

Issues and Perspectives in Business and Social Sciences

The relationship between fast-paced mobile gaming and adolescents' cognitive development: an exploratory study

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Abstract

This exploratory study examined adolescents' perceived cognitive and psychomotor benefits, gameplay performance, and experiences associated with a custom-developed fast-paced mobile game, *OnTimelyPress*. A mixed-methods design was used with 35 adolescents aged 13–19 years recruited through convenience sampling from two Malaysian educational institutions. Participants played several rounds of the game and subsequently completed a researcher-developed questionnaire containing Likert-scale and open-ended items. Gameplay duration from the first and final rounds was also recorded. Quantitative data were analysed using descriptive statistics, correlation analysis and a paired-samples *t*-test, while open-ended responses were categorised thematically. Participants generally reported positive perceptions of focus, memory, response speed, hand-eye coordination and enjoyment. However, the relationship between self-reported cognitive and psychomotor scores was not statistically significant. Gameplay duration increased from the first round to the final round, but the difference was not statistically significant. The qualitative findings showed that participants generally considered the game enjoyable and cognitively demanding, although some had trouble maintaining concentration. The findings indicate positive perceptions of cognitive engagement rather than objectively verified cognitive or psychomotor improvement. Further experimental research using validated assessments, comparison groups and larger samples is required.

Keywords:

Fast-paced mobile games;
Adolescents;
Cognitive engagement;
Psychomotor development;
Game-based learning;
Mixed-methods research

Received:

Oct 18, 2025

Revised:

Aug 20, 2026

Accepted:

Aug 27, 2026

Published:

Sept 8, 2026

1. Introduction

The integration of advanced digital technologies, particularly the Internet and mobile computing, has transformed educational practices by enabling more accessible and interactive learning environments. Mobile devices, such as smartphones and tablets, have become widely used educational tools because of their portability and ease of access. These technological advancements have facilitated the adoption of gamification, an instructional approach that incorporates game design elements into learning activities to promote active, student-centred learning (Deterding et al., 2011; Kapp, 2012; Subhash & Cudney, 2018). Compared with conventional teaching approaches, gamification encourages greater student engagement, participation, and motivation, which can contribute to improved learning outcomes (Buckley & Doyle, 2016; Sailer et al., 2017). Recognising these benefits, educational institutions have increasingly integrated gamification into teaching and learning practices, leveraging the

accessibility of mobile technologies to create more engaging and effective educational experiences (Aliah et al., 2020; Hamari et al., 2014).

Video games have evolved beyond entertainment and have become valuable tools for education, professional training, and social interaction (Granic et al., 2014; Quwaider et al., 2019). The increasing accessibility of smartphones and tablets has further expanded the popularity of mobile gaming by allowing individuals to engage in digital games at any time and place (Mäyrä & Alha, 2020). In addition to recreational use, game-based technologies have been widely adopted in specialised fields such as military training and medical education, where simulated environments provide safe and controlled opportunities for developing practical knowledge and skills (Augier et al., 2018; Min et al., 2022).

Research has demonstrated that digital games can support a range of cognitive abilities, including attention, executive functioning, problem-solving, critical thinking, and visuospatial processing, while also enhancing psychomotor skills, such as hand-eye coordination and visuomotor performance (Bediou et al., 2018; Granic et al., 2014; Kusuma et al., 2018). Beyond their entertainment value, educational games and gamified learning environments have attracted increasing interest because they promote active, student-centred learning, enhance learner engagement and motivation, and contribute to more interactive learning experiences (Hamari et al., 2014; Subhash & Cudney, 2018). By incorporating game design elements such as challenges, immediate feedback, rewards, and progressive levels into educational activities, gamification encourages sustained participation while fostering higher-order cognitive skills, including critical thinking and problem-solving (Kazimoglu & Bacon, 2020; Subhash & Cudney, 2018).

Previous research has primarily examined commercial action video games, educational gamification platforms, and serious games designed for instructional purposes, reporting positive outcomes related to attention, executive functioning, memory, learner engagement, and motivation (Bediou et al., 2018; Granic et al., 2014; Subhash & Cudney, 2018). However, comparatively little research has investigated the potential role of a custom-developed fast-paced mobile game in relation to adolescents' cognitive development, psychomotor development, gameplay performance, academic performance, and gaming experiences within a single study. Furthermore, few studies have adopted a mixed-methods approach that integrates quantitative statistical analyses with qualitative thematic analysis to examine both measurable outcomes and adolescents' subjective perceptions of gameplay.

To address these research gaps, the present exploratory study employed a mixed-methods design to examine adolescents' experiences with a custom-developed fast-paced mobile game, *OnTimelyPress*. This study investigated the relationships between cognitive and psychomotor development, gaming behaviour and academic performance, and differences in gameplay completion time following repeated gameplay. Qualitative thematic analysis was conducted to explore adolescents' emotional responses, perceived cognitive benefits, and gameplay experiences. By integrating quantitative and qualitative findings, this study provides a more comprehensive understanding of adolescents' perceptions and experiences associated with fast-paced mobile gaming, while offering complementary insights into its potential educational applications.

Fast-paced mobile games have attracted increasing attention as potential tools for promoting cognitive engagement and interactive learning in educational settings. Strategic multiplayer games, such as *Mobile Legends: Bang Bang* and *DOTA*, exemplify how complex game environments can encourage teamwork, strategic thinking, decision-making, and problem-solving while engaging cognitive abilities such as critical thinking, focused attention, executive functioning, and spatial cognition, as well as psychomotor skills, including hand-eye coordination (Bediou et al., 2018; Granic et al., 2014). Consequently, gamified learning has emerged as a complementary

approach to traditional education, encouraging learner engagement and active participation (Hamari et al., 2014; Subhash & Cudney, 2018).

This study focused on adolescents' engagement with *OnTimelyPress*, a fast-paced Android-based mobile game developed for this purpose. The game requires players to align clock hands with specified numerical prompts within a limited time, thereby challenging their attention, memory, reaction speed, accuracy, and hand-eye coordination. The study examined the relationship between cognitive and psychomotor development, the relationship between gaming behaviour and academic performance, differences in gameplay completion time across repeated gameplay sessions, and adolescents' emotional responses, perceived benefits, and gaming experiences using a mixed-methods approach.

The primary objectives of this study are to (i) investigate the relationships among adolescents' cognitive development, psychomotor development, and academic performance following gameplay of the fast-paced mobile game *OnTimelyPress*, as well as their associations with selected demographic characteristics; (ii) investigate the relationship between adolescents' gaming behaviour, including gaming frequency and duration, and their academic performance; (iii) determine whether there is a statistically significant difference in gameplay completion time between the first and final gameplay sessions following repeated engagement with a fast-paced mobile game; and (iv) explore adolescents' emotional responses, perceived benefits, and gameplay experiences associated with engaging in a fast-paced mobile game.

The significance of this study lies in its provision of a comprehensive understanding of adolescents' experiences with fast-paced mobile games. Although the quantitative analyses did not identify statistically significant relationships or differences among the variables examined, the qualitative findings indicated that adolescents generally perceived the game as beneficial for supporting memory retention, focus retention, reaction time, hand-eye coordination, motivation, and learning engagement. By integrating quantitative and qualitative findings, this study contributes to the growing literature on game-based learning and provides useful insights for educators, researchers, and game developers seeking to incorporate fast-paced mobile games as complementary educational tools.

2. Literature review

According to the World Health Organization (2019), adolescence is the transitional period between childhood and adulthood, typically characterised by significant physical, psychological, cognitive, and social development. Adolescence is commonly divided into three developmental stages: early, middle, and late, each characterised by distinct developmental milestones and challenges (Sawyer et al., 2018). During this stage, individuals experience rapid changes that shape their identity, maturity, and thinking patterns. Consequently, educational and health interventions should be developmentally appropriate to support adolescents in acquiring values, health literacy, and essential skills.

Cognitive development refers to the progression of thinking, reasoning, and understanding from infancy to adulthood (Santrock, 2021). During adolescence, cognitive development continues to advance through improvements in executive functioning, abstract reasoning, decision making, and cognitive control (Crone & Dahl, 2012). According to Piaget's theory of cognitive development (Piaget, 1952, as cited in Santrock, 2021), individuals progress through four sequential stages of cognitive development: sensorimotor, preoperational, concrete operational, and formal operational. The sensorimotor stage (birth to 2 years) is characterised by learning through sensory experiences and motor activities, during which infants develop object permanence, or the understanding that objects continue to exist even when they are no longer visible to them. During

the preoperational stage (2–7 years), children develop language, symbolic thought, and imagination, although their thinking remains intuitive rather than logical. In the concrete operational stage (7–11 years), children develop logical reasoning for concrete situations and gain an understanding of concepts such as conservation, classification, seriation, and cause-and-effect relationships. Finally, the formal operational stage (11 years and older) is characterised by the development of abstract reasoning, hypothetical thinking, strategic planning, and the application of concepts across different contexts, reflecting continued cognitive maturation during adolescence (Piaget, 1952, as cited in Santrock, 2021; Crone & Dahl, 2012).

Adolescence is a critical developmental period characterised by substantial cognitive, emotional, social and psychological growth (Steinberg, 2020). Adolescence is commonly divided into three developmental stages: early, middle, and late. During early adolescence (approximately 11 to 14 years), individuals begin to transition from childhood, becoming increasingly independent while developing more advanced reasoning and decision-making abilities. In middle adolescence (approximately 14 to 17 years), cognitive development continues through enhanced abstract thinking, moral reasoning, identity exploration, and greater awareness of the long-term consequences of decisions. By late adolescence (approximately 17–20 years), individuals generally demonstrate greater emotional maturity, improved self-regulation, and an increased capacity to balance personal aspirations with adult responsibilities while considering broader societal issues (Santrock, 2021; Steinberg, 2020). Given that the participants in this study were adolescents aged 13–19 years, Piaget's formal operational stage provides a relevant theoretical framework for understanding higher-order cognitive processes, including problem-solving and critical thinking, examined in the present study.

Adolescence is characterised by substantial neurological development that supports improvements in learning, reasoning, and self-reflection. During this period, the brain undergoes extensive synaptic pruning and increased myelination, strengthening neural pathways and improving information processing efficiency. These developmental changes enhance adolescents' capacity for abstract thinking, allowing them to reason about complex concepts, anticipate future consequences, and make more informed decisions. In addition, the continued development of executive functioning promotes metacognitive abilities, enabling adolescents to reflect on their own thinking, evaluate their decisions, and adapt their problem-solving strategies to different situations (Crone & Dahl, 2012).

2.1 Mobile games and cognitive development

Mobile gaming has become popular because smartphones and tablets allow people to play anytime and anywhere (Mäyrä & Alha, 2020). Unlike traditional consoles, mobile games are more accessible and attract players from all over the world. Mobile gaming has evolved from early handheld electronic games to sophisticated smartphone-based platforms that support increasingly complex gaming experiences (Mäyrä & Alha, 2020). The commercial success of arcade games during the 1970s laid the foundation for the digital gaming industry, while the introduction of smartphones, particularly Apple's iPhone in 2007 and Android devices in 2008, revolutionised mobile gaming by enabling widespread access to portable, Internet-connected gaming platforms (Mäyrä & Alha, 2020). Contemporary mobile games, such as *Pokémon GO* and *Mobile Legends: Bang Bang*, showcase the diversity of modern mobile gaming through features such as augmented reality, online multiplayer interaction, and real-time communication, contributing to the widespread popularity and accessibility of mobile gaming experiences (Hamari et al., 2019; Mäyrä & Alha, 2020).

Digital games have evolved beyond entertainment to support psychological well-being, social interaction, and cognitive development in children. Multiplayer games encourage social

engagement and collaboration, while gameplay has been associated with reduced stress and improvements in cognitive abilities, including attention, memory, problem-solving, critical thinking, and cognitive flexibility (Chaarani et al., 2022; Granic et al., 2014). These educational and cognitive benefits have contributed to the growing interest in digital games as learning and skill development tools.

Different video game genres are associated with distinct cognitive benefits depending on their gameplay mechanics. Action games have been linked to improvements in visual attention, spatial cognition, reaction time, attentional control, and executive functioning, whereas puzzle games promote logical reasoning, creativity, memory, and problem-solving through progressively challenging tasks. Similarly, real-time strategy (RTS) games strengthen strategic planning, multitasking, cognitive flexibility, and decision-making by requiring players to manage multiple objectives at the same time (Bediou et al., 2018; Granic et al., 2014). Among these genres, fast-paced games place particularly high demands on sustained attention, rapid decision-making, and visuomotor coordination. Continuous interaction with dynamic and cognitively demanding environments has been shown to enhance executive functioning and facilitate the acquisition of novel cognitive tasks, thereby improving learning efficiency and adaptation to new cognitive challenges (Bediou et al., 2018; Granic et al., 2014; Zhang et al., 2021). Figure 1 illustrates the relationship between cognitive development in adolescence and the influence of mobile gaming.

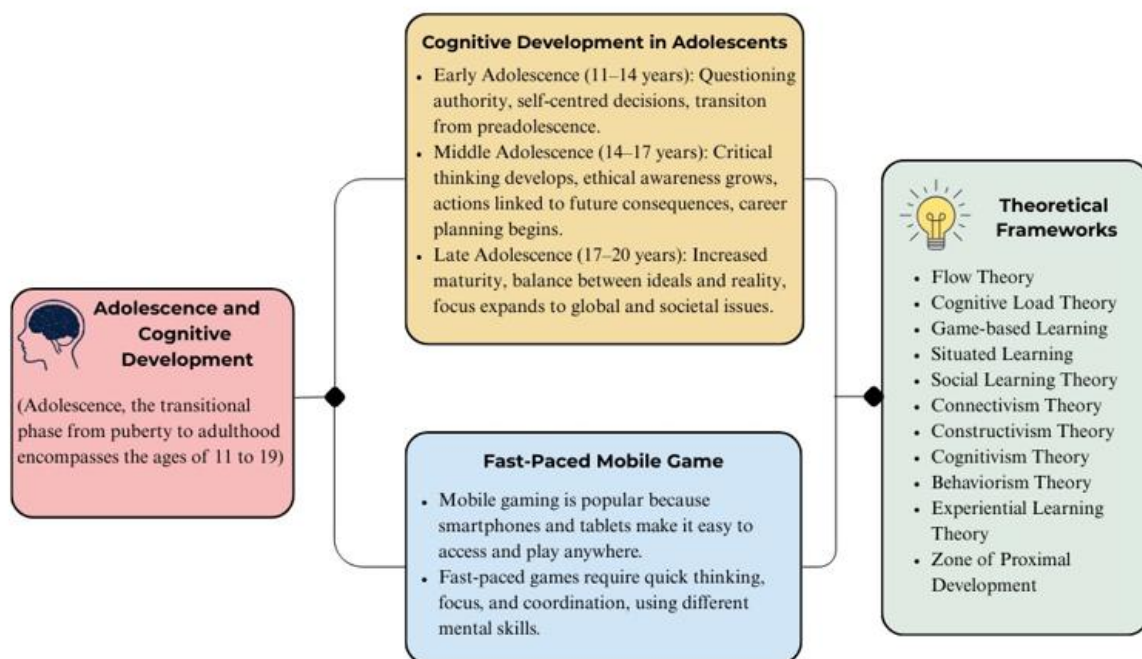


Figure 1: Cognitive development in adolescence and the influence of mobile gaming.

Several educational and psychological theories provide a theoretical foundation for understanding how fast-paced mobile games may influence adolescents' cognitive and psychomotor development. Figure 2 presents the conceptual framework of the study, and Table 1 summarises the alignment between the selected theories, study variables, and research objectives. Together, these theories explain the mechanisms through which fast-paced mobile gaming may influence cognitive development, psychomotor development, gameplay performance, academic performance, and gameplay experience, thereby providing the theoretical basis for the present study.

3. Theoretical framework

Fast-paced mobile games constitute the independent variable in this study and provide learning experiences through which adolescents engage in cognitive tasks. As illustrated in Figure 2, adolescents interact with fast-paced mobile games by actively solving challenges, responding to time-sensitive situations and receiving immediate feedback. These learning experiences are explained by the Experiential Learning Theory (Kolb, 1984), which proposes that knowledge is developed through experience and reflection. Similarly, Constructivism Theory (Piaget, 1952) suggests that learners actively construct knowledge by interacting with their environment, while Behaviourism Theory (Skinner, 1953) emphasises that repeated practice and reinforcement strengthen desired behaviours. Cognitivism Theory (Bruner, 1966) further explains how learners organise, process, and retain information during the game play. Together, these theories explain how active engagement with fast-paced mobile games creates meaningful learning experiences that may facilitate cognitive development in adolescent players.

Table 1: Alignment of theoretical frameworks with the study variables and research objectives

Theory	Key Concept	Study Variable(s)	Research Objective(s)
Experiential Learning Theory	Learning occurs through direct experience, reflection, and repeated practice.	Cognitive development, psychomotor development, gameplay experiences	R01, R03, R04
Constructivism Theory	Learners actively construct knowledge through interaction and experience.	Cognitive development, gameplay experiences	R01, R04
Cognitivism Theory	Learning involves information processing, attention, memory, and reasoning.	Memory retention, focus retention, cognitive response speed, problem-solving	R01
Behaviourism Theory	Repetition, reinforcement, and feedback strengthen learning and performance.	Gameplay performance, repeated gameplay	R03
Zone of Proximal Development (ZPD) Flow Theory	Progressively challenging tasks support gradual skill development. Enjoyable and appropriately challenging activities enhance concentration and intrinsic motivation.	Gameplay performance, cognitive development Learning engagement, concentration, gameplay experiences	R03 R02, R04
Cognitive Load Theory	Appropriate cognitive demands improve information processing and learning efficiency.	Memory retention, focus retention, cognitive response speed	R01
Game-Based Learning Theory	Meaningful gameplay promotes learning, engagement, and educational outcomes.	Academic performance, learning engagement, gameplay experiences	R02, R04
Situated Learning Theory	Learning is enhanced through authentic and contextual learning environments.	Cognitive development, learning engagement, gameplay experiences	R01, R02, R04
Social Learning Theory	Learning occurs through observation, interaction, and shared experiences.	Motivation, gameplay experiences	R04
Connectivism Theory	Learning is supported through digital technologies, information networks, and connected environments.	Learning engagement, cognitive engagement, gameplay experiences	R02, R04

Note. Constructivism Theory, Cognitivism Theory, and Behaviourism Theory collectively explain the learning processes that occur during adolescents' interaction with the custom-developed fast-paced mobile game, while the remaining theories provide complementary perspectives on cognitive development, engagement, and educational outcomes.

Figure 2 illustrates the proposed theoretical framework of this study. Fast-paced mobile games represent independent variables that provide experiential learning opportunities for adolescent players. Through the combined influence of learning experiences, cognitive skill development, and supportive learning environments, gameplay is hypothesised to enhance adolescents' cognitive abilities, thereby contributing to overall cognitive development. These theoretical relationships underpin the four research objectives by explaining how fast-paced mobile games may influence cognitive development, gameplay performance, academic performance, and adolescents' gameplay experiences.

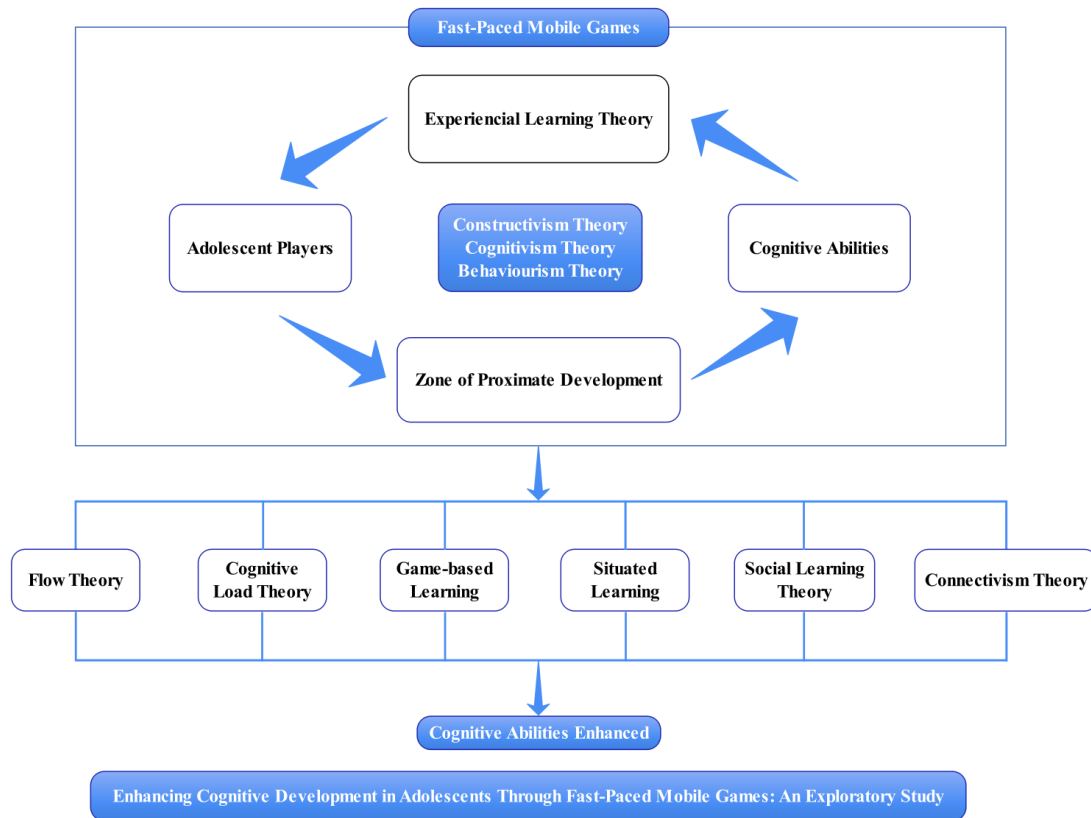


Figure 2: Theoretical framework

3.1 Skill development

The learning experiences generated through gameplay are expected to contribute to the development of adolescents' cognitive abilities, which represent the dependent variable of this study. As shown in Figure 2, the interaction between adolescent players and fast-paced mobile games is expected to enhance cognitive abilities, such as attention, memory, problem-solving, decision-making, and information processing. This relationship is supported by Flow Theory (Csikszentmihalyi, 1990), which explains that optimal engagement promotes concentration and skill acquisition. Cognitive Load Theory (Sweller, 1988) suggests that appropriately designed learning activities optimise information processing without overloading the working memory. The Game-Based Learning Theory (Plass et al., 2015) further explains how game mechanics encourage active learning and sustained cognitive engagement, ultimately contributing to enhanced cognitive development.

3.2 Supportive environment

The relationship between fast-paced mobile games and cognitive development is further strengthened by supportive learning environments. As illustrated in Figure 2, the Zone of Proximal Development (Vygotsky, 1978) serves as the central mechanism linking adolescent players with cognitive abilities by emphasising learning through guidance, scaffolding, and progressively challenging tasks. Situated Learning Theory (Lave & Wenger, 1991) proposes that learning occurs within authentic contexts in which knowledge is acquired through meaningful participation. Social Learning Theory (Bandura, 1977) explains that adolescents develop cognitive strategies by observing, imitating, and interacting with others, whereas Connectivism Theory (Siemens, 2005) highlights the importance of accessing and integrating knowledge through digital networks and technologies. Collectively, these theories explain how supportive learning environments reinforce the cognitive benefits derived from fast-paced mobile games.

4. Methods

This study investigated the relationship between fast-paced mobile gaming and adolescents' cognitive development. Although previous studies have demonstrated that video games and gamified learning environments can enhance cognitive abilities such as attention, memory, problem-solving, and executive functioning, relatively few studies have examined custom-developed fast-paced mobile games designed specifically to investigate adolescents' cognitive development (Boyle et al., 2016; Koivisto & Hamari, 2019). Comparatively little research has examined the cognitive and psychomotor effects of fast-paced mobile games among adolescents, particularly using a mixed-methods approach (Creswell & Plano Clark, 2018) that combines quantitative and qualitative analyses in the Malaysian context. Therefore, an exploratory mixed-methods research design was adopted to investigate this underexplored area by examining the potential effects of fast-paced mobile gaming on adolescents' problem-solving, critical thinking, memory retention, focus retention, reaction time, and hand-eye coordination. The integration of quantitative statistical analyses and qualitative thematic analysis provided a more comprehensive understanding of adolescents' gameplay performance, gaming experiences, and perceived developmental outcomes following engagement with a fast-paced mobile game.

An exploratory mixed-methods approach was adopted to address gaps in the existing literature concerning the potential role of fast-paced mobile games in adolescents' cognitive and psychomotor development. Although previous studies have examined digital games, serious games, and gamified learning, comparatively few have simultaneously investigated the potential effects of fast-paced mobile gaming on adolescents' problem-solving, critical thinking, memory retention, focus retention, reaction time, hand-eye coordination, gameplay performance, and gaming experiences using both quantitative and qualitative methods. Furthermore, Vedeckina and Borgonovi (2021) highlighted the need for stronger theoretical frameworks linking digital games and cognitive development, supporting the use of an exploratory research design. Accordingly, this study integrates quantitative statistical analyses with qualitative thematic analysis to provide a more comprehensive understanding of adolescents' experiences and perceptions after engaging with a fast-paced mobile game.

4.1 Sample and population

The study targeted adolescents aged 11–19 years from two educational institutions in Malaysia: a government secondary school in Seremban, Negeri Sembilan, and a private university college in Petaling Jaya, Selangor. Participants from the secondary school comprised adolescents aged 13 to 17, and the participants from the private university college were between 18 and 19 years old.

These settings were selected to capture a diverse sample representative of adolescents. Approvals for data collection were obtained from the relevant parties, specifically the Malaysian Educational Department and the university college's management. The study initially aimed to recruit approximately 30 participants, a sample size commonly considered adequate for exploratory and pilot studies (Perneger et al., 2015). Ultimately, 40 adolescents were recruited, comprising 27 from the secondary school and 13 from the private university college, despite limited interest among the university students, especially among males.

Participants were recruited through a mobile game demonstration at the two institutions, where eligible adolescents below 20 years of age were invited to participate after being informed of the purpose and procedures of the study. Participation was voluntary, and the participants were recruited using convenience sampling. Data were collected over a 7-day period. During this period, each participant completed a practice session, the first and final gameplay sessions, and the post-gameplay questionnaire on the same day during a single session lasting approximately 8–9 minutes. The practice session lasted approximately 1 minute to familiarise participants with the gameplay mechanics, while the post-gameplay questionnaire required approximately 5 minutes to complete. Participants were allowed to remain in the game for as long as they could continue playing. Across the first and final gameplay sessions, the mean combined gameplay duration was 135.34 seconds (approximately 2 minutes and 15 seconds), although the actual duration varied according to each participant's gameplay performance. Gameplay performance data were recorded automatically during both gameplay sessions, and questionnaire responses were collected immediately after. Although not all students completed the post-gameplay questionnaire, the gaming activity generated considerable interest, and the target sample size for this age group was achieved.

4.2 Research instruments

To ensure a consistent gaming experience across all participants, a custom-developed fast-paced mobile game was created specifically for this study and used as a data collection instrument. The game was designed to standardise gameplay tasks and conditions for every participant, thereby minimising potential variations associated with commercial games, such as differences in gameplay mechanics, difficulty levels, prior familiarity with the game, and player experience.

4.2.1 Feedback questionnaire

A feedback questionnaire was used as the primary data collection instrument. The questionnaire comprised three sections: Section A collected the participants' demographic information. Section B consisted of 12 five-point Likert-scale items (1 = Strongly Disagree to 5 = Strongly Agree) that elicited data on participants' perceived cognitive responses following gameplay (Plass et al., 2015; Boyle et al., 2016). Representative cognitive response items included: (i) *"Are you able to focus on the clock and minute numbers better after playing a few rounds of this game?"* (ii) *"Are you able to remember the clock minute numbers better after playing a few rounds of this game?"* (iii) *"Do you believe playing this type of mobile game will have a positive impact on your thinking speed and response abilities?"*. Participants were required to respond using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).

Qualitative insights into participants' perceived cognitive benefits, emotional responses, and gameplay experiences were assessed in Section C using four researcher-developed open-ended questions. The questions also asked participants to report their perceived gameplay duration for the first and final gameplay rounds and to describe the potential benefits of engaging in this type of game, as well as their feelings and responses after the gameplay. The four questions were as

follows: (i) "How long did it take you to complete the first round of the game?" (ii) "How long did it take you to complete the final round of the game?" (iii) "In your own words, describe the potential benefits of engaging in these types of games. Please provide a minimum of two points." (iv) "Share your feelings or responses after playing this game. Please provide a minimum of two points."

To strengthen content validity, the questionnaire was developed based on the study objectives and an extensive review of the literature on mobile gaming, cognitive development, gamification, and game-based learning, ensuring that the items adequately represented the study constructs. The questionnaire underwent a pilot study and expert review to evaluate its clarity, relevance, and alignment with the intended constructs, and minor revisions were made based on the feedback. A pilot study involving 19 participants outside the target age range was subsequently conducted to assess the internal consistency reliability of the questionnaire using Cronbach's alpha (Taber, 2018). As presented in Table 2, the Cronbach's alpha values if individual items were deleted ranged from 0.889 to 0.908, indicating that each item contributed positively to the reliability of the questionnaire. Furthermore, the overall Cronbach's alpha coefficient was 0.907 (0.910 based on standardised items), exceeding the recommended threshold of 0.70 (Nunnally & Bernstein, 1994) and indicating excellent internal consistency (Taber, 2018). As Cronbach's alpha assesses internal consistency reliability rather than content or construct validity, future studies should further evaluate construct validity using larger samples and exploratory or confirmatory factor analyses.

Table 2: Measurement items' reliability

No.	Questionnaire item	Cronbach's Alpha if item deleted
1	Able to focus on the clock and minute numbers better after playing a few rounds of the game ¹	0.906
2	Able to remember the clock minute numbers better after playing a few rounds of the game	0.889
3	Able to solve the clock-pressing tasks faster after playing a few rounds of the game	0.896
4	Playing this type of mobile game improves thinking speed and response abilities	0.898
5	Hand-eye coordination improves after playing a few rounds of the game	0.897
6	Reaction time becomes faster after playing a few rounds of the game	0.900
7	Focus, memory, hand-eye coordination, and response speed help players remain in the game longer	0.905
8	Playing these types of mobile games helps improve memory of academic lessons	0.897
9	Playing these types of mobile games helps improve classroom focus	0.906
10	Good memory and focus contribute to better academic performance	0.908
11	I enjoyed the overall gameplay experience	0.897
12	I would like lessons to be as enjoyable as this game to improve focus and learning	0.892

Note. The "Cronbach's Alpha if Item Deleted" values ranged from 0.889 to 0.908, indicating that each questionnaire item contributed positively to the instrument's overall internal consistency. No individual item substantially reduced the reliability of the questionnaires.

4.2.2 Gameplay data

Three smartphones equipped with a custom-developed fast-paced mobile game, *OnTimelyPress* were provided to the participants. Adolescents played the game over several rounds, and the gameplay duration was recorded for both the first and final rounds. In *OnTimelyPress*, gameplay performance is measured by gameplay duration, where players attempt to remain in the game for as long as possible by accurately responding to the game tasks. Consequently, a longer

gameplay duration indicates better performance, whereas a shorter duration reflects earlier game termination. After completing the gameplay sessions, the participants completed a feedback questionnaire, providing both quantitative and qualitative insights into their cognitive experiences. The participants were encouraged to answer all questions thoroughly, particularly those related to their gameplay performance and experiences.

4.3 Data analysis

The collected data were analysed using a combination of descriptive and inferential statistical methods. Microsoft Excel was used for initial data entry and basic descriptive analysis, while IBM SPSS (Statistical Package for Social Sciences) Statistics version 27 software enabled more detailed statistical evaluation. Visual representations, including charts and tables, were generated to summarise the findings.

Quantitative data analysis was essential for addressing the hypotheses of this study. Descriptive statistics provided an overview of trends, while inferential analyses tested the relationships between gameplay and cognitive development. The key metrics included were (i) means and standard deviations to measure central tendencies, (ii) Pearson correlation coefficients to explore relationships between variables, and (iii) paired *t*-tests to compare participant performance in the first and final gameplay rounds. These analyses allowed the researchers to draw meaningful conclusions about the relationship between fast-paced mobile gaming and adolescents' cognitive development.

5. Results

The demographic characteristics of the participants, including their age distribution, are shown in Table 3. Most participants were 17 years old (34%, *n* = 12), followed by those aged 18 (26%, *n* = 9) and 14 years (20%, *n* = 7). Participants aged 13, 15, and 19 years accounted for 6% (*n* = 2) each, while only one participant (3%) was aged 16 years. In terms of sex distribution, 21 participants (60%) were male and 14 (40%) were female.

Table 3: Descriptive statistics

		<i>n</i>	Percentage
Age	13	2	6%
	14	7	20%
	15	2	6%
	16	1	3%
	17	12	34%
	18	9	26%
	19	2	6%
Sex	Male	21	60%
	Female	14	40%
Gaming frequency	Very rarely or one to two days per week	18	52%
	Three to four days per week or daily	17	48%
Gaming duration	Less than 1 hour (Less than 30 minutes + Between 30 minutes to 1 hour)	22	63%
	More than 1 hour (More than 2 hours)	13	37%

Note. Gaming frequency categories were combined into two groups for descriptive reporting: "Very rarely" and "One to two days per week" (*n* = 18), and "Three to four days per week" and "Daily" (*n* = 17). Gaming duration categories were combined into "Less than 1 hour" (Less than 30 minutes and Between 30 minutes to 1 hour; *n* = 22) and "More than 1 hour" (More than 2 hours; *n* = 13).

All participants reported previous experience playing mobile games, reflecting the widespread accessibility and popularity of mobile games among adolescents. Regarding gaming frequency, 18 participants (52%) reported playing mobile games very rarely or one to two days per week, whereas 17 participants (48%) reported playing three to four days per week or every day. In terms of gaming duration, 22 participants (63%) reported playing mobile games for less than one hour, while 13 participants (37%) reported playing for more than one hour.

To ensure consistency in gameplay and familiarity with the mechanics, all participants completed a guided practice session before formal data collection commenced. Prior to the data collection session, 49% of the participants had practiced the selected game twice. Overall, these findings indicate that mobile gaming was a common recreational activity among the participants, providing an appropriate context for investigating the relationship between fast-paced mobile games and adolescents' cognitive and psychomotor development.

5.1. Research objective 1

Research Objective 1 aimed to investigate the relationships among adolescents' cognitive development, psychomotor development, academic performance, and selected demographic characteristics (age, sex, gaming frequency, and gaming duration) following gameplay of the fast-paced mobile game *OnTimelyPress*. Pearson's correlation analysis was conducted to examine the associations among these variables, and the results are presented in Table 4.

The analysis revealed a weak positive relationship between cognitive and psychomotor development ($r(33) = 0.281, p = 0.102$). Although participants with higher cognitive development scores tended to report higher psychomotor development scores, the relationship was not statistically significant because the p -value exceeded the predetermined significance level of 0.05. Therefore, cognitive development was not significantly associated with psychomotor development in the adolescent participants.

Additional analyses were conducted to examine the associations between adolescents' demographic characteristics and the study variables. The results showed weak to very weak relationships between demographic characteristics and cognitive development, with Pearson correlation coefficients ranging from $r(33) = -0.050$ to $r(33) = 0.267$, and corresponding significance values ranging from $p = 0.121$ to $p = 0.774$. Similarly, weak relationships were observed between demographic characteristics and psychomotor development, with correlation coefficients ranging from $r(33) = 0.039$ to $r(33) = 0.139$, and significance values ranging from $p = 0.426$ to $p = 0.825$. As all significance values exceeded the 0.05 threshold, none of the demographic variables examined were significantly associated with either cognitive or psychomotor development.

As shown in Table 4, cognitive development demonstrated a moderate positive relationship with academic performance ($r(33) = 0.580, p < 0.001$), indicating that participants with higher perceived cognitive development scores also tended to report higher academic performance. In contrast, psychomotor development was not significantly associated with academic performance ($r(33) = 0.173, p = 0.320$). Among the demographic characteristics, only sex demonstrated a statistically significant positive relationship with academic performance ($r(33) = 0.403, p = 0.016$), whereas age, gaming frequency, and gaming duration were not significantly associated with academic performance.

Although the quantitative analyses did not demonstrate a statistically significant relationship between cognitive and psychomotor development, the qualitative findings indicated that participants generally perceived *OnTimelyPress* as supporting cognitive development,

psychomotor development, and learning-related skills. Participants also described the gameplay as mentally stimulating and appropriately challenging, requiring sustained concentration, rapid decision-making, and quick responses. These findings represent participants' subjective perceptions and should therefore be interpreted as self-reported experiences rather than statistically verified improvements.

Overall, the findings indicate that cognitive development was not significantly associated with psychomotor development, and demographic characteristics were not significantly associated with either of the developmental outcomes. However, cognitive development demonstrated a significant positive relationship with academic performance, and sex was the only demographic characteristic significantly associated with it. While participants perceived *OnTimelyPress* as beneficial for supporting cognitive development, psychomotor development, and learning-related skills, these perceptions were not fully supported by quantitative analyses. Therefore, the null hypothesis regarding the relationship between cognitive and psychomotor development was not rejected, indicating that there was insufficient statistical evidence to establish a significant relationship between these two variables.

Table 4: Pearson correlation between adolescents' demographic characteristics and cognitive, psychomotor development, and academic performance

Demographic	<i>M(SD)</i>	Cognitive development	Psychomotor development	Academic performance
Age	16.40(1.79)	0.188	0.039	0.270
Sex	1.40(0.50)	0.267	0.139	0.403*
Gaming frequency	2.34(1.00)	-0.50	0.101	-0.052
Gaming duration	3.11(0.80)	0.235	0.115	-0.035
Psychomotor development	4.14(0.57)	0.281	1.000	0.173
Cognitive development	3.96(0.58)	1.000	0.281	0.580**

Note. *N* = 35. Values in the table are Pearson correlation coefficients (*r*). *M* = mean; *SD* = standard deviation.

** *p* ≤ .01.

* *p* ≤ .05.

5.2. Research objective 2

Research Objective 2 aimed to investigate the relationship between gaming frequency, gaming duration, and adolescents' academic performance following engagement with the fast-paced mobile game, *OnTimelyPress*. Pearson's correlation analysis was conducted to examine the associations between gaming behaviour and academic performance, while descriptive statistics from the post-gameplay feedback questionnaire are presented in Table 5.

The correlation analysis revealed very weak negative relationships between gaming frequency and academic performance, $r(33) = -0.052$, $p = 0.767$, and between gaming duration and academic performance, $r(33) = -0.035$, $p = 0.843$. As both significance values exceeded the predetermined significance level of 0.05, neither gaming frequency nor duration was significantly associated with adolescents' academic performance. These findings indicate that the frequency and duration of engagement with *OnTimelyPress* were not significantly related to participants' perceived academic performance.

As presented in Table 5, the participants generally expressed positive perceptions of the educational value of *OnTimelyPress*. They agreed that gameplay contributed to improvements in memory retention ($M = 3.89$, $SD = 0.718$), focus retention ($M = 3.89$, $SD = 0.796$), problem-solving ability ($M = 3.77$, $SD = 0.942$), cognitive response speed ($M = 4.29$, $SD = 0.957$), hand-eye coordination ($M = 4.23$, $SD = 0.770$), and reaction time ($M = 4.00$, $SD = 0.939$) of the players. Participants also agreed that these abilities supported learning ($M = 4.20$, $SD = 0.531$), helped them remember academic lessons ($M = 3.86$, $SD = 0.944$), maintained classroom focus ($M = 3.89$, $SD = 0.900$), and assisted their studies through improved memory and focus ($M = 4.37$, $SD =$

0.877). High levels of agreement were also observed for enjoying the data collection experience ($M = 4.40$, $SD = 0.651$) and the view that academic lessons would be more enjoyable if they incorporated engaging elements similar to mobile games ($M = 4.40$, $SD = 0.695$).

Although participants perceived *OnTimelyPress* as beneficial for supporting cognitive abilities, learning engagement, and academic-related skills, these findings represent subjective self-reported perceptions rather than objective measures of academic performance. Consequently, they should not be interpreted as evidence of a statistically significant relationship between gaming behaviour and academic performance. Overall, while adolescents reported positive educational and learning-related experiences following gameplay, the correlation analysis did not provide sufficient statistical evidence to support a significant association between gaming frequency, duration, and academic performance. Therefore, the null hypothesis was not rejected in this study.

Table 5: Descriptive statistics

Areas that were tested during data collection process	Mean	Std. deviation
Improved memory retention	3.89	0.718
Improved focus retention	3.89	0.796
Improved problem solving	3.77	0.942
Improved cognitive response speed	4.29	0.957
Improved hand-eye coordination	4.23	0.770
Improved reaction time speed	4.00	0.939
Improved memory retention, focus retention, and hand-eye coordination	4.20	0.531
Remembering academic lessons	3.86	0.944
Focus on classroom lessons	3.89	0.900
Memory and focus retention assist in study	4.37	0.877
Enjoying the data collection experience	4.40	0.651
Making academic lessons more enjoyable	4.40	0.695

5.3. Research objective 3

Research Objective 3 aimed to determine whether there was a statistically significant difference in gameplay duration between the first and final gameplay rounds following repeated engagement with the fast-paced mobile game, *OnTimelyPress*. A paired-samples *t*-test was conducted to compare the participants' gameplay durations, with the descriptive statistics, paired-samples correlation, and *t*-test results presented in Table 6.

As shown in Table 6, the mean gameplay duration increased from 66.14 seconds ($SD = 18.937$) during the first gameplay round to 69.20 seconds ($SD = 23.298$) during the final gameplay round, representing an average increase of 3.057 seconds. As longer gameplay duration reflects better gameplay performance in *OnTimelyPress*, this finding suggests a modest descriptive improvement following repeated gameplay. However, the difference was not statistically significant ($t(34) = -0.867$, $p = 0.392$). Furthermore, the 95% confidence interval for the mean difference ranged from -10.221 to 4.107, which included zero, further indicating that there was no statistically significant difference between the two gameplay rounds.

The paired-samples correlation analysis demonstrated a moderate positive relationship between the first and final gameplay durations ($r = 0.529$, $p = 0.001$), indicating that participants who recorded longer gameplay durations during the first round also tended to do so during the final round. This finding suggests consistency in individual gameplay performance across repeated sessions rather than significant improvement following repeated gameplay.

Overall, the findings indicate that repeated engagement with *OnTimelyPress* did not result in a statistically significant improvement in gameplay performance among the adolescent

participants. Although the descriptive statistics suggested a modest improvement, the paired-samples *t*-test did not provide sufficient statistical evidence to demonstrate a significant difference between the two gameplay rounds. Therefore, the null hypothesis was not rejected in this study.

Table 6: Paired-samples statistics, correlation, and *t*-test comparing the first and final gameplay durations

Gameplay duration	M (SD)	Corr.	Sig.	<i>t</i> (34)	Sig.	M(SD) difference	SE	95% CI lower	95% CI upper
First gaming duration	66.14 (18.937)	0.529	0.001	-0.867	0.392	-3.057	3.525	-10.221	4.107
Final gaming duration	69.20 (23.298)								

Note. *N* = 35. *M* = mean; *SD* = standard deviation; Corr. = paired-samples correlation coefficient; Sig. = significance value (2-tailed); *SE* = Std. error mean; CI = confidence interval.

5.4. Research objective 4

Research Objective 4 aimed to explore adolescents' emotional responses, perceived benefits, and experiences associated with engaging with the fast-paced mobile game, *OnTimelyPress*. A qualitative thematic analysis was conducted on the open-ended responses collected through a post-gameplay feedback questionnaire. The responses were digitised, coded, and organised into broader themes and subthemes based on recurring patterns identified from participants' feedback. The thematic findings related to adolescents' perceived benefits are presented in Table 7, and their emotional responses and gameplay experiences are presented in Table 8.

As presented in Table 7, four major themes emerged regarding the perceived benefits of engaging with *OnTimelyPress*: Cognitive Development, Psychomotor Development, Learning and Academic Skills, and Non-specific Perceived Benefits. The most frequently identified theme was Cognitive Development, which was reflected in 29 participants' responses (83%). Participants commonly perceived that gameplay enhanced their focus retention, concentration, attention, memory retention, cognitive stimulation, and executive functioning, including decision making and multitasking. The second most frequently identified themes were Psychomotor Development and Learning and Academic Skills, each reported by eight participants (23%). Participants perceived improvements in hand-eye coordination, reaction time, and response speed, while others described benefits related to reinforced learning, remembering academic content, and maintaining focus in the classroom. A small number of responses (6%) were categorised as Non-specific Perceived Benefits because they expressed general positive outcomes without providing sufficient detail to be classified under a specific theme.

The thematic analysis presented in Table 8 identified four major themes describing adolescents' emotional responses and gameplay experiences: Positive Emotional Responses, Gameplay Challenge and Cognitive Engagement, Psychomotor Awareness, and Mixed or Non-specific Responses. The most prominent theme was Positive Emotional Responses, identified in 27 participants' responses (77%), indicating that participants generally perceived *OnTimelyPress* as enjoyable, fun, exciting, and satisfying. The second most common theme, Gameplay Challenge and Cognitive Engagement, emerged in 14 responses (40%), reflecting participants' perceptions that the game was mentally stimulating and required sustained concentration, continuous attention, awareness, and rapid decision-making throughout the gameplay. A smaller number of participants (9%) reported increased Psychomotor Awareness, describing improvements in reaction speed, response speed, and reflexes while interacting with the game. In addition, five responses (14%) were categorised as mixed or non-specific, reflecting a combination of positive and negative emotions, such as feeling challenged, stressed, calm, or disappointed following gameplay. Collectively, these findings suggest that although the participants experienced the

game differently, they generally perceived the gameplay as engaging, cognitively demanding, and enjoyable.

Table 7: Thematic analysis of the perceived benefits (N = 35).

Theme	Sub-theme	Frequency (%)	Sample responses
Cognitive Development	Focus retention, concentration, attention, memory retention, cognitive stimulation, executive functioning (decision-making and multitasking)	29 (83%)	"Help improve focus and attention. Hence can pay more attention during class." (Participant 1, 18 years old) "Enhance in focus ability. To assimilate knowledge faster and find key points easier during learning classrooms." (Participant 7, 17 years old) "Activate my brain and focus. Useful to study mathematic studies." (Participant 35, 18 years old) "Increase ability to focus and improve multitasking ability." (Participant 26, 17 years old)
Psychomotor Development	Hand-eye coordination, reaction time, response speed	8 (23%)	"Better focus and hand-eye coordination." (Participant 4, 18 years old) "Improve reaction time." (Participant 21, 14 years old) "Help me react fast and press on the clock." Participant 32, 17 years old) "Better focus and hand-eye coordination." (Participant 4, 18 years old) "Improved and tested response time." (Participant 5, 18 years old)
Learning and Academic Skills	Classroom learning, remembering lessons, reinforced learning, knowledge acquisition	8 (23%)	"Improved and tested response time. Improved reinforced learning." (Participant 5, 18 years old) "The game can help me remember and help focus study in class." (Participant 24, 17 years old) "This game can help in remembering and assist in remembering mathematic studies." (Participant 33, 15 years old)
Non-specific Perceived Benefit	General positive benefit that could not be categorised into a specific theme	2 (6%)	"Got benefit." (Participant 18, 14 years old) "Teach students how to achieve something." (Participant 31, 17 years old)

Research Objective 4 was achieved through thematic analysis of participants' open-ended responses. Overall, the findings indicate that adolescents perceived *OnTimelyPress* as a positive and engaging fast-paced mobile game that supports cognitive and psychomotor development and learning-related skills while eliciting predominantly positive emotional responses. Participants also perceived the gameplay as mentally stimulating and appropriately challenging, requiring sustained concentration, rapid decision-making, and quick responses. Although a small number of participants reported mixed or non-specific responses, the qualitative findings provide valuable insights into adolescents' perceptions and gameplay experiences, complementing the quantitative findings by offering a deeper understanding of how participants experienced and interpreted the educational potential of the game.

Table 8: Thematic analysis of adolescents' emotional responses and gameplay experiences (N = 35)

Theme	Sub-theme	Frequency (%)	Sample responses
Positive Emotional Responses	Happiness, enjoyment, fun, excitement, satisfaction	27 (77%)	"I was so happy while playing this game. It was fun and enjoyable." (Participant 13, 18 years old) "Feeling happy and enjoy playing this game." (Participant 33, 15 years old) "Excited and satisfied." (Participant 8, 18 years old)
Gameplay Challenge and Cognitive Engagement	Challenging gameplay, sustained focus, attention, awareness, mental alertness	14 (40%)	"Very challenging to maintain focus all the time. But the game still simple and engaging and make you want to do better at the next round." (Participant 9, 19 years old) "It is fun and challenging game, need to put myself into full focus mode in order to stay in this game." (Participant 10, 19 years old) "Heighten awareness. Aware of my timing." (Participant 3, 18 years old)
Psychomotor Awareness	Faster reactions, response speed, reflexes	3 (9%)	"I can react faster on the clock." (Participant 27, 17 years old) "Get react fast and touch on the clock. Very fun to play." (Participant 35, 18 years old)
Mixed or Non-specific Responses	Stress, disappointment, calmness, neutral feelings, vague responses	5 (14%)	"Disappoint because didn't achieve top score. Happy because the game is interesting to be focus on." (Participant 28, 17 years old) "Stress and enjoy." (Participant 30, 17 years old) "I very ok and I so calm." (Participant 22, 13 years old)

6. Discussion, limitations, and conclusion

This study investigated the potential role of the fast-paced mobile game *OnTimelyPress* in adolescents' cognitive development, while also examining psychomotor development, academic performance, and gaming experiences. Using a mixed-methods approach comprising Pearson correlation analysis, paired-samples *t*-test, descriptive statistics, and qualitative thematic analysis, this study examined the relationships among cognitive development, psychomotor development, gaming behaviour, academic performance, and adolescents' perceptions of gameplay.

Research Objective 1 examined the relationships among adolescents' cognitive development, psychomotor development, academic performance, and selected demographic characteristics following engagement with *OnTimelyPress*. Pearson's correlation analyses revealed no statistically significant relationship between cognitive and psychomotor development or between demographic characteristics (age, gaming frequency, and gaming duration) and either developmental outcome. However, cognitive development demonstrated a significant positive relationship with academic performance, whereas psychomotor development was not significantly associated with academic performance. In addition, sex was the only demographic characteristic that was significantly associated with academic performance. The qualitative findings further indicated that the participants perceived improvements in cognitive development, psychomotor development, and learning-related skills following gameplay. These findings are consistent with the cognitivism and experiential learning theories, which suggest that active engagement in cognitively demanding activities can support learning and skill development. However, quantitative analyses have provided only limited statistical evidence to support these perceived benefits.

Research Objective 2 examined the relationship between gaming frequency, gaming duration, and adolescent academic performance. Pearson's correlation analysis found no statistically significant relationship between gaming behaviour and academic performance. However, the qualitative findings indicated that participants perceived fast-paced mobile games as beneficial for supporting cognitive development, learning-related skills, motivation and engagement. These findings are consistent with game-based learning and flow theories, although the quantitative analyses did not provide sufficient statistical evidence to support the perceived educational benefits.

Research Objective 3 examined whether there was a statistically significant difference in the duration of gameplay between the first and final gameplay rounds following repeated engagement with *OnTimelyPress*. The paired-samples *t*-test showed that participants remained in the game slightly longer during the final gameplay round ($M = 69.20$ seconds) than in the first gameplay round ($M = 66.14$ seconds). As a longer gameplay duration represents better gameplay performance in *OnTimelyPress*, this finding suggests a modest descriptive improvement following repeated gameplay. However, this difference was not statistically significant. The paired-samples correlation analysis also demonstrated a moderate positive relationship between the first and final gameplay durations, indicating consistent individual performance across the gameplay sessions. These findings are consistent with Behaviourism Theory, Experiential Learning Theory, and the Zone of Proximal Development, which suggest that repeated practice and appropriately challenging activities may facilitate gradual skill acquisition. However, the observed improvement was insufficient to demonstrate a statistically significant gain in gameplay performance.

Research Objective 4 examined adolescents' emotional responses, perceived benefits, and experiences associated with engaging with *OnTimelyPress*. The qualitative thematic analysis identified four themes related to perceived benefits and four themes describing the participants' emotional responses and gameplay experiences. Overall, participants perceived *OnTimelyPress* as an enjoyable and engaging game that supported cognitive development, psychomotor development, and learning-related skills, with perceived improvements in hand-eye coordination, reaction time, response speed, reinforced learning, remembering academic content, and maintaining focus in the classroom. They also described the gameplay as mentally stimulating and appropriately challenging, requiring sustained concentration, rapid decision making, and quick responses. These findings are consistent with Flow Theory and Game-Based Learning Theory, suggesting that enjoyable and appropriately challenging gameplay enhances learner engagement and supports meaningful learning experiences. The qualitative findings complemented the quantitative results by providing deeper insights into adolescents' gameplay experiences and perceptions.

Overall, the findings indicate that adolescents perceive fast-paced mobile games as beneficial for supporting cognitive development, psychomotor development, motivation, and learning interest. However, the quantitative analyses did not identify statistically significant relationships between the study variables or significant improvements in cognitive, psychomotor, or academic performance or gameplay performance following repeated gameplay. These findings suggest that although adolescents perceived educational and gameplay-related benefits, these subjective experiences were not reflected in statistically significant quantitative outcomes within the scope of this exploratory study. Nevertheless, the qualitative findings suggest that fast-paced mobile games have the potential to provide enjoyable and engaging learning experiences that may promote adolescents' motivation, sustained attention, and active participation in learning.

Therefore, these findings should be interpreted within the proposed theoretical framework. Collectively, the selected educational and psychological theories provide complementary perspectives for understanding adolescents' cognitive development, psychomotor development,

academic performance, gameplay performance, and gameplay experiences. While individual research objectives were interpreted using the theories most closely aligned with the respective findings, the broader theoretical framework provides a multidimensional perspective on how fast-paced mobile games may influence adolescents' learning, development, and gameplay experiences.

6.1 Limitations

Several limitations should be considered when interpreting the findings of this study: First, the study involved a relatively small sample of 35 adolescents from a government secondary school and a private university college in Malaysia. Although convenience sampling with voluntary participation was employed, the sample may not fully represent a broader adolescent population. Recruitment was constrained by the researcher's lack of formal institutional affiliation, which limited access to additional educational institutions, particularly government secondary schools, where institutional approval procedures and security measures restricted external researchers. In addition, the predominantly male sample may have limited the representation of female adolescents' perceptions and experiences with fast-paced mobile games. Consequently, the findings should be interpreted with caution and may not be generalisable to adolescents from different educational settings, geographical regions, socioeconomic backgrounds, or sex distributions. Future research should recruit larger and more diverse samples from multiple educational institutions and examine sex differences in gaming behaviour and their influence on cognitive, psychomotor, and educational outcomes.

Second, the measurement approach of this study has several limitations. Cognitive and psychomotor development were assessed primarily through self-reported questionnaire responses, gameplay completion time, and qualitative feedback rather than through standardised cognitive or neuropsychological assessment instruments. Although these measures provide valuable insights into adolescents' perceptions and gaming experiences, self-reported responses may be influenced by response, recall, or social desirability bias. Furthermore, gameplay completion time alone may not fully capture complex cognitive abilities, such as executive functioning, sustained attention, working memory, or higher-order problem-solving. Future research should incorporate validated cognitive assessment instruments and objective psychomotor measures to provide more robust evidence of the developmental effects of fast-paced mobile games.

Third, this study evaluated only one custom-developed fast-paced mobile game (*OnTimelyPress*) that was specifically designed for the data collection. Although this approach ensured a standardised gaming experience for all participants, the findings may not be generalisable to other fast-paced mobile games with different gameplay mechanics, difficulty levels, reward systems, or cognitive demands. Future research should examine a wider range of commercial and educational mobile games to determine whether similar cognitive and psychomotor outcomes are observed across various game genres and gameplay environments.

Fourth, the study evaluated participants immediately after gameplay; therefore, it only reflects short-term cognitive, psychomotor, and gameplay-related responses. Consequently, the findings do not indicate whether the observed outcomes or perceived benefits are sustained after prolonged engagement with fast-paced mobile games. Future longitudinal or experimental studies involving repeated gameplay sessions over extended periods are recommended to examine the long-term effects of fast-paced mobile gaming on adolescents' cognitive, psychomotor, and academic development.

6.2 Conclusion

In conclusion, this study contributes to the growing body of literature on digital game-based learning by providing empirical evidence of adolescents' cognitive development, psychomotor development, gaming experiences, and perceptions of fast-paced mobile games through a mixed-methods approach. Although the quantitative analyses did not identify statistically significant relationships among the measured variables, the qualitative findings suggest that fast-paced mobile games may promote cognitive engagement, motivation, problem-solving, focus retention, memory retention, and enjoyable learning experiences. These findings contribute valuable preliminary evidence for understanding the educational potential of fast-paced mobile games and provide a foundation for future research employing larger samples, validated cognitive assessment instruments, and longitudinal study designs to further examine their role in supporting adolescents' cognitive, psychomotor, and academic development.

Acknowledgement: This article is based on postgraduate research conducted at a higher education institution. The authors gratefully acknowledge the relevant educational authorities and participating institutions for granting permission and facilitating this study. We also appreciate the academic and administrative personnel who supported the coordination and data collection process. Finally, the authors sincerely thank all the students who voluntarily participated in the study and contributed their time and valuable responses.

Funding statement: This research received no specific grants from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical approval: Ethical approval for this study was obtained from the relevant institutional research ethics committee prior to the commencement of data collection. Permission to conduct the study at the participating government secondary school was granted by the Negeri Sembilan State Education Department (Reference No. JPNS.SPPPPD.100-2/5/4 Jld.16 (23)). This study was conducted in accordance with the established ethical principles for research involving human participants. Participation was voluntary, and informed consent was obtained from all participants before their involvement in the study. Participants were informed of the purpose of the research, their right to withdraw at any stage without penalty, and the measures taken to protect their privacy and confidentiality. No personally identifiable information was collected, and all data were handled confidentially and used only for research purposes.

Data access: research data supporting this publication are available upon request from the corresponding author.

Conflict of interest: The authors declare that they have no affiliations with or involvement in any organisation or entity with any financial interest in the subject matter or materials discussed in this manuscript Acknowledgements

Authors' contribution: Gabriel Vishnu Dharan Uthira Kumaran is the main author who designed the research and developed the Android game used to test the cognitive load and capabilities of adolescents. He was responsible for the data collection, analysis, and overall preparation of the manuscript. Assoc. Prof. Dr. Ng Kok Why served as the corresponding author, provided guidance on structuring and drafting the article, advised on the effective interpretation and presentation of the findings, and ensured that the manuscript met the publication standards of Multimedia University (MMU). He also reviewed and proofread the manuscript prior to submission. Dr. Amutha Navamoney advised on the research methodology and framework. She also guided the main author in obtaining the necessary ethical approvals and permissions from the relevant government bodies, including the Negeri Sembilan State Education Department.

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Appendix 1

Sample feedback questionnaire

Section A	Year	Open ended question
	Sex	Male; Female
	Have you ever played any mobile games before?	Yes; No
	If you played any mobile games, how many times do you play this type of mobile games?	Daily 3 to 4 days a week 1 to 2 days a week Very rarely played
	If you played any mobile games, normally how long do you play this type of mobile games in a day?	Never played these types of games. Less than 30 minutes Between 30 minutes to 1 hour More than 2 hours
Section B	Are you able to focus on the clocks and minutes numbers better after playing few rounds of this game?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Are you able to remember the clock minute numbers better after playing few rounds of this game?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Are you able to solve the clock pressing speed better after playing few rounds of this game?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Do you believe playing this type of mobile game will have positive impact on your thinking fast and response abilities?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Does your hand and eye movements become better after playing few rounds of this game?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Does your reaction time become faster after playing few rounds of this game?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Does fully able to focus, remembering the minutes numbers, hand-eye coordination, and response faster by quickly pressing all the clocks on time during playing the game can help you stay on the game longer?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Do you think playing these types of mobile games can help you improve your remembering academic lessons properly?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Do you think playing these types of mobile games can help you improve your ability to focus on class?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Does having good remembering and focus ability will help you in your study performance?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Do you enjoy the overall of this exercise?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
	Do you want your lessons to be as enjoyable as this so that you can focus and learn in studies better?	1= Strongly Disagree; 2= Disagree; 3= Neutral; 4= Agree; 5= Strongly Agree
Section C	How long took for you to complete the first round of the game? (State how many minutes and seconds)	Open ended response
	How long took for you to complete the last round of the game? (State how many minutes and seconds)	Open ended response
	In your own words, describe the potential benefits of engaging in these types of games. Please provide a minimum of two points.	Open ended response
	Share your feelings or responses after playing this game? Please provide a minimum of two points.	Open ended response