

# Characteristics and Gender Differences of Attention Levels in Adolescents: An Empirical Study Based on the Cognitive Assessment System-Second Edition (CAS2)

Rajeshwary Jesh<sup>1</sup>, Chadra Kandan<sup>2</sup>, Lu Jing Yi<sup>3\*</sup>, Ooi Boon Keat<sup>4</sup>

<sup>1, 2, 4</sup>Social Education and Social Sciences, Management and Science University

<sup>3</sup>Post Graduate Centre, Management and Science University

University Drive, Off Persiaran Olahraga, Shah Alam, Selangor, Malaysia 40100

Email address: 2362407037@qq.com

**Abstract**— This study aims to systematically investigate the core characteristics of adolescents' attentional levels and their associative mechanisms with academic performance and gender. A convenience sample of 60 17-year-olds (30 males, 30 females) was selected. Attention levels were quantified using the Cognitive Assessment System Second Edition (CAS2) across three dimensions: expressive attention, receptive attention, and digit detection. Data analysis employed Pearson correlation analysis and independent samples *t*-tests. Results indicated that, in the association between attention and academic performance, only the numerical detection dimension showed a significant positive correlation with the cumulative grade point average (CGPA) ( $r=0.328$ ,  $p=0.011$ ). Neither receptive attention ( $r=0.214$ ,  $p=0.101$ ) nor expressive attention ( $r=0.057$ ,  $p=0.666$ ) showed no statistically significant association. Regarding gender differences, academic performance (female mean 2.98 vs male mean 2.43,  $t=3.53$ ,  $p=0.001$ ), digit detection (female mean 80.1 vs male mean 60.1,  $t=2.51$ ,  $p=0.015$ ), and receptive attention (female mean 74.7 vs male mean 62.5,  $t=2.91$ ,  $p=0.005$ ) all exhibited significant gender differences, with females performing better across all dimensions. No statistical difference was observed in expressive attention ( $p=0.687$ ). This study clarifies the dimension-specific and gender-differentiated characteristics of adolescent attention development, providing empirical evidence and theoretical reference for the precise design of attention training programmes in educational practice, as well as for the early screening and intervention of attention deficit hyperactivity disorder (ADHD).

**Keywords**— Planning, Attention, Simultaneous and Successive (PASS), Cognitive Assessment System (CAS), Attention deficit hyperactivity disorder (ADHD).

## I. INTRODUCTION

### 1.1 Research Background

Attention, as a core element of cognitive processes, serves as the foundation for individuals to filter information, maintain goals, and regulate behavior (Carmen et al.). For adolescents, the development of attention not only directly impacts academic performance but is also closely linked to long-term developmental outcomes such as social adaptation and emotional regulation (Song et al.). With the advent of the digital age, adolescents are increasingly exposed to multitasking environments, leading to profound changes in their attention patterns — Oliveira et al. (2020) indicate that

prolonged exposure to electronic devices may lower the threshold for attention distraction, thereby impairing classroom learning efficiency.

Existing research shows that the average attention span of secondary school students is approximately 10–12 minutes, with no reliable evidence suggesting this duration can be significantly extended through training (Christie et al.). This biological characteristic imposes clear demands on educational practice: classroom instruction must adapt to attention patterns through strategies such as segmented lesson design and optimized interactive formats. However, rote teaching methods persist in primary and secondary education, disregarding adolescents' developmental attention characteristics and resulting in suboptimal learning outcomes (Fabian et al.).

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders among adolescents, with core symptoms including inattention, impulsivity, and hyperactivity (Carmen et al.). Almaguer-Azpeitia (2023) research indicates that approximately 5%-7% of adolescents are affected by ADHD, and those without timely intervention may face academic failure, social difficulties, or even legal issues. Therefore, accurately assessing adolescents' attention levels and identifying potential risk factors is crucial for early intervention.

### 1.2 Current State of Research at Home and Abroad

#### 1.2.1 The Relationship Between Attention and Academic Achievement

Academic performance is often closely linked to the stability and selectivity of attention. Nathalie et al. (2021) found that attention abilities predict academic achievement more strongly than intelligence factors, particularly in mathematics and language domains. Domestic research also confirms that middle school students' sustained attention duration correlates positively with their Chinese and mathematics scores (Julen Maiztegi et al., 2024).

However, different dimensions of attention exhibit varying correlations with academic performance. For instance, numerical detection ability—reflecting selective attention—

may correlate more closely with science scores, as these subjects involve extensive symbol recognition and logical operations (Chondrogianni & Butcher, 2023); while expressive attention (e.g., Stroop task performance) may correlate with language subject scores (Omar Fahmy et al., 2024). This study will further refine these associations to provide evidence for subject-specific teaching approaches.

### 1.2.2 The Impact of Gender Differences on Attention

Gender differences in attention performance remain controversial. Fernanda Mayara et al. (2024) found women outperformed men in sustained attention tasks, while men showed superiority in spatial attention tasks; however, Nikolaos et al. (2024) argued that gender differences are primarily influenced by sociocultural factors rather than biological variations.

Flannery et al. (2024) found that middle school girls scored significantly higher than boys on auditory attention measures, while boys scored slightly higher on visual attention measures, though this difference was not statistically significant. These disparities may relate to gender role expectations in educational settings—girls are more frequently expected to remain quiet and focused, while boys tend to channel their energy through physical activity. This study will utilize a local sample to conduct an in-depth analysis of the relationship between gender and various dimensions of attention.

### 1.2.3 Development of Attention Assessment Tools

Currently, attention assessment tools are primarily categorized into behavioral observation scales (e.g., Conners scales) and cognitive tests (e.g., CAS) (Sasha, 2025). Among these, the Cognitive Assessment System (CAS), grounded in PASS theory (Planning, Attention, Simultaneous, Successive), measures cognitive functions across multiple dimensions and demonstrates strong validity and reliability (Timothy et al., 2025). As its revised version, CAS2 further optimizes age applicability and task design, and has been widely applied in cross-cultural research (Jack & Tulio).

#### 1.3.1 Research Significance

##### 1.3.1.1 Theoretical Significance

##### i. Advancing Research on Subdimensions of Adolescent Attention

This study precisely measured three core dimensions of attention using the Cognitive Assessment System Second Edition (CAS2). It first established a significant correlation between digital detection and academic performance (CGPA), while receptive attention and expressive attention showed no significant association with academic performance. This finding refines the associative mechanisms between attention and academic performance, providing empirical support for the dimension-specific influence of attention on academics and addressing the ambiguity in previous studies' dimensional classifications.

##### ii. Enhancing Research Conclusions on Gender Differences in Attention

This study found significant gender differences in academic performance, numerical detection, and receptive attention (with females performing better), but no statistical differences in expressive attention. These results indicate that

gender influences attention not uniformly but differentially across dimensions, offering a new perspective on the complexity of gender differences and providing localized evidence from adolescent populations to help reconcile academic debates.

##### iii. Validating the Applicability of PASS Theory in Adolescent Populations

This study employed PASS theory (Planning, Attention, Simultaneity, Sequentiality) as a framework and utilized the CAS2 tool to measure attention dimensions. Results indicate the theory effectively deconstructs adolescent attention. Specifically, the digital detection task—as a cross-sectional indicator of simultaneous processing and attention—demonstrated a correlation with academic performance. This finding corroborates the core tenet of PASS theory that “cognitive processes are directly related to academic performance,” thereby supporting the theory's applicability across cultural contexts (e.g., among Southeast Asian adolescents).

#### 1.3.1.2 Practical Implications

##### i. Providing Evidence for Optimizing Educational Strategies

This study indirectly supports the conclusion that “adolescents' sustained attention spans approximately 10-12 minutes,” suggesting educators should adjust teaching pacing: limit direct instruction to under 12 minutes and incorporate interactive tasks (e.g., group discussions, number games) to maintain attention. Additionally, given the link between numerical detection and academic performance, science instruction could incorporate targeted training in number recognition and symbolic operations to enhance students' numerical attention.

Girls' advantages in numerical detection and receptive attention suggest educators should encourage female participation in STEM fields to challenge stereotypes about women's perceived weakness in science. To address boys' weaker receptive attention, sequential memory and information filtering exercises (e.g., number sequence recognition games) can be designed to improve their information processing efficiency.

##### ii. Providing Reference for Early Intervention in Attention-Deficit/Hyperactivity Disorder (ADHD)

Core symptoms of ADHD include inattention and impulsivity. This study reveals that abnormalities in attention dimensions (e.g., low scores on digit detection tasks) may serve as potential risk indicators. Findings suggest schools can utilize digit detection as an auxiliary screening tool for ADHD: adolescents scoring significantly below the mean should undergo further diagnosis using clinical assessment tools (e.g., Conners scales) to enable early intervention, thereby reducing long-term risks such as academic failure and social difficulties.

##### iii. Guidance for Family and Social Support

Parents can preliminarily assess adolescents' attention levels by observing their performance in numerical tasks (e.g., bookkeeping, number games). If frequent errors, omissions, or slow processing are observed, timed digit-spanning exercises can enhance their numerical detection abilities. Simultaneously, society should reduce gender-based ability

stereotypes to create equitable developmental environments for adolescents. For instance, promoting awareness of girls' advantages in numerical detection can encourage female participation in STEM fields and advance gender equality.

#### 1.4 Research Objectives

This study has three primary objectives:

1. To describe the current status of three dimensions of adolescent attention (expressive attention, receptive attention, and numerical detection);
2. To analyze the correlation between each attention dimension and academic performance (CGPA);
3. To explore gender differences in attention dimensions and academic performance.

## II. THEORY

This study employs the PASS cognitive theory (Planning, Attention, Simultaneous and Successive Processing Theory) as its core theoretical framework, serving as the fundamental basis for study design, instrument selection, and result interpretation.

Proposed by psychologists J.P. Das, J.A. Naglieri, and others in the 1970s, PASS Theory is a systematic cognitive framework grounded in cognitive neuropsychological research. It posits that human cognitive functions comprise four interrelated yet distinct processes (Wanda & Mary, 2019):

Planning refers to the process of setting goals, selecting strategies, monitoring execution, and adjusting behavior—functioning as the cognitive control system (Naglieri et al., 2013). Attention denotes the ability to selectively focus on specific stimuli, maintain concentration, and suppress irrelevant information—acting as the cognitive filtering system. Simultaneous processing involves integrating scattered information into a unified whole (e.g., recognizing the overall pattern in the number sequence 123), applicable to spatial and graphic tasks (Naglieri et al., 2013); serial processing involves sequentially processing information in a linear fashion (e.g., recalling the numerical order of a phone number), applicable to language and temporal sequence tasks (Naglieri et al., 2013).

PASS theory emphasizes that cognitive processes are not abstract intellectual traits, but directly influence an individual's performance in tasks such as learning and problem-solving (Chien-Chih, 2009). For example, selectivity and stability in attention processes affect classroom learning efficiency; synchronous processing ability correlates with mathematics and spatial reasoning scores; and sequential processing ability correlates with language comprehension and reading scores. The theory posits that these four-dimensional cognitive processes can be measured using standardized tools (e.g., the Cognitive Assessment System, CAS) and improved through targeted training. For instance, planning tasks can enhance problem-solving abilities, while attention training can boost classroom focus (Chien-Chih, 2009).

This study is closely grounded in PASS theory, from its research design to the analysis of results. Regarding the rationale for selecting research instruments, the Cognitive Assessment System Second Edition (CAS2) employed in this

study serves as a direct operationalization of PASS theory. Its measurement of attention dimensions is fully grounded in the theory's definition of attentional processes: Expressive Attention (measured via Stroop task): Corresponds to inhibitory control of attention in PASS theory, requiring individuals to suppress irrelevant information (word meaning) and focus on the target (font color); Receptive attention (measured via the Digit Sequence Recognition Task): corresponds to the selectivity and stability of attention, requiring individuals to continuously identify target digit sequences (e.g., 123) amidst distractors; Digit detection (measured via the Timed Marking Task): combines simultaneous processing and attentional speed, requiring individuals to rapidly identify digit patterns while sustaining focus, reflecting the synergistic interaction between attentional processes and simultaneous processing (Erich & Eric, 2003).

Furthermore, this study examined the relationship between attention levels, academic achievement, and gender, aligning closely with PASS theory's assertion that attention processes are core predictors of academic performance. This theory posits that the efficiency of attention processes directly influences information acquisition and processing quality, thereby impacting academic outcomes (Wanda & Mary, 2019). This study's finding of a significant correlation between digit detection and CGPA corroborates this perspective. As a composite indicator of attentional speed and simultaneous processing, efficient performance in digit detection signifies an individual's ability to process symbolic information (e.g., mathematical operations, data analysis) more accurately in academic contexts.

Although this theory does not directly address gender differences, it acknowledges that individual variations in cognitive processes are influenced by multiple factors including biology and environment. The gender-differentiated variations observed in the attention dimension of this study (e.g., higher scores on numerical detection tasks among female participants) can be explained within this theoretical framework: gender-specific patterns of cognitive resource allocation may exhibit differentiation during attentional processes, potentially linked to sociocultural expectations of gender roles.

Concurrently, these findings provide empirical support for PASS theory within an adolescent population. The association between digit detection and academic achievement validates the theoretical assumption that the synergistic interaction between simultaneous processing and attention is crucial for academic performance. The lack of significant association between receptive attention, expressive attention, and academic achievement does not invalidate the theory. Rather, it suggests varying degrees of alignment between different attention dimensions and academic tasks (e.g., expressive attention is more closely linked to language-based tasks, while this study did not differentiate subject-specific grades), offering new perspectives for refining the theory's application.

The study's recommendations—such as targeted training of specific attention dimensions to enhance academic performance and using digit detection as an auxiliary

screening indicator for ADHD—stem from the PASS theory's emphasis on intervention. This theory posits that cognitive processes can be improved through training, enabling direct translation of research findings into practical interventions (e.g., enhancing science learning efficiency via digit detection training).

In summary, the PASS cognitive theory serves as the core theoretical foundation of this study. It not only guided the selection of research tools and the design of study content but also provided a systematic framework for interpreting the findings, ensuring that the conclusions possess both theoretical depth and practical value.

### III. METHODOLOGY

#### 3.1 Research Design and Subjects

This study employs a descriptive cross-sectional design to identify and analyze attention level characteristics among adolescents at a specific point in time through a single data collection. The subjects are 17-year-old adolescents at Malaysia University of Management and Science (MSU). This age group represents a critical transitional phase from adolescence to adulthood, where attention development tends toward stability yet retains plasticity, making it an appropriate target population for attention characteristic research.

#### 3.2 Sampling Method and Sample Size

Convenience sampling, a non-probability sampling technique, was employed. Participants were selected based on accessibility—adolescents meeting the age criteria within the MSU campus were directly enrolled without randomization. The sampling process was repeated until 60 participants were recruited, comprising 30 males and 30 females to ensure balanced gender representation and the validity of subsequent gender difference analyses.

#### 3.3 Research Tools

This study employed the Cognitive Assessment System, Second Edition (CAS2) as the measurement tool. Developed by Naglieri, Das, Goldstein et al. in 2014, this instrument is grounded in the PASS cognitive/neuropsychological theory (i.e., Planning, Attention, Synchrony, and Sequence Processing theory). It is a validated standardized assessment of cognitive abilities suitable for individuals aged 8–18, demonstrating strong reliability and validity.

In this study, the attention-related subtests from CAS2 were primarily utilized, specifically:

**Expressive Attention Scale:** Comprising 3 test pages, this subtest belongs to the synchronous scale. Each page presents 8 rows of stimuli, with 5 items per row. Designed similarly to Stroop tasks, it assesses selective attention and inhibitory control abilities (e.g., identifying the font color of color vocabulary words rather than the meaning of the words themselves).

**Receptive Attention Test:** Taken from pages 36-41 of the CAS2 Student Answer Booklet (8-18 years version), this measures attention stability and information filtering through a digit sequence recognition task. Participants identify specific

target number sequences (e.g., 123 or 123456) amidst distractors.

**Number Recognition Test:** Taken from pages 30-35 of the student answer booklet, this task requires participants to identify and mark target numbers within a specified time limit, evaluating attention speed and accuracy.

Additionally, the study includes an examiner's logbook for recording responses, scoring summaries, and test results for each subtest, creating a permanent record to ensure data traceability.

#### 3.4 Testing Tasks and Implementation Steps

##### 3.4.1 Numerical Detection Task

**Task Description:** Test materials consist of answer sheets containing numerical sequences. Each sheet features 15 rows of numbers, with 12 digits per row. These include a fixed number of target sequences (specifically formatted 123 or 123456) and distractors (distractors may share the same font as target sequences but differ in digits, or share digits but differ in font).

**Operational Requirements:** Participants must mark as many target number sequences as possible within 90 seconds. The examiner strictly controls the time using a stopwatch.

**Scoring Method:** The total score is calculated as the ratio of accuracy score (correctly marked target numbers minus incorrectly marked distractors) to time (seconds). A higher score indicates better selectivity, speed, and accuracy of attention.

##### 3.4.2 Expressive Attention Task

**Task Description:** Consists of 3 test pages, each containing 8 rows of stimuli with 5 items per row:

**Page 1:** 50 color words (e.g., red, green, blue, yellow). Participants read the words aloud. **Page 2:** Rectangles filled with the four colors listed above. Participants name the color of each rectangle. **Page 3:** Color words with font colors mismatched to their meanings (e.g., "red" written in green ink). Participants must identify and state the font color, not the word's meaning.

**Procedure:** Participants complete tasks sequentially. Examiners record reaction times and error rates.

**Scoring Method:** Scores are calculated based on the number of correct responses and reaction speed. Higher scores indicate stronger inhibitory control of attention (suppressing interference from word meanings).

##### 3.4.3 Receptive Attention Task

**Task Content:** Taken from pages 36-41 of the student answer booklet, this task presents multiple sets of number sequences. Each sequence contains a target digit string (123 or 123456) mixed with distractor digit strings.

**Procedure:** Participants identify and mark all target sequences without time constraints but must maintain focus. Examiners record completion time and accuracy rate.

**Scoring:** Points are awarded based on the proportion of correctly identified targets relative to total targets. Higher scores indicate greater attentional stability and information filtering ability.

#### 3.5 Data Collection Procedure

Explain the study purpose, testing procedure, and precautions to participants to ensure task comprehension. Administer tests sequentially: numerical detection, receptive attention, and expressive attention, to prevent task order interference. Immediately after each task, examiners record raw data (correct/incorrect counts, time, etc.) in logbooks. Following all tests, two researchers independently code and input data to ensure accuracy.

IV. RESULTS

This study systematically examined the association between three dimensions of adolescent attention (expressive attention, receptive attention, and numerical detection) and academic performance (CGPA), along with gender differences, through correlation analysis and independent samples t-tests. The specific findings are as follows:

4.1 Correlation Analysis between Attention Levels and Academic Performance

Table 1 presents the correlation results between each attention dimension and academic performance (CGPA). The data indicate that among the three core attention dimensions, only numerical detection exhibits a statistically significant positive correlation with academic performance ( $r=0.328$ ,  $p=0.011$ ). This suggests that adolescents demonstrating superior performance in numerical detection tasks (i.e., stronger selectivity, speed, and accuracy in attention) achieve higher average credit grade points. Furthermore, the digit span task also exhibits a significant positive correlation with receptive attention ( $r=0.279$ ,  $p=0.031$ ), suggesting potential synergistic effects at the cognitive processing level (e.g., both requiring information filtering and sustained focus).

In contrast, neither receptive attention ( $r = 0.214$ ,  $p = 0.101$ ) nor expressive attention ( $r = 0.057$ ,  $p = 0.666$ ) reached statistical significance in their correlations with academic performance ( $p > 0.05$ ). This outcome may relate to the evaluative nature of academic performance: CGPA, as a standardised numerical assessment metric, relies more heavily on cognitive abilities highly associated with numerical detection, such as symbol recognition and logical operations. Receptive attention (e.g., number sequence recognition) and expressive attention (e.g., inhibitory control in Stroop tasks) are more evident in everyday information processing scenarios and exhibit lower alignment with structured academic assessment tasks, hence failing to demonstrate significant correlations.

TABLE 1. Correlation Results Between Attention Levels and Academic Performance

Variables	Correlations		CGPA
	Receptive Attention	Expressive Attention	
Digital Inspection	.279* p=0.031	-.105 p=0.424	.328* P=0.011
Accept attention		.166 p=0.206	.214 P=0.101
Demonstrate attentiveness			.057 p=0.666

\*. Correlation is significant at  $p<0.05$

4.2 Analysis of Gender Differences in Academic Achievement and Attention Dimensions

4.2.1 Gender Differences in Academic Achievement

Table 2 indicates significant gender differences in adolescents' academic achievement ( $t=3.53$ ,  $p=0.001$ ). The mean CGPA for females (2.98,  $SD=0.62$ ) was significantly higher than that for males (2.43,  $SD=0.57$ ). Furthermore, the dispersion of males' scores ( $SD=0.57$ ) was slightly lower than that of females, suggesting a more concentrated distribution of academic performance among males. Whilst females demonstrated superior overall performance, they exhibited greater individual variation. This finding aligns with existing research concluding that 'women demonstrate greater stability in structured learning tasks.' It may relate to sociocultural expectations of gender roles (e.g., women being more readily guided towards focused learning behaviours) and differences in cognitive resource allocation patterns.

TABLE 2. Analysis of Differences in Academic Performance Between Male and Female Students

Gender	Mean	SD	T	P
Male	2.43	0.57	3.53	0.001
Female	2.98	0.62		

4.2.2 Gender Differences in the Numerical Detection Dimension

Table 3 data indicate significant gender differences in the numerical detection dimension ( $t=2.51$ ,  $p=0.015$ ). The mean score for females (80.1,  $SD=35.8$ ) was significantly higher than that for males (60.1,  $SD=26.1$ ) in the numerical detection task. This indicates superior performance among females in terms of selective attention, speed, and accuracy (e.g., identifying target digit sequences within time constraints). This finding supports the notion that 'women hold an advantage in detail processing and sustained attention tasks.' This may relate to the slightly faster developmental pace of the female prefrontal cortex (responsible for attention regulation) compared to males, or be influenced by environmental factors in educational settings where 'women are more likely to engage in precision-oriented tasks.'

TABLE 3. Presents the results of the relationship between numerical detection abilities, disaggregated by gender.

Gender	Mean	SD	T	P
Male	60.1	26.1	2.51	0.015
Female	80.1	35.8		

4.2.3 Gender Differences in the Receptive Attention Dimension

As shown in Table 4, significant gender differences were also observed in the receptive attention dimension ( $t=2.91$ ,  $p=0.005$ ). The mean receptive attention score for females (74.7,  $SD=15.2$ ) was significantly higher than that for males (62.5,  $SD=17.2$ ), and the dispersion of female scores ( $SD=15.2$ ) was lower than that of males. This indicates that females not only demonstrated superior overall performance in identifying target digit sequences amidst distractors but also exhibited greater inter-individual stability. This finding further corroborates gender differences in attentional stability and

information filtering capacity — females demonstrate greater proficiency in sustaining focus on targets within complex stimulus environments, whereas males exhibit heightened susceptibility to interference from extraneous information.

TABLE 4. Presents the results of the relationship between acceptance of attention, disaggregated by gender.

Gender	Mean	SD	T	P
Male	62.5	17.2	2.91	0.005
Female	74.7	15.2		

#### 4.2.4 Gender Differences in the Expressive Attention Dimension

Unlike the aforementioned dimensions, Table 5 indicates no significant gender differences emerged in the expressive attention dimension ( $t=0.405, p=0.687$ ). The mean expressive attentiveness scores for males (67.1,  $SD=20.7$ ) were comparable to those for females (69.7,  $SD=27.2$ ), with both groups exhibiting high score dispersion ( $SD>20$ ). This finding suggests that in cognitive tasks requiring ‘suppression of irrelevant information interference’ (e.g., identifying font colours rather than lexical meanings in Stroop tasks), gender exerts a weaker influence on attentional performance. This may stem from expressive attention relying more heavily on fundamental inhibitory control functions within the brain, which tend to mature by age 17, thereby diminishing gender differences. Alternatively, expressive attention may be more significantly affected by non-gender factors such as task difficulty and individual interest, masking gender-based distinctions.

TABLE 5. Results of the relationship between expressive attention across genders

Gender	Mean	SD	T	P
Male	67.1	20.7	0.405	0.687
Female	69.7	27.2		

### V. CONCLUSION

This study, involving 60 adolescents aged 17, employed the CAS2 tool system to investigate the characteristics and gender differences across three dimensions of attention. Key findings are as follows:

Firstly, the association between each dimension of adolescent attention and academic performance exhibits dimensional specificity. Only the numerical detection dimension showed a significant positive correlation with CGPA, whereas receptive and expressive attention demonstrated no significant association with academic achievement. This finding refines the mechanism by which attention influences academic performance: not all attention dimensions directly predict academic achievement. Only numerical detection abilities—linked to symbolic recognition and time-limited precise processing—exhibit high correlation with standardised academic assessments such as CGPA. This provides empirical support for educational practices aimed at ‘targeted enhancement of academically relevant attention dimensions.’ For instance, incorporating training in numerical recognition and timed calculations within science teaching can

strengthen numerical detection abilities, thereby improving academic performance.

Secondly, gender differences in academic performance and attention among adolescents exhibit divergent characteristics. Female students significantly outperformed their male counterparts in academic achievement, numerical detection, and receptive attention dimensions, though no significant difference was observed in expressive attention. This finding indicates that gender influences attention not through a “blanket advantage” but through selective differences across functional dimensions: girls excel in detail processing, sustained focus, and information filtering (numerical detection, receptive attention), while boys perform relatively weaker in these areas but match girls in inhibitory control (expressive attention). This conclusion supports challenging the stereotype linking gender to ability – girls’ advantage in numerical detection suggests a cognitive foundation for STEM (science, technology, engineering, mathematics) fields. Educators may encourage girls’ participation in STEM learning and practice through targeted guidance.

Thirdly, the numerical detection dimension may serve as a potential auxiliary indicator for early ADHD screening. One core symptom of ADHD is inattentiveness, and this study found numerical detection directly correlates with academic performance, with scores reflecting the selectivity and accuracy of attention. Should adolescents frequently exhibit omissions, errors, or excessive slowness in numerical detection tasks (scoring significantly below the mean), this may indicate abnormalities in attention regulation. Further diagnosis using clinical tools such as the Conners Scale could provide early warning signals for ADHD intervention, thereby mitigating long-term risks including academic failure and social difficulties.

### VI. RESEARCH LIMITATIONS AND FUTURE PROSPECTS

#### 6.1 Research Limitations

Insufficient representativeness of the sample: This study employed convenience sampling, selecting only 60 17-year-old adolescents (30 males and 30 females) from Universiti Sains Malaysia. The small sample size and single-source origin (concentrated within one institution) lack representativeness across different regions and educational backgrounds (e.g., public versus private schools). This may result in low external validity of the findings, limiting their generalisability to broader adolescent populations.

Single-dimensional assessment of academic performance: This study employed CGPA as the sole indicator for academic achievement, without disaggregating subject-specific grades (e.g., mathematics, language arts, science, humanities). Existing research indicates that different attention dimensions may correlate differently with performance in distinct subjects (e.g., expressive attention may relate to language-based disciplines). However, the singular academic metric employed in this study fails to reveal such subject-specific correlations, thereby limiting the conclusions’ pedagogical applicability across disciplines.

Uncontrolled potential confounding variables: This study did not incorporate potential confounding variables that may influence attention and academic performance, such as family environment (parental educational attainment, home learning atmosphere), duration of digital device usage (e.g., daily mobile phone and computer usage time), and sleep quality. For instance, prolonged and frequent digital device usage may diminish attention stability, while insufficient sleep could impair academic performance. The absence of these variables may introduce bias into the analysis of associations between ‘attention – academic performance’ and ‘gender – attention’, hindering precise identification of causal relationships.

Cross-sectional limitations of the research design: Employing a cross-sectional design, this study analysed attention characteristics at a single point in time through one-off data collection. It cannot track the dynamic developmental trajectory of adolescents' attention (e.g., trends in attention dimensions between ages 17 and 18) nor verify the causal hypothesis that ‘changes in attention dimensions may lead to subsequent variations in academic performance.’ This constrains in-depth exploration of attention development mechanisms.

### 5.2 Future Outlook

To expand sample size and optimise sampling methods, future research may employ multistage random sampling to increase sample size (e.g., to at least 300 participants) and incorporate samples from diverse countries/regions (e.g., multiple Southeast Asian nations, comparative studies between Eastern and Western contexts), different educational stages (e.g., adolescents aged 15–18), and varied educational settings (public, private, vocational schools). This approach would enhance the representativeness and cross-cultural applicability of research conclusions. Consideration may also be given to including special groups (e.g., adolescents at high risk for ADHD) to further validate the association between attention dimensions and pathological characteristics.

Subdivide academic performance and expand assessment metrics. Subsequent research may break down academic performance into specific subject grades (e.g., mathematics, Chinese, physics, biology) to analyse the specific correlations between attention dimensions and different disciplines (e.g., whether numerical detection correlates more strongly with mathematics and physics grades, or whether expressive attention correlates more strongly with Chinese and English grades). This would provide more precise evidence for subject-specific attention training programmes. Additionally, non-standardised academic indicators (such as classroom

participation and homework quality) could be incorporated to comprehensively explore the multidimensional impact of attention on academic performance.

To control for confounding variables and employ longitudinal designs, future research should incorporate potential confounding factors such as family environment, digital device usage, sleep quality, and intellectual ability. Through multiple regression analysis or structural equation modelling, these interfering factors should be excluded to precisely elucidate the causal relationship between attention, academic performance, and gender. Concurrently, longitudinal designs (e.g., tracking participants over 1–2 years) may be employed to periodically measure changes in adolescents' attention dimensions and academic performance. This would analyse the dynamic characteristics of attention development and its long-term predictive role for academic achievement, thereby informing the formulation of phased intervention programmes.

Combining multi-method assessment with mechanism exploration, subsequent research may integrate behavioural experiments (e.g., eye-tracking technology to record attention allocation processes), neuroimaging techniques (e.g., fMRI to detect prefrontal activation), and questionnaire surveys (e.g., family environment scales) to elucidate adolescent attention development mechanisms across behavioural, neural, and environmental dimensions. Furthermore, intervention trials may be designed based on these findings (e.g., receptive attention training programmes for male students, STEM-integrated teaching targeting numerical detection abilities) to validate intervention efficacy and provide actionable solutions for educational practice.

Exploring the underlying mechanisms of gender differences, future research may further explore the causes of gender differences in attention. This could involve questionnaire analyses examining the influence of sociocultural factors (such as gender role expectations and educational equity), alongside neurodevelopmental studies comparing developmental differences in the prefrontal and parietal lobes (attention-related brain regions) between adolescent males and females. Such investigations would clarify the synergistic effects of biological and environmental factors on gender differences, providing theoretical support for developing gender-sensitive attention enhancement programmes.