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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 42(0)

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Publication Date
2020

Peer reviewed

The Differential Relationship of Extracurricular Activities and Screen Time with Adolescents' Fluid and Crystallized Cognition

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Abstract

Adolescents are going through a period of rapid growth in cognitive resources, both in crystallized, or knowledge-based, cognition and fluid cognition, or the ability to think and reason flexibly. Past literature reveals an ongoing debate as to whether, or in what way, different activities during childhood relate to these abilities. The current study leveraged the Adolescent Brain Cognitive Development baseline dataset to explore the interplay between nine- and ten-year-olds' extracurricular activities, screen time, and the different components of cognition. Results indicate that adolescents' activities explain more variance in crystallized than fluid cognition. Further, participation in artistic activities is associated with increased fluid and crystallized cognition, though sports is positively associated with fluid but negatively associated with crystallized cognition. Different types of screen time, though notably not video game playing, may be negatively associated with cognition. Screen time explains more variance in fluid cognition than extracurricular activities do, whereas the opposite is true of crystallized cognition. This correlational study suggests potential avenues for further work to disentangle the causal links underlying the relationships between experiences and cognition. Do such activities change adolescents' cognitive skill, or do children self-select to participate in certain types of activities that complement their existing skills?

Keywords: adolescence; screen time; extracurricular activities; cognition; ABCD

Background

Two components are thought to make up general intelligence: fluid and crystallized cognition. However, there is an ongoing debate as to how different environmental factors in the world can differentially impact these components, especially in adolescence when cognitive skills are rapidly developing. Crystallized cognition is thought to be a product of knowledge and skills, continuing to increase throughout the lifespan. Fluid intelligence, on the other hand, is thought to reflect the ability to reason and think flexibly, peaking during early adulthood.

Previous genetic studies show that fluid intelligence is more heritable than crystallized intelligence, though both have a significant heritable component (Cattell, 1980). These findings indicate that crystallized intelligence may be more highly correlated with the activities young children engage in compared to fluid intelligence. In contrast, a recent study leveraging the Adolescent Brain Cognitive Development (ABCD) dataset found that a genome-wide polygenic score for intelligence was more predictive of crystallized rather than fluid cognition (Loughnan et al., 2019). They attribute their results to a gene-environment correlation; children self-select their activities based on their cognitive predisposition. In either case, not all activities are created equal, and different activities may be more closely associated with development of one type of cognition over the other. In general, past work investigating adolescents' activities and associated cognition leave an unsettled debate.

Though participation in many different activities has been shown to benefit performance in that or similar tasks, far transfer, or the generalization of skills to broader domains such as fluid and crystallized cognition, has been harder to demonstrate. Meta-analyses examining training studies on one aspect of fluid cognition, executive functioning, have found little to no far transfer to untrained executive functioning tasks (Kassai et al., 2019; Sala & Gobet, 2020). However, these meta-analyses analyzed studies using training tasks specifically designed to tap executive functions over an intervention period, rather than examining common extracurricular activities and long-term participation in such activities.

Executive functioning has seen improvements from pre to post test in multiple fitness or exercise interventions for adolescents (e.g. Diamond & Lee, 2011, Hillman et al., 2014). Diamond and Lee (2011) note that programs for younger children see greater benefits, and addressing emotional and social development are just as important for increased executive functioning as focusing on physical development. Further, increased aerobic exercise in children has been linked to structural and functional differences in brain areas associated with cognitive skills (e.g. prefrontal cortex), introducing a possible mechanism for how exercise positively impacts cognition (Chaddock et al., 2011). Extracurricular activities, particularly sports, may be well suited to address all three of these aspects of development, to more greatly impact fluid cognition. On the other hand, Fedewa et al. (2015) found that schools that incorporated more physical activity throughout the school day found significant improvements in crystallized cognitive measures of math and reading, but not in fluid cognition measures.

Within the ABCD study itself, multiple investigators have analyzed global cognition, a composite of fluid and crystallized cognition, and its relations to sleep, screen time, and movement. Bustamente (2018) reported that getting the recommended daily amount of physical activity was not associated with global cognition. However, using similar methods, Walsh et al. (2018) found that adolescents who met the daily movement recommendations in addition to also meeting sleep and screen recommendations did see superior global cognition. These opposing findings illustrate the ongoing debate about daily activities and cognitive function. Notably, both studies binarily compared children who did and did not reach recommendations and used only one global measure of cognition. Often, studies exploring adolescents' activities and cognition use different designs, impeding the ability to generalize findings. New research and insights into these relationships would lend greatly to the field.

Studies investigating activities that promote deep thought, especially creative thinking, also reveal seemingly contradictory findings. Such activities could be considered artistic in nature. Fluid cognition, but not crystallized, has been found to be positively correlated with creativity scores (Sligh, 2005), pointing to the possibility that engaging in activities that promote, or use, creativity at young ages may in turn support cognition associated with fluid intelligence. Investigating adolescents in the ABCD dataset, Hoffman and Thompson (2019) report that playing an instrument, another activity associated with artistic expression and creativity, is predictive of fluid cognition.

Conversely, divergent thinking, a measure also associated with creativity, has been found to be predictive of both fluid and crystallized intelligence (Batey, 2009). Burgoyne et al. (2016) also found that chess skill, an activity promoting deep thought, correlated positively with fluid cognition (including processing speed and short-term memory) and with crystallized cognition. In general, though, adolescents who participate in extracurricular activities tend to have better academic performance, whether the activity is athletic or artistic (Reeves, 2008). Many of the students who engage in non-required activities may simply also be high achievers.

Screen usage may have interesting effects on children's cognition. TV watching has been correlated with the development of brain structures associated with cognition as well as with worse cognitive scores, corroborating findings from the ABCD study that limiting screen time to recommendations positively relates to global cognition (Bustamente, 2018; Takeyuchi et al., 2015). Other studies suggest that different types of screen time relate to children's cognition in different ways. Though Sala et al. (2018) generally found only weak to no relationship between video game trainings and general cognitive skill, they did find that spatial reasoning and visual attention, aspects of fluid intelligence, may increase as gaming skill increases, and consistently found that players had higher cognitive ability than non-players. This suggests possible long-term effects not easily assessed in specific intervention or training studies. Paulus et al. (2018) analyzed the ABCD dataset and found that overall screen time was related to brain structures associated with cognitive skill, but that this may or may not translate to cognitive ability. The ABCD study breaks screen time outside of school down into specific types, such as TV, YouTube, video gaming, facetime, etc. These different types of screen time may see differential effects on children's fluid and crystallized cognition that cannot be seen when aggregating them together as some previous research has. As screen time becomes more common in younger children, more research is prudent to better understand the long-term relationship between screen usage and cognition. Currently such studies are few and far between.

One limitation with much of the previous research relating adolescents' daily activities with cognition is that they use a single measure of total cognition or investigate very specific aspects of cognition. The NIH Toolbox within the ABCD study measures five aspects of fluid cognition and two of crystallized individually as well as forming these two composite scores. The ABCD study further provides a rich observational dataset including these measures to investigate how children's own day-to-day activities may influence both their fluid and crystallized cognition.

The goal of the present analyses is to investigate the differential relationship adolescents' extracurricular activities, including screen time, could have with fluid cognition compared to crystallized cognition, over and above factors such as gender, age, and socioeconomic status. These activities will include physical activities such as sports, artistic activities such as music and chess, and recreational screen time usage. These analyses will help add to the debate about if, and if so, to what degree, the different activities adolescents engage in relate to their cognitive skill. The present study will further explore each task within the NIH Toolbox individually, in addition to the composite scores.

Based on prior genetic research, we hypothesize that: 1) such activities may, in general, account for more variance in crystallized cognition compared to fluid. We also predict that 2) Sports and artistic activities may positively relate to both types of cognition, though sports may be more so related to fluid cognition, and 3) most screen time measures may have a negative impact on the different types of cognition, though some, such as video games, may see positive effects on the components of fluid reasoning.

Method

Participants

The ABCD baseline sample consists of 11,875 children recruited at ages 9-11 years (M=118.94 mo, SD=7.46 mo). Children were recruited into this longitudinal study at one of 21 sites throughout the United States, chosen to approximate the US population on key demographic variables, including race, gender, and socioeconomic status. Table 1 summarizes demographic information. Participants were largely recruited through local school systems. Exclusion criteria for recruitment was lack of English proficiency, severe limitations that would prevent the child from complying with protocol, and the inability to complete an MRI scan.

The current study utilized baseline data from ABCD release 2.0 (DOI: 10.15154/1503209). Though many other measures were taken for each participant, here the analyses utilize the cognitive assessments from the NIH Toolbox, extracurricular activity data, and screen time activity data, amongst other demographic and socioeconomic variables.

Table 1: Demographic and Socioeconomic information.

Gender	N	Ethnicity	N
F	5681	Hispanic	2409
M	6188	Not Hispanic	9321
Parent Education		**Family Income**	
<HS diploma	788	<50K	3222
HS diploma/GED	1258	50K – 100K	3070
Some college	3486	>100K	4565
Bachelor	3331		
Graduate degree	2995		
Race		**Family Relationship**	
White	6174	Single	8147
Black	1779	Sibling	1593
Asian	252	Twin	2105
Other	3670	Triplet	30
Parent Married = Yes	7990		

NIH Toolbox Cognitive Assessment

The NIH Toolbox cognition measures were one assessment within a larger group of neurocognitive measures. The toolbox was administered one-on-one with a research assistant using an iPad and was expected to last about 35 minutes. The toolbox is normed for multiple sample ages, the battery of interest being normed for ages 7-17. The toolbox battery consists of seven individual measures designed to cover a range of cognitive abilities, including language ability, episodic memory, processing speed, executive function, working memory, and attention. The scores are also aggregated to form three composite scores, a crystallized, fluid, and total cognition score. The means and standard deviations for the toolbox tasks can be found in Table 2.

The Toolbox Picture Vocabulary Task measures verbal intellect. The task requires participants to match a spoken word to one of four pictures presented on screen. The Toolbox Oral Reading Recognition is a test in which participants pronounce single words. These two measures are derived to form the Crystallized Composite score. The Fluid Composite is derived from scores on the remaining five measures in the toolbox. The Toolbox Pattern Comparison Processing Speed Test measures rapid visual processing, by asking individuals to compare two side-by-side images and decide if they are the same as quickly as possible. The Toolbox List Sorting Working Memory Test asks participants to sequence items based on size. Each item is presented one at a time, so participants must hold each item in working memory until the test. The Toolbox Picture Sequence Memory Test assesses episodic memory by requiring participants to encode and retrieve a sequence of event pictures in the correct order. The Toolbox Flanker Task is designed to test inhibition and conflict monitoring by requiring individuals to identify the direction of a central arrow surrounded by either congruent or incongruent arrows. Finally, the Toolbox Dimensional Change Sort Task measures executive function. Each task provides a raw score, uncorrected standard score, and age-corrected standard score. Uncorrected task scores are used in the present analyses.

Extracurricular Activities and Screen Time

A parent-report questionnaire was used to determine the amount of time spent in multiple extracurricular activities. For each activity, parents were asked: how many years, how many months per year during the most active period, how many days per week, and how many minutes per session did your child participate? A composite of how many hours over the lifespan each child participated in any given activity was produced using these questions. A lifespan estimate was used as any effects would most likely be due to long-term developments. Means and standard deviations for the activity and screen time task data can be found in Table 2. Each dependent variable will be standardized for analysis.

Table 2: Measures summary. Cognitive tasks are uncorrected standard scores, extracurriculars are hours over the lifespan, and screen time are average hours per day.

Dependent Variable	Mean (SD)	Independent Variable	Mean (SD)
Total Cognition	86.22 (9.14)	Sports	533.54 (811.72)
Fluid Cognition	91.55 (10.66)	Arts	234.06 (686.61)
Crystallized Cognition	86.36 (7.06)	Reading	925.53 (2283.94)
Pattern Comparison	88.06 (14.59)	TV & Movies	1.26 (1.04)
Picture Sequence	102.81 (12.07)	YouTube	0.98 (1.14)
List Sort	96.64 (12.09)	Video Games	1.01 (1.11)
Flanker	94.00 (9.14)	Texting	0.23 (0.54)
Card Sort	92.52 (9.51)	Social Media	0.12 (0.42)
Oral Reading	90.85 (6.91)	Video Chat	0.19 (0.49)
Picture Vocabulary	84.45 (8.12)		

Activities were then divided into two categories, sports (exercise) and arts (creativity). The sports composite assessed how many hours the child had participated in: ballet, softball, basketball, climbing, field hockey, football, gymnastics, ice hockey, horseback riding, skating, martial arts, lacrosse, rugby, skateboarding, ski or snowboarding, soccer, surfing, swimming, tennis, track, mixed martial arts, and volleyball. The arts composite combined the number of hours spent participating in: playing a musical instrument, art, theater, crafts, competitive games, and hobbies. A third variable also incorporated was reading for leisure. Though this measure could be considered creative, it is largely language based, and of interest was how this language measure may relate to the cognitive language and crystallized intelligence measures from the NIH toolbox. Because both crystallized measures from the toolbox are linguistic in nature whereas the fluid measures are not, reading could be particularly interesting.

Screen time was assessed using a child-report questionnaire that included the screen activities TV shows or movies, videos such as YouTube, videogames, texting, social media, and video chat. For each screen activity, children were asked to report approximately how many minutes they spend engaging with the activity both on weekdays and on weekends. These measures were used to form a composite of the average number of hours spent in each activity per week. Each screen time measure will be kept separate rather than forming a screen time composite, as different types of screen time may impact cognition differently.

Data Analysis

To assess the relationship between children's activities and their cognitive abilities, we fit General Linear Mixed Models. Each model had a different cognitive task or composite score as the dependent variable. In order to better understand if and how the different activities may relate to each other (e.g. interactions, moderator/suppression effects), the activities were used as independent or predictor variables. Models with fluid and crystallized cognition were run with and without controlling for the other cognitive composite. All models included fixed effects for each of the six screen time measures, the sports and arts composite measures, the reading measure, and the interactions between sports and arts as predictors of cognition. Each of these predictor variables were standardized so resulting coefficients are comparable and can be interpreted in standard deviations.

In order to control for demographic and socioeconomic variables, each model also included fixed effects of age, gender, ethnicity, race, parental marital status, parent education, and family income. Family ID was also included as a random effect in each model. Participants who share a family have the same family ID (i.e. siblings, twins). Though not a full twin analysis, this random effect was utilized with the other controls following previous analyses of the ABCD baseline dataset (see Loughnan et al., 2019).

Models including the interaction between reading for leisure and artistic activities was found to be nonsignificant and did not alter the outcome of the models, so will not be included in the present analyses. The amount of time spent reading or participating in sports was not hypothesized to have a relationship.

Results

Cognitive Measures

Results from the full models including both extracurricular activities and screen time measures are reported. Reported t-tests use the Satterthwaite's method. Regression models for each composite measure of the NIH Toolbox (Total, crystallized and fluid cognition) showed different relations with activities and screen time. Lifetime hours spent engaged in artistic activities was found to be positively predictive of cognitive composite scores (total: $t(10,390)=4.84$, $p<.001$; crystallized: $t(10,450)=6.81$, $p<.001$; fluid: $t(10,350)=2.34$, $p<.05$). Reading for leisure follows the same trend (total: $t(10,400)=11.59$, $p<.001$; crystallized: $t(10,420)=15.28$, $p<.001$; fluid: $t(10,420)=5.93$, $p<.001$). Sports, on the other hand, showed differential impacts on the cognitive composite scores. Sports was not associated with total cognition ($t(10,180)=1.23$, $p=0.22$), was positively associated with fluid cognition ($t(9,987)=3.66$, $p<.001$), but was negatively associated with crystallized cognition ($t(10,410)=-3.60$, $p<.001$). The interaction between sports and art activities was significantly related to fluid cognition ($t(8,843)=-2.53$, $p<.05$), but was not associated with total or crystallized cognition (total: $t(7,974)=-1.89$, $p=0.06$; crystallized: $t(7,827)=0.26$, $p=0.80$). However, this interaction was trending toward significance for total cognition.

The screen time measures also have differing relationships with the cognitive composite measures, though some patterns emerge. In general, the screen time measures are associated with decreases in cognition scores when significant. The average time spent watching TV or movies per week predicts a decrease in cognitive ability for all composite cognitive measures (total: $t(10,200)=-6.02$, $p<.001$; crystallized: $t(10,190)=-6.61$, $p<.001$; fluid: $t(10,380)=-4.09$, $p<.001$). Time spent video chatting mirrors the trend for TV/movies (total: $t(10,350)=-7.53$, $p<.001$; crystallized: $t(10,400)=-5.89$, $p<.001$; fluid: $t(10,430)=-6.69$, $p<.001$). The amount of time children engaged in social media use was also negatively associated with all three cognitive composite scores (total: $t(10,040)=-3.29$, $p<.01$; crystallized: $t(10,020)=-3.54$, $p<.001$; fluid: $t(10,260)=-2.17$, $p<.05$). It should be noted that children spend the least time invested in social media use, most likely because of their young age. Watching YouTube videos was negatively associated with total and fluid cognition (total: $t(10,410)=-3.97$, $p<.001$; fluid: $t(10,450)=-4.08$, $p<.001$), but was only trending toward a significant negative association with crystallized cognition ($t(10,440)=-1.92$, $p=.055$). Texting, however, showed an opposing pattern, in which more time spent texting predicted decreases in crystallized intelligence ($t(10,110)=-2.05$, $p<.05$), but showed no predictive relationship with total or fluid cognition (total: $t(10,150)=-1.49$, $p=0.14$; fluid: $t(10,320)=-0.57$, $p=0.57$). Again, children did not text and video chat as often as some other screen time activities. Interestingly, video game usage showed no significant relationships with the three composite cognition scores (total: $t(10,250)=-0.47$, $p=0.64$; crystallized: $t(10,250)=1.24$, $p=0.22$; fluid: $t(10,400)=-1.23$, $p=0.22$).

Models were also run for the fluid and crystallized composites including the other as a predictor. Both cognitions were positively associated with the other and did impact the predictive nature of some of the activity and screen time variables. Table 3 shows beta coefficients and significance for both the models with and without the opposing cognition as a predictor. Further regression models using each individual cognitive task as the dependent variable were run. Overall, trends followed that of their respective composites, but are not reported due to space constraints.

Table 3: Final estimation of fixed effects for the composite cognitive measures in the NIH Toolbox. Each standardized beta coefficient is listed followed by the significance (indicated *** p<.001, **p<.01, *p<.05, -p<.1).

Fixed Effects	*Total*	*Fluid*	*Fluid (controlling for crystallized)*	*Crystallized*	*Crystallized (controlling for fluid)*
Sports	0.0981	0.3700***	0.4799 ***	-0.2165 ***	-0.2751 ***
Arts	0.3819 ***	0.2343 *	0.0330	0.4132 ***	0.3702 ***
Reading	0.8736 ***	0.5696 ***	0.0970	0.8860 ***	0.7916 ***
*Sports * Arts*	-0.0531 -	-0.0919 *	-0.0958 **	0.0055	0.0228
TV & Movies	-0.4798 ***	-0.4164 ***	-0.1958 *	-0.4038 ***	-0.3336 ***
YouTube	-0.3427 ***	-0.4491 ***	-0.3830 ***	-0.1275 -	-0.0574
Video Games	-0.0419	-0.1399	-0.1843 -	0.0845	0.1101 -
Texting	-0.1354	-0.0667	0.0101	-0.1424 *	-0.1326 *
Social Media	-0.2868 **	-0.2423 *	-0.1222	-0.2358 ***	-0.2002 **
Video Chat	-0.6709***	-0.7614 ***	-5621 ***	-0.4014 ***	-0.2505 ***
Other Cognition	NA	NA	0.5128 ***	NA	0.1853 ***

Proportional Reduction in Error

Further analyses examined the Proportional Reduction in Error for each full model and its subsets, when only adding in screen time or extracurricular activity measures over and above demographic, socioeconomic and family relationship covariates. Results for all models analyzed are summarized in Figure 1. For crystallized cognition, screen activities significantly reduced error by 0.29% ($\chi_2(6)=203.92$, $p<.001$), sports and art activities reduced error by 0.46% ($\chi_2(4)=316.19$, $p<.001$), and the full model combining all activities reduced error by 0.73% ($\chi_2(10)=508.89$, $p<.001$). The same trends follow, albeit to a still significant but lesser degree, for the individual tasks that make up the crystallized cognition composite: oral reading recognition and picture vocabulary. Investigating the error in the fluid cognition composite, screen time significantly reduced error by 0.23% ($\chi_2(6)=190.47$, $p<.001$), sports and arts reduced error by 0.07% ($\chi_2(4)=65.40$, $p<.001$), and the full model significantly reduced error by 0.30% ($\chi_2(10)=248.64$, $p<.001$). Again, the same trend follows for the individual tests that derive the fluid composite score, to a still significant, but lesser degree. Total cognition follows the trends of fluid cognition.

Overall, the full model including activity and screen time measures reduces a greater proportion of the error in crystallized cognition compared to fluid cognition. Within fluid cognition screen time measures reduce a greater proportion of the error compared to sports and art activities, though the opposite trend occurs for crystallized cognition. Sports and art activities reduce a greater proportion of error compared to screen time activities in the crystallized composite score.

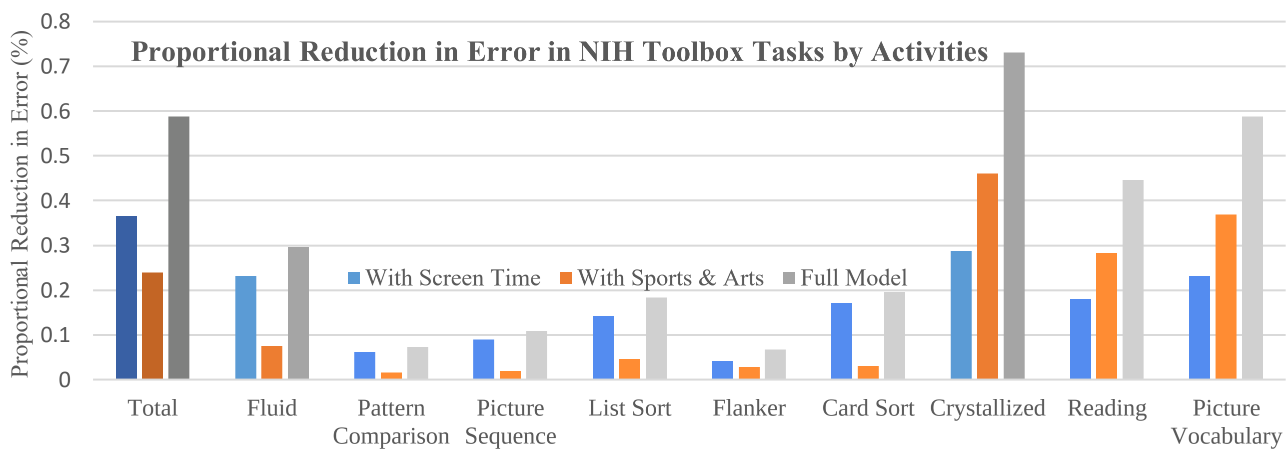

Figure 1: Proportional Reduction in Error (PRE) for each cognitive measure. All bars compare against a model with only covariates included (age, gender, ethnicity, race, parent marital status, parent education, family income and family ID). Left bars indicate PRE when adding only screen time measures, middle bars indicate PRE when adding only extracurricular activity measures, and right bars indicate PRE when adding in both screen time and activity measures.

Discussion

The work presented here looks at the differential relationships between extracurricular activities, broken down into athletic, artistic and reading activities, and types of screen time, with both fluid and crystallized cognition. Overall, the current work adds evidence from a large dataset indicating that there are significant relationships between the activities children engage in and their general cognition. This builds on prior debates about whether such associations even exist in the first place.

First, such activities do account for a larger proportion of overall variance in crystallized than fluid intelligence. Though the proportion of variance explained by such activities is small, they are significant. These results are over and above multiple demographic and socioeconomic variables which alone explain a great deal of variance. These analyses indicate that crystallized cognition may be more amenable to the environment children create for themselves (i.e. Cattel, 1980), or that at least far transfer is less likely to happen in the fluid cognition domain (Kassai et al., 2019; Sala & Gobet, 2020). In an opposing vein of genetic research, recent studies positing a gene-environment correlation also support the notion that crystallized cognition would be more highly related to extracurricular activities. Loughnan et al. (2019) found that a genetic intelligence score was more predictive of crystallized intelligence, and in turn children self-select their experiences based on these cognitive predispositions. The present analyses do not speak to whether these experiences are effectively changing cognition, or whether children with certain cognitive skill levels are then participating in these activities because they are more inclined to enjoy them. Future studies, as well as analyses once data is fully collected in this longitudinal study, could help disentangle a possible causal relationship. Interestingly, within fluid cognition, screen time measures reduced a greater proportion of error compared to sports and art activities, though the opposite trend was seen for crystallized cognition. Screen time, as compared to extracurricular activities, may be more predictive of flexible reasoning, whereas it is less predictive for academic skills.

Second, artistic activities are positively associated with all cognitive skills, though sports are positively associated with fluid cognition but negatively associated with crystallized. The more creative and divergent thinking skills involved in activities such as music, chess and painting may translate to fluid cognition, but these activities can also teach skills such as patience and perseverance that may translate to a classroom setting. Sports enhance blood flow and promote quick decision making and teamwork skills, which may translate to fluid reasoning skills. Sports promoting aerobic exercise specifically may also see differences in prefrontal structures and improved functioning (Chaddock et al., 2011). These results contradict findings by Fedewa et al. (2015) who indicated a positive association between physical activity and crystallized measures. Time spent in sports may take away from time spent in more academic activities. Or, perhaps acquiring sports skill may not involve as much linguistic communication as other activities, and the current crystallized measures are language-based. Interestingly, with the exception of picture vocabulary, which is associated with both sports and arts, each individual measure that was significantly associated with sports was not with arts, and vice versa. Again, it could be that participation in certain activities change the brain areas associated with different types of reasoning. However, the lack of successful far-transfer studies may suggest that preexisting differences in these structures lead children to be skilled at and enjoy different activities, supporting Loughnan et al. (2019).

The activities that make up the sports composite variable need to be more closely evaluated for future analyses involving this dataset. Specifically, some activities included may be more or less similar to each other, and to the other artistic activities. For example, team sports may involve different cognitive or reasoning skills as compared to sports traditionally completed individually, and some sports may have a larger creative component (e.g. ballet) compared to others. New and ongoing analyses investigating these variables using structural equation modeling (SEM) will help better understand the different extracurricular and screen time variables used here, and how best to model them.

Third, screen time measures saw negative associations with cognition in general. TV or movies, social media, and video chatting all saw negative impacts on both types of cognition. However, adolescents in this sample did not engage in social media, texting and video chatting very often if at all. Parents of children who are engaging in these activities may not be regulating their child's technology use and other activities, or may not be spending as much time with their child as other families, which are all important factors in development. In fact, screen time was also associated with greater externalizing behaviors in adolescents (Paulus et al., 2019). It is possible children who use screen media more may also engage in other activities, such as extracurriculars or homework, less. Video game usage did not see a significant relationship with either type of cognition, perhaps because some of the benefits of video game usage (spatial reasoning, attention) help offset some of the costs of screen usage. YouTube was negatively associated with fluid intelligence; perhaps the content adolescents are searching for, or how they learn to search, may translate to academics and crystallized cognition. Texting saw the opposite trend, correlating negatively with crystallized intelligence. Texting could replace one-on-one communication, impeding language development. The crystallized cognition measures, which are linguistic in nature, may reflect this hindered development. Future research should continue to investigate different types of screen usage, including in-school screen usage. Examining change in screen usage over time, once this full longitudinal dataset is collected, could help identify mechanisms underlying screen's association with cognition.

Crystallized cognition, as measured using the NIH Toolbox, is comprised of only two tasks, both of which are highly linguistic in nature. General academic performance could add another dimension to crystallized cognition, and be more comparable to past work (Fedewa et al., 2015). Further, the boundary between crystallized and fluid cognition, as currently measured using the NIH Toolbox, may not be as clear-cut as postulated. New analyses using SEM indicate the potential for considerable overlap among the tasks in a two-factor model. Future analyses providing a better understanding of the distinction between fluid and crystallized cognition in adolescents may in turn provide a better understanding of how non-scholastic activities relate to different facets of cognition.

Overall, these findings support general recommendations for parents: encourage physical activity and limit or structure screen usage. These analyses also highlight the importance of engaging in activities that promote creativity as well as deep thought. However, a key takeaway from the present analyses is that not all screen time is created equal. In fact, video gaming, the screen time parents seem to associate with negative consequences the most, had no relationship with cognition. Still, parents would do well to regulate their child's use of the internet and other social-type screen usage. TV and movies, though an easy distraction, can also be detrimental in large amounts. Adolescents' brains and cognition are rapidly developing, and their day-to-day activities play a crucial role in this growth.

Acknowledgments

Data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development (ABCD) Study (https://abcdstudy.org), held in the NIMH Data Archive (NDA). This is a multisite, longitudinal study designed to recruit more than 10,000 children age 9-10 and follow them over 10 years into early adulthood. The ABCD Study is supported by the National Institutes of Health and additional federal partners under award numbers *U01DA041022, U01DA041028, U01DA041048, U01DA041089, U01DA041106, U01DA041117, U01DA041120, U01DA041134, U01DA041148, U01DA041156, U01DA041174, U24DA041123, and U24DA041147*. A full list of supporters is available at https://abcdstudy.org/nih-collaborators. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/Consortium_Members.pdf. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in analysis or writing of this report. This manuscript reflects the views of the authors and may not reflect the opinions or views of the NIH or ABCD consortium investigators.

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