The Role of Achievement Emotions in Math Performance Outcomes of Students with Autism Spectrum Disorder

by

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Abstract

Background: Many students with autism are gifted mathematicians, while others seem to perform poorly relative to the general population. In typical student populations, math performance is reliably predicted by indicators of cognitive ability and language; however, these relationships have not been consistently replicated among students with autism. Accordingly, it remains unclear how a diagnosis of autism can lead to both math strengths and weaknesses. In order to provide educational support to members of this population, it is necessary to investigate possible factors that may influence their math achievement. The construct of achievement emotions ($A_{ch}E_{m}$s), defined as emotions connected to achievement activities and outcomes, is an unexplored, but potentially relevant factor given that many students with autism have difficulties regulating their emotional states as well as their intense special interests. As such, this exploratory descriptive pilot study aimed to determine whether $A_{ch}E_{m}$s significantly predict math performance in students with autism above and beyond non-verbal cognitive ability and expressive language. Understanding this relationship could support educators in meeting the learning needs of members of this population.

Method: Thirty-one students diagnosed with autism aged 5–16 completed standardized measures of math performance, expressive language ability, and non-verbal cognitive ability. Participants also completed the Achievement Emotions Questionnaire – Elementary School, which measures enjoyment, boredom, and anxiety across learning contexts (i.e., class time, completing homework, and test writing).

Results: Pearson correlations and hierarchical regression analyses conducted for each of the three $A_{ch}E_{m}$s of interest revealed that non-verbal cognitive ability and expressive language explained 61% of the variance in math performance across all three regression models. In addition, contextually-based math anxiety explained an additional 14.8% (p = .014) of the variance in performance. When cognitive ability and expressive language were controlled, math anxiety experienced during class was the only unique contributor (β = -.372, $t[22]$ = -2.68, p = .014). Math homework and test anxiety did not significantly contribute to the model.

Conclusion: Although math performance is significantly influenced by cognitive and linguistic skills among members of this population, class-based anxiety is another factor worth consideration. Further research is warranted to explore the relationships between $A_{ch}E_{m}$s and math performance in greater depth; however, the present results suggest that educators can better support students with autism by implementing strategies designed to reduce anxiety inside the classroom to facilitate learning, and promote positive math performance outcomes.

Preface

This thesis is an original work by Kathleen Howard. The research conducted for the purposes of this thesis was supervised by Dr. Heather Brown at the University of Alberta. This thesis represents part of a broader research project developed by Dr. Heather M. Brown, who developed the corresponding proposal, and selected the measures used. I reviewed the literature specific to this component of the broader study, and conceptualized hypotheses for selecting specific measures that were applicable for this narrower purpose. I collected data from participants using these measures, maintained a database specific for this information, and conducted the data analysis described in this thesis. This study received research ethics approval from the University of Alberta Research Ethics Board, Project Name “Developing a Model of Mathematical Ability for Children with ASD”, No. 58795, April 20th, 2016.

Dedication

This thesis is dedicated to my mother, Joanne, my father, John, and brother, Mac. I am grateful to have learned so much from you over the years, and I thank you for inspiring me to pursue academia in order to support children with autism and their families. You have influenced my life in every way. Thank you for your continued support in everything I do.

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Introduction

In mathematics, students with autism spectrum disorder present with marked variability in performance. Although a systematic review conducted by Chiang and Lin (2007) stated that many students with autism perform within the average range, more recent additions to the literature report different results (e.g., Aagten-Murphy et al., 2015; Iuculano et al., 2014). Across various tasks aimed at assessing number sense, computation skills, and problem-solving abilities in both students with autism and their typically developing (TD) peers, some researchers have reported higher rates of math disability among students with autism (Aagten-Murphy et al., 2015; Kurth & Mastergeorge, 2010), while others have reported higher rates of math giftedness (Iuculano et al., 2014; Jones et al., 2009). Collectively, this literature suggests that students with autism do not present with consistent strengths and weaknesses in math; instead, underlying factors are likely responsible for influencing performance. In this regard, cognitive ability and various aspects of language have received significant attention among TD students, unselected samples of students, and students with autism (Aagten-Murphy et al., 2015; Beal et al., 2010; Jones et al., 2009; LeFevre et al., 2010). For TD students as well as unselected samples of youth, cognition and language predict math performance considerably well (e.g., Beal et al., 2010; LeFevre et al., 2010); these relationships are consistent across studies. In comparison, factors related to cognitive ability and language have been found to be inconsistent in their ability to predict math performance among students with autism (Assouline et al., 2012; Estes et al., 2011; Jones et al., 2009). Given these inconsistencies, factors related to cognitive ability and language are unlikely to solely predict math performance outcomes among students with autism, thus highlighting the need to explore other possible influences at play.

The construct of achievement emotions ($A_{ch}E_{m}$s), or emotions directly linked to achievement activities and outcomes, represents a possible factor that may contribute to the variability in performance observed among members of this student population. Defined by Pekrun (2006) as part of his control-value ($C_{trl}V_{al}$) theory, $A_{ch}E_{m}$s are determined by the combination of both control and value appraisals assigned to achievement activities or outcomes (i.e., the extent to which an individual feels in control of their performance combined with how important their performance is to them). This construct has been linked to math performance among unselected samples of students (Lichtenfeld et al., 2012; Pekrun et al., 2017); however, it has not yet been explored specifically among students with autism. Nonetheless, it is likely that emotions experienced by students with autism would impact their academic performance, particularly because individuals with autism frequently experience difficulty regulating their emotions (Samson et al., 2015). In particular, individuals with autism often attend to cognitive distortions (e.g., catastrophic thinking), and tend to use more maladaptive regulation strategies (i.e., emotional suppression) rather than adaptive approaches (i.e., cognitive reappraisal) (Mazefsky et al., 2014). In spite of these challenges, emotion regulation interventions have been successful in promoting the use of adaptive emotion regulation strategies for these individuals (Beaumont et al., 2015; Samson et al., 2015), suggesting that students with autism can improve their emotion regulation skills when provided with specialized support. Given that $A_{ch}E_{m}$s are expected to predict math performance outcomes among these students, this evidence suggests that emotion regulation interventions designed to address $A_{ch}E_{m}$s could in turn lead to improvements in performance.

Within the context of this study, it may be that challenges associated with emotion regulation commonly experienced by students with autism are able to explain both high and low performance outcomes in math. Students with autism who have intense special interests in math might perform extremely well in this subject area as a result of spending significant periods of time learning, exploring, and talking about math. In this case, a special interest in math would be adaptive in promoting math performance; however, special interests can make it difficult for students with autism to regulate specific appraisals, goals, and emotions, meaning that it might be difficult to adapt this focus to contexts unrelated to math. As such, students who lack a special interest in math may find it difficult to regulate their control and value appraisals as well as their emotions to suit math-related contexts (e.g., class time). Given that $A_{ch}E_{m}$s and performance share reciprocal relationships among unselected samples of students, a decreased ability to regulate negative thoughts and feelings about math could lead to poor performance in this subject area. In summary, students with autism who experience negative math-related $A_{ch}E_{m}$s may be those who perform poorer in math as a result of both emotion dysregulation and unrelated special interests.

Overall, the construct of $A_{ch}E_{m}$s may help explain the considerable variability in math performance outcomes observed among students with autism relative to inconsistent factors associated with cognitive ability and language skills. As such, the present exploratory descriptive study was designed to serve two purposes: 1) to identify the relationships between three select $A_{ch}E_{m}$s (i.e., enjoyment, boredom, anxiety), and math performance, and 2) to determine whether these $A_{ch}E_{m}$s predicted performance above and beyond selected control variables of non-verbal cognitive ability and expressive language.

Literature Review

Math and Autism

Autism is broadly defined by qualitative impairment in social communication, and restricted, repetitive behaviours or interests (American Psychiatric Association [APA], 2013). Generally, autism presents with great variability across individuals, yet regardless of symptom severity, many require specialized support systems (e.g., structured learning environments, systematic instruction, functional approach to problem behaviour, etc.) to succeed in educational settings (Iovannone et al., 2007; Kurth & Mastergeorge, 2010). In the school subject of mathematics, this variability is especially apparent. While an early review of the research on math and autism from 2007 reported that the majority of students with autism "demonstrate average mathematical ability compared with the normed population" (Chiang & Lin, 2007, p. 553), research from the last decade suggests otherwise. Some researchers report that students with autism perform poorly in math relative to the general population (Aagten-Murphy et al., 2015; Bae et al., 2015; Kurth & Mastergeorge, 2010; Oswald et al., 2016), while others provide evidence for mathematical giftedness (Iuculano et al., 2014; Jones et al., 2009; Wei et al., 2013).

Although popular opinion suggests that individuals with autism generally excel at math, research investigating the math performance of these students fails to consistently support this stereotype (Aagten-Murphy et al., 2015; Estes et al., 2011; Oswald et al., 2016). An investigation conducted by Oswald and colleagues (2016) concerning applied math problem solving abilities among adolescents with autism revealed that 22% of the sampled adolescents presented with a math learning disability in this area, while 4% met criteria for math giftedness. In comparison, population-based prospective studies as well as smaller-scale studies concerning unselected samples of youth have demonstrated that 7% of children and adolescents are expected to be diagnosed with a mathematical learning disability in at least one area of mathematics before graduating from high school (Geary, 2011; Barbaresi et al., 2005; Lewis et al., 1994; Shalev et al., 2005). In comparing Geary's (2011) findings with Oswald et al.'s study (2016), adolescents with autism were approximately three times more likely to experience significant challenges in math problem solving (Oswald et al., 2016). Indeed, some authors have found evidence supporting this finding; Bae et al. (2015) and Miller et al. (2017) both found that students with autism in preschool and elementary school were significantly poorer at problem solving relative to age-matched TD children. Titeca and colleagues (2014), however, found the reverse to be true among preschoolers with autism; they found that students with autism performed significantly better than a normed sample of TD students on word problem solving tasks. As such, the math problem-solving skills of students with autism appear to be highly variable; members of this population display both stronger and weaker skills than TD students in this regard.

Further evidence in favour of this variability is also present among investigations exploring arithmetic and computation abilities. Estes et al. (2011) examined basic number skills among students with autism, finding that tasks within this domain were more difficult for these students than expected based on cognitive ability. In particular, 40% of participants performed significantly poorer on basic number skill tasks than anticipated, while only 13% performed significantly better than their predicted level. Basic number skills in terms of numerical estimation and non-symbolic number sense (i.e., comparing quantities of dots) were also identified as relative weaknesses by Aagten Murphy et al. (2015) and Hinniker et al. (2016) respectively. Iuculano and colleagues (2014), however, produced conflicting results indicating that students with autism demonstrated significantly better numerical computation abilities than age matched TD students. Evidently, a consistent pattern in math performance concerning arithmetic and computation is lacking for students with autism as well. Collectively, the evidence suggests that there is great variability in math performance among students with autism. Thus, it becomes critical to explore which underlying factors may be related to this variability in order to better support these students in their learning.

Cognitive and Linguistic Factors Influencing Math Performance

Current models of math ability describe several underlying factors that appear to play important roles in math performance outcomes across studies with unselected samples of students. In the pathways model, developed by LeFevre and colleagues (2010), math performance was largely determined by cognitive precursors. This model proposes that math performance is determined by three unique pathways, or areas of knowledge and skill: linguistic, quantitative, and spatial attention. Accordingly, certain mathematical outcomes can be linked back to corresponding pathways; one or more pathways may be responsible for such outcomes. First, the linguistic pathway (i.e., skill) describes language as a cognitive process that has been consistently implicated as a predictor of mathematical skill in early school years among unselected samples of students (Aunóla et al., 2004; Durand et al., 2005; Hornung et al., 2014; Krajewski & Schneider, 2009; Simmons et al., 2008).

The second pathway identified by LeFevre et al. (2010) refers to the concept of quantitative reasoning, or the ability to compare quantities using the relative concepts of more and less. Researchers have used magnitude comparison tasks that ask participants to distinguish between sets of dots and numerical digits to assess this construct, finding that quantitative reasoning shares mild to moderate correlations with math achievement across all ages for unselected samples of students (Halberda et al., 2008; LeFevre et al., 2010).

The third and final pathway described by LeFevre et al. (2010) highlights the importance of spatial attention in relation to math performance. In this context, spatial attention refers to the combination of attentional capacities and working memory; the latter refers to the ability to attend to, maintain, and manipulate information at the forefront of the mind (Holmes et al., 2008). This ability may be accessed either phonologically, where information is heard (e.g., remembering a recited list), or visually, where information is seen (e.g., remembering a number of quickly presented images). Based on several studies, phonological and visual working memory systems appear to share moderate relationships with math performance outcomes with TD students of various ages (Holmes et al., 2008; Krajewski & Schneider, 2009; McKenzie et al., 2003), thus supporting the existence of this cognitive pathway.

In addition to the cognitive processes outlined by LeFevre et al.'s model (2010), the construct of fluid reasoning (i.e., ability to reason and problem-solve in a flexible manner) is another cognitive factor considered to be crucial to mathematic competence. Similar to the other cognitive variables previously discussed, fluid reasoning has been associated with both early numerical competencies (Kroesbergen et al., 2009), and later math performance as well (Deary et al., 2007; Moenikia & Zahed-Babelan, 2010). In an effort to explain this relationship, Taub and colleagues (2008) propose that students with a high degree of fluid reasoning tend to use strategies that directly influence math achievement. For instance, an elementary student learning to add might solve the problem 7 + 5 by applying the more efficient strategy of counting 5 up from 7 instead of counting from 1. Strategies that require inductive reasoning, or inferring a general conclusion from specific observations, are especially helpful in solving mathematical problems (Haverty et al., 2000). For instance, a student must use inductive reasoning when examining a pattern to quickly identify the repetitive section (i.e., finding the general rule for the entire pattern). Even problems that appear deductive in nature (i.e., where a general rule informs specific cases) are more easily solved once an individual has gained problem-solving knowledge through inductive methods (Haverty et al., 2000). Students with strong inductive reasoning skills tend to perform well in math, suggesting that drawing inferences and conclusions from specific instances is of particular importance (Stevenson et al., 2014). Based on this evidence, the general construct of fluid reasoning and math performance seem to share a relationship among unselected samples of students. This relationship has also been found in youth with autism. For example, when linguistic skill is held constant, non-verbal IQ (NVIQ; representative of visually-based fluid reasoning) and math performance seem to share a moderate relationship (Oswald et al., 2016). However, Troyb and colleagues (2014) found that students with autism performed significantly poorer on a math problem solving task relative to students who no longer met criteria for a diagnosis of autism, even when students from both groups were matched for age and NVIQ. Accordingly, the role of NVIQ likely cannot solely account for differences in math performance outcomes.

Essentially, several cognitive processes (e.g., linguistic skills, quantitative reasoning, spatial attention, fluid reasoning) seem to play relatively consistent roles in math performance outcomes among students within the general population (i.e., TD students, unselected samples of students, students who no longer meet autism diagnostic criteria). LeFevre et al (2010) suggest that within their pathway model, these factors can be extended to identify areas of math strength and weakness in special populations as well. For instance, children with Williams syndrome (a disorder that can lead to both spatial difficulties and delays in quantitative development) may demonstrate relatively stronger linguistic skills, and weaker quantitative skills (LeFevre et al., 2010). With regards to students with autism, however, math performance outcomes fail to follow a consistent pattern of strength and weakness (Aagten-Murphy et al., 2015; Bae et al., 2015; Iuculano et al., 2014; Jones et al., 2009; Kurth & Mastergeorge, 2010; Oswald et al., 2016; Wei et al., 2013), making it very difficult to identify the contribution of each pathway. Accordingly, it may be that math performance outcomes of students with autism cannot be reliably or accurately predicted by indicators of language or cognitive ability alone.

Indeed, researchers attempting to understand the relative role of these factors in predicting math performance among students with autism have failed to produce consistent findings. Several studies have found that Full-Scale IQ (FSIQ), an indicator of overall cognitive ability, is a poor predictor of math ability in youth with autism (e.g., Aagten-Murphy et al., 2015; Chiang and Lin, 2007; Estes et al., 2011; Jones et al., 2009). For example, Estes et al. (2011) reported "significant discrepancies between children's actual [math] academic achievement and their expected achievement based on their intellectual ability were found in 27 of 30 (90%) children. Both lower than expected and higher than expected achievement was observed" (p. 1044). Similarly, Aagten-Murphy and colleagues (2015) also found that a significant proportion of their participants with autism presented with standardized math achievement scores that were inconsistent with what their FSIQ scores would otherwise dictate. In this study, it was particularly surprising that FSIQ did not significantly correlate with math achievement for students with autism ($r = .23$) when a large, significant relationship between these constructs was found among their sample of TD students ($r = .70$; Aagten-Murphy et al., 2015).

With regards to the role of language in relation to math performance, the available findings are somewhat mixed. Several different studies have reported moderately strong relationships between language-related tasks and math performance among students with autism (Miller et al., 2017; Oswald et al., 2016; Titeca et al., 2014). For instance, a study conducted by

Miller and colleagues (2017) found that students with autism performed better in numerical computation tasks relative to tasks associated with word problem solving. While the difference between performance on these tasks was only approaching significance, Miller et al. (2017) proposed that this tendency could reflect an underlying impairment associated with processing and comprehending linguistic information. Linguistic skills have been linked to word problem solving ability in two large-scale studies conducted with unselected samples of youth (Beal et al., 2010; Jordan et al., 2003), suggesting that this proposition may hold some truth. Further support for the role of language in math performance was demonstrated by Titeca and colleagues (2014), who reported a significant moderate correlation between word problem solving and verbally subitizing (i.e., verbally indicating a quantity) for students with autism between the ages of 6 and 7 (r = .54). Oswald and colleagues (2016) found a similar relationship (r = .36) between verbal ability and problem solving for older children with autism (ages 11 through 17), although in this case, it was not deemed statistically significant. In contrast to these findings, however, Assouline and colleagues (2012) found that verbal comprehension was unrelated to math achievement among gifted students with autism from age 5 to 17 (r = .02). Collectively, these findings suggest that language may play a role for some students with autism with regards to mathematical word problems; yet language alone is unlikely to fully explain the variability of math performance outcomes observed among students with autism. Given that a diagnosis of autism seems to lead to math performance outcomes unlike those demonstrated by TD students, investigating factors beyond the inconsistent predictors related to language and cognitive ability is necessary to fully understand why students with autism perform so variably in this domain.

Emotional Factors Associated with Math Performance

Emotions, or variables associated with emotions are potential alternatives that may further shed light on variability in math achievement for students both with and without autism. For instance, a factor analysis conducted by Cerda and colleagues (2015) demonstrated that unselected samples of students with unfavourable predispositions towards math were significantly more likely to perform poorly, while students with favourable predispositions towards math were more likely to perform well ($\beta = .41$, $p < .001$) (Cerda et al., 2015). While Cerda and colleagues explored the general role of emotions in predicting mathematical outcomes, other researchers have explored the relationships between specific emotions and math achievement.

For instance, Pekrun and colleagues (2017) recently investigated the reciprocal relationships between particular emotions tied to achievement and math achievement outcomes for an unselected sample of youth across a span of five years, reporting stable small to moderate correlations pertaining to math-related enjoyment (r = .20 – .45), boredom (r = -.37 – -.45), and anxiety (r = -.37 – -.40). These findings suggest that $A_{ch}E_{m}$s related to math share consistent relationships with math achievement over time.

Beyond emotions themselves, the role of context has also received notable attention in the last decade. Lichtenfeld and colleagues (2012) investigated the relationships between math $A_{ch}E_{m}$s and learning contexts among unselected samples of second and third graders from both Germany and the United States. In their efforts to develop and validate a new instrument to assess emotions related to math achievement, the researchers found small to moderate relationships between three particular learning contexts and three specific $A_{ch}E_{m}$s (i.e., enjoyment, boredom, and anxiety) (see Table 1 below). Similar relationships (in both size and direction) were recently identified by Raccanello and colleagues (2018), who sought to compare

$A_{ch}E_{m}$s experienced by an unselected sample of elementary students across subject domains (correlations pertaining to math depicted in Table 1).

Table 1

Pearson Correlations reported by Lichtenfeld et al. (2012) and Raccanello et al. (2018)

Learning Context	Lichtenfeld et al., 2012			Raccanello et al., 2018		
	Enjoyment	Boredom	Anxiety	Enjoyment	Boredom	Anxiety
Class Time	.14 – .23	-.16 – -.23	-.24 – -.32	.19	-.21	-.28
Homework Completion	.07 – .09	-.12 – -.15	-.14 – -.27	.15	-.22	-.22
Test Writing	.12 – .28	-	-.20 – -.35	.27	-.26	-.37

Note. This table compares the relationships between three math-related $A_{ch}E_{m}$s and three specific learning contexts across two distinct empirical studies. Correlations from both American and German samples are listed from Lichtenfeld et al.'s study (2012).

Based on this evidence, math performance outcomes seem to share relatively consistent relationships with emotions among unselected samples of students. This consistency is important, as some evidence suggests that positive emotional predispositions have the potential to mitigate negative performance outcomes driven by cognitive processes (e.g., fluid reasoning) (Cerda et al., 2015). Accordingly, the role of emotions in relation to math among these students should not be underestimated.

While it seems that emotional predisposition has a consistent impact on math performance outcomes of unselected samples of students, it has been evaluated among students with autism only in a very preliminary fashion. Yet, understanding the mechanisms behind emotions in relation to math for these students could be critical in order to support them in their academic endeavors. For instance, clinically elevated anxiety is the most common comorbid psychological disorder among students with autism (Lopata & Thomeer, 2014; Skokauskas & Gallagher, 2010), leading to regular social, emotional, and academic challenges (Chang et al., 2012). Despite these negative implications, most research concerned with math performance outcomes for students with autism focuses directly on improving fundamental math skills, while ignoring the impact that attitudes and emotions have on math learning (Georgiou et al., 2018). As such, it is necessary to find out whether emotional predispositions towards math displayed by students with autism play an important role in their math performance abilities; if so, this information will prove invaluable in the development of future interventions within the domain of mathematics for students with autism. This is especially noteworthy, as students with autism have previously responded well to interventions intent on improving emotion regulation (Scarpa & Reyes, 2011; Thomson et al., 2015).

Based on this information, understanding how students with autism experience emotions is essential in order to best support their emotional needs. However, there is uncertainty in the literature as to whether individuals with autism can provide accurate self-reports of their emotions (e.g., Berthoz & Hill, 2005; Fitzgerald & Bellgrove, 2006; Wang et al., 2004). One method that may limit the issue of giving inaccurate self-reports involves presenting participants with autism with emotions in a visual format (i.e., an image of a person's face) rather than a written or verbal format alone. Some researchers who have assessed how students with autism label visually represented emotions propose that these individuals can perform this skill as accurately as TD students (Piggot et al., 2004; Wang et al., 2004). In contrast, other researchers who did not employ visual aids in their studies, suggest that individuals with autism struggle to verbally label and describe their emotions (Fitzgerald & Bellgrove, 2006; Hill et al., 2004). As such, presenting emotions in a visual way appears to promote more accurate reports of emotions among students with autism, although this approach has not yet been used to explore relationships between the emotional experiences of these students and their achievement outcomes (e.g., math performance).

Presently, anxiety is the only emotion that has been explored in relation to math performance among students with autism. In their efforts to understand the clinical and cognitive characteristics of students with autism in relation to math problem solving, Oswald et al. (2016) found that math test anxiety significantly accounted for unique variance in math problem solving across their sample (β = -.29, p = .01); this small to moderate effect size is comparable with those pertaining to unselected samples of students in other studies (r = -.30 – -.37) (Lichtenfeld et al., 2012; Raccanello et al., 2018) based on effect size comparisons described by Sullivan & Feinn (2012). This early evidence suggests that emotional predisposition may predict math performance outcomes for students with autism as it seems to for unselected samples of students.

A more recent study conducted by Georgiou and colleagues (2018) further highlighted this possibility when they explored math anxiety and math performance in TD students and students with autism. In both groups, Georgiou et al. (2018) found that students with lower grades in math experienced greater math anxiety and importantly, students who reported liking mathematics also reported experiencing significantly less anxiety relative to those who reported disliking mathematics. Given that these results were identified for both TD students and for students with autism, these findings suggest that anxiety and enjoyment each share a similar relationship with math performance for both populations, to some extent. An additional finding from this study suggested that students with autism experience significantly less math anxiety than matched TD peers; however, this finding is somewhat of an anomaly in the literature. It contrasts with the high rates of anxiety described for members of this population (Lopata & Thomeer, 2014), and more specifically, disagrees with studies that have explored teacher perspectives, where teachers describe that their students with autism experience significantly greater anxiety than their TD peers (Ashburner et al., 2010; Syriopoulou-Delli et al., 2018). Given this inconsistency, the significance of this study may instead lie with the more general similarities between the way TD students and students with autism experience emotions in relation to math. With this relatively small research base, it is expected that emotions related to math and math performance will share similar relationships among students with autism in the current study as those seen in TD student populations (e.g., increased anxiety will be associated with poorer performance in math; increased enjoyment in math will be associated with better performance).

Although these recent studies provide some information regarding the relationship between emotions and math performance for students with autism, the present study intends to improve upon these findings by utilizing an objective measure of math performance, and by exploring emotions on a broader scale. The construct of test anxiety is relatively narrow in scope; it fails to address different feelings, interests, and beliefs (e.g., enjoyment, boredom) in other contexts (e.g., instructional time, completing homework). Accordingly, a broader lens is necessary in order to better understand the role that emotions may play in affecting math performance outcomes among students with autism.

The Role of Control-Value Theory

One framework that could provide this broader lens and potentially explain why some students with autism demonstrate math giftedness while others experience challenges lies with the control-value ($C_{trl}V_{al}$) theory of $A_{ch}E_{m}$s. $C_{trl}V_{al}$ theory is a highly comprehensive theoretical approach designed to explain emotional processes in achievement contexts; it integrates elements of attributional theories of emotions (Weiner, 1985), theories of perceived control (Patrick et al., 1993), expectancy-value approaches (Turner & Schallert, 2001), and frameworks associated with the relationship between emotions, learning, and performance (Fredrickson, 2001; Pekrun et al., 2002). Given this theoretical composition, Pekrun (2006) unsurprisingly describes emotions as multifaceted. He defines emotions as processes resulting from affective, cognitive, motivational, expressive, and physiological systems (Pekrun, 2006). With this level of complexity and breadth, $C_{trl}V_{al}$ theory is well equipped to explain a number of emotional processes within various achievement contexts.

Although $C_{trl}V_{al}$ theory has not yet been explored among students with autism, the internal mechanisms of this theory appear to explain emotional processes in relation to math performance for unselected samples of students (Lichtenfeld et al., 2012; Patrick et al., 1993; Pekrun et al., 2017; Pekrun et al., 2002). Within the context of $C_{trl}V_{al}$ theory, the relationship between these two constructs is anticipated to extend to students with autism, particularly given that this theory recognizes the importance of regulating emotions. For many students with autism, regulating emotions can be incredibly challenging (Samson et al., 2015); however, $C_{trl}V_{al}$ theory provides an explanation as to how this dysregulation could potentially lead to $A_{ch}E_{m}$s capable of reflecting both math giftedness and disability. In this way, it is expected that $A_{ch}E_{m}$s and math performance will share similar relationships for students with autism as they do for unselected samples of students (i.e., $A_{ch}E_{m}$s will correlate with math performance outcomes). In order to fully explain the relevance of $C_{trl}V_{al}$ theory, the separate constructs of $A_{ch}E_{m}$s as well as control and value appraisals will be described first before discussing how they relate to one another. Subsequently, the importance of reciprocal feedback loops will be discussed before highlighting the role of emotion regulation in the various presentations of $A_{ch}E_{m}$s, and its significance with regards to students with autism.

Achievement Emotions

Pekrun (2006) defines $A_{ch}E_{m}$s as emotions tied to either achievement related activities (e.g., class instruction, completing homework, in-class assignment), or achievement related outcomes (e.g., receiving a grade from a previously written exam) (Pekrun, 2006). $A_{ch}E_{m}$s are characterized in a detailed fashion by three dimensions: object focus, valence, and activation level (Pekrun, 2006). First, object focus describes the achievement activity or outcome associated with the emotion. Valence determines whether the emotion is positive or negative in nature, while activation level describes emotions on a continuum from passive (e.g., boredom) to active (e.g., enjoyment, anger). For example, experiencing enjoyment during class would be considered a positive, activating, activity-related emotion, while experiencing anxiety prior to writing a test would be characterized as a negative, activating, outcome-related emotion. Perhaps unsurprisingly, $A_{ch}E_{m}$s have regularly predicted math performance in unselected samples of student populations (Lichtenfeld et al., 2012; Pekrun et al., 2017; Pekrun et al., 2014; Raccanello et al., 2018).

Control and Value Appraisals

In order to understand the presentation of $A_{ch}E_{m}$s, identifying relevant antecedents is necessary. While many external forces are capable of influencing $A_{ch}E_{m}$s (e.g., motivation, genetic background, use of learning strategies), many modern psychological perspectives of emotion agree that both internal (i.e., self-related) and external (i.e., situational) appraisals play key determinant roles in the presentation of human emotions (Moors et al., 2013). Within an educational context, these appraisals, or perspectives, are assumed to be capable of mediating effects from situational factors (Pekrun, 2006). For example, a student's perceived control over their ability to write an exam could mediate the negative effects of an excessively distracting testing environment, allowing them to perform well. Critically, $C_{trl}V_{al}$ theory describes an important relationship between the nature of these appraisals and $A_{ch}E_{m}$s (Pekrun, 2006). Pekrun (2006) emphasizes the importance of two types of appraisals: subjective control over achievement related activities and outcomes (e.g., believing that persistent studying before a test will lead to success), and subjective value of these activities and outcomes (e.g., perceived importance of performing well). Essentially, an individual's feelings (i.e., $A_{ch}E_{m}$s) towards a particular academic activity or outcome are directly affected by the individual's beliefs about the degree of perceived control they have, and how much importance, or value, they place on that activity or outcome.

According to Pekrun (2006), an individual's subjective control is largely determined by causal expectancies and attributions; causal expectancies are prospective in that they concern future event outcomes, while causal attributions are retrospective cognitions reflecting on past event outcomes. In both cases, $C_{trl}V_{al}$ theory describes controllability in terms of internally driven control, where individuals believe they themselves are responsible for their actions and outcomes, and externally driven control, where individuals believe that situational circumstances are responsible (Pekrun, 2006). For instance, externally driven control would be reflected in a student who anticipates performing poorly on an exam in spite of spending days preparing for it because she believes the exam difficulty will determine her mark. In contrast, a student who believes themselves to be in control under these circumstances would believe that studying for a test will lead her to perform well on it.

According to $C_{trl}V_{al}$ theory, positive achievement outcomes are generally expected by individuals when their externally-driven sense of control is low, and their internally driven sense of control is high (Pekrun, 2006). For example, a student might expect to perform well on an exam (i.e., a successful outcome) when they believe their study efforts will lead to a greater chance of success (i.e., high internal control), and that a lack of such effort will lead to failure (i.e., low external control). Alternatively, negative achievement outcomes are typically expected by individuals when their externally driven sense of control is high, and their internally driven sense of control is low (Pekrun, 2006). Essentially, failure is more likely to be expected when an individual has low perceived control over their achievement outcomes, and when a situation is expected to inherently lead to negative outcomes regardless of any action taken, although the role of value must be considered in this equation as well. (Pekrun, 2006).

Value, $C_{trl}V_{al}$ theory's second component, refers to the degree of importance an individual places on an achievement activity or outcome (Pekrun, 2006). Placing high value on a successful outcome means that that particular success is highly fortuitous to an individual, while alternatively placing high value on a failure outcome means that that particular failure is especially devastating to the individual involved (Pekrun, 2006). Essentially, value in this case refers to the magnitude of care a student has towards a particular outcome. Alternatively, value appraisals associated with activity emotions differ slightly in that they may be positive (i.e., the individual finds the activity agreeable), negative (i.e., the individual finds the activity aversive), or absent (i.e., the individual does not care about the activity in a positive or negative way).

Control and Value Appraisals and Achievement Emotions

Establishing the nature of control and value appraisals is important in order to understand and describe various emotions within an achievement context. Indeed, diverse patterns of these appraisals represent, and in part produce, different $A_{ch}E_{m}$s based on object focus (i.e., activity or outcome) and time frame (i.e., prospective or retrospective) (Pekrun, 2006). Accordingly, control and value appraisals can lead to either prospective outcome emotions, retrospective outcome emotions, or activity emotions.

With regards to prospective outcome emotions, outcome expectancies (i.e., driven by controllability) and value appraisals are necessary contributors (Pekrun, 2006). When expectancies are favourable (i.e., an individual expects success or an absence of failure), an individual is likely to experience either anticipatory joy or anticipatory relief. In either case, the intensity of this emotion is correspondingly determined by the degree of value or importance the individual places on the outcome. For instance, a student who expects to perform exceedingly well on an upcoming exam would look forward to this activity and the expected outcome (i.e., anticipatory joy), while a student who merely expects they will avoid failure would be relieved upon learning that they passed their exam (i.e., anticipatory relief). When prospective expectancies are unfavourable (i.e., an individual expects failure or a lack of success), an individual may experience hopelessness or anxiety (Pekrun, 2006). Hopelessness occurs when an individual feels subjectively certain about the anticipated negative outcome, and that they have little to no internal control over their ability to change that outcome (Pekrun, 2006). In this case, the outcome must also carry significant importance or value to the individual. Hopelessness and anxiety are similar, given that an anxious individual is also focused on the likelihood of a negative outcome, and places great importance on that outcome. Anxiety, however, differs in that an individual experiencing anxiety feels as though they have a moderate amount of internal control over their expected outcome (Pekrun, 2006). When combined with high value, this can lead an individual to experience a degree of uncertainty; a quality that also characterizes the more positive achievement emotion of hope (Pekrun, 2006). Hope and anxiety share this similarity; however, anxiety involves focusing on the likelihood of a failed outcome, while hope involves focusing on the likelihood of a successful outcome. In either case, value appraisals must be high in order to experience the given emotion (Pekrun, 2006).

Retrospective outcome emotions represent the combination of an individual's outcome attributions (i.e., determined by controllability) as well as their value appraisals (Pekrun, 2006). Attributing outcomes of success and failure to either internal or external sources primarily determines the type of emotion an individual will experience. Although success and failure are likely to inspire feelings of joy or sadness respectively, these feelings are considered independent from appraisals of control (Pekrun, 2006). That is, regardless of whether an individual feels responsible for causing an outcome or not, they may feel joyful or dejected nonetheless. However, control plays a significant role in the arousal of specific retrospective emotions such as pride, shame, gratitude, and anger (Pekrun, 2006). When an individual attributes an outcome to have been caused largely by internal sources (i.e., their own actions), they will experience either pride in response to success, or shame in response to failure (Pekrun, 2006). Shame is unique in that it can also develop when causal responsibility for a failure outcome is assigned to external sources; feelings of anger may come out under these circumstances as well (Pekrun, 2006). In contrast, gratitude is produced when success is perceived as being caused by external sources (i.e., other people) (Pekrun, 2006). In each of these cases, value appraisals are significant in determining the intensity of how these emotions are experienced; the more important an individual considers an outcome to be, the more intensely they are expected to experience the associated emotion (Pekrun, 2006). Likewise, a student learning of an outcome (e.g., grade, feedback) considered to be of little value or importance is unlikely to experience any of these aforementioned $A_{ch}E_{m}$s. Typically, students might experience combinations of retrospective emotions as a result of multiple perceived causes (Pekrun, 2006). For instance, pride and gratitude might be simultaneously experienced for a student who performs well on an exam; they might recognize their own actions as cause for this result as well as their teacher's instructional methods. In this case, the comparative intensities of these different emotions are dependent on how much the individual considers each source responsible for the outcome (Pekrun, 2006).

Lastly, $A_{ch}E_{m}$s can be discussed with regards to activities as opposed to outcomes. Unlike prospective and retrospective outcome emotions, activity-based emotions are associated with actions, meaning that control and value appraisals associated with outcomes are irrelevant to the presentation of these types of emotions (Pekrun, 2006). As well, value appraisals differ slightly for achievement activities; in this regard, they describe an activity's inherent incentive value (i.e., how much students are motivated to participate). For instance, when a student who positively values a given activity also feels it is controllable, they are likely to feel enjoyment towards that activity independent of any related outcomes (Pekrun, 2006). Essentially, a student incentivized to study mathematics who also feels capable in their ability to study math will likely enjoy this activity. Alternatively, when an activity is not considered positively valuable (i.e., negatively valued or lacking value), feelings of anger, frustration, or boredom may be inspired instead. In particular, when value appraisals associated with an activity are lacking (i.e., the activity is not considered aversive, but fails to motivate a student to participate), a student will likely experience boredom when partaking in that activity (Pekrun, 2006). The degree of boredom they experience depends partially on the degree to which a student feels the activity is within their control; boredom may be induced when a student feels very capable in their abilities, but the activity demands very little of them (Pekrun, 2006). Boredom may also be experienced when the reverse occurs; a student who fails to find incentive value in a demanding activity that feels uncontrollable will also likely find that activity boring (Pekrun, 2006). In this way, control and value appraisals can lead to a variety of different $A_{ch}E_m$s based on whether they involve outcomes or activities, as well as whether they involve past, present, or future events.

Reciprocal Causation

Although Pekrun (2006) emphasizes the role of control and value appraisals as antecedents for various $A_{ch}E_m$s, his $C_{trl}V_{al}$ theory also posits that $A_{ch}E_m$s are capable of affecting these appraisals and associated achievement outcomes in a reciprocal manner. Essentially, emotions directed towards various achievement activities and outcomes can impact learning and achievement; however, the social environment and the activities and outcomes themselves can alter how students feel about the activities as well (Pekrun, 2006). These feedback loops may be classified as positive or negative, a designation which refers to the directionality of a given system rather than desirability (i.e., good or bad). Positive feedback loops are constantly moving in the same direction; an increase in one variable leads to an increase in another, which leads the system to move in one constant direction. In contrast, negative feedback loops include variables that affect each other in opposite directions; an increase in one variable leads to a decrease in another. Variables in this type of loop are constantly working towards a balance or equilibrium. An example of a positive feedback loop might involve a student's test anxiety in math leading the student to perform poorly on a math exam, which might then result with them experiencing even greater test anxiety in math afterwards. Alternatively, a negative feedback loop might consist of a student experiencing extreme anxiety towards math who then studies hard to avoid failing a math test, leading them to succeed and subsequently experience less math anxiety because their level of internal control has increased. Reciprocal causation between $A_{ch}E_m$s and achievement outcomes has been demonstrated repeatedly among unselected samples of students, with most studies focusing on enjoyment, anxiety, and/or boredom (Daniels et al., 2009; Gunderson et al., 2018; Pekrun et al., 2014; Pekrun et al., 2017).

Importantly, these reciprocal relationships between emotions and performance appear to last for long periods of time. Pekrun and colleagues (2017) found stable relationships between end-of-year math grades and emotions towards math over the course of five years (enjoyment, r = .20 – .45; pride, r = .18 – .38; anger, r = -.30 – -.42; anxiety, r = -.37 – -.40, shame, r = -.29 – -.34; boredom, r = -.37 – -.45; hopelessness, r = -.09 – -.22). Intelligence, socioeconomic status, and gender were controlled as part of this investigation, suggesting that $A_{ch}E_{m}$s towards math predict performance and likewise, performance in math predicts the manifestation of various $A_{ch}E_{m}$s above and beyond demographic predictors. Notably, Pekrun et al. (2017) exclusively found evidence of positive feedback loops, meaning that negative emotions towards math (e.g., anger, anxiety, frustration, shame, boredom, hopelessness) predicted negative performance, and negative performance predicted negative emotions. Similarly, positive emotions towards math (e.g., pride, enjoyment) predicted positive math performance, and positive performance in turn predicted the manifestation of positive emotions. Similar results have been found among students in grades 1 and 2, with achievement in math and math anxiety sharing a reciprocal relationship (i.e., positive feedback loop) (Gunderson et al., 2018). Although this particular study found that math anxiety was a slightly stronger predictor for later math performance (r = -.38) than math performance was for math anxiety (r = -.28), both relationships were deemed significant. Essentially, this research collectively emphasizes the existence of positive feedback loops in the forms of both virtuous and vicious cycles. A reciprocal relationship between negative emotions and performance with regards to math could lead to long-lasting negative trajectories in this domain, while a cyclic relationship between positive emotions and performance may allow children to reach their full potential in math (Gunderson et al., 2018). Accordingly, interrupting, or regulating the potential snowball effect associated with negative emotions and math performance could be essential in helping students perform well in mathematics.

The Role of Emotion Regulation

The process of regulating emotions plays a significant role in $C_{trl}V_{al}$ theory; it generally strives to increase positive emotions and correspondingly, decrease negative emotions (Sorić et al., 2013). In particular, Pekrun (2006) defines emotion regulation as a process capable of directly addressing $A_{ch}E_{m}$s, control and value appraisals, and situational variables. This process includes the ability to recognize and understand one's emotions, the ability to manage these emotions to fit surrounding circumstances, and lastly, the ability to use these emotions to achieve goals (Pekrun, 2006).

Within this framework, emotions are managed through four different processes: emotion-oriented regulation, appraisal-oriented regulation, problem-oriented regulation, and situationally-based regulation (Pekrun, 2006). First, emotion-oriented regulation directly targets $A_{ch}E_{m}$s themselves; doing so may involve internally suppressing an emotion, taking drugs aimed to target a particular emotion, or utilizing relaxation techniques (Jarrell & Lajoie, 2017). Appraisal-oriented regulation differs in that it involves changing how a situation, task, or set of circumstances is perceived (Jarrell & Lajoie, 2017). In $C_{trl}V_{al}$ theory, this particular component refers to the extent to which an individual's control and value appraisals cognitively impact their $A_{ch}E_{m}$s (Pekrun, 2006). Problem-oriented regulation and situation-oriented regulation are more externally driven by nature. While problem-oriented regulation involves indirectly targeting emotions by responding to achievement outcomes (e.g., learning strategies to improve competence in math), situation-oriented regulation involves creating an environment that matches a student's individual achievement goals and competencies (e.g., asking for an extension on an assignment) (Jarrell & Lajoie, 2017, Pekrun, 2006). Although $C_{trl}V_{al}$ theory recognizes the role of each of these processes, appraisal and emotion-oriented regulation are possibly the most significant, given that they have received the most attention in the literature (Balzarotti et al., 2010; Jarrell & Lajoie, 2017). These internally driven components of emotion regulation include two well explored regulatory strategies relevant to the current investigation: emotional suppression and cognitive reappraisal (Sorić et al., 2013).

Emotional suppression is an approach used after a student has already become dysregulated; in other words, this strategy works to regulate an emotional response retroactively (Sorić et al., 2013). Essentially, this strategy involves camouflaging or masking the outward expression of an emotion; however, it does not work to change how an individual experiences an emotion internally (Sorić et al., 2013). Suppression is considered a cognitively expensive process that prevents verbal working memory from functioning at an optimal level (Sorić et al., 2013), and is furthermore negatively correlated with using social supports and sharing emotions with others (Gross & John, 2003). Utilizing this approach may also increase physiological responding in a maladaptive sense (e.g., it may activate the fight or flight response). Accordingly, regulatory strategies such as emotional suppression that focus on retroactively regulating an emotional response often fail to generate positive results because the internal experience of the emotion remains unchanged (Gross, 2001; Sorić et al., 2013).

In contrast, antecedent-focused regulatory strategies tend to generate more favourable outcomes (Balzarotti et al., 2010); they are designed to regulate an emotional response proactively; that is, prior to an emotional response (Sorić et al., 2013). Cognitive reappraisal is one such strategy that functions in this manner. Utilizing cognitive reappraisal involves changing the way one perceives a situation or task, which leads to a corresponding emotional change due to altered meaning or emotional impact (Sorić et al., 2013). In particular, this strategy is useful in targeting cognitive distortions (e.g., catastrophic thinking) (Weiss et al., 2014). For instance, a student who fails to use cognitive reappraisal might fall prey to cognitive distortions when receiving a poor grade on a math test; they might think that this singular instance suggests that they never perform well in math and that they will never improve. In comparison, a student who uses this regulatory strategy might consider the same outcome to mean that they did not perform as well as they wanted to this time, and that they will do better next time because they will study more thoroughly. By implementing cognitive reappraisal, the second student in this example effectively avoids using catastrophic or ‘all-or-nothing’ thinking. Among unselected samples of students, reappraisal is associated with reduced experience of negative emotions (e.g., anxiety, anger shame) and increased experience of positive emotions (e.g., enjoyment, relief, gratitude) (Gross & John, 2003), thus effectively serving the primary purpose of emotion regulation as described by Soric et al. (2013).

Cognitive reappraisal is especially significant, given that regulating control and value appraisals is considered to be one of the most critical mechanisms for emotional regulation (Sorić et al., 2013). According to $C_{trl}V_{al}$ theory, students who are capable of regulating their control and value appraisals by using cognitive reappraisal will also be capable of regulating their $A_{ch}E_{m}$s (Pekrun, 2006). For example, $C_{trl}V_{al}$ theory suggests that a student experiencing anxiety in relation to writing an upcoming math exam is likely worried about achieving a negative outcome (failure). In this case, they may expect failure, or merely overly focus their attention on avoiding failure. If this student were to use cognitive reappraisal to adjust their prospective outcome appraisal away from failure and towards success, this might inspire hope within the student rather than anxiety. By focusing on attaining success rather than avoiding failure, this student will likely experience more positive $A_{ch}E_{m}$s, and perform better in math as a result. Accordingly, utilizing cognitive reappraisal may allow students to experience more positive $A_{ch}E_{m}$s. Given that higher levels of perceived control and value generally predict the emergence of positive $A_{ch}E_{m}$s (e.g., pride, enjoyment), while lower levels generally predict the emergence of negative $A_{ch}E_{m}$s (e.g., shame, boredom) (Bieg et al., 2013; Goetz et al., 2006), understanding cognitive reappraisal as a strategy to regulate $A_{ch}E_{m}$s is essential.

Special Considerations for Students with Autism

Despite the adaptive benefits of using cognitive reappraisal, students with autism frequently find it difficult to inherently use this strategy (Weiss et al., 2014). In general, many students with autism experience significant challenges regulating their emotions; Totsika and colleagues (2011) sampled 5–16-year-old students with autism without intellectual disability (ID) and matched sample of TD students. They found that 85% of youth with autism demonstrated clinically elevated levels of hyperactivity, 74% demonstrated emotional problems, and 64% presented with conduct problems. Notably, these rates were substantially higher than those reported from their TD control group (i.e., 19% for hyperactivity, 18% for emotional problems, 22% for conduct problems). Emotion regulation issues have been proposed to be responsible for this increase in emotional and behavioural difficulties (Weiss et al., 2014).

Mazefsky and colleagues (2014) explored this further among students with autism in relation to TD students through the use of a self-report questionnaire pertaining to emotion regulation strategies. Interestingly, while both groups reported the use of adaptive emotion regulation strategies (e.g., cognitive reappraisal), students with autism also used significantly more maladaptive strategies than their TD peers. Specifically, these students tended to remain focused on the stressor (i.e., ruminating on the obstacle, barrier, or event), and/or emotionally "shut down" in response to it (i.e., feeling unable to think or act). Similarly, individuals with autism have been found to ruminate in relation to cognitive distortions (Sofronoff, & Attwood, 2003; Weiss et al., 2014), and often use emotional suppression as a strategy (Weiss et al., 2014). However, they have also shown improvements in their ability to regulate their emotions when explicitly taught cognitive reappraisal strategies (Beaumont et al., 2015; Samson et al., 2015; Samson et al., 2012). Considering that members of this population might be capable of improving their ability to regulate their emotions using cognitive reappraisal, exploring and understanding control and value appraisal mechanisms among students with autism could critically inform potential future interventions. This carries considerable weight in an achievement context, given that $A_{ch}E_{m}$s are expected to predict math performance outcomes among students with autism, and emotion dysregulation in this regard could directly impact emotions and correspondingly, performance.

Perhaps somewhat ironically, the inability to adaptively regulate $A_{ch}E_{m}$s could lead to both superior and poor performance in math among students with autism. For instance, students with autism who have an intense special interest related to math or numbers may perform extremely well in math as a result of spending inordinate lengths of time researching, exploring, and talking about this interest. In a study conducted by Winter-Messiers (2007), students with autism expressed greater enthusiasm, emotion, and response complexity when engaged in conversation about their special interest area relative to other subjects of conversation. When asked questions unrelated to the student's special interest areas, many responded with brief, non-committal answers, such as "I don't know," "whatever," and "I guess." As such, these special interest areas often allow students with autism to develop exceptional localized expertise, however, they may also make it difficult to regulate specific appraisals, goals, and emotions external to these special interest areas. For example, a student with a special interest in math may find it challenging to regulate their appraisals and emotions in social studies, in part because doing so would involve emotionally recognizing the importance of a subject outside of the student's special interest area, as well as an appreciation for the change in academic environment (e.g., class time in social studies rather than math).

Although this pattern of behaviour may pose several challenges to students with autism, there may be a set of circumstances under which special interest areas reflective of emotion dysregulation function as assets for members of this population. When a special interest area matches a necessary skill or task (e.g., an interest in numerical patterns and writing a math test), it may be that a student's inability to regulate their focus and energy away from this special interest allows them to perform at a superior level relative to their TD peers. Indeed, Hans Asperger realized that a special, circumscribed interest "enables [students with autism] to achieve quite extraordinary levels of performance in a certain area" (as cited in Winter-Messiers, 2007). Following this idea, students with autism who have a special interest in math may consequently believe that they are highly skilled mathematicians (i.e., they have a high degree of perceived control), and that math is of great importance (i.e., they deem math valuable). In this way, a student may perform very well in math in spite of, and perhaps because of, poorer emotion regulatory capacities when paired with a congruent special interest related to math. Essentially, students with autism who experience positive $A_{ch}E_{m}$s towards math as a reflection of poor emotion regulation and a circumscribed interest congruent with math may be those who present with math giftedness.

Conversely, emotion dysregulation may also be in part responsible for poor math performance outcomes among other students with autism. Without a congruent match between a student's circumscribed interest and the task at hand (i.e., completing math homework), they may find it difficult to regulate their control and value appraisals accordingly. Students with autism who fit this mould may feel that they lack control over their math performance outcomes (i.e., they have a low degree of perceived control), and that math is of little importance (i.e., they see little value in math related activities and outcomes). Generally, appraisal combinations that include low perceived control and/or low value lead to feelings of anxiety, boredom, shame, and anger. Attending to cognitive distortions and engaging in maladaptive regulatory strategies (e.g., emotional suppression) are suspected to make it increasingly difficult for students with autism to change and regulate these types of negative emotional responses (Weiss et al., 2014). Given that $A_{ch}E_{m}$s and academic performance share reciprocal relationships, it may be that an impeded ability to adjust or regulate negative thoughts and feelings directed towards math could correspondingly lead to poor performance in math as well. Therefore, students with autism who experience negative $A_{ch}E_{m}$s towards math as a result of poor emotion regulation and incongruent special interests may be those who present with a math disability.

In summary, emotion dysregulation frequently experienced by students with autism may explain why some students demonstrate math disability while others demonstrate math giftedness through the presentation of $A_{ch}E_{m}$s. When students with autism demonstrate emotion dysregulation and possess incongruent special interests, they are expected to develop negatively focused $A_{ch}E_{m}$s (e.g., anxiety, boredom) towards math, which may lead them to be especially unwilling to engage in math related activities and perform correspondingly poorly. Conversely, students with dysregulated emotions and congruent special interests (e.g., numbers, patterns) are expected to routinely spend inordinate lengths of time investigating math related concepts, accordingly present with positively oriented $A_{ch}E_m$s (e.g., enjoyment) and perform at a superior level. In this way, $A_{ch}E_m$s may have the capacity to predict both math disability and math giftedness above and beyond inconsistent predictors such as cognitive ability and language.

Current Study

The current study examined $A_{ch}E_m$s in students with autism aged 5 to 16 to better understand the relationships between $A_{ch}E_m$s and math performance among members of this population. Furthermore, this investigation sought to determine whether $A_{ch}E_m$s were capable of predicting math performance outcomes above and beyond standardized measures of cognitive ability and language. For these reasons, the following research questions and hypotheses (in italics) were developed:

1. **What is the relationship between $A_{ch}E_m$s and math performance outcomes for children and youth with autism?** *Among members of this population, it was hypothesized that positive $A_{ch}E_m$s (i.e., enjoyment) would positively correlate with math performance, while negative $A_{ch}E_m$s (i.e., boredom, anxiety) would negatively correlate with math performance.*
2. **Do $A_{ch}E_m$s predict math performance outcomes in children and youth with autism above and beyond standardized measures of non-verbal cognitive ability and language?** *It was predicted that $A_{ch}E_m$s would uniquely predict math performance scores for members of this population above and beyond standardized measures of cognitive ability and language.*

Method

Participants

Data for the present study was drawn from a broader overarching study focused on understanding what general factors influence math achievement among students with autism. While data concerning $A_{ch}E_m$s was gathered as part of this broader study, this was the first time it was analyzed for the purpose of highlighting the role emotional variables may play in math performance outcomes for students with autism. Data from twenty-eight English speaking students were selected from this larger database to conduct this analysis. Participants were only selected if they had completed each of the measures used in the present study (described below); participants who did not complete one or more measures were excluded from the analysis. Additionally, three students who completed all measures were excluded from the analysis due to their highly variable responses on the AEQ-ES. In particular, these students provided inconsistent responses to items within a given scale (e.g., homework anxiety), such that a response to one item was a minimum of three points away from responses on similar items. This variability may reflect that these students experienced difficulty in understanding the items presented on the AEQ-ES, and as such, their data was excluded from the analysis. Notably, these participants did not perform similarly on any measure, and removing their data did not alter the overall results described below.

Student participants were recruited through elementary schools, community agencies, and social media platforms (i.e., Facebook, Instagram). Participant ages ranged from 5 through 16 (M = 10.68, SD = 3.32) and had a confirmed diagnosis of Autism Spectrum Disorder, Asperger's Disorder, Autistic Disorder, or Pervasive Developmental Disorder – Not Otherwise Specific (PDD-NOS) (i.e., as per criteria in the DSM-IV [APA, 2000] or DSM-5 [APA, 2013]). 92.8% of the participants were male. Furthermore, 13 participants had at least one comorbid disorder, including cases of anxiety disorders, Attention Deficit Hyperactivity Disorder (ADHD), and sensory processing disorders. It is especially noteworthy that 28.6% of participants reported having comorbid diagnosis of ADHD, and that 25.0% reported the presence of a comorbid anxiety disorder. Participant demographic information is outlined in Table 2 below.

Table 2

Participant Demographic Characteristics

Characteristic	N	%
Gender		
Male	26	92.8
Female	2	7.1
Diagnosis		
ASD	10	35.7
Autism	14	50.0
High-functioning autism/Asperger's	4	14.3
Source of Diagnosis		
Multidisciplinary team or clinic	15	53.6
Neuropsychologist	2	7.2
Pediatrician	4	14.3
Psychiatrist	6	21.4
Psychologist	1	3.6
Comorbid diagnoses		
None	15	53.6
ADHD	8	28.6
Anxiety	7	25.0
Sensory Processing Disorder	3	10.7
Speech/Language Disorder	2	7.1

Depression	1	3.6
OCD	1	3.6
Learning Disability	1	3.6
Tourette's Syndrome	1	3.6
>1 comorbid diagnosis	7	25.0

Note. Reported data reflects the full sample of 28 participants. Demographic information was obtained through self-reports from parents/guardians through a blank form inquiring about their child's diagnosis. Diagnostic categories listed here were designed to best respect language used in these parent reports.

Sample Size

Effect sizes between $A_{ch}E_m$s and math performance were expected to range from small to moderate ($r = |.10 – .40|$) for this study, while effect sizes for the complete models (inclusive of non-verbal cognitive ability and expressive language) were anticipated to fall within the moderate to large range ($r = |.60 – .80|$). A power analysis conducted with G*Power revealed that a total of 26 participants would be sufficient for detecting the full model effect sizes ($\alpha = .05$; $1 – \beta = .95$) (Faul, Erdfelder, Lang, & Buchner, 2007).

Measures

Math Performance

The construct of math performance was assessed using the Canadian edition of the KeyMath-3 Diagnostic Assessment (Connolly, 2007). The KeyMath-3 is a standardized math performance measure for ages 4–21 that consists of three dimensions (Basic Concepts, Arithmetic, Problem Solving) that together form a total test composite score. Within the KeyMath-3, the foundational math concepts described on the Basic Concepts dimension were specifically designed to match the Ontario math curriculum, where math content for Grades 1 through 8 is structured across five strands or pillars and is therefore expected to assess the primary elements of math that Canadian students are currently learning. These include numeration, algebra, geometry, measurement, as well as data analysis and probability (Ontario Ministry of Education, 2005). The Alberta math curriculum for Grades 1 through 9 is structured similarly, although some of the strands have different names (e.g., Algebra is referred to as Patterns and Relations) (Alberta Education, 2016). Regardless, the overarching constructs remain nearly identical between curricula. The Basic Concepts composite shares a strong correlation with the total test score composite for students in kindergarten up to Grade 12 (r = .96 – .97; Connolly, 2007). Furthermore, the scale's comprehensive content coverage and standardized norms representative of Canadian students made it an ideal measure of math performance in the present study. The Basic Concepts component of the KeyMath-3 takes approximately 45 to 60 minutes to complete, and is administered by orally presenting items to participants with visual aids on an easel as per the standardization requirements of the measure.

The Basic Concepts dimension of the KeyMath-3 assessment also presents with strong psychometric properties. Split-half reliability ranges from .83 to .97 based on a normative sample of Canadian students in kindergarten through to Grade 12 (Connolly, 2007). Alternate form reliability for the Basic Concepts component is reported as .93 for two alternate forms completed by Canadian students across all grades in the standardization sample, with test-retest reliability estimated at .90. (Connolly, 2007). The KeyMath-3 was also compared to other instruments with math components designed in the United States to provide an estimate of concurrent validity, including the Kaufman Test of Educational Achievement – 2nd Edition, the Iowa Tests of Basic Skills, and the Group Math Assessment and Diagnostic Evaluation (r = .60 – .90) (Connolly, 2007; Rosli, 2011). Evidence for construct validity is demonstrated by developmental change observed across members of the standardization sample, where average raw scores increased with grade level (i.e., math knowledge and skill increased with grade) (Connolly, 2007). KeyMath-3 Basic Concepts subtest scores were also positively correlated with one another (r = .49 – .83), indicating that they measure related aspects of the same construct (Connolly, 2007; Rosli, 2011).

Cognitive Ability

Non-verbal cognitive ability (NVIQ) was assessed using Raven's Standard Progressive Matrices – Plus version (R_aSPM+) and Coloured Progressive Matrices (R_aCPM), two standardized variations of a nonverbal figural matrices task (Raven et al., 1995; Raven & Rust, 2008). R_aSPM+ is designed for children between the ages of 7 and 18 and takes approximately 45 minutes to complete, while the R_aCPM is designed for children between the ages of 4 and 11 and takes approximately 15 minutes to complete (Raven et al., 1995; Raven & Rust, 2008). In order to complete either version of this measure, participants were presented with a series of patterns, each with a missing piece. On each item, participants were asked to select the correct piece to fill the space from several options, and items became more difficult as participants moved through them one at a time. Notably, Raven and colleagues (1995) as well as Raven and Rust (2008) designed these separate versions for clinical use, and they recommend that administrators use clinical judgement in selecting either the R_aCPM or R_aSPM+ form for individuals within this age range. Given that the authors developed unique forms of the measure for clinical purposes, and provide age-corrected standard scores on both, R_aCPM and R_aSPM+ were considered to be equivalent assessments of NVIQ for the purposes of this study. Therefore, we did not make a priori decisions regarding age boundaries for administration of the different versions of this measure. Rather, administrators used their clinical judgement to determine which version of the task would be most appropriate for each participant included in this study. (e.g., some 10-year-olds completed R_aCPM while others completed R_aSPM+).

Collectively, the Raven's Progressive Matrices tasks have been used to assess non-verbal cognitive ability in research, clinical, educational, and community settings since the original version was published in 1938 (Wongupparaj et al., 2015). Given the robust psychometric properties of this measure, and that reliable data has been continuously produced over an extensive period of time (Wongupparaj et al., 2015), it was considered to be an appropriate tool for assessing NVIQ in this study. In particular, split-half reliability of the items on the R_aSPM+ and R_aCPM is considered excellent, with versions ranging from .94 to .97 based on normative samples of students from the United Kingdom (Raven et al., 1995; Raven & Rust, 2008). As well, the construct validity of the original versions of the measures has been established through several factor-analytic studies involving large groups of children and young adults, where studies with samples of British children revealed loadings as high as .80 – .83 on *g*, the general intellectual factor (e.g., Das, 1973) (Raven et al., 1995; Raven & Rust, 2008). Furthermore, when compared to older, alternate version of R_aSPM+, results provided evidence of concurrent validity for R_aSPM+, with correlations ranging from .80 to .83 (Raven & Rust, 2008). Likewise, the R_aCPM measure has demonstrated high concurrent validity (r = .91) in relation to the full-scale IQ (FSIQ) construct produced by the earliest version of the Wechsler Intelligence Scale for Children (WISC) (Raven et al., 1995), and moderately high concurrent validity with the FSIQ on the WISC-III (r = .67) (Kleuver et al., 1995).

Expressive Language

The construct of expressive language was assessed using the Clinical Evaluation of Language Fundamentals (CELF-5; Wiig et al., 2013). The CELF-5 generates an Expressive

Language Index (ELI) standardized score based on three age dependent tasks, each of which targets a different element of expressive language (i.e., Recalling Sentences, Formulated Sentences, and one of Word Structure or Sentence Assembly). In an effort to reduce the testing load for participants, we evaluated participant's expressive language skills using the Formulated Sentences task alone, a subtest that generally took participants approximately 10 to 25 minutes to complete. This task is suited for individuals from ages 5–21, and consists of 24 items that assess an individual's ability to orally produce grammatically correct and meaningful sentences that include 1–2 target words. Each response provided must describe part of an accompanying illustration.

The Formulated Sentences subtest was deemed to sufficiently represent expressive language for the purposes of this study, given that this subtest shares a strong correlation with the ELI composite ($r = .84$). Across typically developing American youth in the normative sample, the Formulated Sentences task held good internal consistency with reliability coefficients ranging from .77 to .90, and a test-retest coefficient of .76 (Wiig et al., 2013). Wiig and colleagues (2013) reported excellent internal consistency for this subtest among a special group of 66 youth with autism spectrum disorder with a coefficient of .96. Furthermore, given that Formulated Sentences has a subjective aspect to scoring, interrater reliability was also reported by Wiig and colleagues (2013) for this subtest ($r = .91$). To ensure inter-rater reliability among administrators in this study, we followed procedures outlined by Wiig et al. (2013). Specifically, two trained scorers independently reviewed each participant's responses before comparing their results. When discrepancies arose, a different trained scorer reviewed responses for a third time to settle on a final score (Wiig et al., 2013). Due to the strong psychometric properties demonstrated by this individual scale, particularly those produced from a sample of students with autism, assessing expressive language through this measure was considered to be an acceptable approach. With regards to concurrent validity, the Formulated Sentences subtest on the CELF-5 shared a positive correlation with its former version on the CELF-4 ($r = .71$), although this subtest was not compared to any other similar test of language development (i.e., CELF-5 authors focused on expressive vocabulary scales for other sources of concurrent validity rather than tests requiring oral sentence production) (Coret & McCrimmon, 2015; Wiig et al., 2013).

Achievement Emotions

$A_{ch}E_{m}$s were assessed using the Achievement Emotions Questionnaire – Elementary School (AEQ-ES; Lichtenfeld et al., 2012). The AEQ-ES is a 28 item self-report measure of $A_{ch}E_{m}$s designed for use with youth between the ages of 5 and 12, that uses visual representations to convey meaning at each step on a 5-point Likert scale (i.e., gender-matched cartoon faces). The AEQ-ES includes items that gather information pertaining to participant enjoyment, anxiety, and boredom in three separate learning contexts. The questionnaire first asks participants about their feelings during math class, followed by the feelings they experience when completing math homework, and lastly, inquires about the feelings they experience when writing math tests. Enjoyment and anxiety are measured across each context; however, boredom is only measured on the scales relating to class time and completing homework, given that boredom is not usually experienced in relation to test writing (Lichtenfeld et al., 2012). Critically, the AEQ and its variations (e.g., the AEQ-ES) are currently the only instruments that measure $A_{ch}E_{m}$s beyond test anxiety (Pekrun et al., 2011). The AEQ-ES takes approximately 10 to 15 minutes to administer, and higher scores indicate stronger emotional responses.

Although some participants in the current study exceeded the upper age limit for this instrument, the AEQ-ES was used among these individuals as the AEQ-ES provided several benefits over the original AEQ measure for our study. Although the items on AEQ and the AEQ-ES are generally similar, the AEQ-ES items are tailored to suit the cognitive and linguistic abilities of elementary school students, while the original AEQ items reflect a college reading level. As such, the AEQ-ES items were more suitable for this study to ensure that participants fully comprehended what was asked of them. Likewise, the original AEQ includes over 200 items across eight different $A_{ch}E_{m}$s, requiring a great deal of time and focus to complete (Pekrun et al., 2011). As such, the AEQ-ES was an appropriate measure to maintain participant interest, focus, and cooperation, while gaining a brief assessment of participants' $A_{ch}E_{m}$s.

The variation of the AEQ-ES used in this study (i.e., written in English and focused on mathematics) has demonstrated sufficient to excellent reliability and validity among unselected samples of children (Lichtenfeld et al., 2012; Raccanello et al., 2018; Peixoto et al., 2015). Confirmatory factor analyses conducted by Lichtenfeld and colleagues (2012) and by Raccanello and colleagues (2018) demonstrated that the AEQ-ES corroborates the hierarchical structure of the original AEQ, showing that elementary students are capable of distinguishing between different emotions, and can further recognize differences between context-specific emotions.

When tested among second and third grade students, the internal consistency of the AEQ-ES as represented by Cronbach's alpha fell between .71 and .93 across different emotions and contexts, indicating that the measure's internal reliability ranges from sufficient to excellent. Internal validity for this measure was demonstrated by computing Pearson intercorrelations between emotion scales (Lichtenfeld et al., 2012). Correlations within each learning context (e.g., comparing class enjoyment to class anxiety) fell within the moderate range ($r = |.43 – .76|$), as did correlations between learning contexts (e.g., comparing class ratings to homework ratings)

($r = |.62 - .75|$) (i.e., students who reported experiencing more anxiety in class also experienced more anxiety when completing homework) (Lichtenfeld et al., 2012).

To confirm the instrument's external validity, student scores were positively correlated with parents' judgments pertaining to how much enjoyment, anxiety, and boredom they believed their children experienced across learning contexts (Lichtenfeld et al., 2012). Overall, correlations for enjoyment and anxiety fell within the small to moderate range ($r = |.26 - .49|$), demonstrating convergence. In contrast, correlations for the construct of boredom were smaller ($r = |.14 - .18|$), perhaps indicating that boredom is less openly expressed among children of this age (Lichtenfeld et al., 2012). Lichtenfeld and colleagues (2012) also collected information from participants pertaining to their perceived control and value within the domain of mathematics; this data generally corroborated the theoretical expectations described by $C_{trl}V_{al}$ theory (Pekrun, 2006). Overall, these convergent findings support the external validity of this instrument, and moreover, its applicability to the current study.

To date, the AEQ-ES has not been tested in atypical populations, meaning that students with autism have yet to complete the measure for research purposes. As such, reliability and validity statistics specific to this particular student population have not been described by prior literature. Given that researchers have shown the importance of visually representing emotions for students with autism, however, the AEQ-ES seems especially suited for use with this population due to its inclusion of visual pictures (e.g., Piggot et al., 2004; Wang et al., 2004).

Data Collection Procedure

As per the procedure for the larger overarching study, data collection involved participants and their parent or guardian meeting in a quiet room with a research assistant. Participants were offered the choice to participate in the comfort of their homes or at a designated research lab at the University of Alberta. During the initial session, parents/guardians and students were informed about the study, as well as any risks or benefits associated with participating. After all questions and concerns were addressed, parents/guardians signed a consent form allowing their child to participate, and students completed and signed an assent form as well. Participants completed R_aSPM or R_aCPM, KeyMath-3 Basic Concepts, Formulated Sentences from the CELF-5, and the AEQ-ES among other measures unrelated to the current study in a counterbalanced order across sessions. Given that more data was collected than is reported in the current study, participants completed approximately eight one-hour sessions with the same research assistant to maintain consistency, although only a portion of this time was dedicated to the currently relevant measures. After each session, a gift-card to a store of each participant's choosing was offered to them (i.e., from a designated selection). Within the context of the broader study discussed above, this sampling procedure was approved by the University of Alberta's internal research ethics board before data was collected.

Results

Analysis Plan

The relationships between non-verbal cognitive ability, expressive language, $A_{ch}E_m$s, and math performance were explored through three hierarchical multiple regression analyses (i.e., one per $A_{ch}E_m$). Descriptive statistics were initially obtained for each measure, followed by an analysis of the statistical assumptions for regression (i.e., for each regression model). Once all assumptions were confirmed, Pearson correlations were calculated to compare the strength and directions of the relationships between the variables of interest in this study. Next, one hierarchical regression was run for each relevant $A_{ch}E_m$ (i.e., enjoyment, boredom, anxiety). In each model, the effects of non-verbal cognitive ability and expressive language were controlled by entering these variables in step 1, while the context-specific $A_{ch}E_{m}$s were always placed in step 2. The enjoyment and anxiety regression models contained three context-specific variables in step 2 (i.e., class time, homework completion, test writing), while the boredom model contained two (i.e., class time, homework completion).

Reliability of the AEQ-ES Among Students with Autism

Given that indicators of reliability and validity were not available for students with autism prior to the current study, it was necessary to understand the extent to which the AEQ-ES was capable of reliably measuring $A_{ch}E_{m}$s among these students. As such, internal consistency was calculated for each AEQ-ES scale, as represented by Cronbach's alpha values in the table below.

Table 3

Cronbach's Alpha Across AEQ-ES Scales by Emotion and Context

AEQ-ES Scale	Cronbach's Alpha	Number of Items
Class Enjoyment	.95	4
Homework Enjoyment	.88	2
Test Enjoyment	.94	3
Class Anxiety	.75	4
Homework Anxiety	.79	3
Test Anxiety	.86	5
Class Boredom	.92	4
Homework Boredom	.88	3

Given that all alpha values fell within the acceptable to excellent range (Tavakol & Dennick, 2011), and that these values match those reported by Lichtenfeld et al. (2012), the AEQ-ES was determined to be a reliable measure of $A_{ch}E_{m}$s among the sample of students with autism described in this pilot study.

Exploratory Analyses and Check of Statistical Assumptions

For each variable described below, Table 4 presents the means and standard deviations, minimum and maximum values, as well as kurtosis and skewness statistics to describe normality. First, standardized math performance scores ranged from 55 to 139 with a mean of 94.79 and a standard deviation of 23.17. The large standard deviation recorded for this measure was in line with previous research that demonstrates how large proportions of students with autism often perform either very well or very poorly in math (e.g., Oswald et al., 2016, Estes et al., 2011). For NVIQ, standardized scores ranged from 60 to 145 with a mean of 101.43 and a standard deviation of 18.65. In addition, scaled scores on the Formulated Sentences task ranged from 1 to 16 with a mean of 8.54 and a standard deviation of 3.61. Critically, the descriptive statistics pertaining to the three standardized measures included in this study are highly representative of how students with autism would be expected to perform in each task given that samples of students with autism have performed similarly in prior literature (e.g., Oswald et al., 2016).

Raw scores on the AEQ pertaining to the $A_{ch}E_m$ of enjoyment ranged from 2 to 20 across learning contexts, with means ranging from 5.68 to 14.20 (SD = 3.00 – 5.59). For the $A_{ch}E_m$ of boredom, scores ranged from 3 to 19 across contexts, with means ranging from 6.54 to 8.46 (SD = 3.56 – 4.16). For the $A_{ch}E_m$ of anxiety, scores ranged from 2 to 19 across contexts, with means ranging from 3.21 to 8.89 (SD = 1.69 – 4.25). Kurtosis and skewness values pertaining to this data set indicated the presence of univariate normality in most cases; class-based anxiety and homework-based anxiety were the only variables that presented with a high kurtosis value (i.e., above 2).

Table 4

Descriptive Statistics for Predictor and Outcome Variables

Variable	*M*	*SD*	Minimum	Maximum	Kurtosis	Skewness
Math Performance	94.79	23.17	55	139	-.389	.140
Cognitive Ability (NVIQ)	101.43	18.65	60	145	1.007	.150
Expressive Language	8.54	3.61	1	16	-.248	-.205
$A_{ch}E_m$ Class Enjoyment	14.20	5.59	4	20	-1.192	-.582
$A_{ch}E_m$ Homework Enjoyment	5.68	3.00	2	10	-1.496	-.129
$A_{ch}E_m$ Test Enjoyment	8.68	4.14	3	15	-1.276	.132
$A_{ch}E_m$ Class Boredom	8.46	4.16	4	19	.471	1.052
$A_{ch}E_m$ Homework Boredom	6.54	3.56	3	15	.548	1.094
$A_{ch}E_m$ Class Anxiety	6.39	3.00	4	17	5.225	2.068
$A_{ch}E_m$ Homework Anxiety	3.21	1.69	2	9	4.740	2.085
$A_{ch}E_m$ Test Anxiety	8.89	4.25	5	19	-.065	.959

Statistical assumptions underlying multiple regression were checked following procedures discussed by Tabachnick, Fidell, and Ullman (2007). Collected data met the assumptions of non-zero variance and independence in each regression model given that each participant contributed unique data points to the full dataset, and that responses differed in value across the sample. Data also met the assumption of independent errors as tested by the Durbin-Watson statistic for each model (i.e., enjoyment model = 1.76; boredom model = 1.56; anxiety model = 1.52), suggesting that there were no significant autocorrelations. In addition, an analysis of standard residuals was conducted, which showed that the data contained no outliers (std. residual min = -2.22, std. residual max = 2.55). For all three models, the collected data met the additional assumptions of linearity and homoscedasticity; each of which were respectively confirmed by P-P plots and standardized residual scatterplots. Given that each regression model produced appropriate VIF (i.e., enjoyment model = 1.03 – 4.93; boredom model = 1.03 – 1.21; anxiety model = 1.03 – 2.94) and tolerance (i.e., enjoyment model = .20 – .97; boredom model = .83 – .97; anxiety model = .34 – .97), multicollinearity was not a cause for concern in this study.

All predictor variables presented with acceptable levels of kurtosis and skewness given the sample size described in this study, with the exceptions of class-based anxiety and homework-based anxiety. These variables presented with significant kurtosis and skewness (see Table 4); as a result, the anxiety regression model did not meet the assumption of normally distributed errors. In order to resolve this issue, both variables were transformed using the log-10 transformation function to produce distributions of data points that resembled a normal distribution more closely. This transformation produced acceptable univariate kurtosis and skewness values for both class-based anxiety (kurtosis = .698, skewness = .971) and homework-based anxiety (kurtosis = .732, skewness = 1.069), such that the anxiety model met the assumption of normally distributed errors when the transformed variables were included. As such, results pertaining to the anxiety regression model described below discuss relationships associated with the transformed class- and homework-based anxiety variables, and the untransformed test anxiety variable.

Results

Pearson Correlation Analysis

Prior to conducting regression analyses, Pearson correlations pertaining to all measured variables were computed for comparison purposes. Table 5 reflects these relationships below.

Table 5

Pearson Correlations for Outcome and Predictor Variables

	1	2	3	4	5	6	7	8	9	10	11
1. Math Performance	–	.629**	.554**	-.020	-.119	-.003	.001	-.273	-.577**	-.495**	-.084
2. NVIQ		–	.164	.065	-.108	.016	.225	.077	-.085	-.002	.189
3. Expressive Language			–	-.173	-.308	-.229	-.121	-.196	-.438*	-.650**	-.194
4. Class Enjoyment				–	.670**	.732**	-.610**	-.263	-.360	.057	-.057
5. Homework Enjoyment					–	.866**	-.209	-.536**	-.288	-.144	-.141
6. Test Enjoyment						–	-.221	-.435*	-.343	-.150	-.290
7. Class Boredom							–	.357	.418*	.106	.269
8. Homework Boredom								–	.452*	.456*	.356
9. Class Anxiety									–	.626**	.429*
10. Homework Anxiety										–	.545**
11. Test Anxiety											–

$^*p < .05$, $^{**}p < .01$

Hierarchical Regression Models

Across all three regression models, math performance shared significant correlations with non-verbal cognitive ability ($r = .63$, $p <$ 001) and expressive language ($r = .55$, $p = .001$) (see table 5). In addition, step 1 of each regression model (i.e., containing non-verbal cognitive ability and expressive language) accounted for 61% of the variance in math performance outcomes among students in the selected sample, $F(2, 25) = 19.914$, $p < .001$. Furthermore, non-verbal cognitive ability ($\beta = .553$, $t[25] = 4.34$, $p < .001$) and expressive language ($\beta = .463$, $t[25] = 3.64$, $p = .001$) were significant predictors of math performance. Step 2 differed across the models, with each focusing on a different $A_{ch}E_m$ across learning contexts. Individual $A_{ch}E_m$s and their respective contributions to the variance in math performance are expressed below.

Enjoyment Model. Pearson correlations between math performance and the $A_{ch}E_m$ of enjoyment were not statistically significant across any learning contexts ($r = -.003 – -.12$, $p = .273 – .495$) (see table 5). In addition, contextually-based enjoyment did not substantially improve the prediction model, accounting for only an additional 1.4% of the variance beyond the variables entered in step 1, $F(3, 22) = .271$, $p = .846$. As such, the full model composed of both steps accounted for 62% of the variance in math performance. Thus, in the final equation, the only significant predictors of math were non-verbal cognitive ability and expressive language. Table 6 displays the relevant regression coefficients below.

Table 6

Summary of Enjoyment Model Hierarchical Regression Analysis Predicting Math Performance

Block	Variable	Standardized Beta (β)	T	R^2	ΔR^2
1				.605	.605**
	NVIQ	.553**	4.34		
	Expressive Language	.463**	3.64		
2				.619	.014
	NVIQ	.557**	4.05		
	Expressive Language	.489**	3.50		
	$A_{ch}E_m$ Class	-.100	-.511		
	$A_{ch}E_m$ Homework	.036	.129		

$A_{ch}E_m$ Test	.143	.488	

*$p < .05$, **$p < .01$

Boredom Model. Pearson correlations between math performance and the $A_{ch}E_m$s of boredom were not statistically significant across either learning context (r = .001 – -.27, p = .080 – .499) (see table 5). Similar to the model pertaining to enjoyment, boredom did not improve the prediction model, accounting for only an additional 5.3% of variance in math performance beyond the variables listed in step 1, $F(2, 23) = 1.79$, $p = .189$. Taken together, the full model accounted for 66% of the variance in math performance outcomes; however, non-verbal cognitive ability and expressive language were the only significant predictors in the final equation. Table 7 displays the relevant regression coefficients below.

Table 7

Summary of Boredom Model Hierarchical Regression Analysis Predicting Math Performance

Block	Variable	Standardized Beta (β)	T	R^2	ΔR^2
1				.605	.658**
	NVIQ	.553**	4.34		
	Expressive Language	.463**	3.63		
2				.658	.053
	NVIQ	.579**	4.53		
	Expressive Language	.413**	3.25		
	$A_{ch}E_m$ Class	-.047	.043		
	$A_{ch}E_m$ Homework	-.191	-1.80		

*$p < .05$, **$p < .01$

Anxiety Model. Pearson correlations between math performance and the $A_{ch}E_m$ of anxiety were statistically significant across two particular learning contexts: anxiety experienced during class time (r = -.58, p = .001), and anxiety experienced when completing homework (r = -

.50, p = .004) (see table 5). In contrast, test anxiety was not significantly correlated to math performance (r = -.08, p = .336). In this regression analysis, the full model accounted for 75% of the variance in math performance, with contextually-based anxiety entered in step 2 accounting for an additional 14.8% beyond step 1. This significantly improved the prediction model, F(3, 22) = 4.42, p = .014, meaning that contextually-based anxiety variables collectively accounted for a significant amount of variability in math performance outcomes above and beyond the aforementioned control variables. Furthermore, regression coefficients listed in step 2 demonstrated that the $A_{ch}E_m$ of anxiety significantly predicted math performance in the context of class time alone (β = -.372, t[22] = -2.68, p = .014), indicating that anxiety experienced in this particular context uniquely predicts math performance outcomes above and beyond non-verbal cognitive ability and expressive language. Table 8 displays the relevant regression coefficients below.

Table 8

Summary of Anxiety Model Hierarchical Regression Analysis Predicting Math Performance

Block	Variable	Standardized Beta (β)	T	R^2	ΔR^2
1				.605	.605**
	NVIQ	.553**	4.34		
	Expressive Language	.463**	3.64		
2				.753	.148*
	NVIQ	.542**	4.88		
	Expressive Language	.195	1.34		
	$A_{ch}E_m$ Class	-.372*	-2.68		
	$A_{ch}E_m$ Homework	-.200	-1.10		
	$A_{ch}E_m$ Test	.121	.895		

*p < .05, **p < .01

Discussion

Support for Stated Hypotheses

This exploratory study sought to understand the relationships between math performance and the $A_{ch}E_m$s of enjoyment, boredom, and anxiety among students with autism through a hierarchical regression analysis guided by two research questions. The first question focused on clarifying the nature of the relationships between $A_{ch}E_m$s and math performance through Pearson correlation calculations. It was anticipated that enjoyment would share a positive relationship with performance across learning contexts, while the negative $A_{ch}E_m$s of boredom and anxiety were expected to share negative relationships with performance across contexts. The results demonstrated some support in favour of this hypothesis, particularly with regards to class and homework-based anxiety, which both demonstrated significant negative correlations with performance (see Table 5). Likewise, Pearson correlations analyzed for the boredom model demonstrated negative relationships between contextually-based boredom and performance, although these relationships were smaller than those depicted in the anxiety model, and were not deemed statistically significant. In contrast, the relationships between contextually-based enjoyment and performance were small, with values lying slightly below zero. Contrary to the proposed hypothesis as well as past literature with unselected samples of students (Lichtenfeld et al., 2012), this result suggests that enjoyment and performance were related to each other in a minimal way among this sample of students with autism.

The second research question posed for this analysis explored the extent to which contextually-based $A_{ch}E_m$s could predict performance above and beyond controlled factors of non-verbal cognitive ability and expressive language. $A_{ch}E_m$s were expected to predict performance above and beyond these controlled components in all three hierarchical regressions and this hypothesis was partially supported by the results. Overall, the variance distribution displayed in all three models suggests that math performance outcomes of students with autism are largely grounded in cognitive and linguistic skills; however, the results of this study indicate that the $A_{ch}E_m$ of anxiety in particular represents another contributing factor worth noting. While the regression models for enjoyment and boredom revealed little to no unique contribution to math performance beyond non-verbal cognitive ability and expressive language, the anxiety model demonstrated that anxiety specific to the context of class time uniquely explained a significant amount of variance in performance. Unexpectedly, homework and test anxiety did not follow this same pattern as anxiety specific to these contexts did not uniquely predict math performance among participants in this sample.

Interpretation of Results

The Impact of Anxiety on In-Class Learning

The predictive discrepancy between class anxiety and anxiety experienced in other contexts may lie with the nature of the contexts studied, and where the process of acquiring new knowledge primarily occurs. Among the three contexts of interest, math class represents the primary learning context in which new information is exposed to students. During class, students are typically expected to acquire new knowledge from some combination of their teacher, classmates, and in-class activities. Consistent with the negative association anxiety appears to share with math performance among both unselected samples of students and students with autism (e.g., Oswald et al., 2016, Raccanello et al., 2018), anxiety specifically experienced during class time could distract students and make it difficult to focus; it would likely be difficult to learn new information under these circumstances. As such, having difficulty regulating feelings of anxiety during class could interfere with learning processes, and accordingly, performance.

Distinguishing Class and Home Learning Contexts

Homework-based anxiety, although significantly correlated with performance in a negative direction, did not uniquely predict performance as class-based anxiety did. Class and homework-based anxiety are similar constructs, and it may be that the significant correlation between homework-based anxiety and performance represents a degree of overlap between homework-based anxiety and anxiety experienced in other contexts (i.e., class, tests); however, collinearity diagnostics clearly showed that the variables were measuring differing constructs. The reason that class-based anxiety significantly contributed to math performance in the anxiety regression model while homework-based anxiety did not can be best understood by an examination of the environmental factors that distinguish student homes and classrooms. For instance, individuals with autism often put forth considerable effort to fit in with their TD peers, meaning that they monitor and adjust their behaviour to reflect those around them (Mandy, 2019). Although this form of "social camouflaging" can be adaptive with regards to peer acceptance, it is also associated with higher levels of anxiety, among other mental health concerns (Mandy, 2019). As such, typical classroom settings represent one environmental context where social camouflaging may be especially prevalent among students with autism because they are surrounded by many TD peers. In comparison, home environments likely place fewer social demands on these students. Given this distinction, students with autism are likely more comfortable at home where there are fewer people; they may also feel that they have a greater sense of flexibility at home as well (i.e., breaks can be taken as needed). Furthermore, classroom environments may be overstimulating to students with autism at times; children with autism have consistently demonstrated a higher rate of sensory avoidance and sensory seeking behaviours relative to TD children (Little et al., 2018). Thus, it may be that certain sounds, lights, or other stimuli present in classrooms present considerable obstacles to students with autism in their efforts to learn. According to Lytle and Todd (2009), sensory overstimulation represents one factor capable of inducing extreme stress among children with autism. Given that extreme stress is associated with attention difficulties, impeded cognitive function, and memory impairment (Lytle & Todd, 2009; Morgan, 2006), the impact that in-class sensory overstimulation may have on learning and performance is considerable. At home, students with autism may be less likely to face sensory overstimulation because they have more control over aspects of their environment (e.g., they can choose which lights they would like turned on).

Indeed, the concept of control may be what lies beneath both the social and sensory demands placed on students with autism across learning contexts. In general, it may be that at home, students with autism subjectively feel as though they have a greater sense of internal control; in accordance with $C_{trl}V_{al}$ theory, greater internal control is associated with reduced anxiety (Pekrun, 2006). While the typical classroom environment likely invites a greater degree of unpredictability for all children relative to home environments, students with autism might find this unpredictability especially challenging to cope with given the greater social and sensory demands present in classroom settings. As such, this combination of stressors could lead students to subjectively experience a reduced sense of internal control; in turn, this appraisal would likely lead to elevated feelings of anxiety at school that are more difficult to regulate. Essentially, one possible explanation that may address why class anxiety shared a stronger predictive relationship with math performance relative to homework-based anxiety lies with a variety of environmental factors unique to each context that impact students' internal sense of controllability. Moreover, the environmental demands unique to class time may make math anxiety encountered there more difficult for students with autism to regulate effectively, leading to challenges associated with learning new content that ultimately impede performance.

Understanding Test Anxiety as a Poor Predictor of Performance

The construct of test anxiety reported by the AEQ-ES (Lichtenfeld et al., 2012) was anticipated to significantly contribute to the anxiety regression model in the present study; however, this hypothesis was surprisingly unsupported for this particular sample. Critically, this finding opposes prior research that describes test anxiety as a stronger predictor among students with autism; Oswald and colleagues (2016) for instance, found that test anxiety explained a significant amount of variability in math problem solving among their sample of students (β = -.29, p = .01). Although unexpected, the lack of predictive power for test anxiety in the present sample can be explained in relation to $C_{trl}V_{al}$ theory and through a methodological lens.

First, in relation to $C_{trl}V_{al}$ theory, the predictive discrepancy between class anxiety and test anxiety may have been observed as a result of each context's underlying functions. While math class represents a learning context in which students are exposed to new information, tests and exams are activities that involve students demonstrating what they know, and showing what they have learned. Although these types of achievement activities are valuable and necessary for tracking performance over time, their purpose is to evaluate how well students understand content they have been taught beforehand. Class time, alternatively, involves exposing students to new and unfamiliar concepts. As such, it may be that enduring class time dedicated to math promotes a greater sense of uncertainty and unpredictability, while material covered on math tests is predictable when properly communicated by teachers. In sum, perhaps these students feel a greater degree of anxiety during class time because they feel that their ability to succeed or fail is not yet determined, but when required to complete a test, the outcome is more predictable. This sense of uncertainty, characteristic of anxiety as defined by Pekrun (2006) in his $C_{trl}V_{al}$ theory, may be responsible for these contextual differences.

A second possible reason that could explain why a small relationship between test anxiety and performance was observed lies with specific methodological aspects of the present study. It may be that our chosen measure for math performance was unable to capture the relationship these variables typically appear to share. The KeyMath-3 assessment was administered in a one-on-one environment where participants were told to try their best, and that there were no right or wrong answers. Despite the fact that the KeyMath-3 measure is a standardized assessment of math performance, this procedure does not mimic a typical test-taking environment, nor does it mimic test-taking expectations for most children. As such, it may be that some students with significant test anxiety performed well on this measure given the relaxed context, thus overriding the typical negative relationship we expected to observe.

If the present study's methodology is indeed responsible for the limited predictive power of test anxiety as described above, it should be noted that the relationships between math performance and anxiety associated with class time and homework were likely unaffected by the administrative aspects of the KeyMath-3. Essentially, the specific elements of the KeyMath-3 administration procedure would not affect how much knowledge participants were able to gain from class time and homework, but rather, their ability to show what they know. The KeyMath-3 measure, as well as tests administered to students at schools are both designed for this purpose; students are asked to demonstrate their acquired knowledge. Importantly, the degree to which the content and quality of this acquired knowledge was affected by in-class anxiety or homework-based anxiety would have been determined for students prior to participating in the present study. Administrative procedures associated with the KeyMath-3 measure would not change how participants' learning was affected by anxiety experienced in those contexts; they would only affect how well participants were able to demonstrate that knowledge.

Understanding Enjoyment and Boredom as Poor Predictors of Performance

As with the construct of test anxiety, the $A_{ch}E_m$s of enjoyment and boredom were expected to predict math performance above and beyond non-verbal cognitive ability and language in the present study, yet these predictions were unsupported by the results. Prior to this investigation, $A_{ch}E_m$s had not yet been explored among students with autism; however, enjoyment and boredom were anticipated to share significant small to moderate correlations with performance as they have for unselected samples of students (e.g., Lichtenfeld et al., 2012). Instead, Pearson correlations between performance and both enjoyment and boredom were non-significant in all contexts, and in most cases, were smaller than expected. Given these findings, it may be that the sample size described in this study was too small to capture the true relationships between these $A_{ch}E_m$s and math performance. In studies conducted with unselected samples of students, reported sample sizes are quite large (e.g., 300 students), and the effect sizes for the relationships between performance and anxiety are typically the largest across contexts compared to the relationships pertaining to enjoyment and boredom (see Table 1, p. 12). As such, it may be that the sample described in the present study was large enough to detect the role of anxiety in relation to math performance across learning contexts, but insufficiently large to recognize the relationships between performance and either enjoyment or boredom with regards to class time, homework completion, or test writing. As such, replication studies with larger sample sizes are needed to demonstrate and confirm the existence of these relationships.

Reflecting on Control-Value Theory

$C_{trl}V_{al}$ theory was considered an ideal framework through which this study could be conceptualized, developed, and implemented. The relationships described by Pekrun (2006) pertaining to emotion regulation and achievement emotions provided a detailed theoretical explanation as to why students with autism might perform so variably in math. Although responses to the class-based anxiety scale on the AEQ-ES could be explained by these integral relationships, our hypotheses were otherwise unsupported. Given this outcome, it may be that the findings of this study can inform our understanding of $C_{trl}V_{al}$ theory, highlight potential knowledge gaps, and provide insight as to how this theory might evolve to account for these gaps.

For instance, although the central components of $C_{trl}V_{al}$ theory provide a natural link between emotion regulation and the presentation of various $A_{ch}E_{m}$s, Pekrun (2006) does not address why some $A_{ch}E_{m}$s (e.g., anxiety) might have stronger relationships with performance than others (e.g., enjoyment, boredom) among children and youth. While this theory is undoubtedly notable in framing current perspectives on emotions related to achievement, it may be that the current iteration of $C_{trl}V_{al}$ theory is limited in its ability to explain differences in how individual $A_{ch}E_{m}$s relate to performance. Given that the $A_{ch}E_{m}$s of enjoyment and boredom had weaker relationships with math performance in the current exploratory study, as well as in prior research conducted with unselected samples of elementary students (e.g., Lichtenfeld et al., 2012; Raccanello et al., 2018), it seems that this difference is not specific to one population or group of elementary students. As such, it may be necessary to consider how and why anxiety is a stronger predictor of performance for these students, and correspondingly, why other emotions lack the same predictive power. Furthermore, it is important to note that $A_{ch}E_{m}$s share relationships of more similar strengths in adult populations (e.g., Pekrun et al., 2017), thus highlighting a notable distinction across ages. Perhaps in the case of children and youth, $A_{ch}E_{m}$s impact performance most strongly when they directly impede or interfere with students' learning. In particular, it may be that the $A_{ch}E_{m}$ of anxiety is the most capable of filling this role relative to other negative $A_{ch}E_{m}$s (e.g., boredom) given its ability to interfere with attention, cognitive function, and memory (Lytle & Todd, 2009; Morgan, 2006). Similarly, it may be that positive $A_{ch}E_{m}$s, such as enjoyment, have a smaller impact on performance because they do not enhance a student's ability to learn much beyond their natural ability to do so as determined by other factors (e.g., cognitive ability). In any case, further consideration regarding this gap in $C_{trl}V_{al}$ theory is warranted, and additional research is likely needed to confirm and build upon these ideas.

Additionally, Pekrun (2006) acknowledges that several different factors influence how $A_{ch}E_{m}$s relate to performance outcomes (i.e., cognitive resources, interest and motivation to learn, learning strategies, self-regulation of learning); however, it may be that more information is needed concerning the roles these factors ultimately play. In particular, $C_{trl}V_{al}$ theory recognizes that there may be select cases where negative $A_{ch}E_{m}$s are adaptive in an achievement context for performance, and similarly, where positive $A_{ch}E_{m}$s are maladaptive under the same circumstances as a result of how these aforementioned factors interact. Critically, however, these patterns are considered complex and intricate (Pekrun, 2006). As such, $C_{trl}V_{al}$ theory is unable to clarify the particular nature of these relationships. In the current study, enjoyment and boredom were unexpectedly identified as poor predictors of performance, counter to what $C_{trl}V_{al}$ theory would most likely predict. This may reflect influences from specific combinations of the factors described above; however, $C_{trl}V_{al}$ theory in its current form is unable to provide greater insight into what these relationships might be, thus limiting the extent to which the results may be theoretically interpreted. Critically, it may be that conducting research with students with autism could provide particular insight into how these processes operate. For instance, one possibility is that for students with autism, the typical classroom setting demands a substantial proportion of their cognitive resources, regardless as to whether or not they enjoy the subject matter being taught in that classroom. Essentially, even students with autism who enjoy mathematics may need to dedicate a larger amount of their cognitive reserve towards social camouflaging among their neurotypical peers; this behaviour could limit the extent of the positive influence of enjoyment on math performance. In the case of boredom, it may be that students with autism are engaging in camouflaging with regards to their performance as well. It may be particularly important to them to limit the extent to which they differ from their classmates in terms of their math knowledge and skills, and as such, they may be extrinsically motivated to perform well in spite of experiencing boredom in relation to math. Given these circumstances, it may be that this alternative motivation overrides the role boredom may play in affecting their overall math performance. These theoretical possibilities highlight the need for further research to understand the underlying mechanisms of $C_{trl}V_{al}$ theory. Expanding on these ideas will provide greater insight as to how the external factors described by Pekrun (2006) influence the way $A_{ch}E_{m}$s impact performance and achievement.

Limitations

The findings of this study are informative in that they shed light on how students with autism experience $A_{ch}E_{m}$s related to math, and how these emotions impact their ability to perform in this subject area. In generalizing this information to the larger population of students with autism, there are several limitations to note. Consistent with many studies exploring clinical populations (e.g., Oswald et al., 2016; Georgiou et al., 2018), the sample size in this study was relatively small (*N* = 31) as a result of both the diagnostic area of interest (i.e., autism), and inclusion criteria specific to this study (i.e., completion of the measures of interest). As such, replication studies with larger participant samples are needed to support and enhance generalizability. In addition, the sample described in this study largely underrepresented females with autism, with only 6.5% identifying as female. Given that autism was recently estimated to be approximately three times more prevalent among males in the broader population (Loomes et al., 2017), the participant sample described in the present study is not unexpected; however, this female underrepresentation likely limits the extent to which the findings can be generalized to female students with autism. Similarly, it was necessary for participants in the current sample to speak English given that the researchers were only able to administer measures in this language; as such, the findings should not be generalized to students with autism who speak other languages.

It should also be noted that although the measures used in this study were selected in part to accommodate participants with limited language skills (i.e., KeyMath-3 and both versions of Raven's Progressive Matrices lack explicit reading and writing demands), the participants in this sample may have had lower support needs. This was evident given that all participants were able to communicate verbally with administrators, and follow directions associated with testing. As such, the findings of this study should not be generalized to include students with autism who use non-verbal modes of communication. Caution should also be taken when generalizing the results of this study given that parents and guardians were responsible for confirming participants' diagnoses of autism. These reports may have reflected inaccuracies, particularly in cases where autism was diagnosed many years before the start of this study. As such, researchers developing future studies in this area should strive to confirm autism diagnoses through the use of standardized assessments specifically designed to diagnose autism (e.g., *Autism Diagnostic Observation Schedule, Second Edition*; Lord et al., 2012).

A final concern with the selected sample involves the age range of participants from 5 through 16. School, as well as the tasks and experiences associated with school (e.g., class, homework) at these range-defining ages are far from similar; high school students are likely to experience a greater number of tests, raised homework expectations, and distinctly different classroom environments relative to young elementary school students. As such, individuals functioning at these different ages may relate to the items presented in the AEQ-ES in different ways, thus potentially limiting both the internal and external validity of the current study's findings.

Given the issues presented by the selected sample of participants, it would be worthwhile for future research to consider making appropriate methodological adjustments. While the data analyzed in the present study included a small set of measures, participants actually completed a large battery of measures relevant to the broader study encompassing this smaller one. As such, participants agreed to contribute a significant portion of their time for the purposes of the broader study, and these time demands may have discouraged some parents and guardians from volunteering to participate. Removing these demands could promote recruitment, and accordingly lead to larger, more representative and culturally diverse participant samples, as well as the ability to recruit participants within narrower age ranges. Changes such as this could lead to improvements in both internal and external validity, meaning that findings that could be replicated and more substantially generalized.

Future studies could also increase generalizability by recruiting participants in an adjusted manner. In the current study, recruitment procedures for this study likely impacted the composition of the participant sample. Participants were mostly recruited because parents and guardians with vested interests in their child's math abilities volunteered to participate in this study by contacting the research lab through social media platforms, this approach may have introduced self-selection bias to the participant sample. Essentially, this interest may reflect an overrepresentation of students who typically perform either extremely well or extremely poorly in math relative to the larger population (i.e., their math abilities appeared unusual to their parents, thus generating interest in this study). In future research endeavors, this potential limitation may be avoided by recruiting participants in a more purposeful manner through school-boards and community agencies; actively recruiting participants through these avenues rather than accepting volunteers through social media may better represent the full spectrum of math ability among students with autism.

Implications and Future Directions

This exploratory descriptive pilot study marks an important step towards understanding the emotional experiences of students with autism, as well as the capacity for these emotions to affect school performance. Consistent with broader studies that emphasize anxiety as a highly comorbid mental health problem among students with autism (e.g., Lopata & Thomeer, 2014), the findings of this study suggest that reducing math anxiety related to in-class learning is worth the attention and consideration of educators in order to best support these students. Nonetheless, a great deal of information beyond this statement remains unknown. As such, further research is needed in order to expand upon the ideas and results expressed in this study in a broader capacity.

In addition to the methodological recommendations described above, future studies could improve upon the current findings in a number of ways. First, it would be valuable to gauge the control and value appraisals of students with autism instead of only collecting information about their $A_{ch}E_{m}$s in relation to the three math learning contexts. Given that different combinations of control and value appraisals are capable of leading to the same achievement emotion (e.g., absent value combined with either high control or low control can produce boredom), it would be valuable to collect this information to clarify both where students experience various emotions, as well as why certain emotions emerge in certain contexts. In particular, it may be especially useful to conduct qualitative and/or mixed-methods studies that can represent the voices of participants directly through qualitative data. This data will allow researchers to confirm the theorized mechanisms of $C_{trl}V_{al}$ theory, and potentially help clarify the complex effects that factors such as cognitive resources may have on $A_{ch}E_{m}$s and performance.

In addition, it may be worthwhile to explore the nature of the relationships between $A_{ch}E_{m}$s and performance among students with autism in academic domains other than mathematics. Given the results of this study, it is evident that in-class anxiety associated with math predicts performance in math; however, it may be that stress related to classroom environments is largely responsible for this relationship, or conversely, that anxiety associated math is the driving force. As such, it would be valuable to include measures that address $A_{ch}E_{m}$s and performance in a different school area (e.g., science, language arts), to better understand what factors are responsible for inciting in-class anxiety among these students.

As well, future scholars should consider gathering additional information on math performance besides a one-on-one standardized assessment such as the KeyMath-3 to better assess the relationship between test anxiety and performance. In particular, gathering achievement information from students' schools, or administering an additional math measure that more closely mimics a test-writing environment might allow researchers to be more confident when drawing inferences about these constructs. Lastly, this study is the first to explore the construct of $A_{ch}E_{m}$s among students with autism; as such, replications of this study with the aforementioned recommendations are necessary to validate the use of the AEQ-ES among students with autism, confirm the present findings, and generalize the results.

Current Interventions Available

Evidently, the influence of anxiety on math performance outcomes of students with autism is a relationship that future researchers should undoubtedly consider. As such, interventions intended to foster anxiety management skills and/or positive attitudes towards math should be recognized, studied, and implemented when possible to help meet the in-class needs of these students. At present, more research is needed to identify the best avenues for intervention development and implementation specific to the math learning barriers imposed by anxiety; however, current interventions are available to address general anxiety experienced among students with autism. Cognitive Behavioural Therapy (CBT) is an evidenced-based approach designed to improve emotion regulation and anxiety in particular for these students. In studies from the past decade, researchers have reported significant improvements in coping skills, fewer internalizing symptoms (e.g., anxiety), and reduced behavioural dysregulation among students with autism in response to CBT (e.g., Drmic et al., 2017; Scarpa & Reyes, 2011; Thomson et al., 2015). At present, this form of intervention appears to be the best available option, although this recommendation may change with increased knowledge, research, and time.

Beyond specific student-focused interventions, in-class math anxiety might be further addressed through environmental changes. Teachers should consider adapting classroom routines for their students with autism, and provide them with specialized in-class support specific to their individual needs when possible (Lytle & Todd, 2009; Alberta Learning, 2003). This could include providing students with opportunities to take breaks from the classroom to help manage sensory processing difficulties and social demands, displaying a clear, visual schedule at the front of the classroom, and/or establishing a calming area in the class that students may use (Lytle & Todd, 2009; Alberta Learning, 2003). These techniques have the potential to help students with autism experience a greater sense of internal control in their classroom environments, thus supporting them in regulating their anxiety and improving their ability to learn, and ultimately their performance. Nonetheless, it should be noted that students with autism present with significant variability with regards to both their strengths and support needs (Iovannone et al., 2007; Kurth & Mastergeorge, 2010); teachers are encouraged to implement in-class strategies that highlight the individual strengths of their students, while simultaneously addressing their specific support needs.

Conclusion

The findings of this exploratory descriptive study emphasize the importance of cognitive and linguistic skills in math, while also bringing attention to math anxiety specifically experienced in the context of class time. Although all $A_{ch}E_m$s were expected to predict performance in math, class-based anxiety represented the sole unique contributor beyond the controlled variables. In an effort to address the predictive discrepancy between this specific $A_{ch}E_m$ and others, several possible explanations were proposed. First, math class represents the only learning context in which new information is exposed to students, and anxiety experienced during this time could increase distractibility, and interfere with learning, thus indirectly impacting performance. In addition to this direct tie, it may be that class time represents an environment that would elicit greater anxiety among students with autism relative to their home settings. Social and sensory aspects of typical classroom environments may overwhelm these students, leading to periods of extreme stress. Given that extreme stress is associated with difficulties in learning (Lytle & Todd, 2009; Morgan et al., 2006), these environmental characteristics could accordingly interfere with their performance in math. Beneath social and sensory demands, it may be that controllability is the underlying factor distinguishing home and classroom contexts. The combination of social and sensory factors characteristic of typical classroom settings could lead students with autism to feel as though they have less internal control relative to their environment, which would likely elevate feelings of anxiety, and make anxious feelings more difficult to regulate effectively.

With regards to the difference between test anxiety and class-based anxiety, it seems likely that either the concept of uncertainty or a methodological choice is responsible. During class time, students are routinely exposed to new and unfamiliar content, while tests and exams are designed to assess knowledge on content learned previously. It may be that when properly prepared by teachers, students with autism know what to expect during a test, but that class time represents a context defined by a greater sense of uncertainty. Given that Pekrun (2006) describes anxiety as a result of experiencing moderate internal control and therefore uncertainty, it is possible that math anxiety would be experienced to a greater extent during class time rather than during a math test. Alternatively, the relationship between text anxiety and performance may be one that our methodological approach was unable to capture. Given that the standard administration outlined by the KeyMath-3 measure is unlike that of a typical testing environment, it is possible that some students with significant test anxiety performed well on this measure, even though this anxiety might typically impact their math performance in school.

Beyond the $A_{ch}E_{m}$ of anxiety, the $A_{ch}E_{m}$s of enjoyment and boredom did not significantly contribute to math performance among students in this sample, nor did they share significant correlations with math performance. Given that prior studies with TD elementary students include large sample sizes, and that anxiety is typically the $A_{ch}E_{m}$ that shares the strongest relationships with math performance across contexts, it may be that the sample described by the present study was large enough to capture the relationships between anxiety and math performance, but insufficiently large to detect the relationships between performance in math and enjoyment or boredom.

$C_{trl}V_{al}$ theory provided an ideal framework through which this study could be developed; it offered a detailed explanation of processes capable of explaining why some students with autism perform extremely well in math, while others experience substantial difficulty. Nonetheless, the results of this study pointed out potential gaps in $C_{trl}V_{al}$ theory that may need further exploration to fully comprehend. In particular, the way individual $A_{ch}E_{m}$s compare to one another in terms of predictive power, and the way external factors (e.g., cognitive resources) can influence how $A_{ch}E_{m}$s affect performance are two areas that may need additional clarification.

Future researchers might consider approaching these gaps in a number of ways. Gathering information on the specific control and value appraisals students with autism experience in addition to their $A_{ch}E_{m}$s could provide further insight regarding where and why certain emotions for this particular group. It may be especially prudent to conduct this important research through mixed-methods or qualitative paradigms, where participant voices can be fully represented. In addition, another avenue worth pursuing includes exploring the relationships between $A_{ch}E_{m}$s and performance in other academic domains among students with autism (e.g., science, language arts). Comparing these relationships to those associated with mathematics would highlight what factors are primarily responsible for inciting in-class anxiety among students with autism (i.e., classroom context, mathematics itself, or a combination). Future researchers may also want to consider evaluating math performance in a different or additional way in order to better reflect a test-writing environment. This would likely lead to a more valid estimate of the relationship between test anxiety and math performance that compares well with prior literature (e.g., Oswald et al., 2016). With these considerations, replications of this study are necessary to validate the use of the AEQ-ES among students with autism, confirm these results, and generalize the overall findings.

Given the role math anxiety appears to play, responding to the emotional needs of these students in classroom settings is worth the attention of educators; interventions intended to improve emotion regulation skills and/ or foster positive attitudes in relation to math should be implemented whenever possible. Presently, the most promising type of intervention available is CBT, which has demonstrated positive results with regards to reducing general anxiety (e.g., Scarpa & Reyes, 2011). With further research, more specific interventions designed to address math anxiety may be considered; however, it would be premature to make such recommendations at this time. As an alternative to targeted intervention development, environmental changes may be implemented to reduce the social and sensory demands that typically characterize classrooms (e.g., allowing students to take breaks from class, using a clear visual schedule each day). These techniques have the potential to support students with their attempts to regulate their anxiety experienced in class, and improve their overall sense of internal control as well, although individual support needs should be considered for each student.

In summary, although math performance outcomes of students with autism are largely determined by cognitive and linguistic skills, math anxiety associated with class time is another factor that may affect performance, and accordingly, deserves attention and consideration from educators. Exploring the underlying mechanisms of $C_{trl}V_{al}$ theory further among students with autism has the potential to clarify key relationships embedded in the theory itself, and shed light on both how and why $A_{ch}E_{m}$s and performance relate to one another among members of this particular population. Accordingly, the findings generated by this exploratory study represent an important step towards helping educators guide students with autism through math successfully, while simultaneously identifying paths that future researchers should take to meet this overarching goal.

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