capacity acknowledged that it is more difficult for people with ADHD to do some things, especially in academics, in terms of keeping on track and in self-motivation, that kind of thing, with no structure. And I can acknowledge how difficult it must be to take yourself... that far. So, I think it takes a lot more effort on my part to start working ahead of a deadline than it does for anyone I know... it's much more of an emotional upheaval for me to sit and start writing an essay that's due in three days. My peers get stressed out when they haven't started something... due in a week. It's not even on my radar if it's due in a week... it's first draft is final draft. I will proofread it in the 10 min before it's due. And that's an advantage that they have".

Participant 10: "One of the problems I've got with that is I either go one way or the other. If I'm waffling, I'm not going to get the interest I need from the people I need to kind of get on board with the idea. When I'm concise, what I've said makes perfect sense to me, but other people can't make the connections I've made to make it make sense. So then, I'm kind of stuck because in my head I've just, all I've said is grass is green and they've gone, "What?" And I think, well, hang on a minute. What I've said was so simple. I couldn't mean anything else by that. And then with a bit of a back and forth... I can start to understand, you know, the lack of connections they've made. Now... I'm making the most ridiculous connections, but they make sense to me because there is a very clear-cut link, but I can really feel in those moments that I'm just thinking in such a different way from everyone else".

3.1.2. Positive Characteristics of ADHD

Conversely, participants felt some of their natural ways of engaging with the environment were helpful and beneficial. The themes of *empathy, curiosity, divergent thinking*, and *humour* were all perceived as characteristics associated with participant's own experience of ADHD or as a shared experience with other ADHD individuals, which is supported by previous research [8,11,38–41,45,51].

Participant 3: "I think that everyone I've met with ADHD has a lot of empathy abilities. I think that's quite good for people's skills and understanding and being able to put yourself in people's shoes, no matter what that is. Obviously speaking on behalf of myself from like acting-wise or theatre wise, writing, to things like coaching or counselling and just people-based, like social care people-based jobs. I think we're very good at those sorts of things".

Participant 4: "I would say the positive side would be that it helps me see patterns that would-that no one ever thought about, like the people when I meet them or talk to them, they wouldn't realize that to be like, oh, that's interesting. I've never thought of it that way. Like that's something cause with ADHD my mind jumping to so many different things, I'm able to see patterns and connections that I would say, someone else, maybe... maybe would miss those. So even with that I would say it might be an advantage."

Participant 7: "I'm a very curious person by nature and I think that curiosity plays a big role in my motivation, which in curiosity, and like interests are almost, they live, in a large overlap, like things I'll be curious about are obviously going to be the things I'm interested about. Kind of asking more questions to myself about the problem I'm trying to solve can help me gain interest in the problem because of, they will build, like, if I'm curious about the problem, which means I'm asking questions about it, questions about like details that might not be so obvious or given to me in the beginning".

Interestingly, while they were identified as positive aspects of their experience, none of the participants attributed successful management of their ADHD to these positive

characteristics individually. It was this surprising finding that triggered the re-examination and recategorization of the data in relation to ADHD experience of engagement with the environment at the conceptual–theoretical phase (Figures S1–S4).

3.2. Polar Awareness of ADHD Consciousness

The experience of two states of consciousness in ADHD emerged from the data: *chaotic attention* and *hyperfocus*. *Chaotic attention* is defined as "rapid chaotic movement between unrelated and unconnected thoughts and ideas". Also known as mind wandering [77], participants described experiencing a "busy brain", "monkey mind", "scattered thoughts", and "mental noise". It is characterised by *variable concentration*, or continual engagement and disengagement with the environment or internal thoughts; *exploration*, or engagement with novelty, new learning, and making mental leaps or connections; and *emotional responsiveness*, or emotional expression appearing disproportionate to context. Participants described this state as impairing goal-directed behaviour due to feeling unable to control levels of focus and engagement, resulting in a lack of consistency in completing tasks, difficulty being present in conversations, and inability to maintain engagement if interest is not present. The effort required to engage with some activities while in this state sometimes results in strong emotional responses. In general terms, *chaotic attention* appears omnipresent; however, in relation to goal-directed behaviour it is often accompanied by negative feelings of frustration, overwhelm, uncertainty, lack of motivation, and emotional reactivity.

Participant 4: "It's like, I, I know that theoretical understanding that, okay, my frontal cortex lacks enough dopamine to kind of properly have an advanced plan and to do things on time, but there may be other things. If that lack of dopamine might be the reason why I always seek out different novelty or to do different things, that can be an advantage if it's applied in the correct way, because it keeps something exciting. It keeps that subject exciting rather than just boring and kind of get it done, kind of gives new life to that subject."

Participant 13: "And you know it can be difficult just to control your mood and your feelings and emotions. Certainly, for me, it presents a lot of anxiety with that, which is probably more so from other people's views, you know the typical comments of, 'lazy, can't be bothered, doesn't apply themselves properly. If only she'd apply herself.' You think, 'if only know you knew'".

Participants contextualised *chaotic attention* by placing it in contrast with the polar opposite state of *hyperfocus*. *Hyperfocus* is defined as "a driven, intense, narrow, concentrated focus". Participants described this state as "tunnel vision", "inertic", "in the zone", and "plugged in". It is characterised by *engagement, immersion, connection, flow* and a sense of *awe*. Participants described this state as becoming deeply and passionately engaged, resulting in intense bursts of productivity and a positive sense of alignment of attention. *Hyperfocus* is accompanied by feelings of both excitement and calm, inspiration, thriving, dedication, joy, and accomplishment. *Hyperfocus* is also associated with interest and the ability to use and store information while engaged. However, this state was described as impairing due to its apparent randomness and sense of compulsion.

Participant 4: "When I hyperfocus, I feel like I'm in a different zone, like a different universe almost. My mind seemingly gets sucked in and I forget about everything else. I don't remember, like even I lose the ego state, I guess... and I'm able to be completely absorbed in what I'm doing or in the story that's going on. I wish I could get that state more often, bring that state out more often when I want to, rather than when I'm forced to, but... I like that hyperfocused state, if it's applied to the correct thing."

Participant 13: "So, yes. It's maybe got your pros to... certain degrees. Some people will find something that they're good at and... can focus on that and follow through with things. But they're quite likely to then become hyperfocused and maybe miss other things that are going on around them. You know there's the element of hyperactivity at times as well, just that too much excitement, when you get those little light bulb moments, which are great, but then actually remembering what they are later down the line, it's not quite so easy".

Both *chaotic attention* and *hyperfocus* have been extensively described in the ADHD literature. What emerged from the data was how participants described themselves as experiencing a sense of movement both within and between these states. It was difficult for them to describe one state without relation to the other. Therefore, the model uses an infinity paradigm to capture the experience of ADHD consciousness (Figure 1).

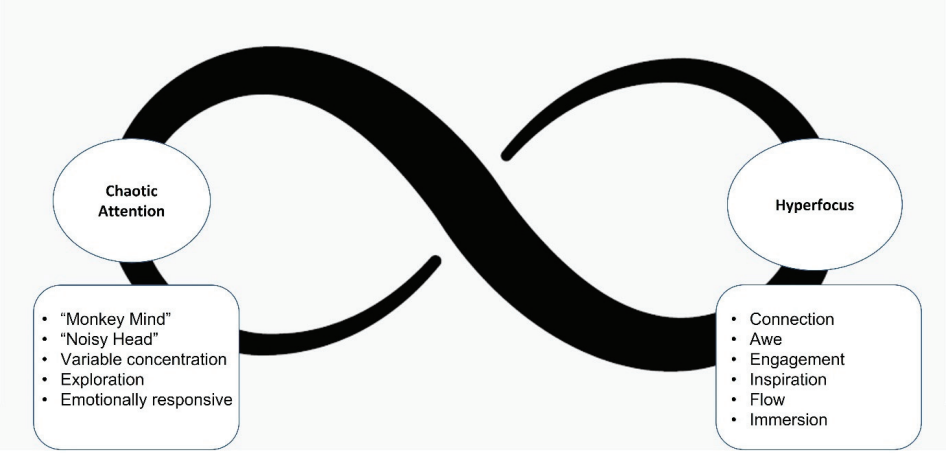

Figure 1. The polar experience of the states of ADHD consciousness.

3.3. Self-Regulation of ADHD Consciousness

Self-regulation strategies demonstrate attempts at internalisation and active management of the states of ADHD consciousness. Three strategies for ADHD self-regulation emerged from the data: *self-absorption*, *self-transcendence*, and *creative awareness* (Figure 2).

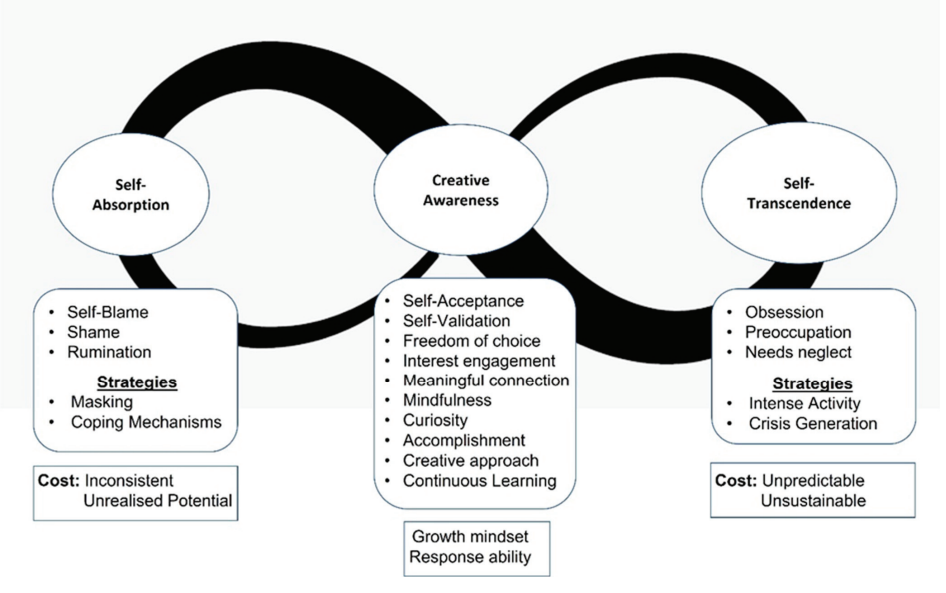

Figure 2. Polar model of ADHD self-regulation strategies for management of ADHD states of consciousness.

3.4. Self-Absorption

Self-absorption strategies are primarily aimed at regulating *chaotic attention*. They are defined as "identifying the internal sense of self as both the origin and primary factor in self-regulatory control". Participants described themselves as "dysfunctional", "rubbish", "broken", "defective", "deficient", "pathetic", "a failure" and having a sense of there being "something inherently wrong with me". *Self-absorption* strategies are characterised by *self-blame, shame, and rumination*. Attempts to regulate *chaotic attention* centre on the assumption that the ADHD individual is at fault due to inherent flaws. *Self-absorption* strategies are accompanied by deep feelings of not belonging, worthlessness, unachieved potential, anxieties around rejection and lack of hope, faith in the future, and capability to achieve success. *Self-absorption* strategies are identified as *masking* and *coping mechanisms*. *Masking* is defined as "hiding behaviours or responses and presenting socially acceptable behaviours to facilitate belonging". Participants described needing to "hide", "pretend", "pass as neurotypical" or "cover up" behaviours.

Participant 12: "So that's the bit I have communicated. I haven't told work. And there is a reason for that. I could do, but I haven't. And the reason I haven't is because quite a few years ago [while] I was still going through... the diagnosis... process, a new man came to work in our team and he was autistic. And there were lots of negative things said, and by senior management, you know,... not outright name calling, but I could see... that they treated them differently. It made me really—I don't want them to do that to me. I can't let them. It sounds like, you know that I've got this weakness, if that makes sense. I didn't want to. I can deal with it myself... I can let a couple of close colleagues who I trust know, so that they can support me if I need it. So I made that decision".

Coping mechanisms are defined as "strategies or behaviours used to reduce unpleasant emotions". Also defined as "need substitutes" in SDT [73,78], examples of coping mechanisms emerging from the data are alcohol misuse, sugary food misuse, technology misuse, dependence on external individuals for organisation or accountability, and dependence on controlling external structures in the environment. Participants aimed to gain a sense of control by actively engaging in negative self-criticism, withdrawal and isolation, focusing on weaknesses, struggling to set boundaries, and attempts to "fix oneself".

Participant 3: "I didn't actually know what was going on in terms of my brain before I had that diagnosis. I actually was screened for a lot of different things before they came to the conclusion of ADHD because I was so clueless of what was going on. I think that was definitely a lot more struggle and unhealthy coping mechanisms going on. I had a lot of obsessive-compulsive tendencies, particularly before my diagnosis... and, I think I was... desperately trying to cope in the subtlest and quietest way possible, even at my own expense. Without these things in place, I would have felt a lot more lost and confused about what was going on. I just felt that there was something inherently wrong with me."

While *self-absorption* strategies may assist with management of *chaotic attention* to some degree, they extract an energetic cost and impact on identity. They were described as inconsistent and exhausting, and participants did not feel they were being themselves or performing to their best.

3.5. Self-Transcendence

Self-transcendence strategies are primarily aimed at self-regulating *hyperfocus*. They are defined as "surrender of self-regulatory control to experience". Participants described themselves as "drawn in", "consumed", "laser focused", and the experience as, "nothing else mattered", "couldn't do anything else", "too engaging", "inhibiting" and "debilitating". *Self-transcendence* strategies are characterised by *obsession*, *preoccupation* and *needs neglect*. Attempts to regulate *hyperfocus* centre on prioritising engagement as long as possible or until a task is complete or a problem solved, sometimes to the detriment of physical needs such as eating, sleeping or toileting. *Self-transcendence* strategies are accompanied by feelings of escapism, futility, pointless activity, narrow focus, engrossment, being stuck, and an inability to stop. *Self-transcendence* strategies are identified as *intense activity* and *crisis gener-*

ation. *Intense activity* is defined as "energetic involvement with experience". Participants described feeling energised for the duration followed by exhaustion, succeeding in making progress and craving more of the experience.

Participant 7: "In one case. . . it was a small start-up, which we've grown, which meant that I needed to be able to for a couple of weeks do the impossible and basically not sleep and just hammer work. But I just was that engaged [it was just] a breeze. I was working probably, you know in some cases, two nights on the trot or two days on the trot without sleep through the night".

Crisis generation is defined as "external pressure or internal feelings of anxiety, excitement, or stress which motivate engagement". Participants expressed a need for external pressure, environmental crisis, or proximal deadlines to reduce options and utilise these strategies.

Participant 6: "So high pressure, for sure. Deadlines. In terms of uni work, the most practical thing I could give you now, my most intense work, most productive time, is when it comes to the point where if I don't do it I won't get done before the deadline; so when there are 16 h until the essay is due. Now we're doing it. Or in emergencies or like crisis situations. If someone has, like, a medical emergency or something, I am my best self. I don't know why I didn't go into, like, paramedic—to be a paramedic as a career. I am just so focused on, like geared towards the situation. I feel like my best self. . . like I always feel really accomplished".

While *self-transcendence* strategies assist with management of *hyperfocus*, they are chaotic in nature, extracting costs in energy and needs fulfilment. They were described as unpredictable and unsustainable, often occurring without conscious choice or control.

3.6. Creative Awareness

Creative awareness strategies appear at the centre of the infinity paradigm. They are defined as "open and receptive attention to the self and the environment". Participants described themselves as "calm", "passionate", "naturally motivated", "creative", "playful", "generating ideas", and "engaged". Creative awareness strategies are characterised by *self-acceptance*, or "an individual's acceptance of positive and negative attributes"; *self-validation*, or "an individual's acceptance of internal experience, including thoughts and feelings"; *freedom of choice*, or "an individual's opportunity and autonomy to perform an action selected from at least two available options, unconstrained by external parties"; *interest engagement*, or "stimulated fully focused attention"; *meaningful connection*, or "in congruent relationship with an individual's values"; *mindfulness*, or "wide flexible present moment awareness"; *curiosity*, or "interest leading to inquiry"; *accomplishment*, or "sense of achievement and capability"; *creative approach*, or "ability to respond to context with originality"; and *continuous learning*, or "desire to improve knowledge". Participants described feeling a sense of ease and capability, where they can adapt to the context, identify options, and respond effectively and successfully. They experience a sense of enjoyment, resourcefulness, and an ability to apply skills and knowledge based on an acceptance and understanding of their internal experience. This includes an awareness of their own needs, and generates confidence to set boundaries, prioritise and engage with effective tools, and request support. Activities that require effort but are also meaningful generate positive feelings of satisfaction with a job well done. Opportunities to problem solve, generate solutions or "think outside the box" provide a chance to contribute in ways that have value.

Participant 1: "I would feel really bright, really optimistic, really sunny and really, full of excitement to deliver whatever I'm doing. Or just I suppose, in the flow of things, which is really exciting and feeling a part of something as well, rather than like a spare part. I will feel, not important in a grandiose way, but I will know that what I'm doing will be valued and is helpful and nobody else could do. That's a really great feeling because it's not like, oh, I'm doing this for praise or something like that. It's just like, I am in the right hole. I'm not a square peg in a round hole, I'm in the right place. I'm in some place where I thrive".

Participant 10: "I didn't have a diagnosis actually until my adult years, but I always knew something was different. I didn't realize I was doing it, but I was making coping mechanisms and things like that, you know, as I was going along, whilst being very true to myself anyway. I never got myself a deep dark rut or whatever, trying to hide who I was. I'd just try and put myself in a position where I was capable. So, no, I think I kind of get it. It's the similar thought process I went through of, "it is what it is". I just think about things differently".

Participant 6: "Let it wash over. You try not to internalize it. Cause. . . we've grown up being frustrated with who we are. Like, why can't you just be better? Right. Try not to make it your fault. And then think about accommodation. Think about what is wrong. What are the most impeding symptoms that you have in your life? Things that you don't like to think about now, how you can change them because you tried neurotypical ways of solving problems in the past. You have obviously, you know. . . I said to the counsellors, like, I've tried everything, and nothing makes me feel better because I'm using the wrong solutions. I'm addressing the wrong problems".

Creative awareness strategies are identified as having a *growth mindset*, or "believing inherent abilities and learned skills can be developed over time", and *response ability*, or "the ability to respond to the present context". Participants described both a desire and active effort to develop their self-knowledge and improve their skills and ability to be successful. They demonstrated strong resilience in the face of lifelong challenges, and a positive outlook for the potential future. Creative awareness strategies exemplify internalised identity commitments and perception of the AIC. Participants shared stories where their skills and abilities resolved situations or provided additional resources to facilitate positive outcomes. They described feeling present, focused, engaged, and able to meet challenges creatively and effectively.

4. Discussion

Participants were clear that experience of consciousness centred around the differences in engagement between *chaotic attention* and *hyperfocus* and the environment generate core perceptions of self. This changing sense of self in reference to the relationship between awareness and experience is echoed in the Buddhist perspective of "groundlessness" of consciousness [79], and is exemplified in ontological phenomenalism [80,81], the emergence of self in Gestalt therapy [82], the "middle mode" of embodied cognition [83] and the "self-as-process" of SDT [73,76].

4.1. Challenges with ADHD Self-Regulation and Identity Construction

Self-absorption and *self-transcendence* emerged from the data as unskilled strategic attempts at self-regulation and internalisation of the polar nature of ADHD consciousness. While these strategies may appear successful on the surface, the unreliability, lack of authenticity, and energetic cost demonstrated a clear negative long-term impact on participants' self-concept and identity construction. From an SDT perspective, each strategy for behavioural regulation and motivation would be identified as originating from a different perceived locus of causality (PLOC) [84]. *Self-absorption* strategies characterised by lack of personal value, sense of inability or competence, and lack of a sense of achievement demonstrate a state of amotivation. Those characterised by dependence on external reward or punishment or arising from reactivity are externally regulated. Finally, strategies characterised by internal pressure such as guilt or shame and need for concealment or driven by egoistic pride or need for recognition represent introjected regulation. *Self-transcendence* strategies demonstrate more characteristics of interest, personal value, and congruence with outcomes; however, due to the nature of these strategies' dependence on external or internal pressure and prioritisation of engagement with activity to the degree of neglecting needs, these strategies are identified as external or identified regulation. Because these strategies are more controlled, external, and low in autonomy (and therefore originate from

goals adopted from outside the self [73,84]), they will be demonstrably less effective in ADHD self-regulation, and identity commitments will be less internalized (Figure 3).

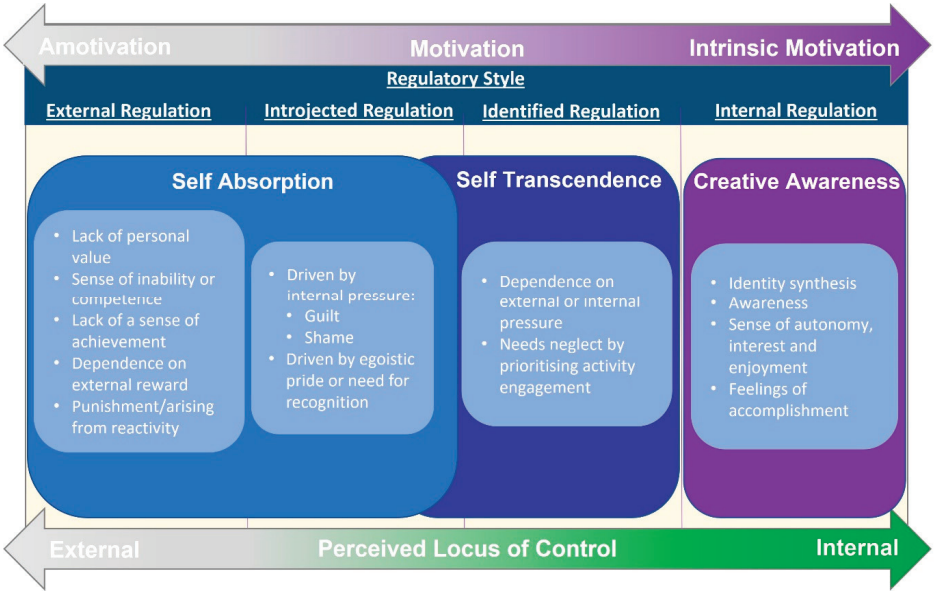

Figure 3. Creative Awareness Theory (CAT) and self-determination theory (SDT) regulatory styles.

4.2. Resources for ADHD Self-Regulation

Creative awareness strategies emerged from the data as participants' description of awareness of the polar opposites of consciousness and self-regulation of that awareness. These skills in self-regulation exemplify Perls et al.'s [82] process of creative adjustment, based on Friedlander's [85] philosophical concept of the polarity principle. Friedlander theorises that the basic characteristic of any phenomenon is that it can go to extremes. For that to be appreciated, it must be different from something else—namely its polar opposite [85–87]. Thus, the two polar extremes are internally connected. This polar opposition can only be distinguished through differentiation, or by considering one phenomenon relative to its polar opposite, e.g., it is relatively light compared to the polar opposite of dark [87]. The centre between these poles is the focus of Friedlander's philosophy, what he calls its "indifference":

"From time immemorial, when dealing with polarities. more attention has been paid to the poles than to the indifference. Yet in this indifference lies the real secret, the creative will, the polarizing one itself, which objectively is absolutely nothing. However, without indifference there would be no world" [87], (p.118).

This indifference is the creative centre of reality, from which differentiation into opposites takes place. This is not a static midpoint, however, but a lively multiplicity of differentiation of many polarities exemplified in Friedlander's resistance to using a singular label or term and instead using variations such as ego, self, being, subject, individual, identity, person, mind, soul, absoluteness, ∞, insistence, will and freedom [87]. The aim of Friedlander's philosophy is to achieve authentic creativity through indifferentiation of one's own awareness, achieving an indifferent clarity of mind leading to integration and becoming centred. This is achieved through an active art of balance, or equilibration, where a person remains centred in indifference with an awareness of the link between opposites, allowing the freedom to react appropriately to the demands of a situation from either pole [87]. Perls [88] describes this equilibration as "differential thinking", which forms the foundation for successful *creative adjustment* at the point of contact with the

environment [82]. Personified as a creative and dynamic acceptance and assimilation of novelty resulting in growth, *creative adjustment* is seen as synonymous with *thriving*, or access to true self-regulation, in SDT [73]. From an SDT perspective, *creative awareness* strategies are characterised by a sense of self-direction, awareness, persistence, a sense of meaning, and vitality while engaging with challenges are all features of a perception of the AIC [89,90]. Combined with a sense of autonomy, interest and enjoyment, identity internalisation and feelings of accomplishment, these characteristics are all features of integrated and intrinsic regulation.

A review of the data also shows that the themes identified in *creative awareness* strategies also support the three basic psychological needs that must be satisfied to sustain psychological interest, wellness and development, defined in SDT as *autonomy*, *competence* and *relatedness* (Table 2) [73,91]. Therefore, participants' experience of *creative awareness* strategies are identified in this analysis as the ADHD experience of SDT's intrinsic regulation, internalisation, or effective self-regulation.

Table 2. Core themes of creative awareness and SDT basic psychological needs.

SDT Basic Psychological Needs		
Autonomy	**Competence**	**Relatedness**
• Self-acceptance • Self-validation • Freedom to choose • Creative approach • Interest engagement • Curiosity	• Accomplishment • Continuous learning	• Meaningful connection • Mindfulness

5. Limitations and Further Research

Charmaz's [56] constructivist grounded theory methodology was specifically chosen for this project in light of the researcher's lived experience of ADHD, which does present a risk of bias. The approach recognises the interpretive and reflexive role of the researcher, fostering awareness of presuppositions and interpretations and their effect on the research. As the theory is "dependent on the researcher's view; it does not and cannot stand outside it" [56] (p. 239), the intention of this study was to view the experience of ADHD through the lens of ADHD with the aim of revealing new perspectives. Recent developments in neurodiversity activism have led to models of 'inclusive research' [92] which promote the contribution of neurodivergent researchers to the field [93–95]. A primary goal of this study was to contribute this viewpoint to the broader literature while simultaneously recognising the influence of this perspective.

In line with grounded theory methodology [56], saturation of data was identified at the completion of 11 interviews. As no new properties were identified, data were considered dense enough for theoretical completeness. While this may not be generalisable by the standards of qualitative research, grounded theory methodology supports quality of data from significant analysis despite a small sample size [96]. The findings from this study are important in exploring a different perspective on the experience of ADHD self-regulation that generates opportunities for increased self-understanding by individuals with ADHD.

We suggest that the CAT can be used in diverse settings to support individuals with ADHD in two areas: through psychoeducation, to better understand their experiences of engagement, and as a framework through which to develop the strategies demonstrated in *creative awareness* for self-regulation. The goals for professionals working with adults with ADHD should be to assist them to identify the impact that the experience of polarity has on self-belief, identity construction and self-concept; increase critical awareness of polarity strategies they are engaging with in a given context; and encourage the use of resources such as curiosity and mindfulness to increase flexibility and creativity in response. Further research is recommended to develop interventions to investigate the feasibility of the model as a basis for treatment. A novel 11-session therapeutic self-development,

psychoeducation and skills training programme grounded in SDT and using the CAT has been piloted to examine participant acceptability, feasibility and efficacy. This programme uses a multi-modal psychotherapeutic approach and educational methodology to assist participants in understanding ADHD and developing self-regulation skills.

6. Conclusions

The ADHD Creative Awareness Theory (CAT) highlights the significance of the polar nature of the interaction of ADHD consciousness and the environment, identified in this study as *chaotic attention* and *hyperfocus*. The challenges of active management of this polar engagement alongside a lack of understanding lead to unskilled maladaptive self-regulation strategies, known as *self-absorption* and *self-transcendence*, which may allow an ADHD individual to operate at a functional level but come at a high cost to their energetic resources, self-concept, identity commitments, and fulfilment of needs. Recognition and understanding of the ADHD interactive polarity generates opportunities for effective self-regulation strategies, or *creative awareness*, which arise both naturally and through skill development from lived experience of ADHD. These strategies reflect the SDT perception of an authentic inner compass and definition of integrated or intrinsic self-regulation, and they contribute to a much-needed growing body of research on the positive human qualities of ADHD.

Recent research indicates that the understanding of ADHD self-regulation is dominated by cognitive behavioural theoretical perspectives [1]. These theories centralise executive function differences as impairing deficits, informing the definition of ADHD and specifying symptom reduction and behavioural control as primary treatment outcomes [54]. We propose that the CAT presents an emergent model of ADHD identity construction and self-regulation that provides both a positive perspective on the capability of individuals with ADHD to coherently self-regulate and a foundational skill set to generate more universal treatment outcomes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/jcm13195963/s1, Figure S1: Concept Map 1—Initial Concepts. Figure S2: Concept Map 2—Theoretical Concepts. Figure S3: Concept Map 3—Self-Focus Process Map. Figure S4: Concept Map 4—Self-Transcendence Process Map.

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Psychotic-like Experiences and Underlying Mechanisms: An Integrative Model of ADHD Symptoms, Rumination, Negative Affect, and Trauma Experience

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Abstract: Background: Psychotic-like experiences (PLEs) are low-intensity subclinical phenomena, often transient in nature. The etiology of PLEs primarily involves neurodevelopmental changes, trauma exposure, and maladaptive coping styles. Attention-Deficit/Hyperactivity Disorder (ADHD) is considered to be one of the factors that increase the risk of future psychosis. Furthermore, ADHD symptoms predict a heightened incidence of traumatic experiences, ruminative thoughts, and negative affect (NA). This present study examines whether rumination and NA mediate the relationship between ADHD symptoms and PLEs and whether trauma experiences moderate these pathways. **Methods:** A total of 188 participants (72% female) aged 18–35 completed questionnaires assessing ADHD symptoms and traumatic experiences and took part in a seven-day experience sampling method (ESM) procedure, completing ratings of PLEs experiences, the intensity of ruminations, and NA. **Results:** Correlation analysis showed significant relationships between all tested variables. Serial mediation analysis revealed a significant indirect effect of rumination and NA in the link between ADHD symptoms and PLEs. There was no significant impact of trauma experience in this relationship. **Conclusions:** Our study underscores the important role of rumination and NA in the co-development of ADHD symptoms and PLEs. Future research should consider investigating the intra-individual dynamics of ADHD and trauma using ecologically valid research methods in the context of PLEs to better understand these complex relationships.

Keywords: psychosis; abuse; neurodevelopmental changes; negative repetitive thinking; negative emotions

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1. Introduction

Psychotic-like experiences (PLEs) refer to hallucinations or delusions defined as subclinical phenomena, encompassing both delusion-like experiences and perceptual abnormalities [1,2] with a limited intensity, transience, or functional impairment. They are situated at the lower end of the psychosis continuum [1], representing a category of low-grade positive psychotic symptoms that do not meet the criteria for a psychosis spectrum disorder [3,4]. Because PLEs are far more common than severe psychotic symptoms in the clinical context [5] and affect approximately 5–7% of adults in the general population [6], their impact and associated costs may be still important [7]. Individuals with PLEs report more distress [8], more depressive symptoms [9], lower general functioning [8], and increased suicide risk [10,11], among others, compared to healthy controls. While PLEs typically resolve naturally over time in most individuals (~80%), a significant minority

(∼7%) progresses into full-blown psychosis [12]. Despite a growing interest in PLEs over the past two decades, the mechanisms underlying hallucinations/delusions remain poorly understood. Research suggests that neurodevelopmental changes [13] and the experience of (early childhood) trauma are potential mechanisms of the risk of psychosis and its different stages (e.g., PLEs, full-blown psychosis; see [14–16]. Also, the use of maladaptive coping strategies, such as ruminative thought and the experience of negative affect, have been shown to increase the risk of PLEs occurrence [17,18]. An integrative theoretical model that links early developmental changes, trauma experience, and coping strategies in the context of PLEs remains necessary. Therefore, this present study focuses on the role of Attention-Deficit/Hyperactivity Disorder (ADHD) symptoms on PLE occurrences, as ADHD is a proxy for neurodevelopmental disadvantage (given the wide variety of associated neurological disorders; see [19]. The objective of this study is to test whether the association between the severity of ADHD symptoms and PLEs is mediated by the potential role of rumination and negative affect in daily life, and if the reported traumatic experiences strengthen this relationship. Hence, we examine whether (a) ADHD symptoms predict more PLEs, whether (b) rumination and negative affect mediate this association, and whether (c) the traumatic experiences over the life course moderate these processes.

1.1. The Role of ADHD and Trauma in the Context of PLEs

The sociodevelopmental–cognitive model of psychosis posits that schizophrenia is a neurodevelopmental disorder [20], which may explain the covariance with other neurodevelopmental disorders, especially Attention-Deficit/Hyperactivity Disorder (ADHD; [21,22]). ADHD symptoms are strongly associated with PLEs [23], and children diagnosed with ADHD exhibit a fivefold increased risk of developing psychotic disorders [24,25]. A systematic review of 15 studies and a meta-analysis of 12 studies conducted by Nourredine et al. (2021) [25] showed that up to 13% of patients diagnosed with schizophrenia were also diagnosed with ADHD, while adult ADHD symptom severity was associated with more paranoid thoughts and auditory hallucinations [26]. Finally, around 80% of schizophrenia patients exhibit a progressive cognitive decline from early adolescence, leading to functional disability and secondary (indirect) illness costs [27,28].

The sociodevelopmental–cognitive model of psychosis emphasizes the role of adverse childhood experiences on gene expression and dopaminergic dysregulation [13], resulting in abnormal stimulus processing, including the salience dysregulation that marks the psychosis spectrum [29,30]. Such neurodevelopmental changes arise from interactions between the environment, genes, and traumatic/adverse experiences, and dopaminergic dysregulation may result in abnormal stimulus processing, paranoid interpretations, and psychotic experiences, a process exacerbated by dysfunctional cognitive schemas [13]. Consequently, individuals with maladaptive cognitive biases are more susceptible to experiencing stress, paranoia, and/or hallucinatory experiences, potentially perpetuating or worsening psychotic beliefs.

Neurodevelopmental theories are supported by the threefold increase in the risk of developing psychotic disorders in individuals who experienced childhood trauma [31]. Childhood trauma may intensify the impact of social stress during adolescence and young adulthood when the risk of developing psychosis increases and the hypothalamic–pituitary–adrenal (HPA) axis becomes overactive or dysregulated [32]. Consequently, individuals at risk of psychosis demonstrate a heightened sensitivity to daily stressors and alterations in HPA functioning [33,34]. Furthermore, research has demonstrated that trauma is associated with an elevated risk of psychosis through the formation of cognitive biases [9,35], which in turn may render victimized people more susceptible to stress, paranoia, and/or hallucinatory experiences, and perpetuate or even exacerbate their psychotic beliefs.

1.2. The Role of Rumination Thoughts and Negative Affect in the Context of PLEs

Emotional dysregulation is a key symptom of ADHD [36] and is evidenced by deficits in self-regulation [37,38]. Self-regulation deficits are evident in low frustration tolerance and

high mood lability [39]. Indeed, individuals diagnosed with ADHD are more likely to report negative emotions, including anger, irritability, and frustration, and to ruminate more [40–42], thus causing persistent thoughts and mental images focusing on negative emotions and symptoms, pondering their causes, meanings, and consequences [43,44]. These symptoms have recently been proposed as one of the primary symptoms of ADHD [45]. Additionally, ADHD-related symptoms indirectly exacerbate depressive and anxiety symptoms through ruminative thoughts, significantly impacting an individual's functionality [43].

The experience of distress or anxiety can elicit intrusive thoughts and more negative emotions [46]. Rumination frequency predicts anxiety and depression symptom severity [44,47] and more negative emotional outcomes and distress from psychosis symptoms [48,49]. Negative emotions play a pivotal role in the emergence of psychotic content and/or symptoms and underlie all emotional and psychotic disorders [50,51]. Such negative emotions are thought to be induced by meta-cognitions ("thinking about thinking"), meta-beliefs, and poor coping that amplify psychological distress [52]. Wells and Matthew's model (1994, 1996) [53,54] on metacognitions focuses on maladaptive coping strategies and metacognitive beliefs that contribute to psychological distress by inducing negative emotions. For example, ruminative thinking, a maladaptive coping mechanism, likely plays an important role in the distressing experience of psychosis. A review reported more rumination in patients with psychosis than in healthy controls [18] and poorer self-regulatory strategies among schizophrenia patients than in the controls [55]. Furthermore, rumination or repetitive negative thinking is more common among adults who have lived through childhood adversity [56–58].

Ruminative thoughts can focus attention on threatening stimuli and create false associations between unrelated events and thoughts (salience dysregulation), which in turn perpetuates ruminative thoughts associated with delusions and more negative emotions [59]. Additionally, re-experiencing traumatic events and using maladaptive coping strategies to regulate emotions may contribute to experiencing auditory or visual hallucinations or persecutory imagery [60–62].

Despite the existence of established links between ADHD symptoms, ruminations, negative affect, trauma, and psychotic-like experiences, their interactions and codependencies remain unclear. Therefore, this present study aims to address this gap in the literature by examining whether ruminations and negative affect mediate the link between ADHD and PLEs and whether the trauma experience moderates these mediation pathways.

1.3. This Study

This present study is focused on the role of ADHD symptoms in the occurrence of PLEs. Our aim is to determine whether the relationship between ADHD and PLEs is mediated by rumination and negative affect experienced in daily life and whether this connection is exacerbated by reported traumatic events. Hence, we examine three key questions: (a) whether ADHD symptoms predict more PLEs, (b) whether the ADHD–PLE relationship is mediated by rumination and negative affect, and (c) whether these effects are moderated by differential exposure to traumatic events through life. This resulted in the following hypotheses:

H1. *ADHD symptoms predict more PLEs.*

H2. *Rumination and negative affect mediate the relationship between ADHD symptoms and PLEs (serial mediation).*

H3. *The link between ADHD symptoms and PLEs (**H1** + **H2**) is moderated by exposure to traumatic life events, such that the positive relationship between ADHD symptoms and PLEs through rumination and negative affect will become stronger in people who developed under conditions of higher levels of traumatic experience (moderated serial mediation).*

2. Methods and Materials

2.1. Participants

Data were derived from 188 participants (including participants in the control group N = 89 and participants in the experimental group N = 99) of a community sample recruited in three Polish cities (i.e., Warsaw, Wroclaw, Szczecin) for an ongoing study into epigenetic processes and associations with momentary stressors and psychotic-like experiences.

Included participants were (1) aged 18–35 years, (2) without a history of psychiatric treatment, and (3) with psychotic-like symptoms (PLEs) based on 16 items presented in the Recruitment Phase below, a global rating of 3–4 points for reference imagery and/or suspicion and persecutory imagery *(e.g., "I often have the feeling that other people are against me.", "I was worried about being stalked.", "I spend my time thinking that my friends are gossiping about me.")*, and/or a global score of 3–4 points for hallucinations *(e.g., "I hear a voice speaking my thoughts aloud.", "I can hear things that other people can't hear, such as the voices of people who are whispering or talking.", "I can see things that other people can't see.").* Participants who scored between 48 and 64 points were assigned to the experimental group, and those with 0–32 points became the control group (a global rating of 0–2 points for reference imagery and/or suspicion and persecutory imagery and/or a global score of 0–2 points for hallucinations). Exclusion criteria included (1) a lifetime history of psychiatric treatment, (2) a current episode of major depressive disorder (MDD), and/or (3) a diagnosis of substance use disorder (other than nicotine dependence).

The study protocol was approved by the Ethics Committees of the Institute of Psychology (Polish Academy of Sciences, Warsaw, Poland, approval number: 16/VII/2022), Wroclaw Medical University (Wroclaw, Poland, approval number: 129/2022), and Pomeranian Medical University (Szczecin, Poland, approval number: KB-006/25/2022).

2.2. Materials

The participants were required to complete a seven-day experience-sampling method (ESM) procedure, a clinical interview comprising a comprehensive Mini-International Neuropsychiatric Interview (M.I.N.I.), and the Comprehensive Assessment of At-Risk Mental States (CAARMS) (see Supplementary Tables S1 and S2 for prevalence scores on M.I.N.I. and CAARMS scales in the study sample). Furthermore, the participants were required to complete a series of questionnaires, including the Traumatic Experience Checklist (TEC; [63]), all described in detail below.

Demographics. Participants were asked to self-report their age, gender, educational level, and family history of psychiatric illness (i.e., depression and schizophrenia spectrum disorders).

The Comprehensive Assessment of At-Risk Mental States (CAARMS; [64,65]) is a semi-structured interview to determine ultra-high risk (UHR) status and measure a range of subthreshold symptoms associated with the prodromal phase of psychotic disorders. The CAARMS provides an intensity and frequency score for each item. It consists of 27 items grouped into seven scales: positive symptoms, cognitive changes, emotional disturbance, negative symptoms, behavioral changes, motor/physical changes, and general psychopathology. The scores for each of the subscales range from 0 to 6. The CAARMS was selected for this study due to its demonstrated efficacy in identifying individuals at ultra-high risk (UHR) for psychosis, exhibiting superior predictive accuracy and flexibility compared to other diagnostic instruments, as evidenced by the findings of Wang et al. (2022) [66].

The Mini-International Neuropsychiatric Interview (M.I.N.I.; [67]) was developed to assess the diagnoses of psychiatric patients according to DSM-IV and ICD-10 criteria. In order to verify the diagnoses, the gold standard was applied through the use of a structured diagnostic interview M.I.N.I. All the items in the questionnaire are answered with a 'Yes' or 'No' answer, starting with the screening questions and ending with the diagnostic blocks to check whether a patient meets the diagnostic criteria. In this study, the Polish version of M.I.N.I. Plus 5.0.0 was used, including all the modules.

The Adult ADHD Self-Report Scale (ASRS; [68]) is an 18-item self-report screening scale for adult Attention-Deficit/Hyperactivity Disorder (ADHD). Responses range between 0—"never" and 4—"very often". The total score ranges between 0 and 72. The Symptom Checklist is an instrument consisting of the eighteen DSM-IV-TR criteria. Six of the eighteen questions from part A (1–6) are the most predictive of symptoms consistent with ADHD. For part A, points are summed for a range of 0–24, with a cut-point $\geq$ 14 for ADHD. The total score can be classified into four categories: 0–9 is low negative, 10–13 is high negative, 14–17 is low positive range, and 18–24 is high positive range. The remaining twelve questions (7–18) are included in part B of the Symptom Checklist. The Cronbach's alpha of the ASRS was 0.92 in our sample. The Adult ADHD Self-Report Scale (ASRS) was selected on the basis of its demonstrated reliability and validity in large-scale, cross-cultural studies, which have effectively captured ADHD symptoms in diverse populations (see [69]).

The Traumatic Experiences Checklist (TEC; [63]) is a 29-item self-report questionnaire addressing potentially traumatizing serious emotional events categorized across three types of trauma, referred to by six subscales: (1) emotional trauma captures emotional neglect and/or emotional abuse in various social settings with six items (*e.g., "Emotional neglect (e.g., being left alone, not shown enough affection) by parents or siblings. Has this happened to you?"*); (2) sexual trauma captures sexual harassment and/or sexual abuse in various social settings with six items (*"Sexual harassment (acts of a sexual nature in which there is NO physical contact) by parents or siblings. Has this happened to you?"*); and (3) bodily threat, which captures physical abuse in various social settings and intentional threat to one's life, bizarre punishment, or intense pain, with six items (*e.g., "Physical abuse (e.g., being hit, bullied or physically hurt) by parents or siblings. Has this happened to you?"*). Scale scores for emotional, sexual, and bodily trauma are calculated by summing the presence scores for the relevant items, with six items each for emotional and sexual trauma and bodily threat. The Cronbach's alpha of the TEC total was 0.74 in our sample, and the subscales were as follows: emotional trauma 0.66, sexual trauma 0.31, and bodily trauma 0.39. The Trauma Exposure Checklist (TEC) was selected on the grounds of its status as a valid and reliable tool for assessing trauma exposure and its associated risk and protective factors. This is evidenced by its robust factorial structure and psychometric properties, as demonstrated in recent studies (e.g., [70]). The experience sampling method (ESM) questionnaires covered various domains of psychotic-like experiences (PLEs). All items included in the statements are presented in Table 1. While most of the items used in the questionnaires were adopted from previous studies [71–73], we also included items adapted from the PQ-16 [74] to capture the presence of PLEs. In the ESM procedure, participants also responded to questions regarding ruminative thoughts and negative affect (NA), as well as to additional questions that were not pertinent to this present study (see Supplementary Table S3). However, only items related to PLEs, ruminations, and NA are analyzed here. The order of items was not randomized.

Table 1. Concepts used in this present study and their definitions.

Domain	#	Scale	Items	CA
PLEs	8			0.85
Hallucination-like	3	1–7	"My thoughts are so strong that I can almost hear them". "I hear things that aren't really there". "I see things that aren't really there".	0.66
Delusion-like	5	1–7	"I have the sense that some person or force is around me, although I can't see anyone". "I see special meanings in advertisements, shop windows, or in the way things are arranged around me". "I am confused whether something I experienced was real or imaginary". "My thoughts are influenced by others". "I can't get these thoughts out of my head".	0.78

Table 1. *Cont.*

Domain	#	Scale	Items	CA
Ruminative thought	1	1–7	"At the moment, I feel that I am stuck on negative thoughts and can't get away from them".	-
Negative affect	5	1–7	"I feel anxious". "I feel down". "I feel lonely". "I feel insecure". "I feel annoyed".	0.86

Note. All scales ran from "not at all" (1) to "very much" (7). # = number of items. CA = Cronbach's alpha. PLEs = Psychotic-like experiences, which comprise hallucinations and delusions experiences.

2.3. Procedure

2.3.1. Phase I

The recruitment of study participants began with an extensive screening process using snowball sampling via social media and survey websites. We recruited 4203 participants for a web-based survey, who completed a 16-item screener to identify the presence of psychotic-like experiences (PLEs) in the previous month (between April and October 2022) derived from the following questionnaires: (1) the Revised Hallucination Scale (RHS; three items, [75–77]); (2) the Revised Green Paranoid Thoughts Scale (GPTS; four items, [78]); and (3) the Prodromal Questionnaire-16 (PQ-16; nine items, [74]). Participants were also asked to complete the 14 screening questions of the Mini-International Neuropsychiatric Interview (M.I.N.I.; [67]) for depression, mania, panic attacks, anxiety, agoraphobia, social phobia, obsessive–compulsive disorder (OCD), post-traumatic stress disorder (PTSD), and alcohol/drug abuse. Participants were also asked to fulfill the Adult Attention-Deficit/Hyperactivity Disorder (ADHD) Self-Report Scale (ASRS; [68]).

2.3.2. Phase II

The second screening step included telephone interviews with participants with the highest PLEs scores, constituting the experimental group, and participants with the lowest PLEs scores, referred to as the control group. To provide clinical validation of the presence of current psychotic-like experiences, selected questions from the Comprehensive Assessment of At-Risk Mental States (CAARMS; [64,65]) were used, examining the following symptoms: (1) ideas of reference (*e.g., "Have you felt that things that were happening around you had a special meaning, or that people were trying to give you messages?"*), (2) suspiciousness and persecutory ideas (*e.g., "Do you feel like people have been talking about you, laughing at you, or watching you?"*), and (3) hallucinations (*e.g., "Do you ever hear things that other people seem not to, such as sounds, or voices?"*). Furthermore, individuals who tested positive for major depressive disorder (MDD) and substance use disorders underwent additional testing using the Mini-International Neuropsychiatric Interview (M.I.N.I.). Those who met the criteria for any of the aforementioned disorders were disqualified from participating in this study.

2.3.3. Phase III

Participants who met all inclusion criteria were invited to a face-to-face diagnostic interview, were informed about the experience sampling method (ESM) procedure, and were provided with all necessary materials. Prior to the commencement of the interview and study procedure, participants were required to complete a series of documents, including an informed consent form. This document detailed the procedures and stages involved in this study, as well as the option to withdraw from the research at any point without providing a reason. It also outlined the remuneration offered, the requirements for obtaining it, and information regarding the processing of personal data, the anonymity of the research, and collective data analysis.

2.3.4. Experience Sampling Assessment

The ESM procedure was conducted over seven days, with six assessments per day (42 assessments in total) administered between 9 a.m. and 10 p.m. with a minimum 60 min gap between prompts (a stratified randomization strategy) via the MovisensXS application on provided smartphones, Version 1.5.23 (Movisens GmbH, Karlsruhe, Germany; https://www.movisens.com, accessed on 28 April 2024). Prior to the beginning of the protocol, participants were provided with detailed instructions and a handout with all relevant information. Participants were informed that they were required to respond to each beep directly or delay it for up to 15 min. Failure to comply with these instructions resulted in the survey being considered incomplete, which accounted for a total of 3.6% of all surveys. In order to encourage participation in the study, respondents who achieved a response rate of at least 80% were awarded a prize of EUR 250. The threshold was set in accordance with recommendations identified in previous studies in the field of experiential sampling methodology [79,80]. Accordingly, the decision was taken to set the minimum response rate in the ESM to 80% in order to ensure the reliability of the collected data, while allowing for the possibility of unforeseen occurrences. Consequently, the requirements were reduced from 100% to the aforementioned 80%. Participants who encountered technical difficulties or required further clarification were encouraged to establish contact with the experimenter via email or telephone. Once the experience-sampling period was complete, participants were invited to the final face-to-face meeting with the experimenter to receive their duly compensated remuneration. Participants were asked if any unusual events had occurred during the previous week and, if necessary, provided information about the availability of psychological support.

2.4. Analysis

Statistical analyses were performed in SPSS 29. The analyses include all participants included in this study, without a distinction between the groups. It should be noted that the groups in this study were recruited for the main project. Nevertheless, the characteristics of the study groups are presented in the following section (see Table 2, Descriptives) and in the descriptive characteristics of the study subgroups (see Supplementary Tables S6 and S7).

Table 2. Descriptives.

Variable		N	%	Mean	SD	Min	Max	Range
Group	Experimental	99	52.7%					
	Control	89	47.3%					
Gender	Men	52	27.7%					
	Women	136	72.3%					
Age				25.21	5.18	18	35	18–35
Education level								
Primary		6	3.2%					
Secondary		79	42%					
Vocational		1	0.5%					
Higher		102	54.3%					
ADHD (ASRS total) [1]				34.05	14.36	0	65	0–72
Part A [2]				10.80	5.37	0	23	0–24
Part B [3]				23.24	9.88	0	46	0–48
Psychotic experiences [4,5]				11.92	5.58	6.48	36.36	
Rumination [4,6]				2.47	1.15	1	6.15	
Negative affect [4,7]				9.64	4.39	4.20	23.20	
Trauma measurement (TEC total) [8]				4.98	3.85	0	17	0–29
Emotional trauma [9]				1.85	1.61	0	6	0–6
Sexual trauma [9]				0.37	0.65	0	2	0–6
Bodily threat [9]				0.96	1.05	0	5	0–6

Note. [1] ADHD was assessed with the Adult Self-Report (ASRS). [2] Part A = Predictive list of ADHD symptoms (ASRS). [3] Part B = Control list of ADHD symptoms (ASRS). [4] As assessed with the experience sampling method (ESM), see the Methods section for details. [5] The average of Psychotic-like experiences (PLEs) over one week. [6] The average of rumination scores over one week. [7] The average of negative affect (NA) scores over one week. [8] Trauma measurement was assessed with the Traumatic Experiences Checklist (TEC). [9] Trauma measurement (TEC) subscales. N = Number of participants. SD = Standard deviation. Min = Minimum. Max = Maximum.

Pearson's correlation analyses were conducted to investigate the relationships between ADHD, PLEs, ruminations, negative affect, general trauma experience, and three subtypes of trauma (emotional, sexual, and bodily threat trauma). We use correlations (r) and betas (β) as effect size indices to express our results, which we regard to be small if they are between 0.10 and 0.19, moderate between 0.20 and 0.29, and large from 0.30 based on normative effect sizes that are commonly found [81–83]. For this typical effect size of around $r = 0.20$, one study needs at least 150 participants but, ideally, up to 250 participants to reduce estimation error in correlations [84]. The medium effect size was based on Cohen's (1988) [85] notion that it should be noticeable to the naked eye of a careful observer. We prefer practical significance (effect sizes) over statistical significance (p-values), which means we adhere to conventional p-values unadjusted for multiple testing) [85,86] and focus on effects significant at $p < 0.05$.

The strong correlations between several independent variables, including PLEs, rumination, and negative affect (ranging from 0.72 to 0.89, see Table 3), could indicate multicollinearity, which can indicate that variables are close to perfect linear combinations of one another, resulting in potentially unstable regression estimates and, thus, wide standard errors and unreliable significance tests [87]. When we examined the Variance Inflation Factors (VIFs, see Supplementary Table S4), they indicated salient but moderate inflation (all VIFs < 4.8, but close to 5, see [87]). When we examined the condition index (CI) of our correlation matrix (a function of their eigenvalue collinearity), however, there was no indication of variable collinearity problems (CI = 3.96 for the fourth and 4.81 for the fifth dimension; see Table S5 and following [87]). We, therefore, have reasonable trust in our multiple regression models estimated with robust confidence intervals, as described below.

Table 3. Correlations between study variables (N = 188).

#	Variable	Mean	SD	1.	2.	3.	4.	5.	6.	7.
1.	PLEs [1]	11.92	5.58							
2.	ADHD [2]	34.05	14.36	0.41						
3.	Ruminations [3]	2.47	1.15	0.67	0.53					
4.	NA [4]	9.64	4.39	0.69	0.56	0.89				
5.	Trauma [5]	4.98	3.85	0.37	0.31	0.33	0.30			
6.	Emotional trauma [6]	1.85	1.61	0.33	0.36	0.36	0.35	0.84		
7.	Sexual trauma [7]	0.37	0.65	0.36	0.23	0.27	0.31	0.60	0.41	
8.	Bodily threat [8]	0.96	1.05	0.26	0.24	0.26	0.19	0.75	0.51	0.34

Note. All correlations were significant at $p < 0.001$. N = Number of participants. SD = Standard deviation. [1] PLEs = Psychotic-like experiences (assessed with the 1-week aggregated ESM data). [2] ADHD = Attention-Deficit/Hyperactivity Disorder (assessed with the Adult ADHD Self-Report Scale; ASRS). [3] Ruminations (assessed with the 1-week aggregated ESM data). [4] NA = Negative affect (assessed with the 1-week aggregated ESM data). [5] Trauma experience is treated as a total score from TEC, and [6,7,8] are treated as subscales of trauma: [6] Emotional trauma captures emotional neglect and/or emotional abuse; [7] Sexual trauma captures sexual harassment and/or sexual abuse; [8] Bodily threat captures physical abuse in various social settings and intentional threats to one's life, bizarre punishment, or intense pain.

Student's t-test for independent samples was conducted to assess the group differences in outcomes between the female (N = 136) and male (N = 52) participants and for the experimental (N = 99) and control groups (N = 89) (see Supplementary Tables S6 and S7 for descriptive characteristics of the subgroups).

To test our hypotheses, serial mediation and moderated serial mediation analyses were conducted using the PROCESS macro for SPSS [88]. The dataset included variables from both ESM measures (PLEs, rumination, and negative affect) and self-report questionnaires (ADHD and trauma). The ESM data were aggregated in order to align with the other variables included in the model, which were measured at a single time point. This aggregation process involved averaging the measurements, including those obtained via ESM (negative affect, rumination, PLEs) and those collected at a single time point (ADHD symptoms, trauma) to create a single score that reflects the participants' experiences over the entire time frame. This approach enabled the analysis of all variables, including those

measured via ESM and those collected at a single time point, on an equivalent level for comparative and inferential purposes. For the ESM data, the results of those who achieved a response rate of at least 80% were included, and missing responses were not included in the calculated average of PLEs, negative affect, and rumination.

First, serial mediation analysis was used to investigate the role of ruminative thoughts (M_1) and negative affect (M_2) in the relationship before ADHD (X) and PLEs (Y), using Model 6 in the SPSS PROCESS macro. Secondly, general trauma experience scores and the three subscales of trauma separately, namely, emotional, sexual, and bodily trauma, were added as moderators of the mediation model, resulting in a moderated serial mediation analysis (using Model 85 in the PROCESS macro) to test whether trauma experience (W) would moderate the role of mediator ruminations (M_1) and negative affect (M_2) in the relationship between ADHD (X) and PLEs (Y). Third, we fit similar models separately for three subscales of trauma to explore whether any particular type of traumatic experience played a unique role in the model. We tested our hypothesis using 95% bootstrapped confidence intervals (CIs) in PROCESS, generated with 5000 bootstrapped samples.

3. Results

The study sample consisted of 72.3% female participants aged 18–35 (M = 25.21, SD = 5.18). Of these, 54.3% had completed higher education, while 42% had completed secondary education; see Table 2. The results for individual questionnaires and sample characteristics are presented in Table 2. The M.I.N.I. diagnoses are provided in Supplementary Table S1, and the CAARMS diagnoses are in Supplementary Table S2. Our sample comprised 61 individuals who met the study criteria of having an initial ADHD diagnosis according to the ASRS part A cut-off point, of which 53 individuals were in the experimental group. According to the M.I.N.I. diagnosis, 25 participants (13% total) met the criteria for ADHD (see Supplementary Table S1). The results of Student's *t*-test for independent samples (see Supplementary Table S6) indicated that women exhibited significantly higher scores in ruminative thoughts over the week ($p < 0.05$, d = 0.39), higher values in negative affect over the week ($p < 0.05$, d = 0.46), and had higher total scores on the trauma questionnaire ($p < 0.05$, d = 0.35), with a particularly notable effect observed in one of the subscales, sexual trauma ($p < 0.001$, d = 0.65). With regards to the study group comparison (High × Low) (see Supplementary Table S7), the results indicated that the participants in the experimental group were younger ($p < 0.001$, d = −0.54) and exhibited significantly higher scores on the ASRS questionnaire for ADHD symptoms ($p < 0.001$, d = 1.76), as well as in part A for the predictive list of ADHD symptoms ($p < 0.001$, d = 1.40) and in part B for the control list of ADHD symptoms ($p < 0.001$, d = 1.70). Furthermore, the results indicated significantly higher scores in the experimental group in the weekly average of PLEs experiences ($p < 0.001$, d = 1.39), higher values in ruminative thoughts over the week ($p < 0.001$, d = 1.23) and negative affect ($p < 0.001$, d = 1.51), and higher scores on the total trauma experience questionnaire ($p < 0.001$, d = 0.95), and all its subscales, including emotional trauma ($p < 0.001$, d = 0.95), sexual trauma ($p < 0.001$, d = 0.69), and bodily threat ($p < 0.001$, d = 0.5).

3.1. Power Analysis

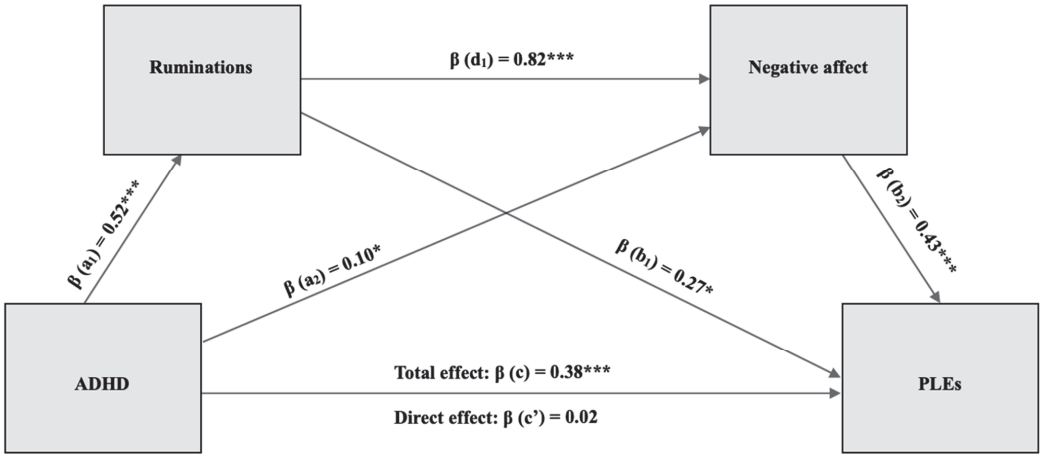
The post hoc power analysis specified a sample size of 188 and an alpha level of $p < 0.05$, considering an effect size (f^2) of 0.15 in the G*Power3 program [89], revealing a power of >0.99. The sample size was adequate for the study to detect medium-sized effects.

3.2. Correlations Analysis

We calculated correlations between the study variables, which are presented in Table 3. All variables included in the model showed a significant correlation (0.19–0.89, $p < 0.001$). Both ADHD and PLEs showed stronger covariance with rumination and negative affect (0.7) than trauma experiences (0.3).

3.3. Serial Mediation

The hypotheses that ADHD symptoms predict PLEs (**H1**) in part through the role of ruminative thoughts and negative affect (**H2**) were tested with a serial mediation analysis using Model 6 in the PROCESS macro for SPSS ([90]; see Figure 1). The results showed that the standardized total effect of ADHD on PLEs was significantly different from zero (β = 0.38, $p < 0.001$, 95% CI = 0.24 to 0.51). The direct effect of ADHD on PLEs was not significant, indicating that mediation is indirect only [91] (β = 0.02, $p = 0.81$, 95% CI = -0.11 to 0.14). The total indirect effect of ADHD on PLEs was found to be significant (β = 0.36, 95% CI = 0.25 to 0.50), as well as through NA only (β = 0.04, 95% CI = 0.003 to 0.11) and through ruminations and negative emotions (β = 0.18, 95% CI = 0.05 to 0.34). The indirect effect through ruminations only was not significant (β = 0.14, 95% CI = −0.01 to 0.31). The total effect explained 18.7% of the variance in PLEs, and the serial mediation model explained 49.5% of the variance in PLEs. Gender and age were added to the model as covariates but turned out not to be significant predictors.



Note. (*) $p < 0.05$ **(***)** $p < 0.001$

Figure 1. Serial mediation model (Model 6).

3.4. Moderated Serial Mediation

Subsequently, to test our last hypothesis (**H3**) that traumatic experiences would moderate the mediation effects, we conducted a moderated serial mediation (see Figure 1) using Model 85 in the PROCESS macro for SPSS [90], in which we added trauma experience as a moderator (W) to our model. This moderated serial mediation pathway model did not support the idea that participants with ADHD who reported more adverse (traumatic) experiences were more vulnerable to PLEs because they ruminate more and report more negative emotions. The trauma scale did not moderate any of the mediation pathways (see Table 4). Furthermore, none of the analyzed subscales of trauma (emotional, sexual, bodily) significantly moderated the serial mediation relationship between ADHD and PLEs (see Table 4). When gender and age were added to these models as covariates, they were not significant predictors in any of them.

Table 4. Moderated mediation model (Model 85) results.

Moderator (W)	Index of Moderated Mediation	S.E.	CI Lower 95%	CI Upper 95%
Trauma total	0.01	0.02	−0.03	0.05
Emotional trauma	0.01	0.02	−0.03	0.05
Sexual trauma	−0.02	0.03	−0.08	0.02
Bodily threat	−0.02	0.03	−0.08	0.03

Note. S.E. = Standard error. CI = Confidence interval.

4. Discussion

The primary objective of this study was to investigate the relationship between Attention-Deficit/Hyperactivity Disorder (ADHD) symptoms and psychotic-like experiences (PLEs) in a non-clinical sample. The results revealed a significant total effect of ADHD symptoms on PLEs, thus supporting **H1**. Moreover, the results confirm **H2**, namely that there is an indirect pathway between ADHD symptoms and PLEs. Additionally, we identified two key processes that link ADHD and PLEs: increased rumination and heightened negative affect. Collectively, these two processes explained 49.5% of the individual differences in the pathway from ADHD symptoms to PLEs. Finally, the findings of the moderated serial mediation analysis (**H3**) indicated that traumatic experiences do not exert an influence on the tested pathway from ADHD to PLEs. Therefore, **H3** was not confirmed.

The findings of this study are consistent with the high prevalence of ruminative thoughts observed in individuals with ADHD (e.g., [92]) and the detrimental impact of rumination on psychological well-being [93]. This present study demonstrates that ruminative thoughts and negative emotions serve as mediators for the majority of the relationship between ADHD symptoms and PLEs. Although mind wandering is a common phenomenon, there is evidence that prolonged rumination may be associated with the experience of negative emotions [94]. It is noteworthy that in individuals presenting with ADHD symptoms, rumination may serve as a distinctive symptom that prospectively indicates functional impairment [95]. Furthermore, given the high prevalence of ADHD and psychotic disorders [96] and the robust association between ADHD and ruminative thoughts, which predict delusional and hallucinatory experiences [97], our study suggests that ruminative thoughts and the experience of negative affect are important elements in the context of diagnosing and as a treatment focus for ADHD and PLEs symptoms. Furthermore, PLEs, as a part of the psychotic disorder continuum, are most closely related conceptually to a general factor or vulnerability for psychopathology (see [98]), and the affective dynamics are a key factor in virtually all mental health problems [99,100].

It is also noteworthy that the majority of participants in this study were young women between the ages of 18 and 35, representing 72.3% of the total sample. The results of Student's *t*-test indicated that, when compared to men, women in the study group exhibited a significantly higher frequency of ruminative thoughts and negative emotions. A substantial body of literature on this topic (e.g., [101–103]) indicates that women are significantly more likely than men to report higher levels of repetitive negative thinking, including ruminative thoughts, particularly at a young age [104]. Therefore, our results corroborate prior findings of elevated levels of ruminative thoughts and, consequently, negative emotions in a cohort of young women, underscoring the significance of these factors in the diagnosis of ADHD and PLEs. However, there is still a need for further data on the specific factors that are associated with an increased risk of mental illness. Therefore, the role of rumination and negative emotions as mediators between ADHD and PLEs may align with the perspective of transdiagnostic vulnerability and should be considered in future studies.

The objective of the second stage of analysis was to examine the potential influence of traumatic experiences on the pathway connecting ADHD symptoms to PLEs through ruminations and NA. The results of the moderated serial mediation analysis did not support the proposed hypothesis (**H3**). Moreover, none of the three subscales of trauma, including

emotional, sexual, or bodily traumatic experiences, moderated the hypothesized model. Nevertheless, the findings of this study indicated that trauma continues to exert a considerable influence on the relationship under examination. The results of the correlation analysis demonstrated a relationship between all studied variables (PLEs, ADHD symptoms, ruminations, NA, trauma, and the subscales). Furthermore, our results indicated significant gender differences in the experience of trauma. Specifically, women indicated a significantly higher total trauma score and, notably, a significantly higher score for sexual trauma. This is in line with previous research, showing that women are more likely to experience high-impact traumas with direct life-threatening exposure, such as sexual trauma [105]. It is noteworthy that, based on the M.I.N.I. interview, 27% of individuals in this current study may meet the preliminary criteria for PTSD. A review of the literature on the experience of trauma consistently identifies it as a factor that increases the risk of future PLEs [106,107]. Therefore, while traumatic experiences may not be explicitly represented in our tested models, they serve to increase the risk of developing psychiatric disorders [108,109].

Furthermore, numerous studies (e.g., [110–112]) have demonstrated a correlation between trauma and ADHD. This is primarily due to the fact that the cognitive and emotional disturbances that occur in response to experienced trauma (e.g., difficulty concentrating, irritability, high arousal) may overlap with or exacerbate ADHD symptoms (e.g., [113,114]). Furthermore, ADHD symptoms are frequently linked to an elevated probability of exposure to traumatic experiences, particularly during early childhood [115]. Consequently, although ADHD and trauma are discrete domains, their co-occurrence in clinical samples is relatively common, with prevalence rates ranging from 10% to 33% [116]. It is also noteworthy that both disorders are characterized by the experience of intrusive, ruminative thoughts (e.g., [45,117]) and the experience of negative emotions (e.g., [118,119]). It is, therefore, recommended that trauma be considered in future research as a topic for further exploration.

Research on PLEs strongly benefits from the experience sampling method (ESM) as it allows for real-time data collection, thereby capturing the full range of variability and reducing the impact of retrospective or distorted memories on the data [120]. Prior studies demonstrated the efficacy of the ESM method in accurately capturing momentary fluctuations in psychotic and/or emotional states, which is crucial for elucidating the dynamics of these variables in everyday life (e.g., [121–123]). Despite the aggregation of our ESM measures to a weekly average, the averaged results from real-time data provide a richer, more precise, and contextually valid dataset than retrospective data (e.g., retrospective questionnaires) and allow for the identification of patterns that may not be apparent with more traditional measures. Although ADHD symptoms and trauma were not assessed with the ESM, they remained significant factors in the relationships examined. Indeed, there is a clear relationship between negative affect lability and the manifestation of ADHD symptoms [124]. Moreover, some studies suggest that emotional lability may be associated with an increased risk of developing additional mental health problems, including ADHD symptoms [125,126]. Therefore, it is recommended that future research also considers ADHD symptoms in real-time to capture their individual dynamics and their potential impact on other mental health factors.

5. Limitations

Nonetheless, a number of factors should be considered in the interpretation of the results. It is possible that there is a degree of overlap between the symptoms of the two diagnostic categories, namely ADHD and PTSD. The potential for symptom overlap may complicate the ability to discern the precise influence (in this case, the moderating role) of trauma in the relationship between ADHD symptoms, trauma, and PLEs. This could result in the masking or overlapping of results. A traumatic event is one of the most common emerging risk factors for future psychosis [127], and individuals in a (pre-) psychotic state exhibit symptoms such as high impulsivity and frustration or deficits in executive functioning that overlap with clinical symptoms of ADHD [128]. Consequently, diagnoses of ADHD, trauma, and psychosis (or PLEs) should incorporate an evaluation of the other

disorders as a standard procedure, and clinicians should be mindful of the potential for these conditions to co-occur or to even function as one syndrome [129]. Such an approach can facilitate the delivery of comprehensive and accurate diagnoses and treatments.

Another consideration is that the traumatic experience scale (TEC) may not adequately capture the full range of traumatic experiences, particularly regarding their diverse forms (emotional, sexual, and bodily), and showed low reliability. Thus, our study could be replicated using a different or stronger trauma instrument. Furthermore, the TEC is a self-report scale. It is, therefore, possible that individuals reporting such experiences may have understated the significance of the traumatic events in question when completing this questionnaire. One of the coping mechanisms employed in response to traumatic events is the utilization of cognitive avoidance, which is evidenced by the suppression of thoughts and memories, rumination, and dissociation [130].

Additionally, the scale we used to measure ADHD symptoms is also a self-report scale based on the criteria for ADHD diagnosis in the DSM-IV [131]. While the revisions to the ADHD diagnosis in the current edition of the DSM-V [36] are subtle, they are more aligned with the current understanding of the disorder's nature. It is noteworthy that the majority of individuals in our study group exhibited relatively low levels of ADHD symptoms, particularly when assessed using part A of the ASRS questionnaire, which has been identified as the most reliable predictor of ADHD symptoms. Moreover, the majority of the sample consisted of adult women, and the diagnostic criteria for ADHD are still not particularly effective in detecting ADHD in women [132]. The presentation of ADHD symptoms differs significantly between women and men, with women exhibiting greater difficulties with inhibition and cognitive flexibility and men displaying more symptoms of hyperactivity [133]. Additionally, women face challenges in receiving an accurate diagnosis, largely due to the more subtle nature of symptoms (i.e., with less overt hyperactivity) and the potential for misdiagnosis of emotional disturbance [134]. Therefore, further research, with particular regard to the potential influence of gender on the diagnostic process, is warranted.

This present study focused on between-person effects, which was the principal objective. However, this approach also constrains our ability to fully comprehend the precise dynamics of within-person change [135]. Therefore, it would be beneficial for future studies to include real-time intrapersonal measures, particularly for ADHD symptoms and trauma, in order to more accurately capture individual variation and between-person differences in dynamics. It is also important to acknowledge the cross-sectional nature of this study, which constrains our capacity to ascertain the causal mechanisms underlying the relationship between ADHD and PLEs and to note that the findings of this study should not be generalized to the general population, as the majority of the participants were female and did not meet the criteria for a clinical diagnosis.

6. Conclusions

In conclusion, the findings of this study underscore the significant role of rumination and negative affect in the relationship between ADHD symptoms and PLEs. By identifying this association, this study provides important findings regarding the complex processes that may contribute to the development of PLEs in individuals with ADHD symptoms. This study is the first to examine this particular relationship. However, given the relative novelty of these findings, further investigation is required to gain a deeper understanding of the underlying mechanisms and potential pathways of influence. It would be beneficial for further research to aim to replicate these results in diverse populations and assess the potential clinical implications for interventions targeting rumination and affect regulation in individuals with ADHD and/or PLEs symptoms.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/jcm13226727/s1, Supplementary Table S1. M.I.N.I. diagnosis. Supplementary Table S2. CAARMS positive symptoms scores. Supplementary Table S3. ESM evaluation not included in the current study. Supplementary Table S4. Variance Inflation Factors.

Supplementary Table S5. Condition Index. Supplementary Table S6. Descriptive characteristics of the gender subgroups M (SD). Supplementary Table S7. Descriptive characteristics of the study subgroups M (SD).

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Article

Computerised Attention Functions Training Versus Computerised Executive Functions Training for Children with Attention Deficit/Hyperactivity Disorder: A Randomised Controlled Trial

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Abstract: Background: Attention deficit/hyperactivity disorder (ADHD) is a prevalent neurodevelopmental disorder characterised by deficits in attention, hyperactivity, and impulsivity. Current treatments, such as stimulant medication and behavioural therapy, ameliorate symptoms but do not address the core cognitive dysfunctions. This study aimed to investigate the effects of two computerised neurocognitive training programs, attention functions training and executive functions training, in children with ADHD. **Methods**: Eighty children with ADHD (ages 8–13) were randomly assigned to one of three groups: Attention functions training (AFT), targeting sustained, selective-spatial, orienting, and executive attention; executive functions training (EFT), focusing on working memory, cognitive flexibility, and problem solving; or a passive control group. Training sessions were administered in small groups twice a week for nine weeks. Participants underwent comprehensive assessments of attention (Continuous Performance Test, Conjunctive Visual Search Task), executive functions (Corsi Block-Tapping Tasks), nonverbal reasoning (Raven's Colored Progressive Matrices), parent-rated behavioural symptoms, and arithmetic performance at baseline, post-intervention, and follow-up. **Results**: The AFT group demonstrated significant improvements in sustained and selective-spatial attention, nonverbal reasoning, inattentive symptoms, and arithmetic performance, and most improvements persisted at follow-up. The EFT group showed gains in nonverbal reasoning and inattentive symptoms, although no improvements were documented in working memory or in parent ratings of executive functions. **Conclusions**: The AFT program that addressed core attentional functions in children with ADHD produced robust cognitive and behavioural benefits, whereas the EFT program yielded behavioural benefits and a limited improvement in executive functions. Future research should explore different training protocols for broader gains in executive functions. These findings support the potential of theory-driven, structured neurocognitive training targeting basic cognitive functions as an effective small-group intervention for ADHD.

Keywords: ADHD; cognitive training; small group; group-based intervention; attention; executive functions; children; active and passive control; follow-up

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1. Introduction

1.1. Background

Attention deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder that often causes substantial deficits in early childhood and usually persists throughout life [1]. The Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR) [2] categorises ADHD as a pattern of behaviour that occurs in a variety of settings (e.g., school, home, with friends) and can interfere with social, academic, and occupational performance. Hence, many researchers investigate a variety of treatment options for individuals with ADHD, including pharmacological approaches, behavioural therapy,

psychotherapies, and biofeedback, to name a few. To date, only stimulant medications, behavioural therapy, and the combination of the two meet the criteria for empirically based treatments [3]. The scientific literature provides evidence for their therapeutic benefits, and both treatments have been shown to improve functioning to some degree and attenuate behavioural symptoms associated with ADHD [4–8]. However, the use of pharmacological treatment is associated with many disadvantages, such as negative parental attitudes toward these medications, physical and emotional side effects, and lack of evidence of long-term effectiveness [9–11]. As for behavioural therapy, it is difficult to adhere to for an extended period of time, it is expensive, and it appears that its effects do not carry over to settings or behaviours that have not been treated [5,12,13]. These drawbacks of existing treatments underscore the need for new and/or complementary treatments.

One of the available treatment options is neurocognitive training, which focuses primarily on cognitive impairments and aims to reduce the long-term negative consequences of ADHD. According to contemporary theories, neurocognitive training addresses different cognitive and attentional components as separate abilities that can be enhanced through targeted and direct training [1,14–19]. Intensive, individually adjusted structured practice of a given cognitive function (e.g., attention or memory) should lead to improvement in the trained function, which, in turn, is expected to trigger transfer and generalisation effects [14,16,20]. One of the currently available neurocognitive treatments is computer-based training. This type of training follows three important guidelines that promote continuous learning and are facilitated by the use of a computer: training tasks should begin with a low level of difficulty and gradually increase according to the individual's performance; the training sessions should be comprised of extensive practice with repetitions; and performance should be monitored through immediate, accurate feedback [1,16,20,21]. To date, some neurocognitive training studies have reported improvement in cognitive abilities that were directly trained [15,22–27], as well as improvement in cognitive abilities that were not trained directly [14,15,23,25,27–30]. In addition, there is evidence that neurocognitive training can lead to reductions in behavioural symptoms of ADHD according to parents and/or teachers [16,18,23,27,31]. Some studies have also reported improvements in different academic outcomes [16,32], while others have not [33–35]. Several meta-analyses have been conducted in recent years to test whether cognitive computer training in ADHD is useful. The results of these meta-analyses [36–38], while documenting weak effect sizes, offer important criticisms regarding the various research methods used to date. Among the various considerations addressed, critical issues pertaining to the design of active control groups were underscored. Firstly, some studies encountered challenges in effectively concealing group affiliation. Secondly, in some studies, the employment of basic, repetitive activities throughout the intervention without variation led to a decline in the motivation of control group participants. Furthermore, several studies lacked long-term follow-up assessments, leaving inquiries about enduring effects unanswered. The present study's design addresses these pertinent criticisms to fortify the research framework.

1.2. The Current Study

Many previous studies have provided evidence for the heterogeneity of the cognitive profiles of individuals with ADHD, emphasising the diverse neuropsychological profiles associated with the disorder [39–46]. Thus, from a neurocognitive perspective, the best approach to portray ADHD is to implement multidimensional models that consider various possible aetiologies that may lead to similar behavioural manifestations (see, for example, [42,44,47–49]).

This study is based on Tsal and colleagues' [42] multifaceted model of attention, which refers to four distinct attention functions: (a) sustained attention, the ability to allocate attentional resources and maintain consistent performance over time, especially in simple, monotonous tasks; (b) selective-spatial attention, the ability to focus attention on relevant spatial information while suppressing adjacent distracting stimuli; (c) orienting of attention, the ability to focus attention on a specific location in the visual field, disengage, and

effectively direct attention to a new location; and (d) executive attention, the ability to inhibit a prepotent response and effectively resolve conflicts between responses while ignoring salient, potentially distracting information [42,50,51]. These attention functions serve, at least to some degree, as separate cognitive functions. According to this model, a deficit in any of these functions, or a combination of deficits in different attention functions, may underlie ADHD. Accordingly, different attention profiles have been found in individuals with ADHD [42,45,52].

In addition to attention, a major line of theoretical ADHD models asserts that deficits in executive functions (EFs) serve as a major causal deficit of the disorder [47,53,54]. EFs are a set of 'high' cognitive abilities, including inhibition, working memory (WM), and cognitive flexibility [55–57]. A broader approach to EFs also incorporates planning, problem solving, reasoning, prioritising and sequencing behaviour, ignoring irrelevant information, categorising, and coping with new information or situations [58,59]. According to both approaches, EFs guide driven behaviour [56,60,61]. Studies examining the performance of EFs in ADHD have yielded mixed results, with some researchers finding EF deficits in ADHD [62–67], while others have not [68–70]. The current study addresses three of the above EFs: (a) cognitive flexibility, the ability to adapt quickly to changing demands or situations, to examine something from multiple perspectives, to create alternatives, and to think outside of the box; (b) working memory, a limited capacity system that allows information to be stored temporarily during a cognitive task, to retrieve information from long-term memory, to link it to new information, and to manipulate it; and (c) planning, the ability to organise behaviour in time and space in situations where the goal can only be achieved through a sequence of actions that do not individually lead to the goal [60,71–74].

The present study examined the effectiveness of cognitive training interventions for children with ADHD through two primary research questions. (1) Do attention functions training (AFT) and executive functions training (EFT) protocols produce differential improvements in cognitive performance, ADHD symptomatology, and academic achievement? (2) Are training-induced improvements maintained at three-month follow-up? These questions address key uncertainties regarding the specificity/generality and sustainability of cognitive training effects in ADHD interventions.

As mentioned earlier, one of the main criticisms of cognitive training studies conducted to date relates to the nature of activities in the active control group training sessions. In non-pharmacological intervention studies, it is challenging to produce a placebo-like treatment, i.e., a treatment that the participants perceive as a real treatment but essentially is not. For instance, when participants in the control group engage in a more monotonous activity compared to the activity in the experimental group, motivation decreases compared to participants in the research group, so differences between groups may result from mere differences in engagement and motivation rather than the unique content of the treatment. To overcome such substantial methodological limitations in previous neurocognitive training studies, the current study compared two training programs: an attention functions training (AFT) program and an executive functions training (EFT) program with a shared structure. This allowed us to maintain the anonymity of group affiliation, overcome differences in engagement and/or motivation, and distinguish between the general effect of an intervention process and the specific effects that each protocol entailed. We also included a passive control (PC) group that enabled us to rule out spontaneous developmental effects, as well as learning and familiarity effects that may result from repeated exposure to the assessment tasks.

The AFT protocol consists of the Cogmission and Computerized Progressive Attention Training (CPAT) software programs [15,16,75,76], which were developed based on leading theories and well-known methods in the field of visual attention. To address one of the main criticisms of previous cognitive training studies (i.e., simple, non-progressive training protocols for the active control group), our goal was to develop two parallel intervention protocols that promote engagement and motivation of participants in both the experimental and the active control groups. Therefore, we developed an EFT protocol that implements

the same criteria that guided the design of the AFT protocol, namely, a gradual increase in difficulty levels, immediate feedback on performance, and a clear display of results that allows the trainer to facilitate training and help the participant set goals for next time. The use of two similar training protocols with a shared structure but different cognitive activities that have the potential to improve various aspects of cognitive functioning in children with ADHD is one of the strengths of the present research design. However, it also presents a major challenge in finding differential effects of the two training protocols.

Another unique characteristic of our training protocols relates to the fact that the training sessions in both groups were delivered in small groups, which added a social aspect to the training. Accordingly, the training protocols included a novel 'small-group work' module, based on the benefits of group therapy, that was specifically designed for them and served as a platform for facilitating meaningful social interactions. Group therapy has many benefits: it serves as a platform for peer learning through the process of interacting with other members and observing and imitating other group members; it leads to a sense of solidarity with others experiencing similar difficulties; and it fulfils the basic need for a sense of belonging by providing a safe and supportive environment to improve one's social skills and share one's personal story [77]. Accordingly, group therapy has been shown to have a positive impact on various outcomes, including psychosocial functioning, self-efficacy, and quality of life [78].

The group work module was carefully structured to promote social interaction and group cohesion through developmentally appropriate activities. Each session included the following. (1) An opening activity focused on getting acquainted and building trust. For example, in 'The Wind Blows' game, participants shared common attributes and experiences, while in 'Our Domino' they discovered shared interests by creating a chain of matching hobbies. (2) Two intermediate breaks featuring cooperative challenges. For instance, in the 'Balance Keeping' game, participants had to work together to balance a marble on an upturned cup placed on a bandana held by the entire group, and in 'Threading the Pen' they coordinated their movements to guide a suspended pen into a bottle using only attached strings. (3) Closing reflections focused on processing the session's experiences as a group. Activities progressed systematically from initial trust-building exercises to increasingly complex cooperative challenges aligned with group developmental stages. Our group work module provided the framework for the training sessions of both protocols, aiming to strengthen attainment and engagement in the intervention program.

2. Materials and Methods

2.1. Participants

The sample consisted of 80 third- through sixth-grade students (mean age = 10.46, *SD* = 1.10) from local public elementary schools. The key inclusion criteria were the following: (1) ages 8–12 years old, corresponding to third through sixth grade; (2) diagnosis of ADHD according to DSM5 criteria by a qualified clinician prior to the study; and (3) provided a signed medical document confirming the ADHD diagnosis. Of this sample, 51 were boys (mean age = 10.75, *SD* = 0.97) and 29 were girls (mean age = 9.95, *SD* = 1.15). Forty-four participants were treated with stimulant medications for ADHD during the study, while thirty-six were not. Table 1 presents the distribution of participants across groups by age, gender, and medication status.

Exclusion criteria included the following: concurrent diagnosis of another mental illness or neurological disorder (other than ADHD or learning disabilities); previous severe head injury; uncorrected vision; additional developmental, sensory, or motor problems; and participation in other non-pharmacological treatment interventions specifically for ADHD (e.g., neurofeedback, cognitive–behavioural therapy, etc.).

Table 1. Distribution of gender, age, and medication status across groups.

	Age			Gender		Medication Status	
Group	***n***	***M***	***SD***		***n***		***n***
AFT	27	10.38	1.12	Boys Girls	18 9	Use Do Not Use	12 15
EFT	29	10.46	1.07	Boys Girls	16 13	Use Do Not Use	13 16
PC	24	10.53	1.15	Boys Girls	17 7	Use Do Not Use	19 5

2.2. Assessment Tools

The study employed multiple assessment tools to evaluate cognitive functions, behavioural symptoms, and academic performance. Table 2 provides a comprehensive overview of these measures, which are detailed below.

Table 2. Overview of assessment tools and outcome measures.

Domain	Assessment Tool	Description	Outcome Measures
Sustained attention	Continuous Performance Test (CPT)	Participants respond to target geometric shapes while ignoring others	• SD of response times • Omission errors
Selective-spatial attention	Conjunctive Visual Search Task (CVST)	Search for blue square among red squares and blue circles	• Response times • Accuracy rates
Visuospatial working memory	Corsi Block-Tapping Task Forward	Reproduce sequence of lit blocks in same order	• Summary score (longest sequence × correct sequences)
Visuospatial working memory	Corsi Block-Tapping Task Backward	Reproduce sequence of lit blocks in reverse order	• Summary score (longest sequence × correct sequences)
Nonverbal abstract reasoning	Raven's Colored Progressive Matrices	Complete visual patterns	• Raw score
Behavioural symptoms	CBCL Questionnaire	Parent-rated behavioural assessment	• Attention problems • Other syndrome scales
Executive functioning	BRIEF Questionnaire	Parent-rated executive function assessment	• Eight sub-scale scores
Arithmetic	Arithmetic Evaluation	Basic arithmetic operations	• Speed (completion time) • Accuracy (% correct)

2.2.1. Continuous Performance Test (CPT)—Sustained Attention

The CPT was used to assess sustained attention, which is the ability to maintain consistent performance over time, especially during repetitive or monotonous tasks. In this task, a series of geometric shapes of different colours were displayed on the monitor, and the participants were asked to respond to the target stimulus by pressing the spacebar and to delay their responses when other stimuli were displayed. The task consisted of a

single block in which the target stimulus appeared in 70% of trials. Two measures were used to assess performance: (a) the standard deviation of response times (SD of RT) for correct responses, which reflects inconsistency in RTs; and (b) the percentage of omission errors. Higher values in these measures reflect lower sustained attention [51,79].

2.2.2. Conjunctive Visual Search Task (CVST)—Selective-Spatial Attention

This task was designed to assess selective-spatial attention, reflecting one's ability to focus on a specific spatial location while suppressing surrounding distractors [80]. In this task, participants were asked to search for a blue square that appeared among an equal number of red squares and blue circles. There were four display sizes of 4, 8, 16, or 32 items. Response times and accuracy rates were recorded for each display size with and without a target [51].

2.2.3. Corsi Block-Tapping Task Forward—Visuospatial Working Memory Capacity

The computerised version we used is based on a studied visuospatial task described in the research literature [81,82] designed to evaluate visuospatial working memory capacity, which enables temporary storage and manipulation of visual–spatial information. The participants were presented with a screen of nine blocks in this task. The blocks light up in a pre-fixed sequence, and the participants were instructed to click the blocks on the screen in the same order they were lit. We calculated the summary score for this task (i.e., the longest sequence remembered multiplied by the number of correct sequences).

2.2.4. Corsi Block-Tapping Task Backward—Visuospatial Working Memory Capacity

This task was also used to evaluate visuospatial working memory capacity, and the computerised version we administered implements the task described by Kessels and colleagues [83]. The task is very similar to the Corsi Block-Tapping Task Forward, except for one major difference: participants are asked to click on the blocks in the reversed order of their original presentation.

2.2.5. Raven's Colored Progressive Matrices (CPM) [84]—Nonverbal Abstract Reasoning

This task was used to assess nonverbal abstract reasoning through pattern recognition and problem solving with visual stimuli. This test is designed for children aged 5–11 years old and consists of 36 items in three sets (A, AB, B), with 12 items per set. This measure produces a single raw score that can be converted into a percentile based on normative data.

2.2.6. Arithmetic Evaluation—Basic Mathematical Operations

The arithmetic task was explicitly designed for this study's specific requirements. It consisted of 40 exercises requiring the use of the four basic arithmetic operations. In total, 20 exercises involved addition and subtraction of numerals up to 20, while the remaining 20 exercises involved multiplication and division up to 100, intermixed throughout. Participants were instructed to solve all exercises as quickly and accurately as possible. Two key measures were derived: (a) speed, quantified by the total time taken to complete the task (in seconds); and (b) accuracy, assessed by the percentage of correct answers out of 40.

2.2.7. Child Behaviour Check List (CBCL)—Parent-Rated Behaviour

The parental questionnaire from the Achenbach System of Empirically Based Assessment (ASEBA) [85] assesses adaptive and maladaptive behaviours and includes eight syndrome sub-scales: (a) anxious/depressed; (b) withdrawn/depressed; (c) somatic complaints; (d) social problems; (e) thought problems; (f) attention problems; (g) rule-breaking behaviour; and (h) aggressive behaviour.

2.2.8. Behaviour Rating Inventory of Executive Functioning (BRIEF)—Parent-Rated Executive Function

The BRIEF parental questionnaire [86] contains 86 items to assess the subjective evaluation of executive functioning. It comprised eight sub-scales: (a) inhibit; (b) shift; (c) emotional control; (d) initiate; (e) working memory; (f) plan/organise; (g) organisation of materials; and (h) monitor.

2.3. Procedure

Participants were recruited based on the recommendation of professionals, such as paediatricians and school counsellors, and through flyers and ads on Facebook. Figure 1 illustrates the time flow of the study. Informed consent was obtained from all parents of participants. Participants were randomly assigned to one of three groups: an attention functions training (AFT) group, an executive functions training (EFT) group, and a passive control group (PC). Affiliation with the AFT and EFT groups was not known to the participants or their parents. To ensure effective blinding, both training protocols were designed with similar structures and appearances. The specific cognitive functions targeted by each task were embedded within engaging activities that were not readily distinguishable to participants, thus minimising the likelihood of inferring group allocation. Parents in both groups received identical information, being told that their children would participate in one of two training programs aimed at improving various functions in children with ADHD. To maintain blindness throughout the implementation process, trainers received training in the programs under the neutral designations of 'Protocol 1' and 'Protocol 2'. Notably, the assessment research team was blind to the participants' group affiliation as well. Each participant was assigned a unique subject number using a random number generator. Participants were included in the final analyses only if they had completed at least 15 out of 18 training sessions. The compliance criterion was met by all participants except for one participant from the EFT group.

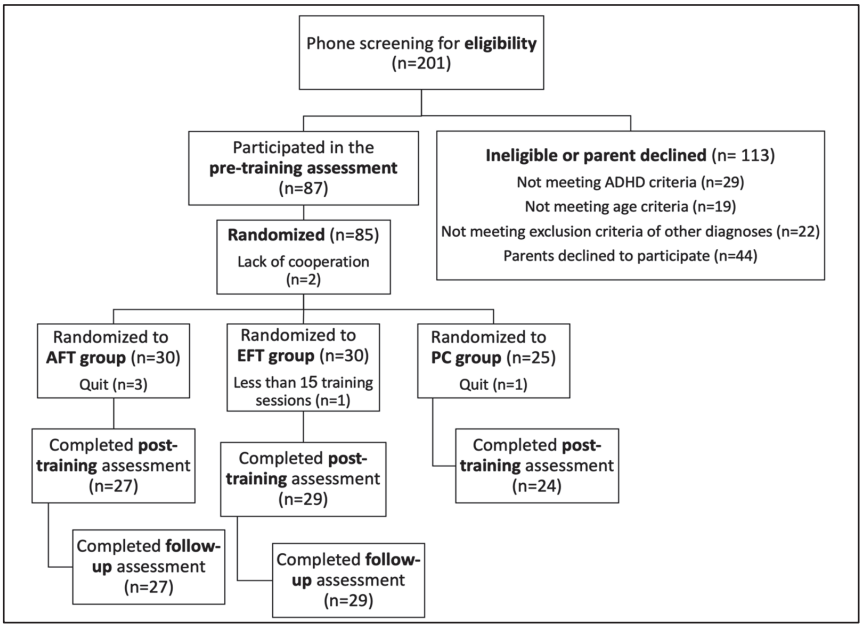

Figure 1. Recruitment and randomisation of the participants.

All trainers were graduate students conducting their thesis research in the Attention Lab or participating in an advanced research seminar on attention. Prior to intervention

implementation, trainers underwent comprehensive preparation that included hands-on experience with all training tasks and supervised practice sessions with a non-participant child. To ensure standardisation across sessions, trainers followed detailed protocols, including specific guidelines for each training program, general session management procedures, and a structured protocol for group activities. Each trainer conducted two daily sessions (one of each type). Sessions were conducted by teams of three trainers, enabling peer observation and mutual support. The first author attended most sessions to monitor implementation fidelity and maintain consistency across different training groups.

Participants were assessed individually by research assistants in the lab at baseline (i.e., before training = T1) and after completion of the training programs (i.e., after training = T2). In addition, approximately three months after completing the training programs, a follow-up assessment (i.e., T3) was conducted for participants in the two intervention groups to examine whether the results obtained at T2 had long-lasting effects. It is important to note that all three assessments were conducted after a 24 h medication washout period for participants treated with psychostimulants. All computer-based tasks were performed on a 24-inch LED monitor.

The training protocols of the AFT and EFT groups had an identical structure. Each session lasted 75 min, and a total of 18 group sessions were held twice a week in a designated room at the university. Figure 2 illustrates the structure and content of the training protocols. The session structure (Figure 2a) consisted of three 17 min computerised training intervals interspersed with group activities. Each group was led by three qualified trainers and consisted of six to seven participants. Each session included an opening, three intervals of individual computerised training work with two breaks of group activities between, and a closing. The content of the computerised training work intervals was the only difference between the two protocols. The trainers were instructed to prompt the participants if they became distracted, to help them set feasible personal goals, and to help them monitor their progress. In addition, a novel group work module was used to promote new, meaningful social interactions among trainees. It included guidelines and activities for the opening, two breaks, and closing parts of the training sessions, in accordance with group developmental stages (i.e., forming, storming, norming, performing, and adjourning) [87,88].

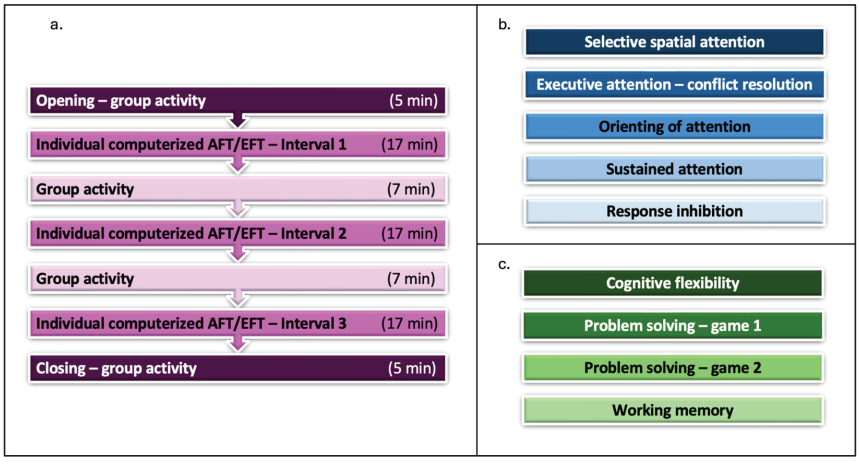

Figure 2. Training protocol structure and content. (**a**) The 75 min session structure, consisting of computerised training intervals and group activities. (**b**) Components of the computerised AFT protocol intervals. (**c**) Components of the computerised EFT protocol intervals.

The AFT group used two training tasks from the Cogmission software developed uniquely for this study: a Conjunctive Continuous Performance Task (CCPT, based on Shalev and colleagues [16]), designed to practice sustained attention, and a Go/No-Go

task (based on Kolodny and colleagues [89]), designed to practice response inhibition. This group also used three training tasks from the Computerized Progressive Attention Training (CPAT) program [16]: (1) the Conjunctive Visual Search Task (based on Treisman and Gelade [80]), designed to improve selective-spatial attention; (2) the Combined Orienting and Flanker Task (based on Eriksen and Eriksen [90] and Posner and colleagues [91]), designed to improve orienting of attention; and (3) the Global–Local Task (based on Navon [92]), designed to improve executive attention and conflict resolution. Each of the tasks consists of a broad hierarchy of difficulty levels, and the transition between them occurs after consistent improvement is obtained and performance reaches a plateau at a given difficulty level [16].

The EFT group used a computerised version of the Set game, invented by Marsha Jean Falco in 1974 [93]. Set is a pattern-recognition card game where players must identify sets of three cards that share or differ in specific attributes, such as colour, shape, or number. It was used to train cognitive flexibility. In addition, this group used four computer games to train problem solving. Three of them were designed by Leo De Sol Games and were based on familiar games: (1) Rush Hour, a traffic-jam-themed game where players need to slide vehicles to clear a path for the red car to exit; (2) Pipes/Plumber, a puzzle game where players must connect pieces of pipe to create a functioning system; and (3) Sliding Puzzle, a traditional game where players must arrange pieces in the correct order by sliding them into the empty space on a grid. The fourth game, Thinkrolls Kings & Queens by Avokiddo, is a challenging adventure puzzle game that incorporates logic and physics, requiring players to navigate mazes and overcome obstacles using reasoning skills. Additionally, three games developed by Mindware Consulting Inc. were used to train working memory based on well-known paradigms in the field: Memory Racer, a fast-paced game based on the N-Back task [94], and two spatial memory tasks—Spatial Memory, requiring recall of locations on a grid, and Path Memory, which challenges players to remember and replicate a sequence of moves through a path.

This research was registered at ClinicalTrials.gov (identifier: NCT06657469).

2.4. Statistical Approach

Most analyses in the current study (i.e., ANOVAs, chi-squares, and *t*-tests) were carried out using SPSS v. 28 (IBM) software. Bayes Factor (BF) calculations were carried out using JASP v. 0.19.1 software. For all analyses, the threshold for statistical significance was set at $p \leq 0.05$, and effect sizes are reported as partial eta squared ($\eta_p{}^2$) for ANOVAs and Cohen's *d* for *t*-tests. In addition, all graphs include the standard error (SE) of each mean.

2.4.1. Assessing the Effects of the Two Training Protocols

Differences between the three groups resulting from the two training protocols were tested using repeated measures ANOVAs with time of assessment (T1 vs. T2) as a within-subjects factor and group (AFT vs. EFT vs. PC) as a between-subjects factor. To evaluate long-lasting effects, further ANOVAs with repeated measures analyses were conducted, including assessments at three different time points (T1 vs. T2 vs. T3) as within-subjects factors and training group (AFT vs. EFT) as a between-subjects factor. The Bonferroni correction method was employed to correct for multiple comparisons in post hoc comparisons. In cases where no interaction between group and time was observed but a main effect of time was obtained, paired samples *t*-tests were performed within each group to assess differences between time points of assessment. In these instances, Bayesian statistics were also utilised, allowing for the testing of both the null and alternative hypotheses. The Bayes Factor (BF) provides a quantitative measure of the relative evidence in the data supporting one hypothesis over another. Specifically, the BF_{10} is calculated as the ratio between the probability of the observed data under the alternative hypothesis (H_1) and its probability under the null hypothesis (H_0). In our analyses, the alternative hypothesis (H_1) always represented the expectation of improvement from T1 to T2. The interpretation of BF_{10} values follows established guidelines: values supporting the alternative hypothesis

(H_1): $1 < BF_{10} < 3$: weak evidence; $3 < BF_{10} < 10$: moderate evidence; and $BF_{10} > 10$: strong evidence. Values supporting the null hypothesis (H_0): $1/3 < BF_{10} < 1$: weak evidence; $1/10 < BF_{10} < 1/3$: moderate evidence; and $BF_{10} < 1/10$: strong evidence. Values close to 1 indicate insufficient evidence to support either hypothesis. This approach complements traditional null hypothesis significance testing by providing a measure of the strength of evidence for both the presence and absence of effects, rather than only evidence against the null hypothesis.

2.4.2. Gender, Age, and Medication Use

Due to potential gender-related differences in some of the assessed measures, a chi-square test of independence was performed to examine the distribution of gender across groups (AFT vs. EFT vs. PC). No significant relationship was found between these variables, $\chi^2_{(2)} = 1.544$, $p = 0.462$, indicating that the distribution of gender did not differ by group. A one-way ANOVA was conducted to confirm the similarity of participants' ages across the experimental groups. No significant difference ($F_{(2,77)} = 0.11$, $p = 0.893$, $\eta_p{}^2 = 0.003$) in age between the three groups was found. Additionally, a chi-square test of independence was also performed to determine if the distribution of participants' medication use was different between the two training groups (i.e., AFT and EFT). No significant relationship was found between these variables, $\chi^2_{(1)} = 0.001$, $p = 0.997$, indicating that the distribution of medication intake did not differ between the two groups. Based on the above results, it was not necessary to control for age, gender, or medication use in all statistical analyses comparing the groups.

2.4.3. Missing Data

One participant from the PC group did not complete the CPT at T2. Furthermore, the parents of one participant from the AFT group and one participant from the PC group did not complete the questionnaires at T2. These participants were only removed from the specific analyses involving the CPT and the questionnaires at T2.

2.4.4. Data Trimming

Exclusion criteria were applied as follows: (a) omission error rate greater than 25% for the CPT (resulting in the exclusion of one outlier from the PC group); (b) average accuracy rate for all no-target trials < 80% in the CVST (no outliers were identified); (c) failure to correctly repeat a sequence of two blocks in the Corsi Block-Tapping Task Forward and Backward (resulting in the exclusion of four outliers: one from the AFT and one from the EFT groups for the Forward task, and one from the AFT and one from the PC groups for the Backward task); (d) identification of outliers using the 3*IQR method (three times the Interquartile Range (3*IQR stands for three times the Interquartile Range. The Interquartile Range (IQR) is a measure of statistical dispersion, specifically a measure of variability around the median, and it is calculated as the difference between the third quartile (Q3) and the first quartile (Q1))) for each measure in the CPM, the arithmetic task, and the questionnaires (resulting in the exclusion of two outliers from the arithmetic task—one from the AFT and one from the EFT groups).

3. Results

In analysing the effects of the AFT and EFT protocols, we distinguished between near and far transfer effects. Near transfer effects reflect improvements in tasks that directly assess one of the cognitive functions that were trained in a given protocol (e.g., improvement in sustained attention following attention training or improvement in working memory following executive functions training). Far transfer effects represent improvements in tasks or domains not directly trained but hypothesised to benefit from enhanced cognitive functioning (e.g., improvements in academic performance or behavioural symptoms following either attention or executive functions training).

3.1. Training Effects on Objective Measures of Attention Functioning and Executive Functioning

Sustained attention was measured using two measures derived from the CPT: (a) the SD of RT, and (b) the omission error rate. A two-way repeated measures ANOVA conducted on the SD of RT revealed a significant interaction of Time × Group ($F_{(2,75)} = 6.26$, $p = 0.003$, $\eta_p^2 = 0.143$), as can be seen in Figure 3a. Bonferroni post hoc tests showed that participants in the AFT group demonstrated improved response consistency, with the SD of RT decreasing by 30 ms from T1 ($M = 147$, $SD = 64$) to T2 ($M = 117$, $SD = 47$; $p = 0.03$, Cohen's $d = 0.53$). No significant changes were measured in the other two groups. A similar two-way repeated measures ANOVA on the omission error rate revealed no interaction of Time × Group ($F_{(2,75)} = 2.37$, $p = 0.10$, $\eta_p^2 = 0.059$).

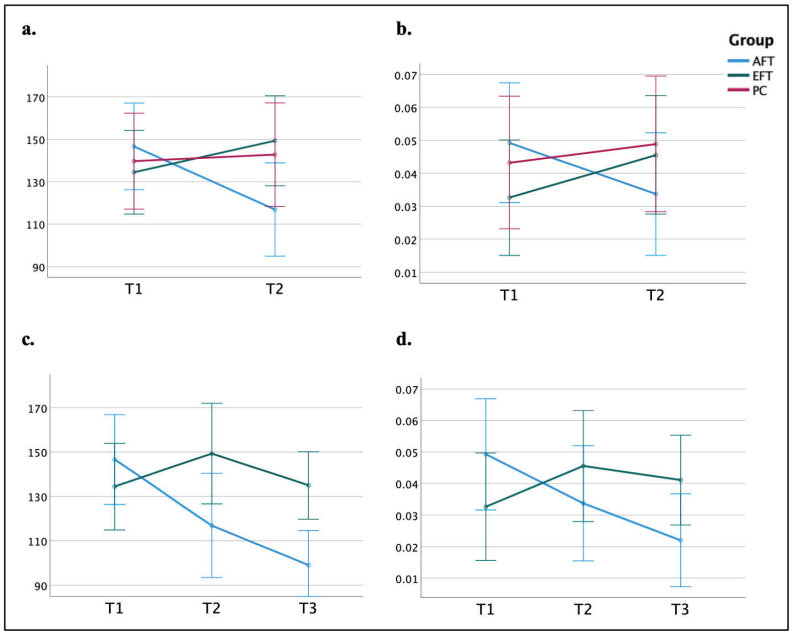

Figure 3. Sustained attention: performance across groups and testing sessions. (**a**) Standard deviation (SD) of reaction time (RT) in the CPT, as a function of time (T1, T2) and group (AFT, EFT, PC). (**b**) Omission error rate in the CPT, as a function of time (T1, T2) and group (AFT, EFT, PC). (**c**) Standard deviation (SD) of reaction time (RT) in the CPT, as a function of time (T1, T2, T3) and group (AFT, EFT). (**d**) Omission error rate in the CPT, as a function of time (T1, T2, T3) and group (AFT, EFT). Error bars represent the standard error of the mean (SEM).

Repeating the above-mentioned analyses with three time-points (T1 vs. T2 vs. T3) and two groups (AFT vs. EFT) revealed significant interactions of Time × Group for both the SD of RT ($F_{(2,54)} = 9.56$, $p < 0.001$, $\eta_p^2 = 0.15$; see Figure 3c) and the omission error rate ($F_{(2,54)} = 4.72$, $p = 0.011$, $\eta_p^2 = 0.08$; see Figure 3d). Bonferroni post hoc tests showed that the AFT group demonstrated progressive improvements in response consistency: the SD of RT decreased by 30 ms from T1 ($M = 147$, $SD = 64$) to T2 ($M = 117$, $SD = 47$; $p = 0.014$, Cohen's $d = 0.57$) and decreased by 48 ms at T3 ($M = 99$, $SD = 37$; $p < 0.001$, Cohen's $d = 0.91$ compared to T1). Furthermore, enhanced sustained attention of the AFT group was also found in reduced omission errors, with a significant decrease of 2.7% from T1 ($M = 0.049$, $SD = 0.056$) to T3 (M = 0.022, SD = 0.030; $p = 0.012$, Cohen's $d = 0.62$). In the EFT group, there were no significant differences in the SD of RT and the omission rate between the different time points (all ps > 0.169). Taken together, these results indicate that participants in the AFT group considerably improved their ability to sustain attention over a long period of

time while performing a monotonous task at T2 compared to T1. Importantly, this effect was even more pronounced in the follow-up, approximately three months after the end of the training. Furthermore, these improvements were large and unique to the AFT group.

Selective-spatial attention was measured using the CVST's mean RTs and the accuracy rates of all eight task conditions (i.e., 4/8/16/32 items' display sizes with and without a target). A four-way repeated measures ANOVA was conducted on the mean RTs with time (T1 vs. T2), the target's presence (target present vs. target absent), and the set size (4 vs. 8 vs. 16 vs. 32) as within-subject factors, and group (AFT vs. EFT vs. PC) as a between-subjects factor. The analysis revealed a significant interaction among Time × Target's presence × Set size × Group ($F_{(5.35, 206.07)} = 2.76$, $p = 0.017$, $\eta_p^2 = 0.067$). To further investigate the interaction source, we calculated the difference in mean RTs between T1 and T2 (i.e., T1 minus T2) separately for each of the eight conditions. Two-way repeated measures ANOVAs were carried out separately for displays with and without target, with set size as a within-subjects factor and group as a between-subjects factor.

For 'target present' displays, a main effect of group was found ($F_{(2,77)} = 9.59$, $p < 0.001$, $\eta_p^2 = 0.199$), suggesting that the improvement in RTs of the AFT group in 266 ms ($SD = 166$) was significantly greater than the EFT group's improvement of 113 ms ($SD = 145$; $p = 0.001$, Cohen's $d = 0.82$) and the PC group's improvement of 101 ms ($SD = 147$; $p < 0.001$, Cohen's $d = 0.88$). For 'target absent' displays, a marginally significant interaction between set size and group was found ($F_{(4.67,179.68)} = 2.82$, $p = 0.053$, $\eta_p^2 = 0.056$). Bonferroni post hoc tests showed that the improvements in RTs of the AFT group were significantly greater than those in the EFT group for set sizes of 8, 16, and 32 (all ps < 0.015), but not for a set size of 4, and significantly greater than those of the PC group for all set sizes (all ps < 0.049) (see Figure 4 for the results of both two-way repeated measures ANOVAs). The parallel analysis of four-way repeated measures ANOVA on the accuracy rates resulted in no significant interaction of Time × Group. It is important to note that the accuracy rates of all three groups were high to begin with during T1 (see Appendix A for descriptive statistics). Taken together, these findings indicate that the AFT group showed greater improvement in RTs at T2 compared to T1 than the EFT and the PC groups with no significant changes in accuracy. Namely, the improvement in RT was not compromised by a decrease in accuracy. Therefore, this improvement reflects enhanced efficiency in focusing on a restricted spatial area effectively, suppressing adjacent irrelevant information.

We used the CVST's T3 results to examine if the results achieved by the AFT group in selective-spatial attention during T2 had a long-lasting effect. This time, we calculated the differences in RTs between T1 and T3 separately for each one of the eight conditions. For the 'target present' displays, a main effect of group was found ($F_{(1,54)} = 7.09$, $p = 0.010$, $\eta_p^2 = 0.116$), suggesting that the difference in RTs of the AFT group ($M = 252$, $SD = 190$) was significantly greater than that of the EFT group ($M = 134$, $SD = 141$). For the 'target absent' displays, similar results were obtained, including a main effect of group ($F_{(1,54)} = 4.71$, $p = 0.034$, $\eta_p^2 = 0.080$), also indicating that the difference in RTs of the AFT group ($M = 299$, $SD = 232$) was significantly greater than that of the EFT group ($M = 171$, $SD = 212$). Therefore, the comparisons between T1 and T3 replicated the results obtained when comparing T1 to T2, indicating that the AFT's improved performance in this task has a long-lasting effect (see Figure 4).

Visuospatial working memory capacity was measured with the Corsi Block-Tapping Task Forward and Backward. Two two-way repeated measures ANOVAs were conducted on the summary scores of both tasks. The analyses did not reveal significant interactions between Time × Group (both Fs < 1.67; both ps > 0.196). In addition, in the analysis of the Corsi Block Backward, there was no main effect of time, whereas in the Corsi Block Forward, a main effect of time was found ($F_{(1,75)} = 9.67$, $p = 0.003$, $\eta_p^2 = 0.114$), suggesting that all groups performed better at T2 ($M = 42.26$, $SD = 18.00$) compared to T1 ($M = 37.04$, $SD = 15.59$), showing an overall mean improvement of 5.22 points (see Appendix B for descriptive statistics). Therefore, we conducted paired samples t-tests to separately estimate the changes between T1 and T2 for each group. For the AFT and

PC groups, no significant differences were found ($t_{(25)} = -1.47$, $p = 0.154$, Cohen's $d = 0.29$; $t_{(23)} = -1.87$, $p = 0.074$, Cohen's $d = 0.38$, respectively), whereas in the EFT group a significant improvement in T2 ($M = 41.4$, $SD = 20.4$) compared to T1 ($M = 35.8$, $SD = 19.0$), representing a mean improvement of 5.6 points, was obtained ($t_{(27)} = -2.08$, $p = 0.048$, Cohen's $d = 0.39$). Nevertheless, the Bayesian factor for this t-test was close to 1 ($BF_{10} = 1.23$), indicating that the data do not provide sufficient evidence for H1 or for H0. Based on the results of the t-tests and the Bayesian factor value, it appears that neither of the groups demonstrated a substantial improvement in working memory at T2.

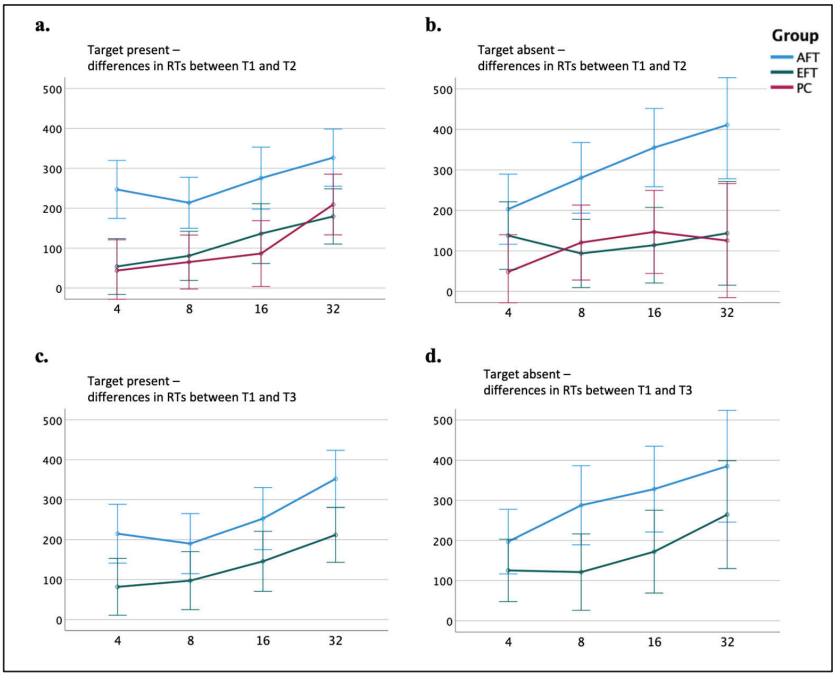

Figure 4. Selective-spatial attention: performance in the CVST by group and testing session. (**a**) Differences in RTs between T1 and T2 of the 'target present' displays as a function group (AFT, EFT, PC). (**b**) Differences in RTs between T1 and T2 of the 'target absent' displays as a function group (AFT, EFT, PC). (**c**) Differences in RTs between T1 and T3 of the 'target present' displays as a function group (AFT, EFT). (**d**) Differences in RTs between T1 and T3 of the 'target absent' displays as a function group (AFT, EFT). Error bars represent the standard error of the mean (SEM).

To assess nonverbal abstract reasoning, the total raw score of the Raven's Colored Progressive Matrices (CPM) was used. Figure 5 presents the performance on the CPM by group and time of assessment. A two-way repeated measures ANOVA revealed a significant interaction effect of Time × Group ($F_{(2,77)} = 3.30$, $p = 0.043$, $\eta_p^2 = 0.078$). Bonferroni post hoc tests indicated that participants in the AFT and EFT groups exhibited improved performance on this task at T2 ($M = 33.56$, $SD = 2.52$; $M = 33.07$, $SD = 2.67$, respectively) compared to T1 ($M = 30.93$, $SD = 4.37$; improvement of 2.63 points, $p < 0.001$, Cohen's $d = -0.80$; $M = 31.45$, $SD = 3.01$; improvement of 1.62 points, $p = 0.002$, Cohen's $d = -0.49$, respectively). However, in the PC group, the change was not significant (T1: $M = 32.13$, $SD = 4.15$; T2: $M = 32.79$, $SD = 2.84$; improvement of 0.66 points, $p = 0.236$).

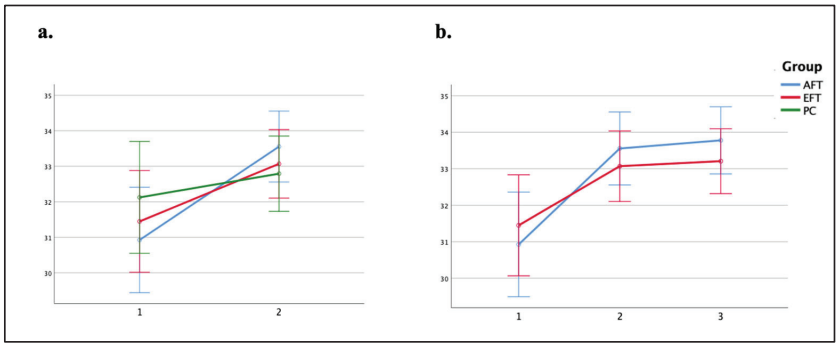

Figure 5. Nonverbal abstract reasoning: performance in the Raven's Colored Progressive Matrices (CPM) by group and testing session. (**a**) Total raw score in the CPM, as a function of time (T1, T2) and group (AFT, EFT, PC). (**b**) Total raw score in the CPM, as a function of time (T1, T2, T3) and group (AFT, EFT). Error bars represent the standard error of the mean (SEM).

To assess if the improvements in both training groups were maintained over time, a similar analysis was conducted with three-time points (T1 vs. T2 vs. T3) and two groups (AFT vs. EFT). This analysis yielded a significant main effect of time ($F_{(1.72, 92.68)} = 32.24$, $p < 0.001$, $\eta_p^2 = 0.374$), indicating that both the AFT and EFT groups exhibited enhanced performance at T2 ($M = 33.30$, $SD = 2.59$; improvement of 2.1 points from T1) and T3 ($M = 33.48$, $SD = 2.39$; improvement of 2.28 points from T1) compared to T1 ($M = 31.20$, $SD = 3.70$; $p < 0.001$, Cohen's $d = -0.72$; $p < 0.0001$, Cohen's d = −0.78, respectively). These findings suggest that the robust improvements achieved at T2 were maintained at T3 as well, as can be seen in Figure 5.

Taken together, the objective measures of attention functioning and executive functioning revealed clear differences between the AFT and EFT protocols. The AFT protocol resulted in robust improvements in sustained attention (mean reduction of 48 ms in SD of RT and 2.7% reduction in omission errors rate) between T1 and T3 vs. no significant change for EFT and selective-spatial attention (mean RT improvement of 266 ms for AFT vs. 113 ms for EFT, $p = 0.001$, Cohen's $d = 0.82$). These improvements were maintained at a three-month follow-up. In contrast, while both protocols enhanced nonverbal abstract reasoning (improvement of 2.63 points for AFT, $p < 0.001$, Cohen's $d = -0.80$; improvement of 1.62 points for EFT, $p = 0.002$, Cohen's $d = -0.49$), neither produced significant improvements in working memory performance (all ps > 0.169).

3.2. Training Effects on Subjective Measures of Attention Functioning and Executive Functioning

To assess inattention symptomatology, we conducted a two-way repeated measures ANOVA using the 'attention problems' sub-scale score of the CBCL questionnaire. This analysis resulted in an interaction between Time and Group ($F_{(2,75)} = 4.94$, $p = 0.010$, $\eta_p^2 = 0.116$), as shown in Figure 6. Bonferroni post hoc tests indicated that participants in the AFT and EFT groups showed a significant decrease in ADHD inattention symptoms as evaluated by parents at T2 ($M = 7.88$, $SD = 3.08$; $M = 6.62$, $SD = 3.58$, respectively) compared to T1 ($M = 9.35$, $SD = 3.51$; reduction of 1.47 points, indicating a 15.7% improvement, $p < 0.005$, Cohen's $d = 0.43$; $M = 8.21$, $SD = 3.21$; reduction of 1.59 points, indicating a 19.4% improvement, $p = 0.001$, Cohen's $d = 0.46$, respectively). In the PC group, there was no significant change between T2 ($M = 8.48$, $SD = 3.84$) compared to T1 ($M = 8.00$, $SD = 3.30$; increase of 0.48 points, $p = 0.376$), indicating that the improvements in attention problems were specific to the training interventions.

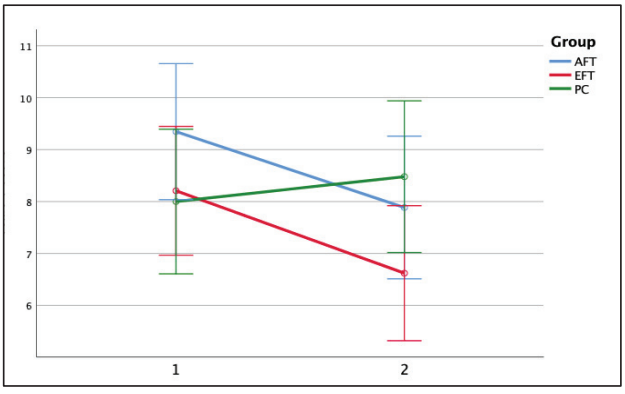

Figure 6. CBCL attention problems syndrome sub-scale's score as a function of time (T1, T2) and group (AFT, EFT, PC). Error bars represent the standard error of the mean (SEM).

In addition, three raw scores from the CBCL questionnaire were used to assess adaptive and maladaptive behaviour: (a) internalising behaviour score (comprising the anxious/depressed, withdrawn/depressed, and the somatic complaints syndrome sub-scales); (b) externalising behaviour score (comprising the rule-breaking behaviour, and the aggressive behaviour syndrome sub-scales); and (c) social problems syndrome sub-scale's score. Three two-way repeated measures ANOVAs on each one of these raw scores were conducted. All analyses yielded similar results, with no Time × Group interaction. Appendix C provides the descriptive statistics and analyses results.

Eight two-way repeated measures ANOVAs were conducted on each one of the BRIEF questionnaire's sub-scales' raw scores, as a subjective measurement of executive functioning. All analyses yielded similar results: no interaction between Time and Group and no main effect of time (all Fs < 1.08; all *p*s > 0.343). See Appendix D for descriptive statistics.

3.3. Training Effects on Arithmetic Performance

A couple of two-way repeated measures ANOVAs on the task duration and on the accuracy of the arithmetic task were conducted. Both analyses revealed no significant interaction of Time × Group (both Fs < 1.51; both *p*s > 0.228), yet a significant main effect of time was found in both analyses, (F(1,75) = 9.81, $p = 0.002$, $\eta_p^2 = 0.116$; F(1,75) = 9.72, $p = 0.003$, $\eta_p^2 = 0.115$, respectively), suggesting that all three groups performed better at Time 2, compared to Time 1 (See Appendix E for descriptive statistics). Consequently, we conducted paired samples *t*-tests, for both measures, to estimate the changes between T1 and T2, separately for each group. For the AFT group, a significant difference in task duration ($t_{(25)} = 2.61$, $p = 0.015$, Cohen's $d = 0.51$) was found, due to a faster performance at T2 ($M = 440$ sec, $SD = 243$) compared to T1 ($M = 528$ sec, $SD = 284$), demonstrating a reduction of 88 s in completion time. Additionally, a significant difference in accuracy ($t_{(25)} = -2.38$, $p = 0.025$, Cohen's $d = 0.47$), due to a higher accuracy at T2 ($M = 88.56\%$, $SD = 16.99$) compared to T1 ($M = 84.62\%$, $SD = 18.86$), reflecting an improvement of 3.94 percentage points. The Bayesian factors of these *t*-tests were greater than 3 ($BF_{10} = 6.58$; $BF_{10} = 4.27$, respectively), indicating substantial support for H1. For the other two groups, no significant improvements at T2 compared to T1 were found (all *p*s > 0.060). Taken together, based on the results of the *t*-tests and Bayesian factor values, it appears that only the AFT group demonstrated a notable improvement in the arithmetic performance between T1 and T2.

Repeating the separate two-way repeated measures ANOVAs analyses with three time points (T1 vs. T2 vs. T3) and two groups (AFT vs. EFT) yielded similar results, namely no interactions of Time × Group (both Fs < 2.11; both *p*s > 0.127), only main effects were obtained for task duration: $F_{(2,104)} = 4.08$, $p = 0.020$, $\eta_p^2 = 0.073$, and for accuracy:

$F_{(2,104)} = 3.80$, $p = 0.025$, $\eta_p^2 = 0.068$). To test whether the trends observed between T1 and T2, as measured by paired samples *t*-tests, were replicated at T3, we repeated them by comparing T1 to T3. None of the comparisons reached significance (all *p*s > 0.060).

3.4. Summary of the Effects of the AFT and the EFT Protocols

To summarise the effects of the AFT and the EFT protocols, the results of the various outcome measures are presented in Table 3. 'Near transfer' refers to improvements in tasks that are similar or directly related to the specific skills trained during the intervention. All other outcomes were classified as 'far transfer' (i.e., improvements in tasks that are different from the specific skills trained, indicating a broader generalisation of the training's effects to other cognitive abilities, behavioural symptoms, or academic performance. Additionally, the plus and minus signs in the table indicate whether long-lasting of improvements were documented, as measured in the follow-up assessment.

Table 3. Outcome measures that produced significant improvements.

	AFT	**EFT**
Near transfer	Sustained attention (+) Selective-spatial attention (+)	Nonverbal abstract reasoning (+)
Far transfer	ADHD symptomatology (N/A) Nonverbal abstract reasoning (+) Arithmetic performance [1] (−)	ADHD symptomatology (N/A)

Notes. [1] The interaction effect was not significant. Paired samples *t*-tests yielded significant results. (+) Significant improvement at T3 compared to T1 ($p < 0.05$). (−) No significant improvement at T3 compared to T1. (N/A) Not assessed at T3.

4. Discussion

ADHD is a prevalent developmental disorder with substantial negative effects across various life domains. While treatments, such as stimulant medications and behavioural therapy, are widely used, their efficacy in addressing core cognitive deficits remains limited. Moreover, previous research on neurocognitive training as an alternative treatment for ADHD has produced inconsistent results, with open questions regarding the transferability of cognitive improvements to real-life functioning and the long-term sustainability of these effects. This study aimed to address these gaps by rigorously evaluating two theory-driven, computer-based neurocognitive small-group training programs for children with ADHD. These programs were designed based on the attention functions model [42] and theories that emphasise executive functions (EFs) as the core deficit of ADHD [47,53,54]. We created parallel intervention protocols targeting attention and EFs while carefully controlling for certain factors, such as engagement, motivation, and contact with trainers, to ensure that any observed effects could be attributed to the interventions themselves. The results of this study provide new insights into the efficacy of neurocognitive small-group training programs in improving cognitive functions in children with ADHD.

Our results demonstrate a significant, unique improvement in sustained attention following training with the AFT protocol, which was maintained in the follow-up assessment. The current study used the Cogmission Version 3.0 Beta software to train sustained attention, and the findings are consistent with some of the previous studies that demonstrated improved sustained attention after training with the CPAT [15,76,95,96]. Studies that implemented other attention trainings manifested mixed results, as some reported no improvement in sustained attention [31,97], whereas Lange and colleagues [98] reported an improvement in vigilance after training. Nevertheless, the latter can be considered an improvement in response inhibition as the only recorded improvement was in commission errors.

The AFT group also presented with faster performance in selective-spatial attention (as measured by the CVST) following training compared to the other two groups. Importantly, no changes in accuracy rates were recorded in any of the three groups, suggesting that

the AFT protocol may have caused participants to be more efficient in selective-spatial attention, as the improvement in response times was not a result of a trade-off between speed and accuracy. The improved speed of reactions was replicated in the follow-up assessment and provided another indication of the long-lasting effect of the AFT protocol. Improved selective-spatial attention was also reported in previous studies with higher education students and children with foetal alcohol spectrum disorder after training with the CPAT [15,95]. It can be concluded that our results demonstrate unique gains that can be attributed to the specific content of the AFT protocol, as reflected by improvements in both attention assessment tasks. Notably, the assessment tasks differed from the training tasks. Hence, the data of the AFT group clearly represent unique near transfer effects of the trained cognitive mechanisms. Importantly, these unique near transfer effects were maintained at follow-up, indicating long-term effects of the AFT protocol.

In light of previous studies presenting improved EFs after compatible cognitive training, it was reasonable to hypothesise that our EFT protocol would yield positive results manifested in objective measures of EFs. However, the EFT group did not show a greater improvement in visuospatial working memory compared to the AFT and PC groups, although it was specifically trained as part of its protocol. Nonetheless, our results do not contradict previous studies that reported improved working memory after training (see for example, [28–30]), as our EFT protocol focused not only on WM. Therefore, it could be argued that the intensiveness in which each EF's component was trained was lower in our protocol. A meta-analysis of training programs for children with ADHD supports this explanation, showing that intensive short-term memory training led to moderate improvements, while less intensive training of attention and mixed EFs showed minimal effects [37].

As for nonverbal abstract reasoning, our results indicated that although the PC group performed similarly at the pre- and post-training assessments, both intervention groups showed significant improvement following training. The results of the intervention groups are consistent with previous studies that demonstrated improved nonverbal abstract reasoning after working memory training or attention training [17,28,29,99–101]. Importantly, in the present study, the results were maintained in the follow-up assessment, indicating the long-lasting effect of both protocols and pointing out that both training protocols are beneficial for nonverbal abstract reasoning. Nevertheless, it is essential to emphasise the similarities between the training tasks of the EFT group and the Raven's test. While the Raven's items require the identification of a missing element to complete a pattern, some training tasks were also based on visual puzzles, in which participants were asked to identify the correct location or direction of different pieces in the pattern to solve it. Moreover, the EFT protocol used the Set game, where participants are required to analyse different visual domains simultaneously, as needed in the Raven. Another EFT component that should be considered in this context is the n-back training task, as a meta-analysis of n-back training programs with healthy adult participants concluded that training significantly positively affected nonverbal abstract reasoning [102]. Accordingly, the EFT results should be considered a near transfer effect, whereas it can be considered a far transfer effect for the AFT group.

Concerning the behavioural symptoms of ADHD, results indicated that parents in both training groups reported a decreased level of attention problems following training, whereas parents of children in the PC group did not report any changes. The lack of improvement following training in the other CBCL child behaviour sub-scales, although intermixed, should be emphasised, as it rules out the expectancy effect (i.e., changes in behaviour that result from participants' or parents' expectations rather than the actual effects of the intervention itself). Taken together, these results indicate a far transfer effect of both training protocols and imply that both are beneficial for behavioural symptoms. A possible explanation relies on the fact that inattention symptoms can be associated with the content of the cognitive components of both training protocols. An alternative explanation lies in our novel 'small group work' module, which includes activities requiring resourceful

thinking and enables them to learn from their peers how to cope with different situations. The unique role description of the trainers could provide another possible explanation, as they might have raised awareness by prompting the trainees whenever they became distracted. Similarly to our findings, several previous studies reported reduced ADHD symptomatology after training compared to a control group [16,31,33,103]. However, a closer look at their results reveals that the expectancy effect could not be ruled out. The one exception is Shalev and colleagues [16], who demonstrated a decreased level of ADHD symptoms after attention training compared to an active control group, rated by blind observers.

The results of the BRIEF's parental questionnaire sub-scales indicated that no improvement in subjective evaluation of participants' EFs occurred in the EFT or the AFT groups. This was somewhat surprising, as it could have been argued that the parents should have expected improvements in areas like the ones that are addressed in the BRIEF questionnaire, especially because they can easily be related to behavioural symptoms of ADHD. This lack of improvement further supports the specificity of the observed improvement in ADHD symptoms that was recorded in the CBCL's attention problems sub-scale, suggesting, once again that it may be attributed to the training protocols. Previous cognitive training studies that also applied the BRIEF questionnaire presented inconsistent findings [97,103].

With respect to arithmetic performance, we hypothesised that both training protocols would be beneficial. The results somewhat supported this hypothesis, in that the performance of the AFT group showed some improvement after the training, demonstrating faster and more accurate arithmetic performance compared to before. While this tentatively suggests that the AFT protocol may have positive carryover effects to untrained academic areas (i.e., far transfer), the lack of an interaction effect precludes strong conclusions. No effect on arithmetic performance was found in the EFT group. Taken together, our findings are not in line with the meta-analysis by Rapport and colleagues [37] which concluded that neurocognitive training has no positive effect on academic achievements, regardless of the trained cognitive functions. One important question is why the improvement in arithmetic was not persistent as were the improvements in attention and in nonverbal abstract reasoning. A possible explanation is that the sustainability of improvements in domain-general abilities and domain-specific abilities may differ. Domain-general cognitive abilities, such as abstract reasoning, may benefit more directly and sustainably from enhanced attentional functioning, as both rely on similar underlying neural networks supporting general cognitive processing. In contrast, arithmetic performance, being a domain-specific skill, likely requires ongoing practice and explicit instruction in addition to improved attentional resources. While enhanced attention can support mathematical computations through better focus and reduced cognitive load, maintaining gains in domain-specific academic skills may require the continued integration of improved attentional functions with subject-specific practice. This pattern suggests that while attention training can provide cognitive support for academic performance, sustained improvement in domain-specific skills might require complementary academic instruction to consolidate these gains.

The present AFT protocol consistently yielded robust near transfer effects on sustained attention and selective-spatial attention. Moreover, this protocol produced several encouraging far transfer effects pertaining to different aspects of everyday functioning: behavioural (reduced ADHD symptoms), cognitive (improved performance on nonverbal abstract reasoning test), and academic (enhanced arithmetic performance). One of the unique characteristics underlying the AFT protocol's effectiveness is that the trained attentional functions are basic cognitive functions, unlike the EFT protocol, which addresses more advanced cognitive functions. Such higher-order cognitive functions rely on a variety of basic cognitive functions; hence, the EFT protocol may have been less focused compared to the AFT protocol, which may explain its attenuated efficiency in reinforcing direct links between performance on each training activity and specific cognitive mechanisms.

4.1. Limitations and Future Research

As mentioned above, the current study was designed to address several essential criticisms within the neurocognitive training field; however, it has several limitations that warrant consideration. The EFT protocol's content was purposefully designed to tackle a key criticism regarding previous cognitive training studies (i.e., involving simple, non-progressive training protocols for the active control group). However, the challenge lies in detecting differential effects between the two training protocols given their highly similar content. This similarity makes it difficult to isolate the unique contributions of each protocol, which may limit our ability to identify distinct effects. A second limitation pertains to the number of participants in each group (slightly under 30 participants), contributing to limited statistical power. Despite recruiting approximately 200 potential families, over 50% did not meet our inclusion criteria or declined participation (e.g., families residing far from the university campus or with children engaged in many extracurricular activities). Another limitation we encountered from the outset was the difficulty in recruiting teachers to complete behavioural symptom and academic performance questionnaires intended for use in the study.

As for future research directions, isolating the influence of the small-group work module on the outcome measures would be insightful, as this module was incorporated into both training programs, precluding an examination of its unique contribution. Another important future research direction would be to compare the results of the AFT protocol to an upgraded protocol that also encompasses an academic skill-focused component or a training program solely focused on that specific academic skill without neurocognitive training. Lastly, when investigating the influence of the AFT and EFT protocols with larger samples, an important future research direction would be to analyse the recorded improvements in relation to participants' individual characteristics. Specifically, examining how baseline attentional/cognitive profiles, age, ADHD subtypes, and comorbid conditions might moderate training outcomes could reveal important individual difference factors. Such an analysis could shed light on which participant is most likely to benefit from each type of training protocol, potentially leading to more personalised intervention approaches.

4.2. Implications

The promising effects of the AFT protocol suggest that it is a neurocognitive training intervention that holds great potential for children with ADHD. Several key elements appear to contribute to its efficacy, including the fact that it is (a) theory-driven, (b) focused on a small number of basic cognitive functions, (c) structured, (d) intensive, (e) gradually increasing in difficulty level, (f) personally adjusted according to the trainee's abilities, and (g) incorporating feedback addressing both cognitive and socio-emotional needs of trainees. If appropriately addressed, these key elements could serve as the foundation for successful interventions targeting children with various cognitive impairments and therefore could be implemented by clinicians and professionals, regardless of their specific training in executing the AFT protocol. Clinicians and professionals could utilise these key elements as a 'recipe' for successful neurocognitive training. Alternatively, they could integrate any of these 'ingredients' to enhance their existing non-pharmacological treatment methods.

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Institutional Review Board Statement: The research was conducted in accordance with the Declaration of Helsinki and approved by the university ethics committee (protocol code: 13113032; date of approval: 25 January 2016; protocol code: 12123944; date of approval: 13 February 2017).

Informed Consent Statement: Written informed consent was obtained from the parents of all participants involved in the study after they received a written, detailed explanation of the research.

Data Availability Statement: The datasets supporting the reported results are available upon reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Means and standard deviations of average RTs and accuracy rates in the CVST for all groups in all eight conditions at Time 1, Time 2, and Time 3.

Time	Target's Presence	Set Size	Group	Average RTs (ms)		Accuracy Rates		*n*
				M	*SD*	*M*	*SD*	
1	Target present	4	AFT	956	188	0.974	0.035	27
			EFT	933	191	0.969	0.049	29
			PC	929	194	0.945	0.056	24
		8	AFT	954	214	0.970	0.049	27
			EFT	963	187	0.944	0.068	29
			PC	958	185	0.973	0.033	24
		16	AFT	1110	291	0.920	0.088	27
			EFT	1108	257	0.922	0.075	29
			PC	1086	230	0.935	0.072	24
		32	AFT	1284	280	0.868	0.126	27
			EFT	1261	266	0.886	0.093	29
			PC	1286	274	0.842	0.102	24
	Target absent	4	AFT	1068	248	0.985	0.027	27
			EFT	1129	267	0.961	0.056	29
			PC	1087	244	0.971	0.046	24
		8	AFT	1172	336	0.985	0.023	27
			EFT	1149	269	0.976	0.047	29
			PC	1141	249	0.969	0.060	24
		16	AFT	1384	459	0.990	0.020	27
			EFT	1312	291	0.982	0.034	29
			PC	1267	307	0.959	0.066	24
		32	AFT	1666	596	0.987	0.033	27
			EFT	1646	425	0.984	0.028	29
			PC	1548	422	0.974	0.035	24

Table A1. *Cont.*

Time	Target's Presence	Set Size	Group	Average RTs (ms)		Accuracy Rates		*n*
				M	*SD*	*M*	*SD*	
2	Target present	4	AFT	709	188	0.972	0.052	27
			EFT	879	263	0.959	0.047	29
			PC	884	194	0.949	0.071	24
		8	AFT	740	208	0.978	0.042	27
			EFT	882	194	0.970	0.039	29
			PC	893	191	0.964	0.045	24
		16	AFT	834	214	0.937	0.055	27
			EFT	972	205	0.938	0.061	29
			PC	1000	198	0.939	0.051	24
		32	AFT	957	247	0.894	0.089	27
			EFT	1082	234	0.921	0.108	29
			PC	1076	224	0.917	0.075	24
	Target absent	4	AFT	865	275	0.964	0.048	27
			EFT	991	244	0.977	0.039	29
			PC	1039	296	0.962	0.048	24
		8	AFT	892	301	0.980	0.038	27
			EFT	1055	323	0.988	0.029	29
			PC	1020	197	0.968	0.050	24
		16	AFT	1028	322	0.989	0.021	27
			EFT	1198	265	0.977	0.032	29
			PC	1120	242	0.973	0.059	24
		32	AFT	1255	403	0.983	0.044	27
			EFT	1503	433	0.977	0.039	29
			PC	1422	454	0.967	0.053	24
3	Displays with target	4	AFT	741	208	0.961	0.042	27
			EFT	851	213	0.967	0.036	29
		8	AFT	764	224	0.976	0.045	27
			EFT	866	232	0.973	0.033	29
		16	AFT	857	225	0.950	0.060	27
			EFT	963	279	0.926	0.059	29
		32	AFT	933	226	0.928	0.092	27
			EFT	1049	258	0.913	0.081	29
	Displays with no target	4	AFT	871	256	0.961	0.047	27
			EFT	1004	254	0.980	0.038	29
		8	AFT	885	243	0.983	0.034	27
			EFT	1027	283	0.964	0.065	29
		16	AFT	1056	360	0.983	0.039	27
			EFT	1140	282	0.979	0.037	29
		32	AFT	1281	405	0.985	0.036	27
			EFT	1382	394	0.968	0.049	29

Appendix B

Table A2. Means and standard deviations of the summary scores of the working memory tasks for all groups at Time 1 and Time 2.

Time	Group	Summary Scores of the Tasks					
		Corsi Block-Tapping Task Forward			Corsi Block-Tapping Task Backward		
		M	*SD*	*n*	*M*	*SD*	*n*
1	AFT	40.23	15.41	26	38.58	17.91	26
	EFT	35.82	18.99	28	35.17	15.97	29
	PC	35.00	10.72	24	44.04	10.78	23
2	AFT	44.69	16.60	26	38.50	16.08	26
	EFT	41.43	20.43	28	39.14	14.37	29
	PC	40.58	16.89	24	38.35	14.56	23

Appendix C

Table A3. Means and standard deviations of the internalising behaviour, the externalising behaviour, and the social problems syndrome sub-scale of the CBCL for all groups at Time 1 and Time 2.

Time	Group	Internalising Behaviour Score		Externalising Behaviour Score		Social Problems Score		*n*
		M	*SD*	*M*	*SD*	*M*	*SD*	
1	AFT	11.92	8.35	9.04	6.80	4.73	3.70	26
	EFT	9.72	7.05	10.00	7.27	4.14	3.71	29
	PC	10.26	6.75	12.52	10.04	5.57	4.13	23
2	AFT	11.15	9.36	9.19	7.25	4.69	4.81	26
	EFT	8.07	7.44	10.34	7.47	3.52	3.19	29
	PC	9.78	7.38	11.43	10.79	4.09	3.64	23

Table A4. Results of repeated measures ANOVAs on the scores of the internalising behaviour, the externalising behaviour, and the social problems syndrome sub-scale of the CBCL, with Time 1 vs. Time 2, and all 3 groups.

Scale	F	*df*	*p*	η_p^2
Internalising behaviour	0.22	2.75	0.800	0.006
Externalising behaviour	0.43	2.75	0.650	0.011
Social problems syndrome	1.34	2.75	0.269	0.034

Appendix D

Table A5. Means and standard deviations of the BRIEFs questionnaire's sub-scales for all groups at Time 1 and Time 2.

Time	Group	Subscales' Total Raw Scores																*n*
		Inhibit		Shift		Emotional Control		Initiate		Working Memory		Plan/Organise		Organisation of Materials		Monitor		
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	
1	AFT	16.54	4.54	15.42	3.81	20.58	5.77	17.31	2.57	23.58	3.11	26.96	4.80	14.73	2.71	17.12	3.65	26
	EFT	18.24	4.84	15.66	3.23	19.59	5.40	17.03	2.96	22.90	3.30	26.97	4.20	13.10	3.22	16.97	2.81	29
	PC	20.09	5.67	16.57	3.84	21.57	5.19	16.39	2.98	23.30	3.05	26.61	4.87	13.61	3.88	18.26	3.41	23

Table A5. *Cont.*

Time	Group	Subscales' Total Raw Scores																*n*
		Inhibit		Shift		Emotional Control		Initiate		Working Memory		Plan/Organise		Organisation of Materials		Monitor		
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	
2	AFT	15.88	4.29	14.15	3.80	17.46	5.19	16.31	3.02	22.15	3.34	26.50	4.92	14.12	2.72	15.38	3.49	26
	EFT	16.76	4.45	14.03	2.97	16.52	4.63	15.66	3.36	20.86	3.74	25.76	4.90	12.48	3.33	15.79	3.02	29
	PC	18.78	5.59	14.96	4.12	18.61	5.57	15.96	3.56	21.96	4.38	25.61	5.31	12.96	3.17	16.74	3.91	23

Appendix E

Table A6. Means and standard deviations of the arithmetic task duration and accuracy for all groups at Time 1, Time 2, and Time 3.

Time	Group	Arithmetic's Task Duration (ms)		Arithmetic's Accuracy (%)		*n*
		M	*SD*	*M*	*SD*	
1	AFT	528	284	84.62	18.86	26
	EFT	569	254	81.61	18.93	28
	PC	505	280	88.23	15.66	24
2	AFT	440	243	88.56	16.99	26
	EFT	554	289	84.38	14.62	28
	PC	419	265	90.10	13.40	24
3	AFT	477	275	86.73	19.54	26
	EFT	516	271	78.57	21.93	28

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