Youth Executive Function and Experience During the First Year of the COVID-19 Pandemic

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Honors Thesis

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Abstract

The COVID-19 pandemic presented a series of stressors that could relate to psychological difficulties in children and adolescents. Executive functioning (EF) supports goal achievement and is associated with life success, including the sub-domains of updating, inhibition, and switching. One's previous EF abilities predict future emotional experience in the presence of early adversity experiences, but little research has examined the global COVID-19 pandemic as a stressor. Therefore, this thesis examined pre-pandemic EF ability and an individual's stability, or growth, in EF over time as predictors of self-reported emotional, cognitive, and social experiences during the first year of the COVID-19 pandemic among children and adolescents. This longitudinal study used pre-pandemic EF data and an online COVID-19 survey administered during the first year of the pandemic (early and mid-pandemic timepoints). Multiple linear regressions with age as a covariate found that EF abilities predicted mid-pandemic but not early pandemic experience. Better pre-pandemic EF and updating abilities predicted worse mid-COVID-19 pandemic emotional and cognitive experiences, and better switching ability predicted worse cognitive experience only. These results were largely maintained when controlling for income, gender, diagnosis presence, mental health burden, and ADHD symptom burden. There was no relationship between pre-pandemic EF growth over time and early- nor mid-pandemic experience. Better cognitive abilities may contribute to worse functioning mid-COVID-19 pandemic by supporting the future-oriented thinking and meta-cognition needed for stress-induced worry and rumination during the pandemic.

The first year of the COVID-19 pandemic was marked by significant changes in children and adolescents' lives. The pandemic disrupted school routines, limited social and leisure activities, and created financial instability and uncertainty about the virus's spread. Early studies have linked reduction in one's emotional distress during the early parts of the COVID-19 pandemic with protective factors, including positive coping methods, resilience, and feelings of social connectedness (Domínguez-Álvarez et al., 2020; Magson et al., 2020; Zhang et al., 2020). This thesis focused on executive functioning as one of these potential protective factors.

Executive function (EF) refers to a collection of mental tools necessary to regulate one's thoughts and actions; EF is considered essential for the completion of goal-driven behavior (Engelhardt et al., 2019). There is evidence that earlier strong EF abilities predict one's future emotional experience in the presence of early adversity (e.g., Tsai et al., 2020). Appelhans et al. (2021) used a longitudinal study to find that pre-pandemic self-reported EF deficits were linked to changes during the pandemic in physical activity and unhealthy eating among young adults. However, here we examine the role of behavioral EF -measures through various tasks and mental health reactions and experiences during the COVID-19 pandemic.

This thesis aimed to assess the relationship between EF abilities measured prior to the COVID-19 pandemic, and children and adolescents' reported experiences during the pandemic. By using an extant longitudinal dataset of mental health, behavioral measures, and COVID-surveys in youth, I evaluated pandemic emotional, cognitive, and social experiences in the context of pre-COVID EF data. There were two main hypotheses: 1. Among youth in our sample, pre-pandemic EF would predict more positive emotional, cognitive, and social experiences during the first year of the COVID-19 pandemic, and 2. Children and adolescents' growth of pre-pandemic EF over time would predict more positive emotional, cognitive, and social experience during the first year of the COVID-19 pandemic.

Executive Function

According to the "unity and diversity" theory of EF, there is both a common EF factor across different EF skills, as well as a series of related sub-domains of EF (Friedman & Miyake, 2017). Three commonly studied sub-domains of EF are *inhibition*, referring to the suppression of a prepotent response; *updating*, which refers to adding new information or changing information in one's working memory as needed; and *switching*, being flexible when alternating between different activities (Engelhardt et al., 2019; Friedman & Miyake, 2017; Karr et al., 2018). *Common EF* consists of the general common factor that forms across these different EF abilities (Friedman & Miyake, 2017). These components have been assessed in children and adolescents through behavioral tasks (e.g. Miyake & Friedman, 2012) and brain activity (Engelhardt et al., 2019).

EF plays a role in many aspects of one's life, including academic success and physical and mental health. Common EF and its domains have been linked to health behaviors (Hall et al., 2008), mind-wandering (Kane et al., 2007), academic achievement (Ahmed et al., 2019), and IQ (Engelhardt et al., 2016). Deficits of common EF and its domains have been associated with most psychopathologies, including major depression, conduct disorder, oppositional defiant disorder, substance use disorder, obsessive-compulsive disorder (OCD), schizophrenia, post-traumatic disorder (PTSD), and attention deficit hyperactivity disorder (ADHD) (see Snyder et al., 2015 for review). Additionally, EF plays a role in adulthood wealth and public safety. For instance, Moffitt and colleagues (2011) followed 1000 children from birth to age twenty-two, all born in the same year and city. After controlling for IQ and socioeconomic status, they found that self-control as measured from age 3 to 11 predicted harmful lifestyle during adolescence, including smoking, dropping out of school, and unplanned teenage pregnancy, and, in adulthood, health problems, substance dependency, financial difficulties, and criminal conviction (Moffitt et al., 2011). Overall, EF consists of several mental tools that play a fundamental role in a person's psychological and physical health throughout the lifespan and, consequently, could play an influential role in the mental health of young people during the COVID-19 pandemic.

EF is linked to processing speed. Processing speed is the length of time necessary to process information, formulate an appropriate reaction to it, and execute this reaction (Foong et al., 2018). It is strongly related to EF, especially updating (e.g., Fry & Hale, 1996). Some researchers argue that it is a separate, more primitive cognitive process that aids or setbacks the performance of EF, a more complex mental operation (Salthouse, 1996). For instance, Mulder et al. (2011) found evidence of processing speed deficit as mediating group differences between very preterm and term children in EF and their domains. Processing speed has been alternatively considered an additional EF domain by other researchers (e.g., Brown et al., 2011). Similar to EF, it is a predictor of real-world positive functioning (Puig et al., 2012), its deficit is related to psychopathology (Nigg et al., 2017), and it improves throughout the lifespan (Kail, 1991). Thus, in addition to general EF and EF subcomponents inhibition, switching, and updating, we test measures of processing speed in relation to pandemic response.

Growth and stability of EF across development

EF is an essential part of the cognitive development process from childhood through adolescence (Best & Miller, 2010), and longitudinal studies allow individual change, or growth, of EF to be observed across time. However, within-individual variability has largely been studied within limited contexts and age ranges. Li-Grining (2007) notes that EF's longitudinal change over time can happen in terms of *stability*, meaning that it has neither improved nor deteriorated over time, or *change,* when it has either improved or deteriorated. Past longitudinal research comparing toddlers in multiple timepoints has assessed EF variability. Moderate variability in common EF has been seen in toddlers at 24 and 39 months of age (Carlson et al., 2004) and among 2- to 4-year-olds observed 16 months apart (Li-Grining, 2007). Kochanska & Knaack (2003) observed high stability in children, comparing them at 22, 33, and 45 months of age. Additionally, McClelland et al. (2014) found that individual EF stability between ages two to four was associated with positive parenting (e.g., friendly and encouraging actions). Within-individual variation of EF has been understudied during middle childhood and adolescence, and it is important to evaluate how recent changes in EF ability may relate to outcomes during the COVID-19 pandemic, because of the known impact of other adverse experiences on youth well-being.

Adverse childhood experiences (ACEs)

There is a well-established link between adverse childhood experiences (ACEs) and *future* EF deficits (see Lund et al., 2020 for a review). ACEs refer to a wide range of negative childhood events, including household dysfunction and psychological, physical, or sexual abuse (Felitti et al., 1998). Prior research focused on EF as the mediator of *later* functioning among those who experienced early adversity. Kopetz et al. (2019) found that institutionalized children had less risk-taking behavior compared to a control group at age 12. The authors conceptualized that risk-taking was mediated by thrill-seeking and planning abilities, and that these planning could be impaired by EF deficit. The connection between ACEs, EF deficit, and mental health consequences persists throughout the lifespan. Accordingly, there is evidence that low EF in adulthood mediates the relationship between ACEs and broad mental health distress during adulthood (Trossman et al., 2021). Similarly, EF can be a protective factor against internalized symptoms, like anxiety and depression. For instance, Tsai et al. (2020) found that higher early adolescence EF had a protective effect against future anxiety in adolescents exposed to stressful life events.

Early studies have looked at EF in the context of the COVID-19 pandemic. Kira et al. (2021) found that the trauma from COVID-19-related stress predicted lower self-reported working memory and inhibition among adult Syrian refugees. In addition, Chahal and colleagues (2021) found that pre-pandemic coherence in the brain networks associated with EF was inversely related to increased internalized symptoms during the COVID-19 pandemic. This relationship was seen among those with earlier puberty maturation, suggesting that EF-related brain activity buffered against the internalizing symptoms that are more likely to occur in those with earlier pubertal maturation (Chahal et al., 2021). However, it is still unclear how pre-pandemic EF in youth – as measured with behavioral assessments rather than surveys – relates to cognitive, social, and emotional functioning during the COVID-19 pandemic.

The COVID-19 pandemic

Social isolation

The COVID-19 pandemic has been in existence for a full year and, as the outbreak and disruptions in routine continue, the long duration of impact could contribute to other types of mental health issues. Accordingly, several pre-pandemic cross-sectional and longitudinal studies evaluated children and adolescents' social isolation or loneliness using self-report questionnaires (see Loades et al., 2020 for review). They observed that loneliness and social isolation were associated with depression symptoms, generalized anxiety, social anxiety, and decreased well-being and mental health. Similarly, the adverse psychological effects of self-isolation experienced during previous disease outbreaks, such as the H1N1 epidemic, included post-traumatic stress symptoms in children in highly impacted countries (Brooks et al., 2020; Sprang & Silman, 2013). There is evidence that the length of loneliness is a better predictor of later mental health problems than the loneliness intensity (Qualter et al., 2009). During the severe acute respiratory syndrome (SARS) outbreak, longer periods of individual quarantine – meaning isolation due to possible exposure to contagious disease - were associated with post-traumatic stress symptoms, anger, and avoidance behavior in adults (see Brooks et al., 2020 for review). By having two different COVID-19 pandemic assessments times, we were able to assess change in mental health over an extended period of time.

Cognitive distress

There could also be an interplay between emotional distress and cognitive performance during the COVID-19 pandemic. Anxiety and stress could impact cognitive performance through an increase in mind wandering, during which unrelated thoughts could compete with processing needed for EF (Boals & Banks, 2020). Lavigne-Cerván et al. (2021) found that children and adolescents who were confined during the COVID-19 pandemic had higher anxiety and reduced sleep quality and self-reported EF compared to those who were not. In this study, youth participants who were in quarantine due to a country-wide mandate in Spain were compared to non-confined youth, as represented by the average levels of anxiety, sleep quality, and EF scores Those who reported higher anxiety also reported lower EF when compared to those without anxiety. Additionally, online learning might prove to be difficult, especially for those with learning disorders. Youth with ADHD has been shown to have more difficulties with online learning, trouble concentrating, and more overall cognitive burden during the pandemic (Becker et al., 2020; Porter et al., 2021)

Emotional distress

Several studies have identified emotional distress among children and adolescents during the COVID-19 pandemic and a series of factors associated with it. Anxiety, depression, and stress were more prevalent among those who reported being negatively impacted by quarantine, while they were less prevalent among those who were talking to parents about the pandemic and the perceived benefits of spending time at home (Tang et al., 2021). Anxiety and depression were also inversely associated with knowledge about the virus, preventative measures, pessimism over the future spread of the virus, and problem-focused coping styles (i.e., focused on problem-solving, social support, and beneficial rationalization), while they were positively associated with smartphone and internet addiction and emotion-focused coping styles (i.e., endurance, avoidance, fantasy, denial, and expression of emotions) (Duan et al., 2020; Zhou et al., 2020). Depression symptoms were also positively related to family and/or friends infected with the virus and fear of physical injury (Duan et al., 2020). Also, resilience and positive coping methods (e.g., positive appraisal, problem-solving, and seeking help) were found to be protective factors against depressive, anxiety, and stress symptomatology, while negative coping (e.g., avoidance and self-isolating) was a risk factor for these and trauma-related symptoms among adolescents (Zhang et al., 2020). Engagement coping (i.e., focused on the source of stress) was directly related to psychosocial adjustment, while dispositional coping (i.e., focused away from the source of stress) was positively associated with a negative outcome and to COVID-19-related stressors (e.g., fear of the future) (Domínguez-Álvarez et al., 2020).

Longitudinal studies beginning before and continuing during the outbreak allow for a more nuanced perspective on changes across the pandemic. Magson et al. (2020) compared adolescents' mental health before and during the outbreak. They found an increase in anxiety and depression symptoms and reduced life satisfaction. This was associated with higher COVID-19-related distress, while social connectedness was inversely related. Difficulties with online learning and conflict with fathers were positively associated with depression symptoms during the pandemic, while conflict with both parents moderated a decrease in life satisfaction. Also, there were low to moderate levels of COVID-19-related distress and low concern with the virus itself, but more concern with social life and extra-curricular activities.

Age may be a significant factor in how pandemic-related experiences related to mental health and EF. There are mixed findings regarding age differences in the pandemic's emotional burden. A higher age range (e.g., being an adolescent or at a higher grade) has been associated with increased prevalence of anxiety, stress, and depression symptoms and sleep disturbance (Lavigne-Cerván et al., 2021; Tang et al., 2021; Zhou et al., 2020). However, it has been associated with positive outcomes (e.g., social bonding) and positive coping skills (Domínguez-Álvarez et al., 2020). Other studies have also found no age difference in emotional distress during previous outbreaks (O'Reilly et al., 2020) nor the COVID-19 pandemic (Magson et al., 2020).

Pre-existing Burden

Pre-existing psychopathologies could be an issue during the COVID-19 pandemic, but there is no conclusive evidence as far as emotional distress. It has been speculated that previous psychopathology could be a risk factor during the COVID-19 pandemic (Fegert et al., 2020). For instance, Porter et al. (2021) found, through a longitudinal study, that pre-pandemic ADHD symptom burden predicted children and adolescents' higher cognitive and emotional burden during the pandemic. Among young and older adults, Pan et al. (2021) compared adults with and without previous mental health diagnoses before and during the beginning of the pandemic.

There was a significant increase in depression, loneliness, worry, and anxiety among those without mental health disorders. Interestingly, there was not a significant increase in symptoms among those with previous mental health disorders, but a decrease in depression and worry among those with higher severity and chronicity. As previously reviewed, EF has been associated with a number of psychopathologies, which may be attenuated or amplified by the COVID-19 pandemic. Consequently, EF abilities could be a protective factor within one's emotional, cognitive, and social experiences during the COVID-19 pandemic.

Conclusions

The COVID-19 pandemic is a stress-inducing context for children and adolescents. This context influences youth social, emotional, and cognitive experiences, the quality of which has been associated with a number of protective and risk factors. EF consists of a number of cognitive skills that play a fundamental role in several aspects of one's life and development, including response to adverse events. Although early COVID-19 studies reviewed above have looked at EF-related measures – including self-report and brain connectivity - as possible buffers to a negative experience amid the COVID-19 pandemic, here we examine EF tests collected in-person prior to the pandemic. Therefore, the current study addressed two things. First, whether EF abilities were a predictor of children and adolescents' outcomes during COVID-19, including emotional, cognitive, and social functioning. Second, whether pre-pandemic individual longitudinal growth in EF over time predicted children and adolescents' outcomes during the COVID-19 pandemic.

Materials and Methods

Design Overview

The primary question was whether pre-pandemic EF abilities and its growth over time predicted emotional, cognitive, and social experience during the COVID-19 pandemic. There were two main hypotheses. First, that higher pre-pandemic EF abilities would predict more positive emotional, cognitive, and social experiences amid the first year of the COVID-19 pandemic in youths. Second, higher growth of pre-pandemic EF over time would also predict more positive COVID social, cognitive, and emotional experiences in youths. The primary predictor variables were pre-pandemic common EF and its within-individual change over time. EF abilities were measured through eight tasks across the domains of inhibition, updating, and switching; Stop Signal, Animal Stroop, N-Back, Digital Span, Symmetry Span, Cognitive Flexibility, Local-Global, and Connections (Engelhardt et al., 2015; Engelhardt et al., 2019). The primary outcome variables were self-report of social, cognitive, and emotional experience amid the COVID-19 pandemic, as measured with the COVID-19 Adolescent Symptom and Psychological Experience Questionnaire (CASPE) (Ladouceur, 2020). Analyses were conducted on existing data from an ongoing longitudinal study with a community sample of children and adolescents over-recruited for mental health difficulties. The participants analyzed here completed one to four-yearly pre-pandemic EF measures and answered one or two online surveys about their experience amid the COVID-19 pandemic. The most recent cognitive data were used as the pre-pandemic EF abilities for hypothesis one, while for hypothesis two, those with at least three annual EF timepoints pre-pandemic were used to assess each participant's EF change EF over time.

Participants

We analyzed data from a total of 148 participants from a community sample of children and adolescents from a longitudinal EF study who completed one to hour yearly in-lab, pre-pandemic data collection timepoints, and answered the online CASPE survey one or two times during the COVID-19 pandemic. One participant was excluded due to unusually low EF performance across multiple tests (e.g., z-score = -3.18). The pre-pandemic data were collected from November, 2016 to March, 2020, while the COVID-19 survey's first collection timepoint spanned May to July, 2020, and the second spanned January to March, 2021. The average time interval between the most recent in-lab EF visit to the early-pandemic timepoint was around 13 months (*M* = 1.12 years, *range* = 0.2-3.68) and 21 months to the mid-pandemic timepoint (*M* = 1.77 years, *range* = 0.88-4.28).

Across all samples, the majority identified as white, and a great number of participants had a mental health diagnosis, with ADHD (with and without comorbidity) being the most common. See Appendix A Table 1 for the complete demographic information for each subsample, including race/ethnicity, income, diagnosis, and medication. Subsequent analyses exploring different covariates within the first hypothesis, during COVID-19 timepoint two, had different sample sizes, shown in Appendix A Table 2.

All data collection was reviewed and approved by the University of Texas at Austin Institutional Review Board. Parents of children younger than eighteen years of age provided informed consent while children provided assent before each data collection time point. Adult participants provided informed consent before each data collection time point. Participants within this sample were included in previous publications (Engelhardt et al., 2019; Nugiel et al., 2020; Roe et al., 2021). Pre-pandemic and COVID-19-era data used in this study was also used by Barendse et al. (2021, pre-print) and Porter et al. (2021).

Different inclusion criteria were applied to the two hypotheses. Additionally, each hypothesis was analyzed for each of the two COVID-19 survey timepoints, resulting in a total of four subsamples.

Hypothesis 1: Better EF abilities pre-pandemic will relate to better COVID-19 experiences.

The first hypothesis, included only the most recent pre-pandemic EF datapoint and was split into two sub-samples based on completion of the two COVID-19 timepoints. The sub-sample for the first COVID-19 timepoint included 134 participants (M_{age} = 15.2 years, *SD* = 3.03, *range* = 9.45-22.1). This sample included 61 females, 69 males, three non-binary, and one ‘prefer not to say’. The sub-sample for the second COVID-19 timepoint included 106 participants (M_{age} = 15.7 years, *SD* = 2.99, *range* = 10.1-21.7), of which 52 identified as females, 50 males, two non-binaries, and two ‘prefer not to say’. There were 92 overlapping participants between the two sub-samples for the first hypothesis.

Hypothesis 2: More EF growth over time will relate to better COVID-19 experiences.

The second hypothesis only included those with at least three pre-pandemic EF timepoints and at least one COVID-19 survey, again with each COVID-19 timepoint analyzed separately. The sample for the first COVID-19 timepoint had 76 participants (M_{age} = 15.9 years, *SD* = 2.76, *range* = 10.9-22.1), of which 29 were females, 44 males, two non-binaries, and one ‘prefer not to say’, and the second COVID-19 timepoint had 60 participants (M_{age} = 16.5 years, *SD* = 2.75, *range* = 11.6-21.7, 25 females, 31 males, two non-binaries, and two ‘prefer not to say’). There were 55 overlapping participants between the two sub-samples for this hypothesis.

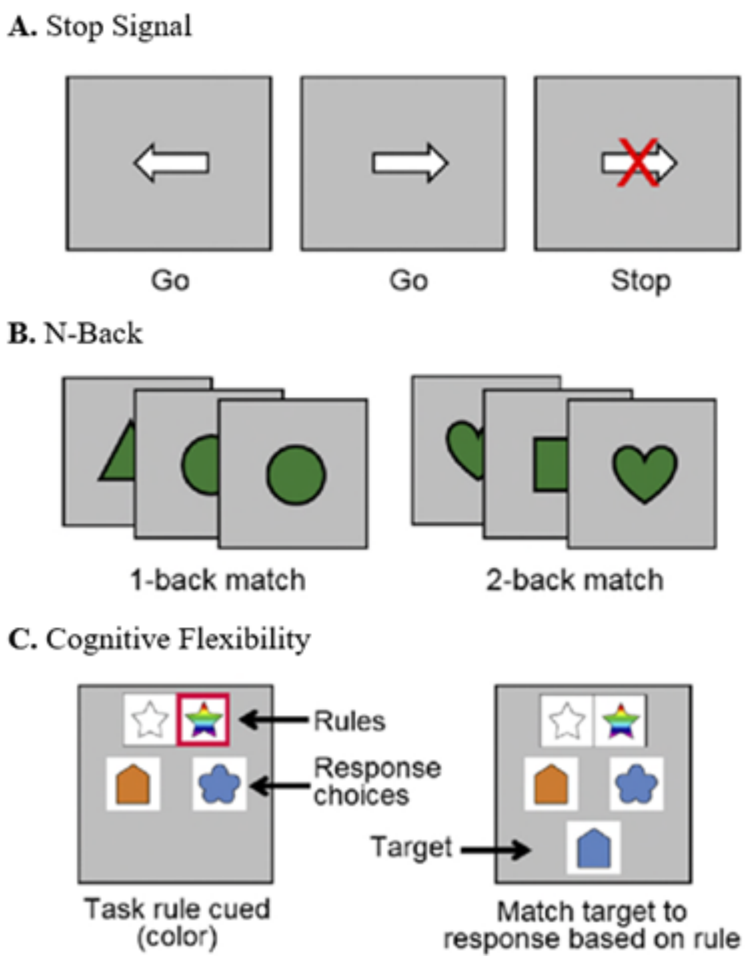
Materials and Measures

Inhibition tasks

Stop Signal. This was a 6-minute-long computer task that consisted of two types of trials: "go" and "stop" trials (Engelhardt et al., 2015; Engelhardt et al., 2019). During a "go" trial, participants were presented with an arrow pointing to the left or right, and they were instructed to indicate as fast as possible its direction, pressing the "F" key on a standard keyboard to signal left and "J" for right. During a "stop" signal trial, a red X showed up on top of the arrow soon after it appeared, which indicated that the participant should refrain from pressing any key. The time interval between seeing the arrow and red X varied depending on whether the participant correctly stopped (increasing 50ms if they were successful) or not (decreasing 50ms). See Figure 1A for an illustration of the task. Accuracy was calculated as the number of the correct go trials divided by the total number of go trials, 96. Engelhardt et al. (2015) found reliability using the Stop Signal Response Time measure (SSRT) was ($\alpha = 0.42$) and validity through a confirmatory factor model (See Appendix A Table 3 for complete task validity information). Individual trials were excluded if performance was lower than 70%, excluding task data from nine participant's most recent pre-pandemic timepoint.

Figure 1

Three EF Computer Tasks Illustrations



Note. Illustration of three EF computer tasks, with one from each sub-domain: A. Stop Signal, B. N-Back, and C. Cognitive Flexibility. Adapted from Nugiel et al. (2020).

Animal Stroop. This paper task consisted of correctly naming animals despite being presented with competing information (Engelhardt et al., 2015). There were three conditions, each lasting 20 seconds and repeated twice. In the congruent condition, participants were presented with three sheets with a series of illustrations of four animals – duck, sheep, pig, and cow – which they had to verbally name as many as possible. In the structural control condition, the same figures had a blank hexagon instead of the animal heads, and the participants were again instructed to identify the animals correctly. During the incongruent condition, each animal figure had the correct body but another animal's head, and the participants were instructed to name the animal bodies. Accuracy was calculated by summing the correct trials in the two repetitions of the incongruent condition and dividing by the total number of trials (n = 72). Engelhardt et al. (2015) assessed validity (Found at Appendix A Table 3) and found reliability across the congruent (α = 0.83), structural (α = 0.81), and incongruent (α = 0.86) conditions.

Updating tasks

N-back. This was a computer memory game where the participant was presented with a series of single shapes and asked to respond if the current shape matched the one before it (1-back) or the two before (2-back) (Engelhardt et al., 2015; Engelhardt et al., 2019). An instruction image appeared before each trial, indicating which rule the participant had to use. Performance was calculated as the number of 2-back trial correct responses subtracted by the number of 2-back false alarms - calculated as the participant's number of false alarms subtracted from the total number of possible ones (n =50) - dividing the total number of trials 2-back trials (n = 64). See Figure 1B for task illustration (Nugiel et al., 2020). Participant task data was excluded if there were fewer than four 2-back correct responses or more than 18 false alarms, which excluded seven individual scores at the most recent pre-pandemic timepoint. N-back's accuracy across trials, calculated as the difference between correct and incorrect responses, had high reliability (α = 0.84) and validity as a measure of updating, see Appendix A Table 3 (Engelhardt et al., 2015).

Digit Span. This paper task had two versions: the Wechsler Intelligence Scale for Children (WISC; Wechsler, 2003) Digital Span task, completed by adolescents up to the age of seventeen, and the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 2011) Digit Span task, completed by those seventeen or older. Both versions had two conditions in common. The forward condition consisted of hearing an increasingly long series of numbers and repeating it verbally back. The backward condition was similar to the forward one, but the participants were asked to repeat the series of numbers they heard in reverse order. All conditions ended after the participant got both trials of the same number of digits wrong, and there were 16 trials per condition. Accuracy was assessed by combining accuracy in the forward and backward conditions. Digital Span's within backward trials reliability was $\alpha = 0.57$ and task's validity has been assessed, found at Appendix A Table 3 (Engelhardt et al., 2015).

Symmetry Span. This computer task involved switching between two distinct segments (Engelhardt et al., 2015). First, the participant saw a 3x3 grid where a series of red squares flashed through the screen. After a certain number of red squares appear, the participant was asked to select in a blank grid the location and order in which each square appeared. In the second part, the participant was presented with an image composed of black and white squares, and the participant determined whether it was symmetrical. Then, the final task consisted of alternating between seeing the 3x3 grid with a flashing square, determining whether the black and white image was symmetrical, and indicating the position and order of the previously shown red squares. The number of flashing squares the participants needed to memorize increased throughout the task. Performance was evaluated by dividing the total number of red squares correctly recalled by the total possible trials ($n = 40$). The Symmetry Span task – as measured in the accuracy task trials – had its reliability ($\alpha = 0.77$) and validity assessed, described at Appendix A Table 3 (Engelhardt et al., 2015).

Switching tasks

Cognitive Flexibility. This computer task presented the participants with a changing rule across trials – to sort a target by its shape or color (See Figure 1C above for illustration; Engelhardt et al., 2019). The rule indicator (a red square around the relevant rule) appeared for 1.5 seconds and then disappeared. Then, the target appeared, and the participant had 2.0 seconds to signal a match with one of two response options via a keyboard. The switch conditions consisted of those in which the rule was different than the previous one, while the non-switch conditions included those in which these rules were the same. Accuracy was calculated as the total correct trials divided by the total possible trials, 46. Tasks data were excluded if accuracy was lower than 60%, removing data from four participants' most recent pre-pandemic timepoint. Engelhardt et al. (2015) explored the reliability ($\alpha = 0.94$) and validity (see Appendix A Table 3) of a similar task Plus-minus, which also involved switching between different rules.

Local-Global. This paper task included both switching and non-switching conditions (Engelhardt et al., 2015). All conditions involved looking at a larger letter or shape composed of different smaller letters or shapes, and each trial lasted thirty seconds. In the non-switching condition, the participant was asked to ignore the small letters/shapes and verbally name the big letters/shapes formed by them. Alternatively, participants were asked to ignore the big letters/shapers while naming the small ones in a subsequent version of the non-switching condition. In the switching condition, the participant needed to alternate between naming the small and big letters/shapes. The total number of trials for the non-switching condition was 120 letter trials and 140 shape trials, while the switching condition's total was 60 and 70 for letter and shape trials, respectively. Performance was calculated as mean accuracy – correct responses divided by the total possible trials - in the switching conditions. Engelhardt et al. (2015) assessed this task's validity (found at Appendix A Table 3) and found that reliability of Local Global within each condition was - non-switching condition, naming small letters/shapes (α = 0.84) or big letters/shapes (α = 0.75), and switching condition (α = 0.80).

Connections. This was a paper task that consisted of two conditions: switching and non-switching (Engelhardt et al., 2015). There were 47 circles spread across a page, in a 7x7 distribution, containing either or both numbers and letters. The non-switching conditions consisted of connecting a series of circles which contained only letters or, in another trial, only numbers to be linked in alphabetical (e.g., A-B, B-C) or ascending numerical order (e.g., 1-2, 3-4), respectively. In the switching conditions, these circles contained both numbers and letters on the same page, demanding that the participant alternate connecting letters to numbers (e.g., A-1, 1-B) or numbers to letters (e.g., 1-A, A-2). The order of the conditions was: numbers only, letters only, numbers to letters, and letters to numbers. This sequence was repeated twice, and the participant had twenty seconds to work on each trial. The total number of trials for the non-switching condition was 196, with total 98 trials in each of the number-only and letter-only conditions, while the switching condition's total was 98, with 49 in each of the letter-to-numbers and numbers-to-letters conditions. Accuracy in the switching conditions, as in the correct answers divided by the number of total possible trials, referred to the task accuracy. Engelhardt et al. (2015) assessed this task's validity (found at Appendix A Table 3) and reliability for the numbers-only (α = 0.88), letter-only (α = 0.83), number-to-letter (α = 0.76), and letter-to-number (α = .076).

Processing Speed

Symbol Search. This paper task consisted of two versions: the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2003) Symbol Search task, which was used for youth from up to the age of seventeen, and the Wechsler Abbreviated Scale of Intelligence (WAIS-II; Wechsler, 2011) Symbol Search task, completed by those seventeen or older. Both versions presented two distinct single-line-based geometric figures next to another set of five similar illustrations in each row. The participants determined whether any of the two-figure set was the same as any of the figures within the five-figure set. For the WISC-IV Symbol Search version, the participant crossed the word “yes” to indicate a match or “no” if there was none. In the WAIS-II version, the participant crossed a line through the repeated figure within the five-figure instead of crossing “yes.” If there was no match, they marked the word “no” at the right end of the row. There were 60 possible trials within both versions, and the participants had two minutes to complete as many of them as possible. Processing speed was calculated by dividing the number of correct answers from the total time used in the task. Engelhardt et al. (2016) assessed this task’s reliability ($\alpha = 0.79$) and validity, included at Appendix A Table 3.

Pattern and Letter Comparisons. In these paper tasks, the participant was presented with either two lines of patterns with a blank line between them, or two sets of letter combinations (Engelhardt et al., 2016). If the illustrations were the same, the participant wrote a capital letter “S” between them. On the other hand, if they were distinct, they would write a capital “D.” There were two 30-second trails, with a total of 30 exercises (arranged in two columns of fifteen patterns). The letter combinations within each line had the same number of letters (e.g., HCF and RCF), but were of different lengths across the page. Processing speed was calculated as the number of seconds per trial (30 seconds) was divided by the mean of correct response across both trials. Engelhardt et al. (2016) found this task’s reliability (pattern $\alpha = 0.84$; letter $\alpha = 0.85$) and validity, included at Appendix A Table 3.

Pre-COVID-19 Mental Health Burden

The Child Behavior Checklist (CBCL) (Achenbach & Rescorla, 2001) measured pre-COVID-19 general mental health symptom burden as completed by a participant's parent (if younger than 18). The 113-item questionnaire included questions about social, thought, and attention problems along with internalized and externalized symptoms. The mental health burden was measured as the total sum of these subcategory scores, with a higher score reflecting higher burden. It consisted of rating a series of statements about the child during the present or within the previous six months through a three-point scale, "Not True," "Somewhat or Sometimes True," and "Very True or Often True." An example of an internalized symptoms question was rating the statement "Too fearful or anxious" or "Feels too guilty" Similarly, the statement "Screams a lot" is an example of the externalized symptoms one. The combined raw score was used as a mental health symptom burden. This questionnaire showed, through confirmatory factor analysis, agreement with clinician-report of psychopathy presence and mean reliability ($\alpha = .80$) (Dutra et al., 2003).

Pre-Pandemic ADHD Symptom burden

Parents of participants younger than 18 completed the Conners-3 parent report about ADHD symptoms in their child (Conners, 2008). This questionnaire included 43 statements about their child, in which the parent-rated on a four-point scale - ranging from 0 "Not True (Never, Seldom)" to 3 "Very much true (Very often, Very frequently)" – to indicate how often they were true or had happened within the past month. Examples of a sample statement were "Restless or overactive" or "Has a short attention span." ADHD symptom burden included their total scores across questions about inattention, hyperactivity, impulsivity, and self-concept. Those who had missing data within the questionnaire questions had a prorated score calculated.

The Conners-3 has a high internal consistency coefficient (α = .88-.91) and its validity was assessed through factor analyses (Kao & Thomas, 2010).

Demographic Characteristics

The participants' date of birth was used to calculate age during the EF in-person sessions and COVID-19 survey completions. Gender was collected in the first COVID-19 survey but not in the second one. Therefore, this study included the most recent reported gender from the first COVID-19 timepoint and, if not available, the most recent in-person EF data timepoint. Data collection from the most recent pre-pandemic EF data timepoint included race and ethnicity, diagnoses, medication, and income information.

CASPE

Youth experiences during the pandemic were measured with the COVID-19 Adolescent Symptom and Psychological Experience Questionnaire (CASPE) (Ladouceur, 2020), which included questions about social, cognitive, and emotional experiences. See Appendix A Table 4 for complete questions used in both timepoints and grading. There were two social experience questions, which asked about frequency and time spent interacting with friends online. For instance, "Since your school has closed, how often do you talk/chat with friends online (including on your cell phone, on social media, or through online gaming)?" with the alternatives of "Every day or almost every day," "Several times a week," "About once a week," "Less often". These questions changed slightly from timepoint one and two, to accommodate the different moments in the year, but the content remained the same as the original questionnaire (Ladouceur, 2020). The cognitive experience portion included two questions. The first one included rating the extent to which the participant has experienced, in the past week, eleven statements (e.g., "easily distracted" and "easily switching tasks"), with a five-point Likert scale, ranging from "very slightly" to "extremely." The survey included five questions about emotional experience. For instance, participant were asked to rate how stressful they perceived the pandemic's uncertainty through a five-point Likert scale ranging from "very slightly" to "extremely." All questions were ranked with a five-point Likert scale, with statements reflecting positive emotions were reverse coded. This was a newly developed questionnaire, and no published study has yet evaluated its reliability and validity.

Positive questions were positively scored, while negative questions were reverse coded. The points from each question were summed with the other questions within their respective topic to compose the emotional, social, and cognitive experience scores. Subsequently, the three variable scores were converted to POMS, which refers to the participant score minus the measure's minimum possible score, divided by the measure's maximum score minus the minimum one, with a higher score reflecting better functioning. Using POMS scale facilitated comparison across the three experience variables. This data set was reverse coded to be a perfect negative correlation with Porter et al. (2021)'s data, who used the same data but scored the questions so that a higher score represented higher mental health burden.

Procedures

Pre-Pandemic Data Collection

The pre-pandemic data was collected through a three-hour-long in-person session that included the EF tasks and other measures not evaluated in this study. Participants and their parent/legal guardian (if participant was <18 years of age) gave consent and/or assent. Subsequently, some youth received actigraphy watches and were presented with a fake MRI scanner, intended for a subsequent neuroimaging data collection. The parent/guardian of youth <18 years filled out a series of questionnaires – including the CBCL and Conners-3 - in the first room, while the youth participant completed the data collection section in a separate room with the researcher. All tasks were verbally explained to the participant, followed by a brief practice before the actual task. The behavioral tasks administered were, respectively, Pattern Comparison, Stop Signal, Connection, N-Back, WISC/WAIC Symbol Search, Cognitive Flexibility, Animal Stroop, Symmetry Span, Letter Comparison, and Local-Global (Engelhardt et al., 2015; Engelhardt et al., 2019). There was a water break prior to Symbol Search. Then, a saliva sample was collected along with a biodata interview, followed by a snack break before completing three subsequent tasks - Wechsler Abbreviated Scale of Intelligence (WASI-II) (Engelhardt et al., 2016), WISC/WAIC Digit Span, and Test of Word Reading Efficiency, 2nd edition (TOWRE-2). There was an optional bathroom break between the first and second three tasks and another series of questionnaires before ending the session. After the completion of this visit, both the parent (if present) and youth participant received financial compensation.

The COVID-19 Surveys

The data collected during the COVID-19 pandemic occurred through an online survey at both timepoints. The participants and their parents (if older than 18) received an email explaining the study's intent along with a link for an online survey. They were additionally contacted through phone calls and/or text messages. The survey started with a consenting page, then there were adapted questions from the CASPE (Ladouceur, 2020), and subsequent questions about school, sleep, technology usage, and additional open-ended questions about their experience during the COVID-19 pandemic (with more questions of this type during the second timepoint). The participants included their email at the end of the survey if interested in receiving a $5 Amazon e-gift card, which they were later sent through email.

Statistical Analysis

Data were analyzed with R-4.1.1 (R Core Team, 2021) and R-Studio (RStudio Team, 2020). We visually inspected the data for outliers, while being as inclusive as possible. Unless noted otherwise, age during the respective COVID-19 timepoint was added as a covariate and all p-values were adjusted using the False Discovery Rate (FDR) correction (Benjamini & Hochberg, 1995).

Pre-Pandemic EF abilities as a COVID-19-era predictor

The first research question was whether EF predicted COVID-19 experience. I calculated the mean accuracy scores of all EF tasks across their respective domains - inhibition, updating, and switching - to compose the three EF domain variables. Common EF was calculated as the mean of the inhibition, updating, and switching scores. Multiple linear regressions was conducted with the common EF, inhibition, updating, and switching scores as a predictor and each of the COVID-19's social, cognitive, and emotional experience scores as outcome variables. All analyses were separately performed for COVID-era experience measurements during the first (May-July 2020) and second (January-March 2021) timepoints.

Pre-Pandemic EF growth as a COVID-19-era predictor

To evaluate whether pre-pandemic EF stability was a predictor of COVID-19 experience, multiple random slope models were used across three annual EF timepoints per person. If participants had four annual sessions, only the three most recent ones were selected. These analyses include calculating the slope of the regression lines between each individual's pre-pandemic common EF and the three domains. Afterward, these slopes were added as a predictor variable for a series of multiple linear regression models with each of the three COVID-19 experiences variables – social, cognitive, and emotional experience – as outcome variables. Again, these analyses were conducted for each COVID-19 timepoint.

Additional Exploratory Analyses

Data from participants with both COVID-19 timepoints (n= 92) were used to explore whether the two timepoints' social, cognitive, and emotional experiences differed through three within-subject t-tests. Also, additional exploratory linear models were used to determine whether a series of covariates affected EF and processing speed results. Diagnosis presence/absence, gender, processing speed, mental health burden, ADHD symptom burden, and income were added as predictor variables alongside EF and their domains in separate multiple linear regression models. The outcome variables throughout all analyses were social, cognitive, and emotional experiences during the COVID-19 pandemic. Processing speed was calculated as the mean of the three processing speed tasks. Whether these variables – above and beyond age - were a significant predictor of experience during the COVID-19 pandemic separately was also evaluated.

Results

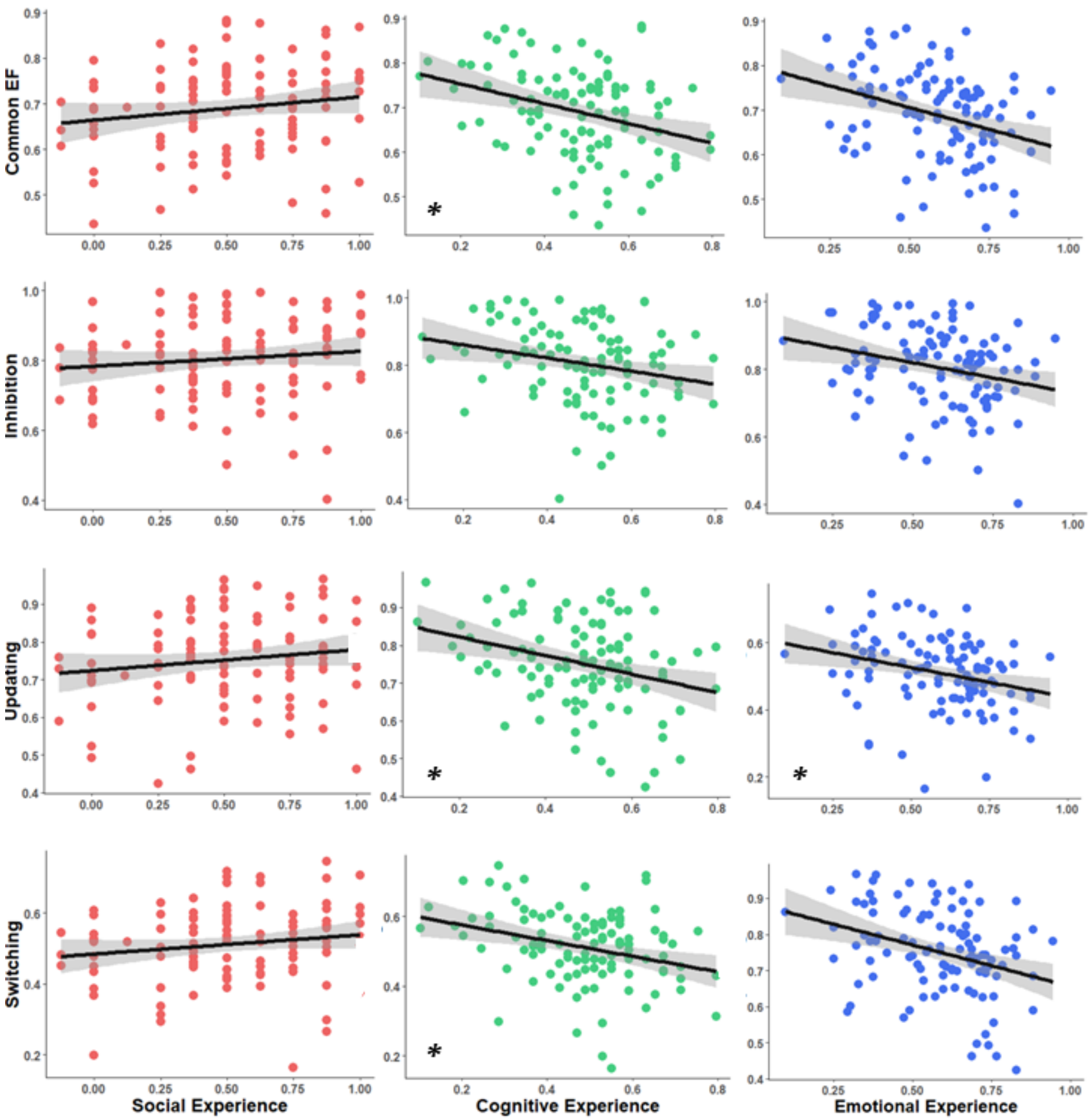
Question 1: Pre-Pandemic EF abilities as a COVID-19-era predictor

We tested whether common EF, and its subdomains of inhibition, updating, and switching, were predictors of early pandemic (May-July 2020) social, cognitive, and emotional functioning in youths. I hypothesized that better EF abilities would predict better functioning. Counter to the hypothesis, there was no relationship between any EF factor and any aspect of early pandemic functioning. At COVID-19 timepoint one, social experience and pre-pandemic common EF ($\beta = 0.29$, $p = 0.67$), inhibition ($\beta = 0.35$, $p = 0.74$), updating ($\beta = 0.039$, $p = 0.88$), and switching ($\beta = 0.26$, $p = 0.64$) relations were not significant. Similarly, common EF ($\beta = 0.14$, $p = 0.67$), inhibition ($\beta = 0.07$, $p = 0.93$), updating ($\beta = 0.11$, $p = 0.88$), and switching ($\beta = 0.08$, $p = 0.64$) were not significant predictors of early-COVID-19 cognitive experience. Finally, youth early-pandemic emotional experience had no relationship with common EF ($\beta = -0.0012$, $p = 0.99$), inhibition ($\beta = 0.014$, $p = 0.93$), updating ($\beta = -0.07$, $p = 0.88$), and switching ($\beta = 0.11$, $p = 0.64$).

We next assessed whether common EF or any of its three domains predicted mid-pandemic (January-March 2021) social, cognitive, and emotional experiences in youths. I hypothesized that better EF abilities would predict more positive social, cognitive, and emotional experiences during COVID-19. While we found significant relations with cognitive and emotional experiences with EF at this timepoint, they were not in the predicted direction (Figure 2). There were no significant predictors of social experiences: common EF ($\beta = 0.46$, $p = 0.23$), inhibition ($\beta = 0.20$, $p = 0.56$), updating ($\beta = 0.32$, $p = 0.23$), and switching ($\beta = 0.43$, $p = 0.24$). Mid-pandemic cognitive experience was related to pre-pandemic common EF ($\beta = -0.48$, $p = 0.022$), updating ($\beta = -0.33$, $p = 0.013$), and switching ($\beta = -0.41$, $p = 0.049$) abilities, such that better EF, updating, and switching abilities predicted worse cognitive functioning. Inhibition was not related to cognitive functioning (β = -0.24, p = 0.38). Worse updating abilities was a significant predictor of better emotional experience, β = -0.39, p = 0.013, while worse common EF was a significant predictor before multiple comparisons correction, (β = -0.43, p = 0.037, uncorrected; p = 0.055, corrected). Inhibition (β = -0.17, p = 0.52) and switching (β = -0.25, p = 0.24) were not significant predictors of mid-pandemic emotional functioning. Common EF, inhibition, updating, and switching as predictors of mid-pandemic experience was tested with just the participants who completed both surveys (n = 92), yielding weaker but consistent results as the main findings at this timepoint (See Appendix B Table 1).

Figure 2

Research Question 1, COVID-19 Timepoint 2



Note. Common EF, and subdomains of inhibition, updating, and switching as predictors of social, cognitive, and emotional experience at the COVID-19 pandemic second timepoint (January-March 2021). The relationships are displayed without age regression, while all reported statistics had age as a covariate. *$p < 0.05$, FDR corrected.

Question 2: Pre-Pandemic EF growth as a COVID-19-era predictor

We next tested whether change over 3-years in common EF, and its subdomains of inhibition, updating, and switching, were predictors of early pandemic social, cognitive, and emotional functioning in youths. It was hypothesized that higher growth preceding COVID-19 would predict more positive early pandemic functioning. Against these expectations, all results were null. Pre-pandemic common EF (β = -7.00, p = 0.41), inhibition (β = 1.29, p = 1.00), updating (β = -0.72, p = 0.70), and switching (β = 0.60, p = 0.72) slopes were not significant predictors of early-pandemic social experience. Similarly, early pandemic cognitive experience was not related to pre-pandemic slopes of common EF (β = 0.19, p = 0.94), inhibition (β = *-0.21*, p = 1.00), updating (β = -0.48, p = 0.70), and switching (β = -0.65, p = 0.72). Lastly, the pre-pandemic slopes of common EF (β = 1.13, p = 0.94) inhibition (β = 0.0048, p = 1.00), updating (β = *-0.74*, p = 0.70), and switching (β = -0.55, p = 0.72) did not relate to early pandemic emotional experience.

We then investigated these relationships at the mid-pandemic (January-March 2021) timepoint, hypothesizing that higher growth in pre-pandemic EF, updating, inhibition, and switching abilities would predict better mid-pandemic social, cognitive, and emotional functioning. However, these results were also all null. Pre-pandemic common EF (β = 1.68, p = 0.49), inhibition (β = 1.40, p = 0.51), updating (β = 1.29, p = 0.73), and switching (β = 1.28, p = 0.57) slopes were not significant predictors of social experience, cognitive experience (common EF (β = -0.69, p = 0.49), inhibition (β =-0.54, p = 0.51), updating (β = -0.42, p = 0.73), and switching (β = -0.64, p = 0.57)), or emotional experience (common EF (β = -1.29, p = 0.49) inhibition (β = -1.06, p = 0.51), updating (β =-1.55, p = 0.73), and switching (β = -0.53, p = 0.57).

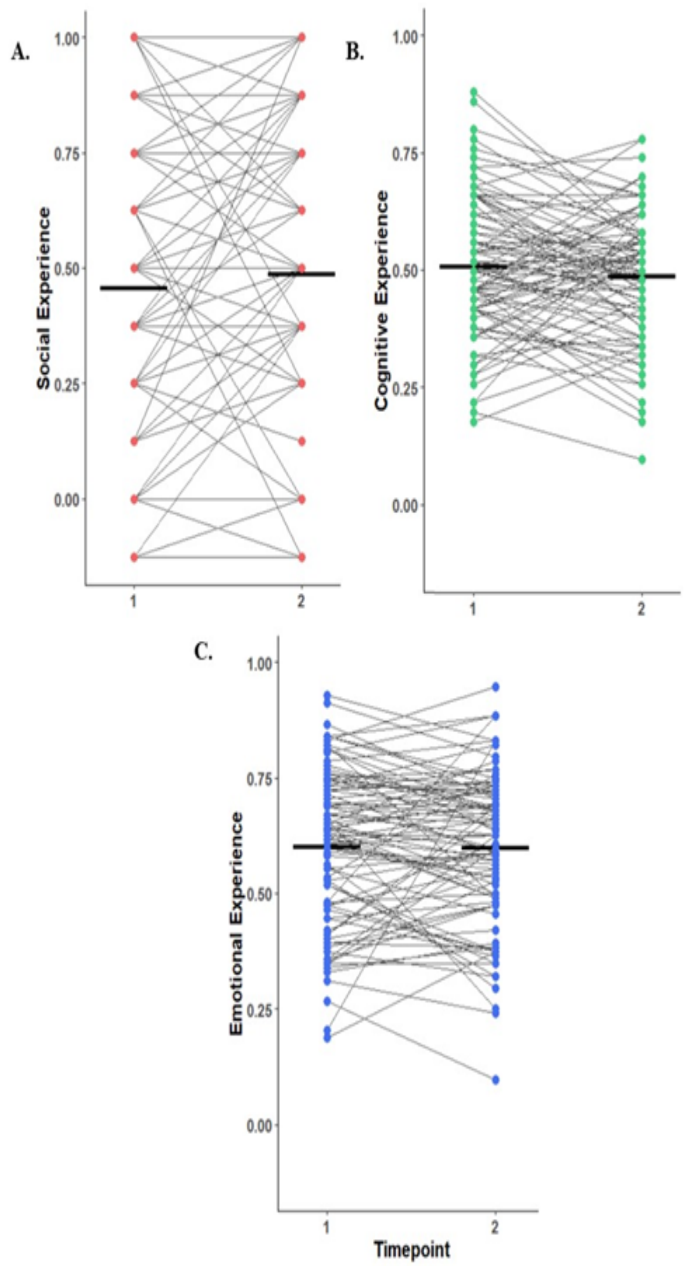
Additional Exploratory Analyses

COVID-19 Timepoint-to-Timepoint Change

For participants who completed both COVID-19 timepoint surveys, a within-subjects t-test was used to evaluate whether early- and mid-pandemic social, cognitive, and emotional experience differed (n = 92). As shown in Figure 3, there were no significant group-level differences between early and mid-pandemic social ($t(91) = -1.013$, $p = 0.47$), cognitive ($t(91) = 1.39$, $p = 0.47$), and emotional ($t(91) = 0.26$, $p = 0.80$) experiences, although there was great variability within individuals.

Figure 3

Early and Mid-COVID-19-Era Experience Change



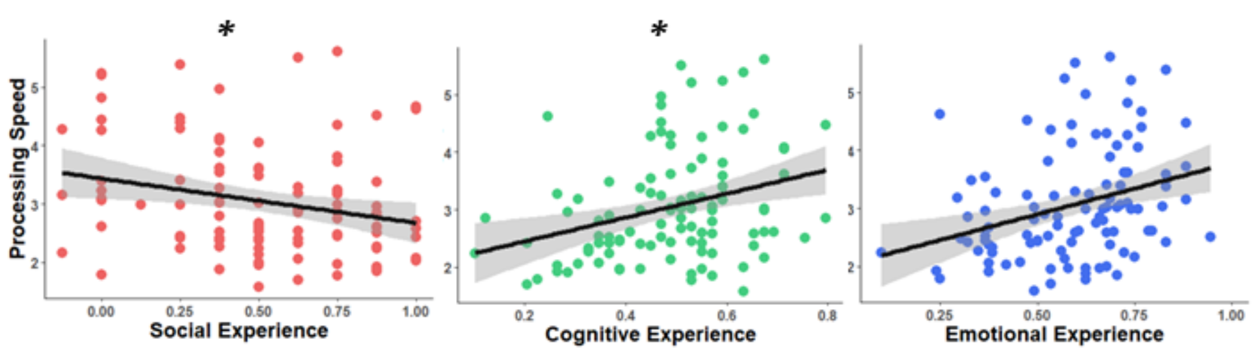
Note. Individual change in CASPE scores between early and mid-pandemic collection timepoints (n=92). A. Social, B. Cognitive, and C. Emotional experiences. Points represent individual participants, with thin lines connecting each participant's early and mid-pandemic experiences. Bolded horizontal lines indicate group mean within each timepoint.

Processing Speed

I evaluated whether pre-pandemic processing speed was a predictor of early and mid-pandemic social, cognitive, and emotional experience (see Figure 4). Pre-pandemic processing speed ability was significantly related to early-pandemic social experience before FDR correction (β = -0.078, *uncorrected p* = 0.033, *adjusted p* = 0.098), such that faster processing speed predicted higher online social engagement. Processing speed was not a significant predictor of early-pandemic cognitive (β = -0.016, p = 0.42) or emotional (β = -0.016, p = 0.42) experience. At the second pandemic timepoint, better pre-pandemic processing speed abilities significantly predicted worse cognitive functioning, β = 0.046, p = 0.023, and better social functioning, β = -0.097, p = 0.023, similar to what was observed with EF measures. Better processing speed also marginally predicted worse emotional experience (β = 0.041, p = 0.062). A sensitivity analysis including only participants with data from both COVID-19 timepoints was performed, and yielded weaker results, but with the same pattern (See Appendix B Table 1).

Figure 4

Processing Speed and COVID-19 Timepoint 2



Note. Relationship between processing speed and mid-pandemic social, cognitive, and emotional functioning. All linear regression statistics had age as a covariate, but the graphs are displayed without age regression. *p < 0.05 corrected for multiple comparisons.

I additionally assessed whether controlling for age and processing speed affected the EF results on mid-pandemic social, cognitive, and emotional functioning. When put in the model together with age, pre-pandemic EF, inhibition, updating, switching, and processing speed were not independent significant predictors of mid-pandemic social, cognitive, and emotional functioning in these models; pre-pandemic EF and processing speed measures shared considerable variance in pandemic outcomes (See Appendix B Table 2).

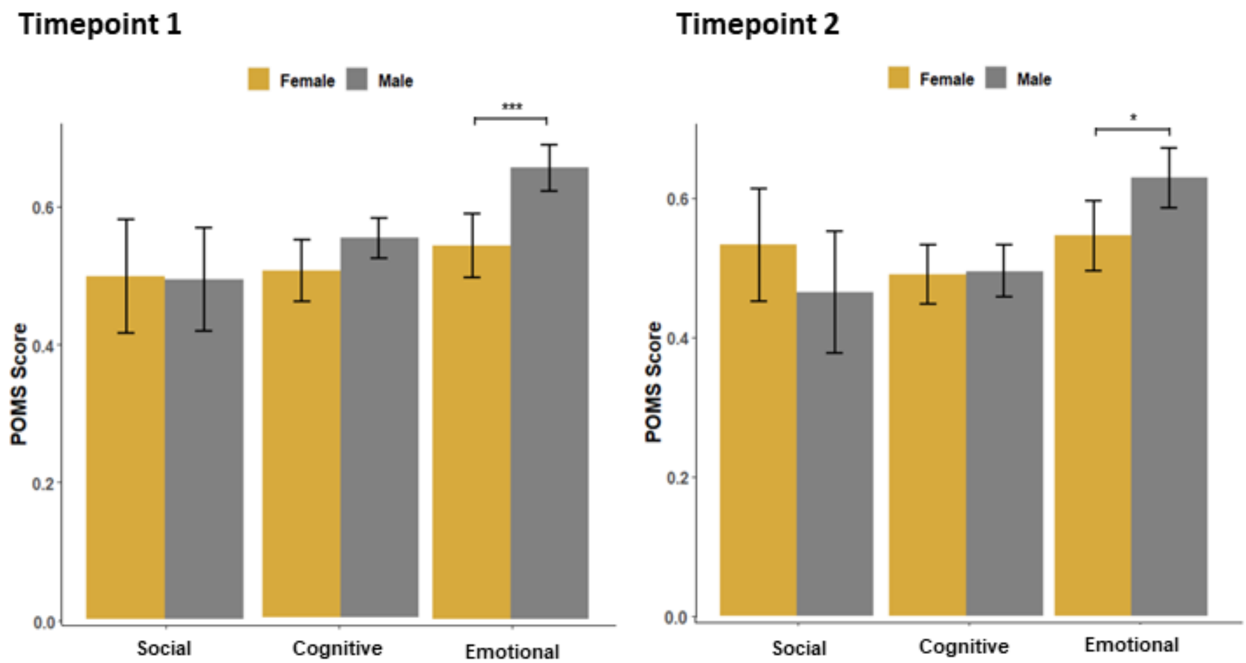
Gender

We tested whether there were gender differences in early- and mid-pandemic social, cognitive, and emotional functioning (Figures 5). There were no gender differences in social function during the beginning ($t(128) = 0.086$, $p = 0.47$) and middle ($t(100) = 1.15$, $p = 0.93$) of the COVID-19 pandemic. There were also no gender effects in cognitive experience during the first ($t(128) = -1.82$, $p = 0.11$) and second ($t(100) = -0.19$, $p = 0.85$) COVID-19 timepoints. There was a significant gender difference in emotional experience both early ($t(128) = 3.99$, $p = 0.00033$) and in the middle of ($t(100) = -2.51$, $p = 0.041$) the COVID-19 pandemic, such that males reported better emotional functioning than females during both timepoints.

Controlling for gender did not alter the predictor abilities of common EF, inhibition, updating, and switching in mid-pandemic functioning above (See Appendix B Table 1).

Figure 5

Early and Mid-COVID-19 Pandemic Gender Differences



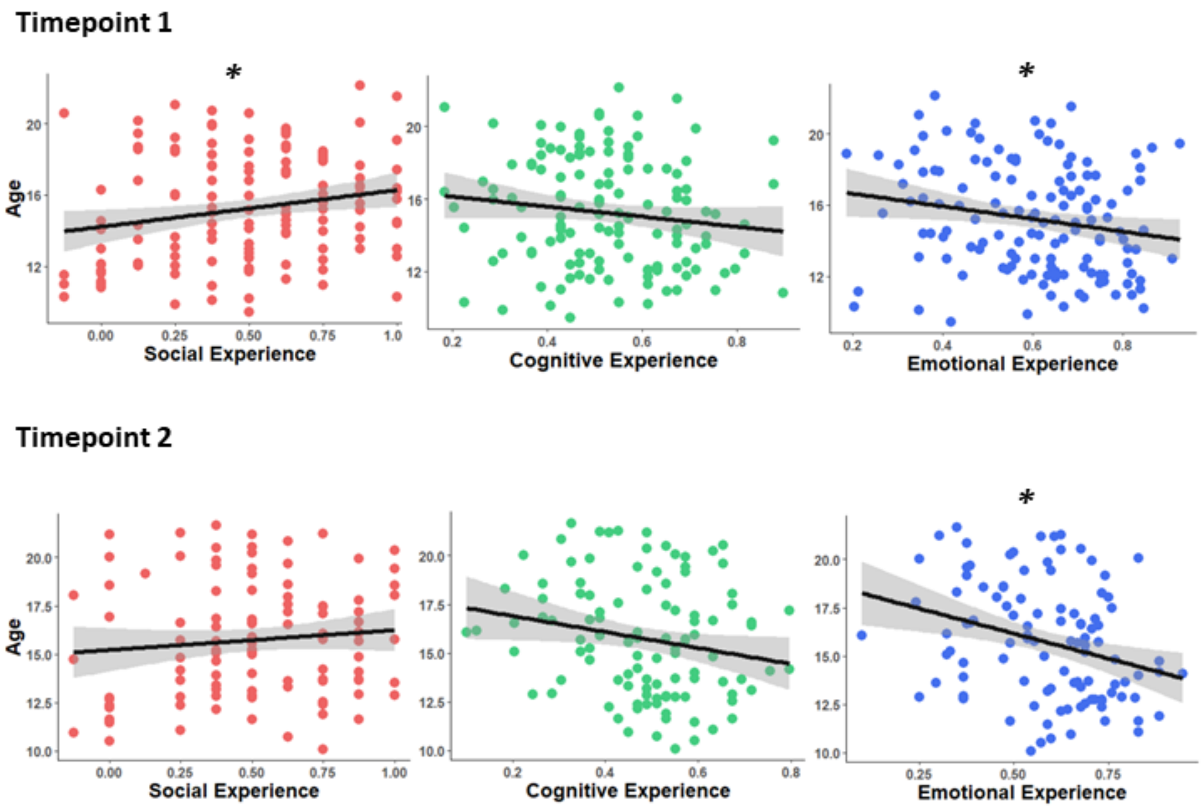
Note. Gender difference in early-pandemic social, cognitive, and emotional experiences. Showing M ± SE data. ***$p < 0.001$.*$p < 0.05$.

Age

I next tested whether youth age was a predictor of COVID-19 functioning during the two timepoints (See Figure 6). Age significantly predicted more early-pandemic social functioning ($\beta = 0.022$, $p = 0.034$), meaning that older youth more frequently interacted with peers online, but age did not predict mid-pandemic social interactions ($\beta = 0.011$, $p = 0.28$). Age was not a significant predictor of early cognitive experience ($\beta = -0.0069$, $p = 0.11$), although there was a significant relationship mid-pandemic before FDR correction ($\beta = -0.0096$, *uncorrected p* = 0.041, *adjusted p* = 0.061), indicating older individuals experienced slightly worse cognitive functioning. Also, older age was a significant predictor of more negative report of emotions on both the early (β = -0.011, p = 0.034) and mid (β = -0.017, p = 0.0059) COVID-19 pandemic surveys.

Figure 6

Age and COVID-19 Emotional and Social Experience



Note. Age as predictors of early and mid-pandemic emotional, cognitive, and social experience. **p < 0.05, FDR-corrected for multiple comparisons.*

Income

I tested whether the most recent pre-pandemic income was a predictor of youth experience during the two COVID-19 timepoints. Income was not a significant predictor of the early-pandemic social (β = -0.000000086, p = 0.97), cognitive (β = 0.0000030, p = 0.97), and emotional (β = 0.0000033, p = 0.97) experiences. Similarly, income did not significantly predict mid-pandemic social (β = 0.0000030, p = 0.69), cognitive (β = -0.0000029, p = 0.91), and emotional (β = 0.0000089, p = 0.98) functioning. Controlling for age and income did not alter the original results between common EF, inhibition, updating, and switching and mid-COVID-19 pandemic social, cognitive, and emotional functioning (See Appendix B Table 2 for complete results).

Mental Health Burden

Pre-pandemic mental health burden was explored as a predictor of social, cognitive, and emotional experience during the two COVID-19 timepoints using parent-reported CBCL (n = 97). Symptom burden did not significantly predict children and adolescents' early pandemic social ($\beta = 0.007$, $p = 0.46$), cognitive ($\beta = -0.06$, $p = 0.084$), and emotional ($\beta = -0.10$, $p = 0.24$) functioning. Similarly, mental health burden did not significantly predict youth mid-pandemic social ($\beta = 0.0030$, $p = 0.79$), cognitive ($\beta = 0.053$, $p = 0.28$), and emotional ($\beta = 0.071$, $p = 0.61$) functioning.

Additionally, controlling for age and mental health burden did not alter the inhibition, updating, and switching results (See Appendix B Table 2 for full results). However, common EF was a predictor of second timepoint pandemic cognitive functioning was significant before FDR ($\beta = -22.27$, $p = 0.0188$), but only marginally significant after the correction ($p = 0.056$) when mental health burden was included as a covariate. Similarly, switching was only a significant predictor of mid-pandemic cognitive experience before FDR correction ($\beta = -20.16$, *uncorrected* $p = 0.021$, *adjusted* $p = 0.062$) in this model.

ADHD Symptom Burden

I tested whether pre-pandemic ADHD symptoms predicted early- and mid-pandemic social, cognitive, and emotional experience using Connors-3 parent-report (n=97). There was no significant relationship between pre-pandemic ADHD symptom burden and early pandemic social ($\beta = 0.014$, $p = 0.35$), cognitive ($\beta = -0.088$, $p = 0.12$), and emotional ($\beta = -0.12$, $p = 0.35$)

functioning. Pre-pandemic ADHD symptoms were not a significant predictor of mid-pandemic social (β = 0.0014, p = 0.94), cognitive (β = 0.055, p = 0.42), and emotional (β = 0.26, p = 0.18) functioning. Controlling for pre-pandemic ADHD symptom burden, along with age, did not alter the original relationship between common EF, inhibition, updating, and switching and youth mid-pandemic experience. See Appendix B Table 2 for these results.

Diagnosis Presence

I also tested whether there was a group-level difference between those with a diagnosed mental health issue and those who were undiagnosed on early- and mid-pandemic functioning. There were no differences between these groups in social functioning during the first months of the COVID-19 pandemic (t(132) =-0.71, p = 0.48) or in the middle (t(104) =0.28, p = 0.78). Similarly, there was no diagnosed-based group difference in cognitive experience during the first (t(132) = 1.8, p = 0.22) and second (t(104) = 0.71, p = 0.78) timepoints. Lastly, there was no diagnosis-presence difference in early (t(132) = 1.24, p = 0.31) and mid- (t(104) = -0.29, p = 0.78) pandemic emotional experience. Adding diagnosis presence as a covariate with age did not alter the main EF results. See Appendix B Table 2 for results.

Discussion

Pre-Pandemic cognitive abilities relate to mid-pandemic experiences

Executive function

It was hypothesized that better pre-pandemic EF abilities would predict more positive social, cognitive, and emotional functioning during the two COVID-19 timepoints. However, our study found that better EF predicted worse mid-pandemic functioning. More specifically, stronger common EF, updating, and switching abilities significantly predicted worse youth cognitive functioning, while (although marginally) common EF and updating predicted worse youth emotional functioning. We consider these findings in the context of existing literature on rumination, worry, and pre-pandemic quality of life.

Our findings suggest a potential relationship between more advanced cognitive development and worry in youth. Perica and colleagues found that higher pre-pandemic hippocampal-prefrontal connectivity predicted higher mid-pandemic anxiety among 10-19-year-old individuals (Perica et al., *in press*). These brain networks have been associated with memory formation, emotional processing, and high-order cognitive processing, including decision making and planning abilities. Based on these results, the authors hypothesized that adult-like cognitive abilities support future thinking that promotes stress-induced worry (Perica et al., *in press*). EFs are higher-order mental processes that support this type of cognitive activity (Kopetz et al., 2019). Additionally, Muris et al. (2002) found a positive association between broad cognitive abilities and worry among youth. These cognitive abilities are hypothesized to promote thinking about future events and anticipate the adverse outcomes needed for worry, especially among older children and adolescents (Muris et al., 2002; Songco et al., 2020). Therefore, more mature cognitive abilities could have worsened mid-pandemic cognitive and emotional functioning through heightened worry by supporting planning, meta-cognition, and future-focused thinking.

The relations between better EF and worse emotional and cognitive functioning are also consistent with the biocognitive vulnerability-stress model. This model describes how normative adolescent brain and EF development needed for negative cognitive style (i.e., negatively interpreting life events) are required for depression (Alloy & Abramson, 2007). Two processes would mediate this relationship: first, cognitive resources are required to evaluate hypothetical undesirable consequences of current stressful events, leading to the feeling of hopelessness; Second, updating is hypothesized to be especially fundamental for the development of rumination and self-regulation due to its role in keeping information in one's mind (Alloy & Abramson, 2007; Altamirano et al., 2010; Wagner et al., 2014; Zetsche & Joormann, 2011). Our study's findings are remarkably consistent with this model: the domain of updating drove the relationship between EF and COVID-19 functioning. Thus, we propose that better EF abilities – especially updating - could have acted as prerequisites for rumination and negative interpretations of the stress-inducing pandemic and, therefore, related to worse mid-COVID-19 pandemic emotional and cognitive experiences.

Alternatively, these findings could be reflecting better pre-pandemic overall quality of life in those with better EF skills. Better EF has been associated with higher extraversion (Campbell et al., 2011), optimal school performance (e.g., Duncan et al., 2007) and quality of life (Brown & Landgraf, 2010; Zhang et al., 2021). Therefore, individuals with better pre-pandemic EF could have experienced more enjoyment out of social and academic experiences that were unavailable mid-pandemic, including in-person peer interaction, school engagement, and quality time at school. The loss of these experiences could have contributed to worse mid-pandemic emotional and cognitive functioning, as that survey was collected halfway through the unusual school year of 2020-2021.

Processing Speed

There was strong agreement between EF and processing speed results. Better processing speed predicted more negative mid-pandemic cognitive experience and marginally predicted worse emotional experience. Processing speed is highly correlated with EF abilities, and, consequently, better processing speed could relate to worse pandemic emotional and cognitive functioning through similar mechanisms as discussed above. These findings are consistent with previous literature describing the strong link between EF and processing speed (e.g., Fry & Hale, 1996), and similar relations between faster processing speed and better quality of life (Ojeda et al., 2012), and academic performance (Mulder et al. 2010). Processing speed and EF are not always collected within the same datasets, and thus our study presented an important opportunity to examine them both within the same individuals. The similar impact of processing speed and EF on pandemic results indicate that better cognitive functioning may relate to worse pandemic cognitive and emotional outcomes, rather than something specific to EF. Processing speed showed a protective role on mid-pandemic social functioning, as better processing speed predicted more frequent online social interactions; we did not see this result with the EF data. Previous studies have shown a similar protective effect of processing speed within social interactions. For instance, Bachman and colleagues (2011) found that faster processing speed predicted social functioning (e.g.., interpersonal and professional interactions) one year in advance among individuals with adolescent-onset of psychosis. The first year of the COVID-19 pandemic was marked by social distancing guidelines, which may have limited children and adolescents' in-person opportunities for social interaction. Within this context, our results suggest that better processing speed could facilitate adaptation from this shift from in-person to online means of interacting with others. Shultz et al. (2016) found that slower processing speed - but not executive dysfunction - mediated the relationship between children's previous pediatric traumatic brain injury and less social involvement, while the interaction of EF and processing speed was associated with better adaptive abilities. Also, faster processing speed has been independently associated with better adaptive skills among youth survivors of childhood cancer (Thornton et al., 2021). Therefore, better processing speed could relate to better mid-pandemic social functioning through more optional adaptation.

No Early Pandemic Effects

It is noteworthy that we found no relationship between pre-pandemic common EF, and the domains of inhibition, updating, and switching, with early COVID-19 functioning. Our results underscore the importance of timing in pandemic surveys, suggesting distinctions between the early and mid-pandemic periods. The initial months of the pandemic – including May to July of 2020 – were marked by widespread uncertainty and fear about COVID-19. On the other hand, the pandemic and its social distancing guidelines had continued or changed for several months by the second COVID-19 timepoint (January-March,2021). It is possible that in times of international uncertainty and shutdown that cognitive abilities do not impact interpretation and coping in youth. Subsequently, however, cognitive abilities could have been more critical (as assessed during the second timepoint), when there was more information available about the COVID-19 as a virus, and there was more individual variation in how households managed their pandemic response. The information needed for future-oriented thinking could have contributed to more worry and rumination among those with better cognitive abilities at this later timepoint. Great within-individual change in early and mid-pandemic social, cognitive, and emotional functioning, can be observed in Figure 3.

Metacognition (i.e., awareness of self-cognitive processes) could also explain timepoint differences in self-reported emotional and cognitive experience. A portion of the CASPE emotional functioning questions inquired about individual's emotional states in comparison to before the COVID-19 pandemic (e.g., "Compared to before the COVID-19 outbreak") instead of at the current week (e.g., "In the past 7 days") (Ladouceur, 2020). Similarly, some cognitive questions asked participants to indicate whether they perceived to be "More Focus," for instance, compared with before COVID-19 (Ladouceur, 2020). Better long-term recollection of cognitive state has been associated with better metacognition, and also with stronger EF abilities (see Roebers, 2017, for a review). Therefore, the association between better cognitive abilities and self-reported worse emotional and cognitive experience could be mediated by metacognition abilities. These metacognition abilities would be more strongly needed for mid-pandemic retrieval compared to early-pandemic, due to the longer time interval between the pre-COVID-19 period and survey completion. This additional cognitive demand could also have mediated EF and processing speed as better predictors of mid-pandemic functioning instead of early pandemic functioning.

Gender and Age

Girls were found to experience worse emotional functioning than boys early- and mid-pandemic. These findings are consistent with other studies that found higher rates of internalized symptoms among female youth than males during early (Duan et al., 2020; Zhou et al., 2020) and mid-pandemic (Perica et al., in press). This pattern could reflect increased stress vulnerability among females (e.g., Natsuaki et al., 2009) or normative higher depression and anxiety rates among girls outside of the context of the pandemic (e.g., Alloy & Abramson, 2007). However, these results were independent of our EF results, suggesting a somewhat separate phenomenon impacting reports of pandemic well-being, and an effect limited to emotional responses, rather than cognitive or social responses.

Older participants also experienced worse emotional functioning early- and mid-pandemic. This finding is consistent with the idea that cognitive maturation relates to worse COVID-19-era functioning, and indicates that development more broadly – independent of cognitive development – is also related to worse emotional functioning during COVID-19. Our age result also agrees with earlier studies showing higher anxiety in older youth during the first few months of the pandemic (e.g., Duan et al., 2020; Zhou et al., 2020). No other study has yet looked at age differences in youth mid-pandemic internalized symptoms of anxiety and depression. As our EF results held after accounting for age, our age results may relate to increasing internalized symptoms observed during the adolescent period overall, independent of the pandemic (see Davey et al., 2008 for a review).

Older youth interacted with peers online more often than younger participants during the beginning of the pandemic, but not mid-pandemic. Two possible related explanations for this pattern are first, that older participants already communicated more often through online platforms pre-pandemic, and as social distancing guidelines continued, younger youth came to adopt online communication at a higher rate, or second, it could indicate that older participants adapted more quickly to social distancing measures but that this difference diminished as the pandemic endured. Future studies should examine online interactions in adolescence in more detail, as our surveys were not extensive in this regard.

Pre-Pandemic Mental Health and Socioeconomic Status

Common EF, updating, and switching results remained largely unaltered when separately controlling for mental health burden, ADHD symptom burden, diagnosis presence, or income. These results indicate that cognitive ability predicted pandemic emotional and cognitive functioning across important differences in individual experience. Controlling for these variables was particularly important considering previous evidence of the relationship between EF and processing speed with socioeconomic status (Hackman et al., 2015), mental health burden (Robson et al., 2020), and most psychopathologies, especially ADHD (Gur et al., 2019; Snyder et al., 2015). Also, these pre-pandemic covariates were particularly important to examine in this sample, as 53% of participants had at least one mental health diagnosis, with ADHD being the most common diagnosis (81%). However, some of the common EF and switching predictive power on pandemic cognitive experiences was lowered when accounting for pre-pandemic mental health burden, and thus mid-pandemic cognitive experience partially reflected this pre-existing condition.

Pre-Pandemic EF growth did not predict early and mid-pandemic experiences

Contrary to our second hypothesis that higher pre-pandemic EF growth would predict more positive COVID-era functioning, EF growth did not predict youth social, cognitive, and emotional functioning during either COVID-19 survey timepoint. The lack of significant relationships could reflect insufficient power within this study, as Willoughby et al. (2019), in a larger sample of children (n = 6,040) from pre-kindergarten to the second grade, found a small but significant association between within-individuals EF change over time and academic achievement. Regardless, here, growth in EF pre-pandemic did not act as a protective, nor risk, factor for COVID-19-era positive functioning, indicating that level of cognitive abilities preceding COVID-19 were more important than their amount of pre-pandemic change.

Strengths and Limitations

The collection of multiple EF and processing speed measures within a relatively large sample of adolescents is a strength of the current study, compensating for possible noise within each task. In addition, the two COVID-19 timepoints allowed for a more complete picture of the first year of the COVID-19 pandemic, which is especially important as COVID-19 has been a fast-changing global event. Also, the richness of the pre-pandemic data collection, with the inclusion of several pre-pandemic measures beside EF (e.g., ADHD symptom burden), allowed exploration of important covariates, and highlighted the consistency of the present results. Further, the collection of both diagnosed and undiagnosed youth longitudinally broadens the generalization of our results to more groups.

The present study has several limitations. The EF measures were only administered before the COVID-19 pandemic, not during. Administering a self-reported EF measure such as the questionnaire Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000) during the pandemic could have been one way to measure the association between COVID-19 EF and COVID-19 experience. Direct comparisons of social, cognitive, and emotional experiences before and during the COVID-19 pandemic were not possible as in-person collection was not possible during these periods of the pandemic, and the CASPE was only administered during the first year of the COVID-19 pandemic (Ladouceur, 2020). However, other pre-pandemic mental health measures (e.g., CBCL) were included and explored as covariates (Achenbach & Rescorla, 2001), and did not impact our EF results. Lastly, the social functioning measure evaluated the only frequency of online social interactions, which might not directly reflect other important qualitative and quantitative aspects of these social interactions.

Future directions

Future studies would benefit from exploring the relationship between EF and social functioning with measures evaluating a broader definition of social functioning, including quality of social interactions with peers and family, and feelings of social connectedness. In addition, longitudinal studies would benefit from comparing youth pre-COVID-19 EF and processing speed abilities to these abilities post-COVID-19 to explore the potential effect of the pandemic as an adverse childhood experience on cognitive abilities, and the growth of EF over time. Similarly, it could be interesting to explore whether the relationship between better cognitive abilities and worse functioning can be seen during other stress-inducing situations besides the COVID-19 pandemic that are not so global in nature.

Conclusions

These findings indicate that stronger pre-pandemic cognitive abilities – supported by EF and processing speed - predicted worse emotional and cognitive functioning mid-pandemic, but not during the first few months of the COVID-19 pandemic. These findings suggest that stronger pre-pandemic cognitive abilities could have promoted greater stress-induced rumination and worry among youth during this global, constantly shifting experience. Older participants showed worse early and mid-pandemic emotional experience, suggesting further support for the link between more mature development and worse COVID-era experiences. Processing speed was shown to have a beneficial role in more frequent mid-pandemic social interaction. EF growth was not a significant predictor of youth early- and mid-pandemic experiences, indicating that most recent ability levels were more important predictors of COVID-19-era functioning than change in those abilities in the years preceding the pandemic.

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Appendix A

Table 1

Demographic Information

	Question 1 Are EF abilities a predictor of experience during the pandemic?		**Question 2** Is the stability of EF over time a predictor of experience during the pandemic?	
	COVID-19 Timepoint 1 (n = 134)	**COVID-19 Timepoint 2 (n = 106)**	**COVID-19 Timepoint 1 (n = 76)**	**COVID-19 Timepoint 2 (n = 60)**
Age				
Mean (SD)	15.2 (3.03)	15.7 (2.99)	15.9 (2.76)	16.5 (2.75)
Median [Min, Max]	15.1 [9.45, 22.1]	15.7 [10.1, 21.7]	16.0 [10.9, 22.1]	16.7 [11.6, 21.7]
Gender				
Female	61 (46%)	52 (49%)	29 (38%)	25 (42%)
Male	69 (51%)	50 (47%)	44 (58%)	31 (52%)
Non-binary	3 (2%)	2 (2%)	2 (3%)	2 (3%)
Prefer not to say	1 (1%)	2 (2%)	1 (1%)	2 (3%)
Race/Ethnicity				
American Indian / Alaskan Native	3 (2%)	3 (3%)	0 (0%)	0 (0%)
Asian	1 (1%)	0 (0%)	0 (0%)	0 (0%)
Black	4 (3%)	4 (4%)	2 (3%)	2 (3%)
Hispanic/Latinx (Multiracial)	18 (13%)	17 (16%)	10 (13%)	9 (15%)
Hispanic/Latinx (not Multiracial)	14 (10%)	7 (7%)	4 (5%)	2 (3%)
Multiracial	6 (4%)	6 (6%)	5 (7%)	4 (7%)
White	87 (65%)	69 (65%)	55 (72%)	43 (72%)
Other	1 (1%)	0 (0%)	0 (0%)	0 (0%)

Table 1 (cont.)

	Question 1		Question 2	
	T1	**T2**	**T1**	**T2**
Diagnosis				
ADHD	39 (29%)	32 (30%)	27 (36%)	23 (38%)
ADHD (with comorbidity)	17 (13%)	11 (10%)	10(13%)	4 (7%)
ASD	1 (1%)	1 (1%)	1 (1%)	1 (2%)
Dyslexia	6 (4%)	4 (4%)	2 (3%)	1 (2%)
OCD (with comorbidity)	6 (4%)	4 (4%)	5 (7%)	3 (5%)
TS	2 (1%)	2 (2%)	2 (3%)	2 (3%)
No Diagnosis	63 (47%)	52 (49%)	29 (38%)	26 (43%)
Medication				
Diagnosed, medicated	25 (19%)	20 (19%)	17 (22%)	12 (20%)
Diagnosed, not medicated	45 (34%)	34 (32%)	28 (37%)	21 (35%)
Not diagnosed, not medicated	62 (46%)	52 (49%)	29 (38%)	27 (45%)
Missing	2 (1.5%)	0 (0%)	2 (2.6%)	0 (0%)
Income				
Mean (SD)	153000 (127000)	143000 (120000)	156000 (108000)	139000 (85600)
Median [Min, Max]	123000 [0, 1000000]	120000 [0, 1000000]	136000 [3600, 500000]	123000 [4000, 325000]
Missing	16 (11.9%)	15 (14.2%)	12 (15.8%)	10 (16.7%)

Note. Table with the demographic information of participants broken down by research question and COVID-19 timepoint. The age of the participants refers to their age when completing the respective COVID-19 survey. Comorbidity with ADHD and OCD included anxiety, ASD, depression, ODD, dyslexia, and TS. T1 = COVID-19 Timepoint 1; T2 = COVID-19 Timepoint 2.

Table 2

Sample sizes for Mid-Pandemic Covariates Analyses for Hypothesis 1

	Sample Size (n) out of 106
ADHD Symptom Burden	97
Gender	102
Income	91
Mental Health Burden	97
Processing Speed	104

Note. Analyses including mental health burden, ADHD symptom burden, income, and processing speed had reduced sample size due to missing data. Those who identified non-binary or preferred not to report gender were removed from the gender analyses.

Table 3

Validity of Pre-Pandemic Behavioral Tasks

Source	Task	Validity Factor (standardized loading)
Engelhardt et al., 2015	Stop Signal	Inhibition (.15); Common EF (.12)
	Animal Stroop	Inhibition (.42); Common EF (.39)
	N-Back	Updating (.67); Common EF (.63)
	Digit Span	Working memory (.52); Common EF (.53)
	Symmetry Span	Working memory (.64); Common EF (.63)
	Cognitive Flexibility	Switching (.32); Common EF (.30)
	Local-Global	Switching (.60); Common EF (.54)
	Connections	Switching (.68); Common EF (.62)
Engelhardt et al., 2016	Symbol Search	Processing speed (.75)
	Pattern Comparison	Processing speed (.82)
	Letter Comparison	Processing speed (.81)

Note. Validity measures of EF (Engelhardt et al., 2015) and processing speed (Engelhardt et al., 2016) tasks assessed by confirmatory factor models.

Table 4
COVID-19 Adolescent Symptom and Psychological Experience Questionnaire (CASPE)

Variable	Question	Alternative	Scoring
Emotional Experience	COVID-19 presents a lot of uncertainty about the future. In the past 7 days, including today, how stressful have you found this uncertainty to be?	Very Slightly or Not at all, Slightly, Moderately, Quite a Bit, and Extremely.	Very Slightly or Not at all (**5**) to Extremely (**1**).
	The COVID-19 outbreak has changed and disrupted many existing plans. In the past 7 days, including today, how stressful do you find these disruptions to be?	Very Slightly or Not at all, Slightly, Moderately, Quite a Bit, and Extremely.	Very Slightly or Not at all (**5**) to Extremely (**1**).
	COVID-19 is a new virus. In the past 7 days, including today, how worried were you that someone in your household or extended family (i.e., grandparent, uncle/aunt, cousin) might become sick?	Very Slightly or Not at all, Slightly, Moderately, Quite a Bit, and Extremely.	Very Slightly or Not at all (**5**) to Extremely (**1**).
	Please indicate to what extent the emotions or feelings below describe how you have been feeling in the past 7 days, including today, because of the COVID-19 outbreak? Emotions: Anxious, Angry, Content, Afraid, Happy, Sad, Worried, Irritable, Concerned, Stressed, Relieved, Distressed, Lonely, Bored, Hopeless, Frustrated, Disappointed, Calm, and Appreciative.	Very Slightly or Not at all, Slightly, Moderately, Quite a Bit, and Extremely.	Negative emotions: Very Slightly or Not at all (**5**), to Extremely (**1**). Positive emotions: Very Slightly or Not at all (**1**) to Extremely (**5**).

Table 4 (cont.)

Variable	Question	Alternative	Scoring
	Compared to before the COVID-19 outbreak, how much more have you felt this way in the past 7 days, including today? Emotions: Relaxed, Hopeful, Confident about the future, Hopeless, Anxious/stressed, and Cheerful.	Not at all, A Little, Some, A Lot, and A Great Deal.	Negative emotions: Not at all (**5**) to A Great Deal (**1**). Positive emotions: Not at all (**1**) to A Great Deal (**5**).
Cognitive Experience	Events such as the COVID-19 can affect how we think. In the past 7 days, including today, to what extent have you experienced the following: Experiences: Thinking a lot about COVID-19, Easily distracted, Forgetful in daily activities, Easily switching tasks, More Focus, More Disorganized, Having racing thoughts, Zoning out, Able to sustain attention on tasks, Able to plan activities or work, and Able to review work	Very Slightly or Not at all, Slightly, Moderately, and Quite a Bit, and Extremely.	Cognitive distress: Very Slightly or Not at all (**5**) to Extremely (**1**) Positive cognitive functioning: Very Slightly or Not at all (**1**) to Extremely (**5**).
	How long do you think it will be before things "go back to normal"?	Less than 1 month, 2-3 months, 3-6 months, 6-12 months, 12 months +, and Never.	Less than 1 month (**6**), 2-3 months (**5**) to Never (**1**).
Social experience	Since your school has closed [or "Since September," during the second timepoint'], how often do you talk/chat with friends online (including on your cell phone, on social media, or through online gaming)?	Every day or almost every day, Several times a week, About once a week, and Less often.	Every day or almost every day (**4**) to Less often (**1**).

Table 4 (cont.)

Variable	Question	Alternative	Scoring
	In the past 7 days, including today, approximately how much time each day do you talk/chat with friends online (including on cell phone, on social media, or through online gaming)?	< 30 min, 30 min–1 hour, 1-2 hours, 2-4 hours, 4-6 hours, and >6 hours.	< 30 min (**1**) to >6 hours (**6**).

Appendix B

Table 1

Research Question 1 Participants Common to the two COVID-19 Timepoints

Early Pandemic

	Social Experience	Cognitive Experience	Emotional Experience
Common EF	$\beta = 0.0049$, $p = 0.99$	$\beta = 0.0052$, $p = 0.99$	$\beta = -0.0019$, $p = 0.99$
Inhibition	$\beta = 0.32$, $p = 0.93$	$\beta = -0.020$, $p = 0.93$	$\beta = 0.018$, $p = 0.93$
Updating	$\beta = 0.30$, $p = 0.90$	$\beta = 0.019$, $p = 0.90$	$\beta = -0.086$, $p = 0.90$
Switching	$\beta = 0.28$, $p = 0.88$	$\beta = 0.0078$, $p = 0.97$	$\beta = 0.12$, $p = 0.88$
PS	$\beta = -0.071$, $p = 0.45$	$\beta = -0.016$, $p = 0.45$	$\beta = -0.019$, $p = 0.32$

Mid Pandemic

	Social Experience	Cognitive Experience	Emotional Experience
Common EF	$\beta = 0.50$, $p = 0.25$	$\beta = -0.37$, $p = 0.066$	$\beta = -0.47$, $p = 0.066$
Inhibition	$\beta = 0.15$, $p = 0.68$	$\beta = -0.23$, $p = 0.34$	$\beta = -0.22$, $p = 0.34$
Updating	$\beta = 0.38$, $p = 0.23$	$\beta = -0.22$, $p = 0.15$	$\beta = -0.40$, $p = 0.029$*
Switching	$\beta = 0.51$, $p = 0.22$	$\beta = -0.34$, $p = 0.16$	$\beta = -0.32$, $p = 0.18$
PS	$\beta = -0.11$, $p = 0.041$*	$\beta = 0.037$, $p = 0.041$*	$\beta = 0.045$, $p = 0.033$*

Note. Common EF, inhibition, updating, switching, and processing speed as predictors of early and mid-pandemic functioning among those with data during both COVID-19 timepoints (n = 92). All analyses controlled for age and multiple comparisons. *$p < 0.05$.

Table 2

EF and PS as Predictors of Mid-pandemic Experience Controlling for Covariates

	Social Experience	Cognitive Experience	Emotional Experience
PS			
Common EF	$\beta = -0.055$, $p = 0.81$	$\beta = -0.33$, $p = 0.81$	$\beta = -0.32$, $p = 0.49$
Inhibition	$\beta = 0.077$, $p = 0.52$	$\beta = -0.091$, $p = 0.52$	$\beta = -0.048$, $p = 0.52$
Updating	$\beta = -0.03$, $p = 0.50$	$\beta = -0.23$, $p = 0.74$	$\beta = -0.33$, $p = 0.50$
Switching	$\beta = 0.17$, $p = 0.77$	$\beta = -0.27$, $p = 0.77$	$\beta = -0.097$, $p = 0.77$

Table 2 (cont.)

	Social Experience	Cognitive Experience	Emotional Experience
EF			
PS	$\beta = -0.10$, $p = 0.12$	$\beta = 0.022$, $p = 0.35$	$\beta = 0.022$, $p = 0.40$
Gender			
Common EF	$\beta = 2.65$, $p = 0.39$	$\beta = -22.78$, $p = 0.028$*	$\beta = -43.56$, $p = 0.083$
Inhibition	$\beta = 0.42$, $p = 0.88$	$\beta = -10.04$, $p = 0.60$	$\beta = -11.00$, $p = 0.88$
Updating	$\beta = 1.86$, $p = 0.38$	$\beta = -15.067$, $p = 0.019$*	$\beta = -39.71$, $p = 0.019$*
Switching	$\beta = 3.31$, $p = 0.27$	$\beta = -22.38$, $p = 0.025$*	$\beta = -31.19$, $p = 0.24$
Income			
Common EF	$\beta = 5.33$, $p = 0.24$	$\beta = -21.78$, $p = 0.029$*	$\beta = -48.10$, $p = 0.10$
Inhibition	$\beta = 2.78$, $p = 0.63$	$\beta = -10.34$, $p = 0.50$	$\beta = -19.59$, $p = 0.63$
Updating	$\beta = 3.72$, $p = 0.18$	$\beta = -15.00$, $p = 0.029$*	$\beta = -44.23$, $p = 0.029$*
Switching	$\beta = 4.41$, $p = 0.35$	$\beta = -18.26$, $p = 0.039$*	$\beta = -26.19$, $p = 0.35$
Mental Health Burden			
Common EF	$\beta = 5.58$, $p = 0.11$	$\beta = -22.27$, $p = 0.056$	$\beta = -50.44$, $p = 0.075$
Inhibition	$\beta = 2.78$, $p = 0.49$	$\beta = -8.33$, $p = 0.49$	$\beta = -15.59$, $p = 0.49$
Updating	$\beta = 3.76$, $p = 0.11$	$\beta = -15.05$, $p = 0.032$*	$\beta = -45.47$, $p = 0.029$*
Switching	$\beta = 4.28$, $p = 0.22$	$\beta = -20.16$, $p = 0.062$	$\beta = -29.04$, $p = 0.22$
ADHD Symptom Burden			
Common EF	$\beta = 5.57$, $p = 0.11$	$\beta = -24.07$, $p = 0.039$*	$\beta = -41.84$, $p = 0.11$
Inhibition	$\beta = 2.71$, $p = 0.56$	$\beta = -9.36$, $p = 0.56$	$\beta = -8.62$, $p = 0.70$
Updating	$\beta = 3.84$, $p = 0.11$	$\beta = -16.07$, $p = 0.035$*	$\beta = -40.30$, $p = 0.035$*
Switching	$\beta = 4.13$, $p = 0.29$	$\beta = -21.28$, $p = 0.045$*	$\beta = -24.43$, $p = 0.30$
Diagnosis Presence			
Common EF	$\beta = 0.45$, $p = 0.25$	$\beta = -0.50$, $p = 0.017$*	$\beta = -0.43$, $p = 0.066$
Inhibition	$\beta = 0.18$, $p = 0.61$	$\beta = -0.27$, $p = 0.30$	$\beta = -0.16$, $p = 0.61$

Table 2 (cont.)

	Social Experience	**Cognitive Experience**	**Emotional Experience**
Updating	$\beta = 0.31$, $p = 0.25$	$\beta = -0.33$, $p = 0.013$*	$\beta = -0.38$, $p = 0.013$*
Switching	$\beta = 0.43$, $p = 0.25$	$\beta = -0.41$, $p = 0.048$*	$\beta = -0.25$, $p = 0.25$

Note. These analyses included age as a covariate and p-values were FDR-corrected. PS = processing speed. *$p < 0.05$.