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Di Lonardo Burr, S.M. and LeFevre, J.-A. (2020) Confidence is key: unlocking the relations between ADHD symptoms and math performance. Learning and Individual Differences, 77. 101808. ISSN 1041-6080

https://doi.org/10.1016/j.lindif.2019.101808

Confidence is Key: Unlocking the Relations between ADHD Symptoms and Math Performance

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This manuscript was accepted for publication in *Learning & Individual Differences* on November 28, 2019. This preprint is the peer-reviewed accepted version but has not yet been copyedited and may differ from the final version published in the journal.

Abstract

Are ADHD symptoms uniquely related to affect about mathematics in university students? Undergraduates (*n* = 425) completed three math performance measures (i.e., arithmetic, computational skills, and word problem solving) and self-report measures of ADHD symptoms, state anxiety, and confidence about math and literacy (i.e., affect and perceived self-efficacy). Students who reported more ADHD symptoms were less confident in both their mathematics and literacy skills. ADHD symptoms were indirectly linked to math performance through math confidence. People who reported more ADHD symptoms were anxious before starting the study, but this anxiety level remained constant. In contrast, people with lower math confidence had higher levels of state anxiety, and this level of anxiety increased during the study. In summary, ADHD symptoms were related to academic confidence in general; links with math performance were mediated through math confidence. There was no evidence for a specific link between attentional symptoms and mathematics.

Word count: 148

Keywords: ADHD; adults; math anxiety; math performance; academic confidence

1.0 Introduction

Attention problems influence students' academic success more than any other childhood psychiatric symptoms (Breslau et al., 2009). Attention Deficit/Hyperactivity Disorder (ADHD) is defined as a persistent pattern of hyperactivity, impulsivity and/or inattention that interferes with an individual's functioning or development (American Psychiatric Association, 2013). ADHD is a lifelong disorder, affecting 4-5% of the adult population (Kessler et al., 2005). ADHD is more prevalent among men than women, with an estimated ratio of 2:1 (Ramtekkar, Reiersen, Todorov, & Todd, 2010). People with ADHD diagnoses continue to experience academic challenges in post-secondary education: They score three to five grade equivalents lower on standardized reading and arithmetic tests than their typically-developing peers (Voigt et al., 2017) and they make up 25% of students who seek academic accommodations (Green & Rabiner, 2012). Furthermore, ADHD and anxiety disorders co-occur with rates approaching 25% in many studies (reviewed by Schatz & Rostain, 2006). Thus, anxiety that is specific to academic activities may be a particular challenge for university students with ADHD (Prevatt, Dehilli, Taylor, & Marshall, 2012).

Many of the behaviours that are challenges for people with ADHD diagnoses, such as avoiding difficult tasks, difficulty with organization, and difficulty with sustaining attention on boring or repetitive tasks, may also interfere with success in university. Accordingly, the prevalence of ADHD symptoms may be related to academic difficulties for university students regardless of whether they have ever received a diagnosis of ADHD (Canu, Elizondo, & Broman-Fulks, 2017; Hartung et al., 2016; Kooij et al., 2010; Wood, Lewandowski, & Lovett, 2019). The goal of the present research was to examine the relations among ADHD symptoms, anxiety, academic confidence, and academic performance, specifically mathematics, in university students. Canu et al. (2017) conducted a similar study with university students and concluded that ADHD diagnosis and ADHD symptoms were linked specifically to anxiety about mathematics. In the present research, we used a wider range of academic self-assessments to more clearly specify the links among ADHD symptoms and affect towards academic subjects.

1.1 Impairments among Individuals with ADHD & ADHD Symptoms

ADHD is one of the most common cognitive developmental disorders in childhood (Gupta & Kar, 2010) and is associated with learning difficulties that negatively affect many academic areas, including reading, writing, and mathematics (DuPaul, Gormley, & Laracy, 2013; Frazier, Youngstrom, Glutting, & Watkins, 2007). Additionally, children with ADHD are more likely than their peers to have negative attitudes towards schoolwork, which could further influence their academic performance (Chiang & Shur-Fen Gau, 2014). Childhood difficulties persist into adolescence: Teenagers with ADHD are eight times more likely to drop out of high school than their typically-developing peers (Kent et al., 2011). Furthermore, concurrent ADHD and learning disabilities are common and have overlapping cognitive challenges such as deficits in executive functioning and working memory (e.g., Mayes, Calhoun, & Crowell, 2000). Attentional problems are common and closely connected to academic affect and performance in clinical samples, thus, it is plausible that these factors also may be linked for adults in educational contexts.

Because attentional problems put people at risk for academic difficulties, the presentation of ADHD symptoms even without a diagnosis can be enough to cause functional impairment (Birchwood & Daley, 2012; Merrell & Tymms, 2001; Wood et al., 2019). In adolescents, the presence of ADHD symptoms was the most significant independent psychopathological predictor of academic performance beyond anxiety and depression (Birchwood & Daley, 2012).

College students with diagnosed ADHD and those who reported clinical levels of ADHD symptoms but no diagnosis were not different on measures of functional impairment, anxiety, depression, or procrastination and time management (Wood et al., 2019). In contrast, both groups reported more impairment in all domains than their peers who reported neither a history of ADHD nor high levels of ADHD symptomology. Thus, the presence of ADHD symptoms is a risk factor for academic performance, independently of a clinical diagnosis.

In studies of university students, ADHD symptoms have also been associated with more school dissatisfaction, more anxiety towards academics, and higher levels of perceived stress (Combs, Canu, Broman-Fulks, Rocheleau, & Nieman, 2015; Kwon, Kim & Kwak, 2018). Jarrett (2016) examined ADHD and anxiety symptoms (i.e., severity of symptoms, state anxiety, trait anxiety, general wellness) in relation to self-reported executive functioning deficits in college students and found that individuals who had both ADHD and anxiety showed greater deficits on self-organization and problem-solving tasks than those with only ADHD or only anxiety. In summary, university students who have ADHD or high levels of ADHD symptoms experience more anxiety about academic activities than their peers; specifically about studying and taking tests (Prevatt et al., 2012), and this anxiety may be linked to difficulties in their academic performance.

1.2 Mathematics and Attentional Challenges

Mathematics is important because it is an essential component of education – it is also positively correlated with staying in school longer and with higher overall academic achievement (Duncan et al., 2007). Despite its importance, mathematics is an area of concern for some university students who may choose to avoid subjects that involve mathematics (Maloney, 2016). More generally, mathematical skills are important for diverse activities such as making decisions about finances and health or interpreting statistics reported by the media (Rolison, Morsanyi, & O'Connor, 2016; Reyna, Nelson, Han, & Dieckmann, 2009). Thus, avoidance of mathematics may have consequences both for students' success in university and in life more generally.

With respect to ADHD and academic impairments, mathematics may be a particular area of concern because ADHD co-occurs in 5-30% of children and adolescents with math disabilities (see review by DuPaul et al., 2013). Independently of whether they have math learning disabilities, children with ADHD are more likely to be impaired in mathematics than their typically-developing peers (Mayes & Calhoun, 2006; Tosto, Momi, Asherson, & Malki, 2015). However, limited information is available on the relations between ADHD and math performance for adolescents or adults with ADHD or attentional challenges more generally.

1.3 Math Anxiety & Attentional Challenges

In adults, it has been suggested that relations between ADHD and math performance may be partially explained by math anxiety (Canu et al., 2017; Ma & Xu, 2004). Math anxiety is a feeling of apprehension, tension, and/or fear that is negatively correlated with math performance (Ashcraft, 2002; Douglas & LeFevre, 2018; Hembree, 1990; Maloney, 2016; Maloney & Beilock, 2012; Skagerlund, Östergren, Västfjäll, & Träff, 2019). Women report higher levels of math anxiety than men (Devine, Fawcett, Szűcs, & Dowker, 2012; Hembree, 1990; Maloney, Waechter, Risko, & Fugelsang, 2012). University students with math anxiety tend to avoid coursework and career paths that involve math (Ashcraft & Krause, 2007; LeFevre, Kulak, & Heymans, 1992; Maloney, 2016). Thus, math anxiety is of concern for post-secondary students' success.

Some research has linked ADHD to math anxiety. Ma and Xu (2004) found that high school students with ADHD were more at risk for math anxiety than typically-developing students. Canu et al. (2017) explored the issue of whether ADHD and math anxiety were related for university students. They compared 40 students who had been diagnosed with ADHD as children and still had high levels of ADHD symptoms to 163 non-diagnosed individuals with ADHD symptoms below the clinical cut-off. They also measured math anxiety, trait anxiety, specific test anxiety, and arithmetic skill. Students with ADHD diagnoses had higher math anxiety than students without diagnoses, but the two groups did not differ on arithmetic performance. Moreover, students with ADHD diagnoses showed a greater increase in negative affect when completing the arithmetic test than individuals without diagnoses. Correlational analyses on the whole sample corroborated these results, showing that prevalence of ADHD symptoms was correlated with both math anxiety and test anxiety even when trait anxiety was controlled (Canu et al., 2017).

Canu et al. (2017) inferred that, because people with ADHD (or high levels of ADHD symptoms) were more anxious about math than people without ADHD, mathematics *performance* may be a risk area for them. However, arithmetic performance (on a single measure) was not correlated with ADHD symptoms in their study. Thus, there was no support for a direct link between ADHD or ADHD symptoms and math performance. Moreover, the conclusion that students with ADHD might be *specifically* at risk for math anxiety was not strongly supported. Canu et al. did not assess the students' feelings about other academic subjects, nor did they test whether ADHD symptoms predicted test anxiety and math anxiety independently. An alternative interpretation of their findings is that the math anxiety observed with higher levels of ADHD symptoms reflects a generally high level of anxiety about academic performance.

1.4 The Present Study

In the present study we investigated the relations among ADHD symptoms, anxiety (i.e., state anxiety and anxiety about academic subjects), and math performance among university students. We hypothesized that people with higher ADHD symptoms would be anxious about academic activities, in general, rather than specifically about mathematics. We assessed attentional symptoms with the Adult ADHD Self-Report Scale (ASRS; Kessler et al., 2005). This scale is based on the World Health Organization (WHO) Composite International Diagnostic Interview© (2001) and the questions are consistent with the DSM-IV and the DSM-V criteria for ADHD. The ASRS alone cannot be used to diagnose ADHD. Nevertheless, many students who have symptoms of ADHD but do not meet the diagnostic threshold are functionally impaired (Hartung et al., 2016). Thus, in the present study, we examined how the prevalence and strength of ADHD symptoms were related to mathematics in a large and diverse sample of university students.

We hypothesized that relations between students' ADHD symptoms and their math performance would reflect overall heightened anxiety and lowered confidence about their academic abilities, rather than a math-specific affective bias (cf. Canu et al., 2017). People who have ADHD symptoms also have symptoms of anxiety (e.g., difficulty concentrating or paying attention, feelings of nervousness or restlessness; Alexander & Harrison, 2013) and university students with ADHD or ADHD symptoms report anxiety related to academics in general, not to specific subjects (Combs et al., 2015; Kwon et al., 2018; Prevatt et al., 2012). To evaluate this hypothesis, we measured students' affect and self-efficacy beliefs for mathematics, reading, and writing. Math anxiety is typically assessed with questions that are situation specific and not easily generalized to literacy. Instead, we used questions about affect and self-efficacy from a measure that was designed to apply to both domains. Specifically, for both mathematics and literacy, participants were asked how nervous they were about that activity, how much they tended to avoid that activity, and how skilled they perceived themselves to be. These constructs were labelled *confidence* to distinguish them from the more specific assessments of anxiety. Although there is much less research on affective and self-efficacy beliefs about reading and writing than about mathematics, nevertheless it is a recognized area of affective concern among students (Huerta, Goodson, Beigi, & Chlup, 2017; Klassen, 2002; Martinez, Kock, & Cass, 2011).

Next, we formulated a theoretical model (see Figure 1) that describes the links among math confidence, literacy confidence, ADHD symptoms, and situation-specific state anxiety during math performance. We tested the model in a large group of university students (n = 425). The overarching assumption in the present model was that any relations between ADHD symptoms and academic performance would be mediated through indices of math and literacy confidence. This assumption is based on the view that high-functioning individuals with attentional challenges would have less confidence about their academic abilities, even if their performance was ameliorated through remediation or compensatory strategies. The persisting lack of confidence would be evident for both mathematics and literacy because both of these domains are central features of university studies. As shown in Figure 1, we predicted that students with higher-levels of ADHD symptoms would be less confident about mathematics and literacy, and express higher general (state) anxiety at the beginning of the study. Although the model as a whole reflects the relations among ADHD symptoms and confidence in academics (i.e., mathematics and literacy), we made specific predictions for each section of the model.

1.4.1 ADHD symptoms and confidence in academics. The first section of the model, shown with red pathways in Figure 1, outlines the predicted relations among ADHD symptoms and confidence in mathematics and literacy. We expected that students who reported more ADHD symptoms would have lower confidence about both mathematics and literacy because individuals with ADHD tend to have academic difficulties in all areas of study (DuPaul et al., 2013; Frazier et al., 2007; Prevatt et al., 2012).

1.4.2 ADHD symptoms and state anxiety. The second section of the model, shown with blue pathways in Figure 1, outlines the predicted relations for state anxiety. We expected that reported ADHD symptoms would be related to higher anxiety levels at the beginning of the study (i.e., participants are generally anxious about this academic activity), but would not predict a change in anxiety over the course of the study (i.e., no increase in anxiety). Assuming that ADHD-related anxiety is not specific to math, we predicted that anxiety levels in relation to ADHD symptoms would remain stable when participants are asked to complete math tasks. In contrast, we expected that lower math confidence would directly predict higher state anxiety levels at the start of the study (because participants knew beforehand that they would be asked to complete math tasks), and that performing the math activities would lead to an increase in state anxiety for those individuals with low math confidence.

1.4.3 Relations among ADHD symptoms, confidence, anxiety, and math performance. The third section of the model, shown with green pathways in Figure 1, outlines the predicted relations among ADHD symptoms, confidence, state anxiety, and math performance. We expected that any links between ADHD symptoms and math performance (i.e., basic arithmetic, word problems, and a comprehensive computational measure) would be mediated by math confidence and state anxiety. Given that Canu et al. (2017) found no direct link between ADHD and math performance but did find a relation between math performance and anxiety, we propose that math-specific affect and self-efficacy will mediate between ADHD symptoms and math performance. Furthermore, because word problems involve reading comprehension (Vilenius-Tuohimaa, Aunola, & Nurmi, 2008), we hypothesized that there would be a direct link between literacy confidence and word problem performance.

(Insert Figure 1 approximately here)

2.0 Method

2.1 Participants

Five hundred and eighty-four undergraduate students from a Canadian university accepted the invitation to participate in the study. The students were enrolled in either introductory Psychology or Cognitive Science courses and received partial course credit for their participation. After exclusion criteria were applied (see Results for exclusion details), data for 425 people (72.8%) were analyzed (M_{age} = 20.02 years; 64.0% female). Of the 425 participants, 235 (55.3%) were enrolled in Bachelor of Arts degrees; the other 190 (44.7%) were enrolled in various Science degrees, including Bachelor of Commerce (14.6%), Bachelor of Science (13.2%), and Bachelor of Computer Science (7.5%). All participants identified themselves as English speakers, with 85.2% identifying English as their first language. Other first languages included Mandarin (4.7%), French (2.4%), and Arabic (1.9%). The remaining 7.7% of participants reported other first languages with a frequency of < 1%. The majority (85.4%) of participants had attended high school in Canada. The study was approved by the Carleton University Research Ethics Board.

We asked participants if they had been diagnosed with ADHD or any learning disability. Of the 425 participants, 5.9% reported an ADHD diagnosis, 1.4% reported a math disability, 1.2% reported a reading disability, 1.2% reported a learning disability other than math or reading, 0.5% reported both ADHD and a math disability, and 0.2% reported both ADHD and a reading disability. Because the focus of the study was on ADHD symptoms, individuals with diagnosed ADHD and learning disabilities were included in all analyses.

2.2 Procedure

Participants were recruited through an online system. They received course credit for completing the study. When participants logged in and selected the study, they received a link to a survey created with an online survey tool (i.e., Qualtrics). Prior to starting the survey, participants gave electronic informed consent. The survey took approximately 20-30 min to complete. Participants completed the measures in the order they are listed below with the exception of the state anxiety rating that was completed for a second time after participants completed all the math measures.

2.3 Measures

2.3.1 The Math Background and Interests Questionnaire (MBIQ). The Math Background and Interests Questionnaire is a measure that includes demographic information, including gender, age, language, and program of study (11 items). The math and literacy items, evaluated on 5-point Likert-type scales, asked participants to rate affect and self-efficacy towards mathematics (n = 5), reading (n = 3) and writing (n = 3; see Table 1; All of the MBIQ items can be found in the Appendix). A principal component analysis (PCA) with varimax rotation of these 13 items resulted in two components that accounted for 61.6% of the variance (see Table 1). We named the first component *math confidence* because it involved items related to math affect and self-perceived math skills. Similarly, we named the second component *literacy confidence* because it involved items related to reading and writing affect, and self-perceived reading and writing skills. Mean scale scores were used for descriptive analyses. Higher scores indicate greater confidence. Saved regression factor scores from the PCA were used for both correlational analyses and model testing. Cronbach's alpha for the mathematics items and literacy items was .86 and .90, respectively.

2.3.2 State Anxiety Rating. Participants were asked, "please rate your current level of anxiety with 0 being 'not at all anxious' and 10 being 'extremely anxious'". They completed this rating twice, once after the MBIQ and again at the end of the study, after completing the math measures. About 9% of students did not enter a state anxiety rating at one or the other time point. This question consisted of a sliding scale. In order to record a response, participants had to interact with the slider, even if they wanted to leave it in its start position (i.e., 0, indicating no anxiety). Thus, it is possible that these individuals intended to record a response of 0 but did not actually move the slider and thus no response was recorded. These items were treated as missing data.

(Insert Table 1 approximately here)

2.3.3 Abbreviated Math Anxiety Scale (AMAS). The AMAS is a 9-item self-report measure of math anxiety (Hopko, Mahadevan, Bare, & Hunt, 2003). Participants rated their anxiety for various math tasks, such as "Having to use the tables in the back of a math book", on a 5-point scale, with "1" representing low anxiety and "5" representing high anxiety. Total scores range from 9 to 45. Hopko et al. (2003) reported good internal consistency (Cronbach's $\alpha = .83$)

and test-retest reliability (*r* = .85) for the AMAS. The internal consistency (i.e., Cronbach's alpha) for the current sample was .93.

2.3.4 Adult ADHD Self-Report Scale (ASRS). The ASRS is an 18-item self-report measure of ADHD symptomology for people aged 18 years or older (Kessler et al., 2005). This scale is based on the World Health Organization (WHO) Composite International Diagnostic Interview© (2001). The questions are consistent with the DSM-IV and the DSM-V criteria for ADHD. Participants rated themselves on various ADHD symptoms, such as "I make careless mistakes when working on a boring or difficult project", on a 5-point scale, with "0" representing never and "5" representing very often. The 18 items belong to two subscales: 9 items correspond to symptoms of inattention and 9 items correspond to symptoms of hyperactivity/impulsivity. According to the ASRS scoring manual, scores of 24 and over on either subscale are indicative of ADHD. The ASRS has high reported internal consistency (e.g., .89) and concurrent validity (e.g., .84; Adler et al., 2006). The internal consistency (i.e., Cronbach's alpha) for the current sample was .81. Total scores were used in the present research.

Note that, to meet the diagnostic threshold for ADHD outlined in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-V; American Psychiatric Association, 2013) a) an individual must have at least six symptoms in either the hyperactivity or impulsivity sub-groups, b) the symptoms must have been present prior to age 12, c) the symptoms must be present in two or more settings, and d) the symptoms must interfere with or reduce the quality of social, academic or occupational functioning (American Psychiatric Association, 2013). Thus, the ASRS alone cannot be used to diagnose ADHD.

2.3.5 Basic Arithmetic Fluency Task (BFT). This task was designed specifically for this study to assess speeded simple arithmetic ability. Participants were presented with one screen consisting of 54 single-digit addition (e.g., 4 + 5) and single-digit multiplication (e.g., 6 × 7) problems. Participants had 1 min to answer as many problems as quickly and accurately as possible on each screen. The sum of correct responses for each screen was calculated and the total score was the average sum across the two screens. Scores could range from 0 to 54. Cronbach's alpha for the reliability based on the two screens for the study sample was .89.

2.3.6 Word Problems. This task was designed specifically for this study. Participants were presented with 10 word problems that required basic arithmetic skills (i.e., addition, subtraction, multiplication, and division). For example, "Sam is 12 years old. He is 6 years older than Mary and 3 years younger than Tim. How old is Tim?" All questions were presented one at a time in multiple-choice format. Foil answers were created so that they were either close in magnitude to the correct answer, the result of a common arithmetic mistake, or the result of a common math misconception. Scores are the total number of correct responses. The split-half reliability (i.e., Spearman-Brown coefficient) for the current sample was .83.

2.3.7 Brief Math Assessment 3 (BMA-3). The BMA-3 is an untimed task based on the Wide Range Achievement Test: Third Edition (WRAT 3, 1993; Steiner & Ashcraft, 2012). Participants were presented with 10 questions, on one screen, that include multi-digit arithmetic, algebra, and fraction questions; the questions increase in difficulty as the test progresses. Scores are the total number of correct responses. The original inventory requires participants to produce answers, but for this study, participants were presented potential answers in multiple-choice format. Foil answers were created so that they were either close in magnitude to the correct answer, the result of a common arithmetic mistake, or the result of a common math misconception. The internal consistency (i.e., Cronbach's alpha) for the current sample was .81.

3.0 Results

Five hundred and eighty-four students responded to the online survey. To ensure that the arithmetic data accurately reflected performance and not random responses, we analyzed data only for the 425 participants (72.8%) who solved at least three items correctly on each of the basic arithmetic fluency task, BMA-3, and word problems, as any scores of < 3 would be below the expected mean (M = 2.5) if one were simply guessing or responding randomly. This criterion also excluded any participants who left all responses to the math tasks blank. Of these 425 participants, none scored < 4 on any of the math measures, suggesting that they were not responding randomly. Once participants were filtered out based on math performance, ASRS and MBIQ responses were checked to ensure that individuals did not provide the same rating for every item of the measure. Based on these criteria, no additional participants were removed from the analysis.

3.1 Descriptive Statistics

With the exception of gender and program, descriptive statistics for the measures used in the analyses are shown in Table 2. The measures of math confidence, math anxiety, state anxiety, and the BMA-3 scores were normally distributed, with reasonable ranges and standard deviations. Some of the measures showed moderate levels of skew. ADHD symptoms were positively skewed because many individuals reported low levels of these symptoms. Literacy confidence was negatively skewed because many participants reported high levels of literacy confidence. This result was expected given that the participants were all university students who, regardless of their area of study, are frequently required to read and write. Nonetheless, there was still a range of scores on literacy confidence ratings within the sample (see Table 2). Arithmetic fluency scores were positively skewed because a few individuals were able to answer a large number of questions. Word problem solving was negatively skewed. Many individuals performed very well on this measure, which was not timed and required only simple arithmetic. Despite these deviations from normality, there was a range of performance across the measures (see Table 2); the significant skew values reflect the large sample size.

(Insert Table 2 approximately here)

For the AMAS math anxiety measure, scores showed the full range possible from 9 to 45. The mean of 23.2 was similar to that of 22.7 reported by Dykeman (2017) for 6,439 college students. The math confidence measure from the MBIQ was highly correlated with the AMAS (r = -.70 for both the scale average and regression math confidence scores) and showed very similar patterns of relations with the other variables. To maximize the comparability of math confidence with literacy confidence, and to include a more comprehensive measure that evaluated both anxiety and self-efficacy, only math confidence was used in the model.

For ADHD symptoms, scores ranged from 8 to 59. The minimum and maximum possible values for this measure are 0 and 72, respectively. The measure consists of two sections: Nine questions for inattentive symptoms and nine questions for hyperactive symptoms. People who have scores > 24 on either set of questions are classified as “highly likely to have ADHD” (Kessler et al., 2005). Thirty-one participants (7.3%) had scores > 24 on the inattentive symptoms subscale, seven participants (1.6%) had scores > 24 on the hyperactive symptoms subscale, and nine participants (2.1%) had scores > 24 on both subscales. Thus, based on their scores, 47 participants (11.1%) from this sample would be classified as “highly likely to have ADHD”. This proportion is quite similar to the 12.3% of college students (in a sample of 1,080) who endorsed high levels of ADHD symptoms on the ASRS (Garnier-Dykstra, Pinchevsky, Caldeira, Vincent, & Atria, 2011). Although 11.1% is higher than the estimated proportion of adults who have an ADHD diagnosis (i.e., approximately 5%), having ADHD symptoms and being diagnosed with ADHD are not synonymous. As discussed, multiple factors are used to diagnose ADHD.

3.2 Correlations

Correlations among ADHD symptoms, math confidence, literacy confidence, state anxiety, and math outcomes are shown in Table 2. Similar to the relation between ADHD symptoms and math anxiety reported by Canu et al. (2017), ADHD symptoms and math confidence were significantly correlated. ADHD symptoms were also significantly correlated with literacy confidence. Thus, people with more ADHD symptoms felt less confident about core academic subjects (i.e., math, reading, and writing).

The three math performance measures were significantly but moderately inter-correlated. Word problem and BMA-3 scores were more highly correlated with each other than with the basic arithmetic fluency score. The latter was a timed test and therefore it may have tapped into different aspects of math performance than the other two measures. Nevertheless, all three math measures were correlated with math confidence.

Math confidence was correlated with state anxiety at the beginning and end of the study whereas literacy confidence was not correlated with state anxiety at either time point. The participants knew when they started the study that the focus was on mathematics. In summary, the confidence measures appeared to have construct validity in relation to the outcome measures.

Overall, there was an increase in state anxiety from the beginning of the study to the end of the study, $t(361) = -9.51$, $p < .001$. The correlations between ADHD symptoms and beginning state anxiety versus end state anxiety did not significantly differ, $z = 0.73$, $p = .23$. Furthermore, after controlling for beginning anxiety, ADHD symptoms did not significantly predict state anxiety at the end of the study ($\beta = .03$), $t(360) = 0.688$, $p = .49$. Thus, although people with more ADHD symptoms had higher levels of anxiety than those with fewer ADHD symptoms, this relation did not change as the study progressed. In contrast, the correlation between math confidence and beginning state anxiety was lower than that between math confidence and end state anxiety, $z = 4.35$, $p < .001$. After controlling for beginning anxiety, math confidence significantly predicted end anxiety ($\beta = .50$), $t(360) = 8.16$, $p < .001$. Thus, compared to people with high math confidence, people with lower math confidence were more anxious at the beginning of the study and their anxiety increased by the end of the study.

With respect to math performance, ADHD symptoms were only significantly correlated with arithmetic fluency, whereas math confidence was significantly correlated with all three math performance measures. Because arithmetic fluency is a timed test, it is possible that the requirement to respond quickly was the source of the correlation with ADHD symptoms.

3.3 Model Testing

The model presented in Figure 1 was tested using path analysis with Mplus Version 7 (Muthén & Muthén, 1998-2012). Path analysis was chosen to evaluate the model because it assesses the overall fit between the model and the pattern of data, allowing all of the hypotheses about the variables to be tested simultaneously. It also allowed us to capture the temporal relations among the measures, in particular, that state anxiety was measured twice and the arithmetic performance occurred between these measurements and after the assessment of academic confidence. All the measures used in the model showed good reliability and construct validity in the present study. Although state anxiety was measured with a single question, the correlation between beginning and end time points suggests that participants were consistently evaluating their anxiety with this measure.

Occasionally participants failed to enter a response for state anxiety (see Method section for more details). These missing data accounted for 1.76% of the total data. Accordingly, the model was estimated using full information maximum likelihood (FIML), which uses all available information. Model fit was examined using a combination of the comparative fit index (*CFI*), root mean square error of approximation (*RMSEA*), and standardized root mean square residual (*SRMR*). A model is considered to have acceptable fit if the CFI is $> .90$, the RMSEA is $< .08$, and the SRMR is $< .08$ (Kline, 2011). Based on these criteria, the model had acceptable fit (see Figure 2). The only hypothesized paths that were not significant were those between state anxiety and the two simpler math measures (arithmetic and word problems) and between literacy confidence and word problems.

(Insert Figure 2 approximately here)

3.3.3 ADHD Symptoms and Confidence. As shown in Figure 2, there were significant negative paths between ADHD symptoms and both math and literacy confidence. As expected, people with higher ADHD symptoms reported lower levels of academic confidence.

3.3.2 ADHD Symptoms and State Anxiety. As predicted, there was a direct path from ADHD symptoms to state anxiety reported at the beginning of the study, but not to state anxiety at the end of the study. People with higher ADHD symptoms thus had higher levels of state anxiety, but this anxiety was stable across the study. In contrast, the model shows direct paths between math confidence and state anxiety at both the beginning and the end of the study. The latter reflects the observed increase in anxiety: People with lower math confidence experienced an increase in anxiety, presumably as a consequence of attempting the three math performance measures. The participants were informed before beginning that they would be asked to do math tasks. In contrast, no direct paths between ADHD symptoms and math performance were found because math confidence mediated those relations.

3.3.3 ADHD symptoms, confidence, anxiety, and math performance. People who reported higher levels of math confidence achieved higher scores on the math outcome measures. Furthermore, the relations between ADHD symptoms and math performance were mediated by math confidence. In contrast, the correlations between literacy confidence and the math measures were not significant. With respect to mediation analyses, researchers suggest that the focus on the significance between the independent and dependent variables (in this case ADHD symptoms and math performance) is unjustified (Rucker, Preacher, Tormala, & Petty, 2011). Instead, Rucker et al. suggest that for mediation analyses, attention should be shifted towards assessing indirect effects. Thus, we include the indirect effects between ADHD symptoms and math outcomes in Table 3. The indirect effects were significant and suggest that ADHD symptoms are related to math performance through math confidence.

(Insert Table 3 approximately here)

The relations between state anxiety and math performance were also mediated by math confidence, with one exception: The direct paths between the BMA-3 and both beginning and end anxiety were significant. Above and beyond math confidence, higher state anxiety and increased state anxiety was linked to poorer math performance on the BMA-3. This pattern suggests that state anxiety was not severe enough to affect the simple math skills required for word problem solving and basic arithmetic but did influence the more complex computations on the BMA-3. In general, anxiety is most likely to impair performance on complex or attentionally-demanding tasks (see Eysenck, 1992). The finding that BMA-3 performance was also related to increased state anxiety at the end of the study suggests that anxiety and performance have reciprocal relations (Maloney, 2016).

3.4 ADHD Symptoms, Confidence, Gender, and University Program

To further understand the potential correlates of ADHD symptoms in university students, ratings of ADHD symptoms were analyzed in a 2(Gender: Male, Female) by 2(Program Choice: Arts vs. Sciences) between-subjects ANOVA. Men reported higher levels of ADHD symptoms than women (32.3 vs. 29.4), $F(1, 419) = 9.18$, $p = .003$, $\eta^2 = .02$. This finding is consistent with the ADHD literature where a higher prevalence rate of adult ADHD has been reported for males than females (Ramtekkar et al., 2010). There was no significant effect of program choice and no significant interaction between gender and program. Thus, ADHD symptoms were not directly related to program choice in university students.

To further understand how confidence relates to gender and program choice, mean confidence scores were analyzed in a 2(Confidence Type: Math, Literacy) by 2(Gender: Male, Female) by 2(Program Choice: Arts, Science) mixed ANOVA. Participants had higher confidence in their literacy than their math skills (4.1 vs. 3.2), $F(1, 408) = 242.66$, $p < .001$, $\eta^2 = .37$. Science students had higher overall confidence than Arts students (3.8 vs. 3.6), $F(1, 408) = 6.29$, $p = .013$, $\eta^2 = .02$. These main effects were qualified by a significant confidence type by degree interaction, $F(1, 408) = 66.06$, $p < .001$, $\eta^2 = .14$. Post-hoc tests using Bonferroni adjustment revealed that students enrolled in Arts programs reported significantly higher literacy than math confidence (4.3 vs. 2.9), whereas students in Science programs reported significantly higher math than literacy confidence (4.0 vs. 3.5), *p*s < .001. There was also a significant confidence type by gender interaction, $F(1, 408) = 57.07$, $p < .001$, $\eta^2 = .12$. Women reported significantly higher literacy than math confidence (4.3 vs. 3.0) whereas men reported significantly higher math than literacy confidence (4.0 vs. 3.5), *p*s < .001. No other main effects or interactions were significant. This pattern of results is consistent with previous studies that have examined program and career choice in people who are math anxious (Ashcraft & Krause, 2007; LeFevre et al., 1992) and studies that have examined math anxiety and gender (Devine et al., 2012; Hembree, 1990; Maloney et al., 2012). Furthermore, they support the construct validity of math versus literacy confidence in the present research (Huerta et al., 2017).

4.0 Discussion

How are ADHD symptoms, academic confidence, state anxiety, and math performance related? To our knowledge, only one previous study (Canu et al., 2017) examined the relations among ADHD, math anxiety, and math performance for university students. Canu et al. concluded that mathematics was a special area of concern for people with ADHD. However, there was no evidence of a direct link between ADHD and math performance in Canu et al. nor did they consider the overall prevalence of academic confidence or state anxiety among people with ADHD symptoms.

The results of the present research supported an alternative model of the relation between ADHD symptoms and academic confidence. We found direct links between ADHD symptoms and three affective measures: math confidence, literacy confidence, and state anxiety. All of the affect measures were equally related to ADHD symptoms. Thus, contrary to the findings of Canu et al. (2017), we did not find support for a privileged connection between ADHD symptoms and affect about mathematics. Instead, our findings are consistent with research showing that students with ADHD are generally anxious about academic activities (Barkley, Fischer, Smallish, & Fletcher, 2006; Daley & Birchwood, 2010; Voigt et al., 2017), presumably because their struggles with academic subjects occur in multiple domains (DuPaul et al., 2013; Frazier et al., 2007). Finally, the present findings are contrary to those of Canu et al. (2017), who found that negative affect increased for individuals with ADHD/ADHD symptoms after completing a mathematics task. In contrast, in the present study, negative affect increased for people with lower math confidence but did not change for people who reported higher levels of ADHD symptomology.

The links we found between math confidence and math performance replicate the findings of many studies of math anxiety and math performance (e.g., Hembree, 1990; Maloney, 2016; Suarez-Pelliconi, Núñez-Peña, & Colomé, 2016). Similarly, self-concept and self-efficacy have been linked to performance in academic areas such as math and writing (Huerta et al., 2017; Lee, 2009; McMullan, Jones, & Lea, 2012; Pajares, 1996, 2003; Zimmerman, 2000). Similar to Canu et al. (2017), we found that state anxiety increased more for people who are less confident about math when they are asked to complete simple math tasks. Presumably, this change in state anxiety was a result of participants' struggles with the math questions during the study.

Skagerlund et al. (2019; see also Douglas & LeFevre, 2018) found that math anxiety was linked directly to math performance, but that some of the relation was indirect through working memory ability and symbolic number processing. They interpreted their results as evidence that math anxiety has multiple causes; some of it may be developmental, some of it may be related to shared cognitive deficits between math performance and math anxiety, and some to the effects of math anxiety on students' choice of activities in university (see also Suarez-Pelliconi et al., 2016). The present results do not address the causes of low math confidence but do support previous findings of consistent links between math anxiety, math self-efficacy, math avoidance, and math performance (e.g., Maloney 2016; Ramirez, Shaw, & Maloney, 2018; Skagerlund et al., 2019).

To further understand ADHD symptoms and math confidence, we explored the relations between self-reports of ADHD symptoms and other variables known to be related to either ADHD symptoms (i.e., gender) or to math confidence (i.e., program choice in university). As expected, men reported a higher frequency of ADHD symptoms than women. Across the lifespan, the prevalence rate of ADHD is higher among men (Ramtekkar et al., 2010). In contrast, there were no significant differences in ADHD symptoms for Arts versus Science students. Thus, ADHD symptoms appear to be linked to academic confidence in general, not to subject-specific confidence. This pattern is consistent with previous findings in which people with ADHD have learning difficulties in many academic areas (DuPaul et al., 2013; Frazier et al., 2007).

Women reported higher literacy confidence than math confidence whereas men reported higher math than literacy confidence. Furthermore, people enrolled in Arts programs reported higher levels of literacy confidence than math confidence, whereas people enrolled in Science programs reported higher levels of math confidence than literacy confidence. These findings provide support for the construct validity of literacy confidence versus math confidence. ADHD symptoms were related to gender whereas academic confidence was related to both gender and program choice. Previous studies have suggested that university students who are anxious about math tend to avoid coursework and career paths that involve mathematics (Ashcraft & Krause, 2007; LeFevre et al., 1992). Furthermore, women often report higher levels of math anxiety than men (Devine et al., 2012; Hembree, 1990; Maloney, et al., 2012). Thus, our findings for math and literacy confidence support the view that these measures are valid indicators of academic anxiety in university students.

4.1 Limitations & Future Research

We note that the findings of the present study cannot be generalized to people who have been diagnosed with ADHD. The results also cannot be generalized beyond undergraduate students. Moreover, the online administration of this study is a potential limitation. The exclusion rate (i.e., 27%) was high because we had to rule out the possibility that participants were not fully engaged in the study. Nevertheless, we ended up with a large sample and observed very similar patterns as in more typical in-person testing, that is, similar correlations between math confidence and math performance, gender differences in math confidence and literacy confidence, and expected relations between academic confidence and program choices. Students often complete schoolwork and assessments at home and take exams online. Thus, the online environment may closely reflect the circumstances in which a student would normally complete their schoolwork. The online environment might even have reduced anxiety that participants would have otherwise felt had they completed the study in a lab setting with an examiner present. Nevertheless, some participants still reported high levels of anxiety, suggesting that the anxiety experienced by some people goes beyond the pressure of completing a task supervised in a laboratory setting.

Another limitation of our study was that only mathematical outcome measures were included, and these captured relatively simple and limited aspects of math knowledge. We predicted, but did not find, a significant link between literacy confidence and word problems. One possible explanation is that the word problems contained simple language and participants were not required to answer any comprehension questions about the word problems. In future research, inclusion of more complex outcome measures from various domains (i.e., reading and writing as well as mathematics), will provide a more complete picture of the relations among ADHD symptoms, academic confidence, and academic performance. Finally, to better understand these findings, researchers should more closely examine the role of working memory deficits in this domain. Both ADHD symptoms and math anxiety could have similar consequences for academic performance in that they may reduce available working memory resources (e.g., Dovis, Van Der Oord, Wiers, & Prins, 2013; Chang & Beilock, 2016; Martinussen et al., 2005).

4.3 Conclusions and Implications

In summary, the current research suggests that the correlation between ADHD symptoms and math performance is related to confidence in academics in general, not just in mathematics: People with higher levels of ADHD symptoms were less confident in their academic skills (for both literacy and mathematics) than people with lower levels of ADHD symptoms. The present study is among the first to closely examine how ADHD symptoms and confidence in academics are related to math performance in adults (cf. Canu et al., 2017). ADHD affects approximately 4-5% of the general adult population (DuPaul, Weyandt, O'Dell, & Varejao, 2009; Kessler et al., 2006) and 25% of students who seek academic accommodations at university have ADHD (Green & Rabiner, 2012). Thus, it is crucial to identify areas in which people may struggle and define ways to provide relevant support. If ADHD symptoms and concomitant low levels of confidence persist across the lifespan, then it is important to know if these factors limit students' progress and performance. Educators should also be aware of potential difficulties that students with ADHD symptoms face so that classrooms can be designed to support academic success, and therapy and coaching can be provided to help with symptom management. Overall, the present results indicate that people with ADHD symptoms may lack confidence in their academic skills. Addressing this lack of confidence could help support people with ADHD symptoms in academic settings.

Declaration of Conflicting Interests: The authors declare that they do not have conflicts of interest regarding this research.

Acknowledgements: This project was funded by the Natural Sciences and Engineering Research Council of Canada through a Discovery Grant to Jo-Anne LeFevre.

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Appendix: The Math Background and Interests Questionnaire

Gender

- ☐ Male
- ☐ Female
- ☐ Other

What is your current age (in years)? _________

What program are you currently in?

- ☐ BA
- ☐ BSc
- ☐ BEng
- ☐ BEd
- ☐ BCogSc
- ☐ BComm
- ☐ BCompSci
- ☐ BPAPM
- ☐ MA
- ☐ MSc
- ☐ MSW
- ☐ MBA
- ☐ PhD
- ☐ Special Student
- ☐ Other: _________

Year in program

- ☐ 1st
- ☐ 2nd
- ☐ 3rd
- ☐ 4th
- ☐ 5th
- ☐ 6th or more

What is your current major? _________

In what country did you attend elementary school?

- ☐ Canada
- ☐ Iran
- ☐ China (and/or Hong Kong)
- ☐ Nigeria
- ☐ United Arab Emirates
- ☐ Taiwan
- ☐ Another Country: _________

In what country did you attend high school?

- ☐ Canada
- ☐ Iran
- ☐ China (and/or Hong Kong)
- ☐ Nigeria
- ☐ United Arab Emirates
- ☐ Taiwan
- ☐ Another Country: _________

What was the last grade (or equivalent course level) in which you took a mathematics course in high school?

- ☐ Grade 9
- ☐ Grade 10
- ☐ Grade 11
- ☐ Grade 12
- ☐ Grade 13

What languages do you speak?

- ☐ English
- ☐ French
- ☐ Mandarin
- ☐ Cantonese
- ☐ Farsi
- ☐ Arabic
- ☐ Igbo
- ☐ Swahili
- ☐ Creole
- ☐ Hindi
- ☐ Other: _________

What do you consider your first language?

- ☐ English
- ☐ French
- ☐ Mandarin
- ☐ Cantonese
- ☐ Farsi
- ☐ Arabic
- ☐ Igbo
- ☐ Swahili
- ☐ Creole
- ☐ Hindi
- ☐ Other: _________

Please rate your level of skill in these areas of mathematics:

	Very Low		Moderate		Very High
Basic mathematical skill (e.g., arithmetic skill)	☐	☐	☐	☐	☐
More complex areas of mathematics (e.g., calculus, algebra)	☐	☐	☐	☐	☐

How often do you:

	Almost Always		Sometimes		Almost Never
Avoid situations involving mathematics?	☐	☐	☐	☐	☐
Find that situations involving mathematics make you nervous?	☐	☐	☐	☐	☐

	Extremely difficult		Moderately difficult		Not at all difficult
How difficult was mathematics for you in high school?	☐	☐	☐	☐	☐

Please rate your level of skill in English om the following areas:

	Very Low		Moderate		Very High
Basic reading skills (e.g., reading an instructional manual for information)	☐	☐	☐	☐	☐
Complex reading skills (e.g., reading a novel for a University English course)	☐	☐	☐	☐	☐
Basic written communication skills (e.g., summarizing a set of notes for a friend or writing a letter)	☐	☐	☐	☐	☐
Complex written language skills (e.g., writing a paper for a University course)	☐	☐	☐	☐	☐
Spelling Skills	☐	☐	☐	☐	☐

How often do you:

	Almost Always		Sometimes		Almost Never
Avoid situations that require reading in English?	☐	☐	☐	☐	☐
Avoid situations that require writing in English?	☐	☐	☐	☐	☐
Find that situations involving writing make you nervous?	☐	☐	☐	☐	☐

	Extremely difficult		Moderately difficult		Not at all difficult
How difficult was English for you in high school?	☐	☐	☐	☐	☐