Cambridge Educational Research e-Journal

ISSN: 2634-9876 Journal homepage: http://cerj.educ.cam.ac.uk/

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To cite this article:

Cai, Y., Tsapali, M., Zewelanji, S., Parr, T., & Ellefson, M. R. (2021). Age-related changes in sustained attention for older children from high poverty communities in the USA. *Cambridge Educational Research e-Journal*, 8, 36-51. https://doi.org/10.17863/CAM.76200

Link to the article online:

Published online: 31 October 2021

Link to Apollo

Cambridge Educational Research e-Journal | Vol. 8 | 2021

DOI: https://doi.org/10.17863/CAM.76200

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Highlights

- Children's accuracy, reaction time to correct responses, and efficiency scores significantly improved across the academic year.
- There may be an ongoing development of sustained attention throughout childhood in ethnic minority children from high poverty areas.
- There should be a greater focus on ethnic minority children from high poverty areas in the field of child psychology.

精彩提要*

- 在整个学年内，儿童在持续性注意测试上的准确度、正确得分的反应时间和效率得分有显着提高。
- 来自高度贫困地区的少数族裔儿童的持续性注意力在整个童年时期可能会不断发展。
- 在儿童心理学领域，研究者应当更多关注来自高贫困地区的少数族裔儿童。

*Chinese Translation | Yufei Cai

Cambridge Educational Research e-Journal | Vol. 8 | 2021

DOI: https://doi.org/10.17863/CAM.76200

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Keywords

sustained attention, continuous performance task, high poverty communities, repeated-measures design

Abstract

Sustained attention influences academic achievement because maintaining focus on a task for an extended period supports the acquisition of new skills. Investigating the development of sustained attention has been an important topic in educational and psychological research. This study includes secondary data analysis of data collected as part of a larger project that provided opportunities for children to learn chess after school. This study analysed data related to sustained attention, which was measured by the Continuous Performance Task across one academic year in a predominantly African American sample. This sample consists of 149 participants ($n_{females}$ 66, M_{age} = 9.57 years, SD = 0.89 years) attending schools in high poverty communities in the USA. To the best of our knowledge, this study was the first to examine changes in sustained attention in ethnic minority students from high poverty areas using a longitudinal design. A repeated-measures ANOVA model was used for the statistical analysis. The results indicate that participants' performance on the sustained attention task improved significantly from the beginning to the end of the school year. Although past studies have examined changes in sustained attention in children using this same task, no studies have used a repeated-measures design in ethnic minority samples. These findings demonstrate the possibility that sustained attention improves continuously in children, despite the difficulties associated with growing up in high poverty environments.

关键词

持续性注意力，
持续性注意测试，
高贫困社区，
重复测量设计

Chinese Translation

Yufei Cai

摘要

研究表明，持续性注意力会影响儿童的学业成绩，因为长时间专注于一项任务有助于习得新技能。持续性注意力发展一直是教育和心理学领域的重要课题。本篇论文数据源自一项更大的研究项目，参与者大多是在美国高贫困社区就读的非裔美国人。此项目为儿童课后学习国际象棋提供了机会，并研究国际象棋是否能提高儿童的执行功能。我们抽取了在美国高贫困社区就读的149名儿童（人数 = 66 名女性，平均年龄 = 9.57 岁，标准差 = 0.89 岁），并分析该群体在为期一学年的持续性注意力的表现。据我们所知，我们是首个使用纵向设计来研究来自高贫困地区的少数族裔学生的持续注意力的变化的研究团体。该研究使用重复测量方差分析法来进行统计分析。结果表明，从学年开始到结束，参与者在持续性注意测试上的表现都有显着提高。尽管之前的研究使用了相同的测量方法来检测儿童持续注意力的变化，但这些研究并没有在少数族裔的样本中使用重复测量设计。我们的研究表明，尽管在高度贫困的环境中长大有许多困难，但少数族裔儿童依然有可能不断提高他们的持续注意力。

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DOI: https://doi.org/10.17863/CAM.76200

Introduction

Attention refers to a group of physiological and behavioural responses that are influenced by environmental stimuli and can be consciously manipulated by the individual (Rueda et al., 2005). Specifically, sustained attention refers to the ability to pay attention for a specific period of time and process a large amount of information (Catroppa & Anderson, 1999). Sustained attention plays an important role in determining a child's school performance because it can impact whether a child can hold something in mind for an extended period and avoid distractions (Derryberry & Rothbart, 1997). As a result, difficulties in sustaining attention have been shown to negatively influence a child's capacity to acquire and process new information (Brueggemann & Gable, 2018), which may hinder their school performance.

Theoretical underpinnings

To better understand sustained attention in children, this section discusses the underlying theoretical underpinnings of sustained attention.

The resource-control theory can be used to explain sustained attention (Thomson et al., 2015). The resource-control theory suggests that the total amount of attentional resources that an individual can use to carry out cognitive activities are fixed. "Self-generated thought is the default state of the individual, such that there is a continuous bias for attentional resources to be absorbed by mind wandering" (Thomson et al., 2015, p.89). This theory suggests that there is a consistent preference for attentional resources to be allocated towards mind wandering. Brain regions that have been shown to be responsible for sustained attention are frontal-parietal and dorsal attention networks (Esterman & Rothlein, 2019). To avoid mind wandering, people need to exert executive control to direct their limited attentional resources to focus on essential tasks otherwise, these resources will be consumed by thoughts that are unrelated to the task. However, given that attentional resources are limited, a person's sustained attention performance fluctuates throughout the day as he or she uses their resources to complete different tasks (Harwood, 2019). The resource-control theory suggests that individuals who have a more substantial capacity to exert executive control over their task are more likely to maintain focus for a more extended period and prevent attentional resources from being occupied by other irrelevant thoughts than those who do not have such capacity (Fortenbaugh et al., 2017).

Another theory that can be used to explain the performance of sustained attention task is the resource-depletion theory (Warm et al., 2018). The resource-depletion theory suggests that humans have a limited capacity for information-processing. For example, the sustained attention task is laborious and time-consuming. A decrease in response on a sustained attention task occurs if the person's attentional resource is depleted by the task over time, which indicates the failure of sustained attention. Compared with resource-control theory, resource-depletion theory does not draw a coherent conclusion about the relationship among sustained attention, executive control, and mind wandering (Esterman & Rothlein, 2019). Therefore, the resource control theory is often thought to be the most comprehensive theory, explaining the relationship among sustained attention, mind wandering, and executive control (Esterman & Rothlein, 2019).

On the other hand, one of the limitations of the resource-control theory is that it has not been directly tested. Thus, it is not backed up by empirical evidence. Also, previous studies indicate that there is individual variation in exercising executive control during a sustained attention task (McVay & Kane, 2012). A better understanding of sustained attention might be gained by testing this theory with empirical methods. In the following section, the relationship between academic performance and sustained attention is discussed.

Academic performance and sustained attention

Previous findings indicate that sustained attention plays an important role in academic achievement (Rabiner et al., 2016; Rhoades et al., 2011; Steinmayr et al., 2010). For example, Steinmayr et al. (2010) investigated whether sustained attention and intelligence predict academic achievement in 11th and 12th grade students (N = 231). Their findings suggested that sustained attention moderated the relationship between verbal intelligence and academic achievement. Children with below-average sustained attention ability were more likely to have lower school performance than those with stronger sustained attention ability. In addition, literacy and numeracy skills seem to be correlated with sustained attention. A longitudinal study by Rabiner et al. (2016) investigated the relationship between sustained attention and academic achievement (i.e., reading ability and mathematics skills) in students who were at risk of developing conduct problems (N = 386) by following the students from elementary school to the end of high school. Their findings indicated that students with higher sustained attention scores scored higher on a literacy test compared to students with lower sustained attention scores. Specifically, early sustained attention difficulties seemed to predict lower academic performance in fifth grade. Subsequently, children who showed difficulty in paying attention during middle school also had lower grades, possibly leading to higher dropout rates and lower high school completion rates. Children with difficulties in sustained attention

DOI: https://doi.org/10.17863/CAM.76200

tend exhibit a wide range of problems during school. For example, they take long to complete academic tasks, require substantial teacher supervision, or have issues following instructions (Peck et al., 2005). These problems tend to lead to lower literacy and numeracy achievement (Rabiner et al., 2016). Furthermore, Rabiner et al. (2016) found that students with sustained attention difficulties were also more likely to be rejected by peers and had higher rates of school dropouts. These research studies suggest that sustained attention is correlated with academic achievement and school functioning. Thus, it is crucial to study children's sustained attention skills to better support children's academic achievement and school performance.

However, the above mentioned studies are limited in their generalizability. For example, Steinmayr et al. (2010) included only German students attending a preparatory course for university study. German students who were selected in this study already had higher academic achievement than those who did not attend the preparatory course. Therefore, Steinmayr et al. (2010)'s results might not be generalisable to ethnic minority children from high poverty areas. Moreover, although Rabiner et al. (2016) included a sample of 42.5% of African American students from high poverty neighbourhoods, these students were prone to developing conduct problems, which might negatively influence their classroom participation and subsequently their academic achievement (Clark et al., 2002). Rabiner et al. (2016) concluded that children who had difficulty with sustained attention showed lower scores on literacy and numeracy achievement, but this may be explained by their conduct problems instead of difficulty in sustained attention. As a result, future studies should include children from various socioeconomic backgrounds, including high poverty communities, to better understand the extent to which findings are generalisable to ethnic minority children from high poverty areas. The following section discusses the developmental trajectory of sustained attention in children.

The development of sustained attention

Previous studies indicate that there is an ongoing developmental trajectory of sustained attention in children. For example, Rebok et al. (1997) used the Continuous Performance Test, a measure for sustained attention, in a longitudinal study of children aged 8, 10, and 13 years from urban areas (N = 435; 63.7% were African American, and 35.3% were white). Their results showed significant age differences across all task metrics. More specifically, between 8 and 10 years and between 10 and 13 years, accuracy and efficiency increased significantly. Omission errors decreased between 8 and 10 years, with a sharper decrease between 10 and 13 years. Similarly, Klenberg et al. (2001)'s longitudinal study also used the Continuous Performance Task to measure the development of sustained attention in Finnish children aged 8 to 16 years (N = 153). Here, sustained attention skills continued to improve from 5- to 9-years-old into adolescence, but only minor improvements were observed in children after 10-years-old. A recent longitudinal study by Lewis et al. (2017) with Australian children found a continuous developmental trajectory of sustained attention skills between 6 and 11 years, but a small developmental plateau between 8 and 9 years. However, it should be noted that these studies' samples were limited in their generalisability because they did not include ethnic minority children or children from high poverty areas.

In summary, existing studies suggest that sustained attention improves throughout childhood and into adolescence with different rates of change at different ages (Klenberg et al., 2001; Lewis et al., 2017; Rebok et al., 1997); poverty seems to play a role in the course of this development (Brody et al., 2004; Dilworth-Bart et al., 2007; Groot et al., 2004; Hackman et al., 2015; Ruff & Rothbart, 2001). However, the generalizability of these longitudinal studies is limited by the characteristics of their samples and therefore cannot be considered representative of ethnic minority populations. Thus, the developmental trajectory of sustained attention in African American children who live in high poverty areas remains unclear. A brief overview of environmental factors that may shape children's development of sustained attention is presented in the following section.

Factors that influence the development of sustained attention

Many factors might influence the development of sustained attention in children, including chess training and socioeconomic status. Playing chess is a cognitively challenging activity that involves the utilisation of different executive function skills, such as sustained attention, inhibition, cognitive flexibility, and working memory (Aciego et al., 2012; Bart, 2014; Berkman, 2004; Elkies & Stanely, 2003; Kazemi et al., 2012; Sala & Gobet, 2017). There is some evidence that children completing chess training have better performance in literacy and numeracy than controls (Boruch, 2011; Hong & Bart, 2007). Specific evidence of how chess training could improve executive functions and mathematic achievement has been shown in a study by Khosrorad et al. (2014). Children with mathematic disorders (N = 20) from Tehran were randomly assigned to a control or experimental group. Children in the experimental group received chess training for a year. Results suggested that children who received the chess training had significant improvement on their tests of executive function, including inhibition,

DOI: https://doi.org/10.17863/CAM.76200

sustained attention, and planning. Specifically, omission error, commission error, and reaction time improved significantly on the Continuous Performance Task for those who received chess training compared to those who did not. One critical limitation of this study was the diagnostic status of the participants, which limited the generalizability of the result. This study's result was also unrepresentative of typically developing children in developed countries.

Another factor that might influence the development of sustained attention is socioeconomic status. Socioeconomic status is often measured by household income, the qualification of free lunch, parental educational attainment, or parental occupational prestige (Adler et al., 1994; Duncan et al., 2002; Pollack et al., 2007). There seems to be a link between the socioeconomic status of a child's family and sustained attention skills (Dilworth-Bart et al., 2007; Groot et al., 2004; Hackman et al., 2015). Research investigating the relationship between sustained attention and socioeconomic status is predominantly quantitative. For example, in a meta-analysis, Lawson et al. (2018) found a small to medium effect size ($r = 0.22$, 99% CI [0.17, 0.27]), suggesting that there was a significant but weak relationship between socioeconomic status and executive function. In addition, a lack of educational resources, a chaotic neighbourhood, high rates of violence, and parents' struggles to provide a healthy home environment in high poverty areas also seem to have a negative impact on children's development of sustained attention (Belsky et al., 2007, Brody et al., 2004; Lynam et al., 2000; McLoyd, 1998; Miech et al., 2001; Razza et al., 2010). On the other hand, contradictory evidence has been found in a cross-sectional study by Burneo-Garcés et al. (2019), which investigated the development of executive function in children at 7, 9, and 11 years of age ($N = 274$) from a medium or low socioeconomic neighbourhood in Ecuador. Sustained attention was measured by the Continuous Performance Task. Results showed that children aged 7 and 9 years had slower reaction times (measured in milliseconds) on the sustained attention task than children aged 11, regardless of socioeconomic status disparity. The results by Burneo-Garcés et al. (2019) demonstrated that low socioeconomic status might not compromise the development of sustained attention in children, and such improvement could occur with age. One limitation of this study was that it only included children from Ecuador, so it could not be generalized to children from other countries. In addition, the measure of socioeconomic status was based on several factors, such as school funding, income, health-care accessibility, and employment. It should be acknowledged that Ecuador's living standards are different from those of developed countries, so more research is needed to determine whether low socioeconomic status can hinder the development of sustained attention in children.

In summary of the above findings, more research should be geared toward examining the developmental trajectory of sustained attention in children from high poverty neighbourhoods in developed countries. As indicated above, a gap exists in the literature when it comes to studying sustained attention skills in ethnic minority children from high poverty areas. The following section will summarise the limited research that exists for this population.

Sustained attention in ethnic minorities

Ethnic minorities in the United States are more likely to grow up in poverty (Barbarin & Soler, 1993). A report by Cheasty et al. (2014) showed that children from ethnic minority backgrounds constituted 49.8% of all children in 2019. Fourteen percent of children grew up in poverty, and nearly 71% of these were ethnic minorities. Thus, it is essential to study sustained attention in children from ethnic minority backgrounds to have a comprehensive picture of cognitive development. Yet, most studies in sustained attention examine children who are of white background (Ahmed et al., 2019). The longitudinal study by Ahmed et al. (2019) examined the relationship between executive function and academic achievement in children aged 4.5- to 15-years-old ($N = 1273$). Results suggested that early measures of sustained attention in children did not correlate with later achievement in adolescence, demonstrating that sustained attention could not be used to predict academic achievement at age 15 years. However, a critical limitation of this study was the ethnicity of participants – 80% of participants were white, and only 13% were African American. Most importantly, African American children from high poverty families were more likely to have missing data at the age of 15 years than other children in this study. Therefore, Ahmed et al. (2019)'s longitudinal finding of sustained attention and academic achievement could not be generalised to African American children.

Another longitudinal study by Samuels et al. (2016), which investigated the relationship between executive function and academic achievement in children aged between 12- to 15- years old ($N = 322$), concluded that executive function at the age of 12 years was a significant predictor of academic achievement at 15 years old. This result contradicted the finding of Ahmed et al. (2019)'s study. Such contradictory research findings might be due to the difference in sample characteristics. The sample in Samuels et al. (2016)'s study consisted of 42% African Americans, 32% Hispanic, 8% Asian American, and 17% European American from an urban school. Even though this longitudinal study showed that executive function was a significant predictor of academic achievement in African American children, the sample

DOI: https://doi.org/10.17863/CAM.76200

was unrepresentative of children who were African American from high poverty neighbourhoods. In light of these contradictory, limited, and unrepresentative findings, more attention should be given to African American children from high poverty neighbourhoods.

Given that most children from ethnic minorities are growing up in poverty (Anderson et al., 2021), and receiving less attention in the field of child psychology, further research that investigates the cognitive development of children from high poverty communities is warranted. Specifically, income can limit parents' choices regarding housing, day care, education, and neighbourhood, influencing their children's living environments. A longitudinal study by Willoughby et al. (2017) investigated the association between executive function and academic achievement in African American children aged 3 to 5 years (N = 1292) from high poverty neighbourhoods. Results showed that participants from high poverty areas had delayed executive function development. Compared with children of white ethnic background, African American children from high poverty communities were at greater risk of being exposed to environmental stress and received fewer educational resources, which subsequently led to worse academic achievement in kindergarten than their peers (Raver et al., 2013). Therefore, it is critical to investigate children's cognitive development in high poverty communities to understand the generalizability of previous findings and clarify the developmental trajectory of sustained attention in ethnic minority children.

After discussing the importance of understanding sustained attention in ethnic minority children from low socioeconomic status neighbourhoods, the following section focuses on the strengths and weaknesses of methods that can be used to measure sustained attention in children.

Measures for sustained attention

Multiple tasks can be used to measure sustained attention in children. One example is the Continuous Performance Task (CPT). The task was initially designed to measure sustained attention deficits in adults after a traumatic brain injury (Rosvold et al., 1956) and was administrated under a highly controlled setting to increase internal validity and decrease bias. Later, the task was modified for use with children (e.g., Servera & Cardo, 2006) and adapted to measure sustained attention in many different populations. Generally, the protocol consists of 300 trials, with each trial presented for 250 msec (milliseconds), during which participants press a button each time they see a target stimulus (or stimuli) appear. The key metrics are the amount of time taken to press the key (response time), accuracy (correct responses and omissions), and errors (incorrect responses and omissions).

Another task that could be used to measure sustained attention is a behaviour rating scale. Behaviour rating scales are frequently used to assess targeted behaviours in children, and it allows professionals to make a general statement about a child's behaviour (Chafouleas et al., 2007). The Test of Everyday Attention for Children (Manly et al., 2016) and the Behaviour Rating Inventory of Executive Function (Gioia et al., 2000) are two examples of behaviour rating scales that can be used to measure children's sustained attention. According to Wolraich et al. (2003), behaviour rating scales could be used to collect information, compare outcomes during and after the intervention, and allow cross-comparison in different research studies (Wåhlstedt et al., 2008). Researchers use the behaviour rating scale frequently because it is low-cost, easy to implement, and convenient compared with the Continuous Performance Task. However, the behaviour rating scale could be subject to bias because it is a retrospective measure (McConaughy & Ritter, 2008). As a result, the Continuous Performance Task is often used in longitudinal studies (Klenberg et al., 2001; Rebok et al., 1997) and was employed for the present study.

The present study

The current study is an analysis of data that were collected as part of a larger project that provided opportunities for children to learn chess after school (Ellefson et al., 2020, https://osf.io/yac8e/). It should be noted that the original project explored whether chess-related activities would influence children's executive functions, behavioural outcomes, and academic achievement over two years. Hence, chess training might have an influence on children's sustained attention. As outlined above, there is some evidence that chess training influences the development of executive function in children because it involves the utilisation of complex cognitive skills, such as higher-order thinking, concentration, sustained attention, visualisation, and planning (Berkman, 2004; Elkies & Stanely, 2003). To fill the gap in existing literature, the current study is a data analysis project that examines the changes in performance on a sustained attention task over the course of one academic year for ethnic minority students attending elementary schools in high poverty communities. The current study addresses the first three data points of the original project, which were collected at the beginning, middle, and end of the first academic year. Previous studies suggested that children's performance on the sustained attention task increased with age, especially from 8- to 10-years-old (Lewis et al., 2017; Klenberg et al., 2001; Rebok et al., 1997). The present study included students in grades 3 and 4 aged between 8 and 11 years at the beginning of

DOI: https://doi.org/10.17863/CAM.76200

the original project. Participants undertook after-school chess lessons for one academic year. We hypothesise that sustained attention scores improve over the academic year in ethnic minority students from high poverty areas.

Method

Participants in the current study

The sample size in the original project was 462 children, but the current study used a subset of the data from 149 children who completed the sustained attention task from the beginning to the end of the academic year. Participants were recruited from ten schools located in high-poverty, urban areas of the east coast of the USA. In the current study, 149 participants ($n_{females}$ = 66, M_{age} = 9.57 years, SD = 0.89 years) completed the sustained attention task during all three data collection points. Majority of the participants identified as African American (or mixed with African American parents). Specifically, this sample consisted of 127 African Americans (85.2%), 12 Latinos (8.1%), 1 Asian (0.7%), 1 mixed African American and Latino, 2 Pacific Islanders (0.7%), 4 mixed African American and white (0.7%), and 2 (1.3%) white students. There were 66 females (43.1%) and 87 males (56.9%) within the sample. In the original study, socioeconomic status was assessed based on whether children qualified for free or reduced school meals or not. The qualification of free lunch has been shown to be a valid measure of socioeconomic status in children from poverty areas (Nicholson et al., 2014). Reduced-price lunches were available to children when their household income were at or below 130 to 185 percent of the Federal Poverty Line (USDA Economic Research Service - National School Lunch Program, 2021). The Federal Poverty Line is an economic measure used by the United States government to calculate the lowest level of income that a person needs for a living wage in the United States (U.S. Federal Poverty Guidelines Used to Determine Financial Eligibility for Certain Federal Programs, 2017). Also, the National Centre for Education Statistics report in 2017 stated that more than 75 percent of school students qualified for free or reduced lunch in high-poverty schools. In the original study, over 90 percent of participants qualified for free or reduced school meals.

Measures: the continuous performance task

The Continuous Performance Task was used to measure the children's sustained attention (based on Servera & Cardo, 2006) at three time points at the beginning, middle, and end of the academic year. To be more engaging, it was called the "Number Challenge." Briefly, participants saw various numbers ranging from 1 to 9 presented in the centre of a computer screen. Participants were instructed to press the space bar each time they saw any number that was not a 4. When they saw the number 4, they were asked not to press and wait until the next number appeared. The task included a total of 300 number presentations. Each number appeared on the screen for 250 msec. The gap between numbers was 500 msec. The number 4 was twice as likely to appear on the screen than any other individual number (20% for 4, 10% for each of the other eight numbers). Numbers were continuously presented regardless of whether participants made responses or not. The overall screen background was black, with the numbers appearing in white font. The task took just over 4 minutes to complete. To perform well on this task, participants needed to have good sustained attention skills because it required them to remain focused on each number and resist the action of pressing the spacebar when they saw the number 4. Three metrics were collected from this task: (1) Accuracy – the total number of correct responses and omissions, (2) Reaction Time to Correct Responses (RTc) – the average response time for accurate responses only in milliseconds, (3) Efficiency – a metric of how quickly participants can be accurate, computed as Efficiency = Mean Accuracy / Mean RTc.

This task has a good internal consistency (Cronbach's alphas ranging from .64 to .96) and a test-retest reliability coefficient of 0.79 (Shaked et al., 2020). Cicchetti (1994) stated that a reliable assessment should have a test-retest coefficient between 0.70 and 0.79. Various studies suggest that the Continuous Performance Task has at least an adequate reliability (interclass correlations: rs = .57–.84; Chen et al., 2009; Soreni et al., 2009; Weafer et al., 2013; Zabel et al., 2009). Also, Conners (2004) suggested it is a gold standard measure for sustained attention. This task was chosen for this study because it was administered in a highly controlled setting, where stimuli were controlled so that each participant experienced and completed the task in the same way as others to ensure high internal validity.

Procedures in the original project

Before the start of the academic year, parents and students were invited to participate in the overall project through flyers, teacher announcements, and advertisements. The chess session was an afterschool program, and it ran for one academic year, with additional data collected after the academic year ended. Before the start of each session, children were given a healthy snack. A snack was given to children to prevent fatigue and hunger because the session was held after school. All participants signed an informed consent form, which ensured their volunteer participation and confidentiality. Participants completed their assessment battery, which consisted of the sustained attention

DOI: https://doi.org/10.17863/CAM.76200

task along with different executive function tasks in a computer lab or the library of participants' schools. Data were collected in September (i.e., before receiving chess intervention), January (i.e., in the middle of receiving the chess intervention), and June (i.e., at the end of the intervention). Participants logged in to a secure internet site using a participant number to complete executive function tasks via a secure server run by the University of Cambridge. The executive function tasks were administered online because it was low cost and it protected participants' privacy. For this sample, the sustained attention task is correlated with the other executive function tasks included in the test battery (Patel et al., 2021). Detailed information about the procedure can be found in (Ellefson et al., 2020, https://osf.io/yac8e/).

Procedures in the current project

The first author undertook the data analysis reported here as part of her master's dissertation. Before accessing the data, the first author signed a confidential agreement and completed a data request form to ensure the project adhered to all ethical and professional guidelines. The first author only requested the data related to sustained attention so as to examine the growth of sustained attention over the academic year as outlined in the data analysis plan and preregistration, which is available on The Open Science Framework (Cai et al., 2021, http://osf.io/rge67). The Open Science Framework (OSF; Foster & Deardorff, 2017) promotes openness and transparency in research. It is a valuable platform for sharing and discussing findings with other researchers in the field of education. This manuscript reflected the analyses outlined in the preregistration as part of the first author's master's degree and the data that she had access to.

Data processing and analysis

Changes in sustained attention across the three data collection points were compared using a repeated-measures ANOVA in SPSS. Outliers were detected using boxplots, and subsequent values were winsorised to reduce their possible effects (Field, 2018). Missing cases were handled using mean substitution (McKnight et al., 2007). Preliminary analyses were conducted to check if the data met the assumptions for ANOVA. The assumption of normality was tested using the Kolmogorov-Smirnov test (Massey Jr, 1951), and it showed that the null hypothesis was rejected ($D(149) = 0.14$, $p < .001$). However, according to Field (2018), the sample size in this study was considered to be sufficiently large to proceed with the parametric test.

Results

A repeated-measures ANOVA was conducted. Mauchly's test indicated that the assumption of sphericity had been violated, $\chi 2\ (5) = 2121.620$, $p < .001$, and degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.36$). The results indicated that participants' accuracy, reaction time to correct responses, and efficiency scores were significantly improved across the academic year (Table 1). More

Table 1 Summary of the overall performance on the key continuous performance task metrics collected at the beginning, middle and end of the academic year

Metric	Time in the academic year	Mean	SE	95% confidence interval lower bound	95% confidence interval upper bound
Accuracy	Beginning	189.87	5.85	178.31	201.43
	Middle	199.88	4.88	190.24	209.52
	End	211.57	3.66	204.35	218.77
RTc	Beginning	388.04	10.20	367.90	408.20
	Middle	369.14	8.10	353.13	385.15
	End	357.19	7.27	342.83	371.55
Efficiency	Beginning	551.84	21.75	508.86	594.81
	Middle	583.58	19.05	545.94	621.23
	End	632.52	16.30	600.32	664.73

Notes – RTc is the reaction time to correct responses in msec.

DOI: https://doi.org/10.17863/CAM.76200

Table 2 Summary of the overall effect on the key continuous performance task metrics collected at the beginning, middle and end of the academic year

Metric	Wilks' lambda	F-test	Degree of freedom	Error degree of freedom	Partial eta square	*p*-value
Accuracy	.92	6.28	2	147	.08	.002
RTc	.95	3.78	2	147	.05	.03
Efficiency	.92	6.46	2	147	.08	. 002

specifically, there was a significant effect of changes in performance (i.e., accuracy, efficiency, and reaction time to correct responses; see Table 2). Reaction time to correct responses decreased significantly from the beginning to the end of the academic year, suggesting that participants responded faster to correct trials over time. Also, the mean for accuracy and efficiency increased significantly from the beginning to the end of the academic year, demonstrating that participants had more accurate and efficient responses across the academic year. These results supported the hypothesis that participants' scores on the sustained attention task improved across the academic year.

Discussion

The current study explores the development of sustained attention skills in children from high poverty communities. This study used the Continuous Performance Task to analyse changes in performance from the beginning to the end of a single academic year in late elementary school. To the best of our knowledge, this study is novel in terms of examining the changes in sustained attention in children from high poverty communities using a repeated-measures design.

Previous findings that included children from middle income communities in Finland and Australia (Klenberg et al., 2001; Lewis et al., 2017) have shown that children's accuracy, efficiency, and reaction time to correct responses improved between 6- to 10-years-old. In line with previous studies (Betts et al., 2006; Burneo-Garcés et al. 2019; Klenberg et al., 2001; Lewis et al., 2017), which concluded that the improvement of sustained attention was due to age-related maturation, the current study finds corresponding results in a sample that consists of predominately African American children from high poverty areas. More specifically, participants' accuracy, efficiency, and reaction time to correct responses all improved significantly. These findings are in line with Rebok et al. (1997), who found that efficiency and accuracy improved significantly in 435 children (63.7% African American from urban areas) who were assessed at the age of 8, 10, and 13 years. Although previous studies were limited in their findings due to sample characteristics, the current findings suggest that those results are indeed generalisable to ethnic minority children from high poverty areas, which is an under-researched population in the field of child psychology. However, because of the confounding effect of chess training, these results should be interpreted with caution.

Moreover, past studies (Brody et al., 2004; Dilworth-Bart et al., 2007; Groot et al., 2004; Hackman et al., 2015; Hughes & Ensor, 2005; Ruff & Rothbart, 2001) have indicated that poverty might dampen children's development of sustained attention due to scarcity of educational resources and unstable neighbourhood environments. Specifically, given that ethnic minority children are more likely to grow up in poverty and receive less attention in the field of child psychology than children who are white (Anderson et al., 2021), more research should be conducted to better understand the development of sustained attention in children from ethnic minority backgrounds so that researchers have an insight into their cognitive development and effective, targeted interventions can be devised. Unlike previous longitudinal studies, which included predominately European and white children (Ahmed et al., 2019; Lewis et al., 2017; Usai et al., 2014), the current longitudinal study implies that the development of sustained attention may be attributed to age-related changes, without overlooking the confounding influence of chess training.

Having said this, the improvement of sustained attention may also be due to chess intervention. As introduced earlier, the original project investigated whether chess-related activities would influence children's executive functions, behavioural outcomes, and academic achievement over two years. Owing to a recruitment issue, the original project did not have a control group, so there was no direct comparison on the

DOI: https://doi.org/10.17863/CAM.76200

level of improvement between children who received the intervention and those who did not. Therefore, it is plausible that chess training had a confounding effect on the present study's findings.

Limitations and future directions

While this study replicates past studies' findings and complements the body of literature by examining the developmental trajectory of sustained attention in children living in communities experiencing high levels of poverty, the study is not without limitations.

First, this study only used a single task to evaluate sustained attention skills. There is some concern that performance-based tasks like the Continuous Performance Task lack ecological validity. Moreover, the findings may be due to participants' increase familiarity with the task over time, therefore future studies should include a variety of sustained attention tasks and authentic reasoning tasks in which children utilise their sustained attention skills. Additionally, future studies can incorporate behaviour rating scales (e.g., Test of Everyday Attention for Children, Manly et al., 2016) or questionnaires by parents or teachers (e.g., Behaviour Rating Inventory of Executive Function, Gioia et al., 2000; Conners Third Edition Parent Short Form, Conners, 2008) to measure sustained attention in children.

Secondly, a replication on a larger scale is needed before becoming generalisable to either children within communities experiencing high levels of poverty or African American children being raised in more affluent communities. Nevertheless, this study is insightful to the communities concerned. Future studies should aim to explore the development of sustained attention with alternative demographic characteristics.

Thirdly, this study did not have a control group that could facilitate the comparison between the level of improvement in children who received the chess training and children who did not have the chess training. Therefore, the cause of improvement in sustained attention may be explained by chess training or other extracurricular activities. Playing chess is a cognitively demanding exercise that has been shown to improve executive function skills (Berkman, 2004; Elkies & Stanely, 2003; Gliga & Flesner, 2014; Khosrorad et al., 2014). Therefore, chess training might have positively influenced the development of sustained attention in this study. Future studies should include a control group to better examine the effect of chess training on executive functions. Other than playing chess, students might be engaged in extracurricular activities that could improve their sustained attention skills. For example, one of the extracurricular activities, which is outdoor exercise, has been shown to improve sustained attention in children (Ballester et al., 2015). Children who were regular soccer players have been shown to perform better on sustained attention tasks than those who were not, because exercise has been found to improve brain function and structure over the lifespan (Ballester et al., 2015; Voss et al., 2011). Therefore, outdoor exercise could also be a confounding variable that positively influenced the development of sustained attention. Additionally, other confounding characteristics such as gender and parental education were excluded from the data analysis. Future studies should consider these variables and ensure that testing assumptions are met for statistical analysis when investigating the development of sustained attention in ethnic minority children from high poverty areas.

Implications for educators, practitioners and policymakers

There are several implications deriving from this study that can be useful for educators, practitioners, and policymakers. This study complements previous work in this area (Betts et al., 2006; Klenberg et al., 2001; Lewis et al., 2017) that has examined sustained attention in children, demonstrating that children's sustained attention skills improve between the ages of 8 and 11 years. Most importantly, this study includes children from high poverty areas. Teachers should continue to offer support to this vulnerable group to ensure the continuous development of sustained attention and executive function skills. Evidence suggested that children with better sustained attention skills learned more from teachers' instructions as they moved through grades (Benson et al., 2013). In school, educators can use different techniques to boost sustained attention in children from different age groups. For example, research suggested that vigorous classroom-based physical activity positively influenced children's sustained attention and academic performance. Therefore, teachers might be encouraged to include classroom-based physical activity as part of their class curriculum (Coe et al., 2006). Physical activity might increase students' resistance to boredom and boost alertness, allowing them to pay more attention to their schoolwork (Shephard, 1996). Another method of boosting sustained attention over time in children is to utilise study breaks. For instance, Betts et al. (2006) indicated that children aged between 8 and 12 years might benefit from a similar study-break schedule because they exhibited a similar plateau in sustained attention.

Specifically, Betts et al. (2006) suggested that children learned and attended more efficiently when information was divided into digestible portions. Therefore, teachers should present study materials in digestible amounts and use study breaks to keep children focused during school time. Although this study could not determine

DOI: https://doi.org/10.17863/CAM.76200

whether the chess intervention contributed to the improvement of children's sustained attention or not, further studies should examine this relationship, as a positive association could have important practical and policy implications for the introduction of chess clubs in schools located in low socioeconomic status neighbourhoods.

Moreover, this study can also inform policymakers about the developmental trajectory of sustained attention skills, especially for children growing up in high poverty communities. This study suggests that the period from 8 to 11 years of age is a critical growth period. Policymakers should provide educational resources to support school programmes that yield positive gains in developing sustained attention in children. In addition, Serpell and Esposito (2016) emphasised the importance of incorporating computer-based training into students' curricula to foster the healthy development of sustained attention in children who were from high poverty neighbourhoods. Specifically, computer-based training could be used to improve memory, attention, and problem-solving abilities (Serpell & Esposito, 2016). Corresponding results have also been found in the study by Luo and Zhang (2020), indicating that participants who received computer-based training had fewer omission errors, more efficiency, and higher accuracy on sustained attention tasks than those who did not receive it. As such, educational professions could use computer-based training to cultivate a challenging, cognitively enriching, and emotionally engaging environment that might support the development of sustained attention in children. However, not all cognitive training is successful (for reviews see Ribipour & Raz, 2012; Moreau & Conway, 2014; Nutley & Söderqvist, 2017; Sankalaite et al. 2021). For example, Moreau and Conway (2014) argued that cognitive training lacked ecological validity and had limited real-world application because it was administrated in a highly controlled setting. In addition, the sustainability and the transferability of cognitive training still remain unclear (Chein & Morrison, 2010; Holmes et al., 2010; Thorell et al., 2009). For instance, after receiving a working memory training, preschool children showed significant improvements on attentional tasks and working memory measures, but not on inhibitory control or problem-solving tests (Thorell et al., 2009). Therefore, more research would be needed before policymakers take advantage of this critical period and utilise these cognitive exercises to maximise potential achievement in children from high poverty communities.

Conclusion

This study investigated children's changes in sustained attention across one academic year during elementary school. It adds to the body of literature examining changes in sustained attention in children from high poverty communities. However, since this study is a secondary data analysis, it is limited by the variables, measures, and sample size that were available from the original study. Despite the limitations associated with the study including the absence of a control group, this study demonstrates the continuous development of sustained attention in children across time. Future studies could attempt to replicate the current findings on sustained attention with different age groups and socioeconomic backgrounds. Policymakers should make the best use of cognitive exercises to improve sustained attention in ethnic minority children during this critical period.

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Teresa Parr: Funding Acquisition, Project Admininistration, Investigation, Resources, Data Curation.

Michelle R. Ellefson: Supervision, Funding Acquisition, Project Admininistration, Investigation, Resources, Data Curation, Writing – Review & Editing.

Acknowledgements

The data presented here are the result of work by a large team from the University of Cambridge, Virginia State University, Virginia Commonwealth University and Ashley-Parr, LLC (listed alphabetically by last name): Temitope Adeoye, Mariah Adlawan, Amanda Aldercotte, Annabel Amodia-Bidakowska, Cortney Anderson, Christopher Ashe, Joseph Beach, Aaron Blount, Alexander Borodin, Lyndani Boucher, Aaron Blount, Lakendra Butler, Yufei Cai, Tavon Carter, Emma Chatzispyridou, Parul Chaudhary, Laura Clarke, Taelor Clay, Jackson Collins, Brittany Cooper, Aiden Cope, Briana Coardes, Breanna Cohen, Aiden Cope, Amenah Darab, Moneshia Davis, Shakita Davis, Asha Earle, Mary Elyiace, Nadine Forrester, Sophie Farthing, Pippa Fielding Smith, Aysha Foster, Gill Francis, Kristine Gagarin, Amed Gahelrasoul, Marleny Gaitan, Summer Gamal, Katie Gilligan, Cynthia Gino, Reinaldo Golmia Dante, Zejian Guo, Aditi Gupta, Jennifer Hacker, Shanai Hairston, Khaylynn Hart, Donita Hay, Rachel Heeds, Sonia Ille, Joy Jones, Madhu Karamsetty, Spencer Kearns, Marianne Kiffin, Hyunji Kim, Wendy Lee, Steven Mallis, Dr. Geoff Martin, Tyler Mayes, Alexandria Merritt, Roshni Modhvadia, Dedrick

DOI: https://doi.org/10.17863/CAM.76200

Muhammad, Susana Nicolau, Christian Newson, Seth Ofosu, Esther Obadare, Jwalin Patel, Chloe Pickett, Tanya Pimienta, Connor Quinn, Kelsey Richardson, Michael Randall, Fran Riga, Tennisha Riley, Natalie Robles, Leah Saulter, Kristin Self, Tiera Siedle, Julian Smith, Abi Solomon, Adam Sukonick, Amelia Swafford, Krystal Thomas, Richard Thomas, John Thompson, Tris Thrower, Jr. , Quai Travis, Maria Tsapali, Jorge Vargas, Tony Volley, Christopher Walton, Elexis White, Karrie Woodlon, Zhuoer Yang, Shamika Young, Sterling Young, Cheyenne Yucelen, Anne Zonneveld. These researchers were directed by the PI/Co-PIs: Drs. Michelle Ellefson, Zewelanji Serpell, and Teresa Parr. Correspondence about the overall grant / project should be directed to Dr Michelle Ellefson (mre33@cam.ac.uk). An overall summary of the project is available from https://osf.io/yac8e/ (Ellefson et al., 2020)

Thanks to the editors and peer reviewers for their suggestions for this manuscript.

Additional thanks go to Meng Liu for proofreading of the translated abstract and highlights.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A110932 to the University of Cambridge. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

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