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Further development of the Children's Mathematics Anxiety Scale UK (CMAS-UK) for ages 4–7 years

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Abstract

There are currently many mathematics anxiety rating scales designed typically for adult and older children populations, yet there remains a lack of assessment tools for younger children (< 7 years of age) despite a recent focus on this age range. Following previous testing and validation, the 26-item iteration of the Children's Mathematics Anxiety Scale UK (CMAS-UK) for ages 4–7 years was further validated with 163 children (4–7 years) across two schools in the UK to test the validity and reliability of the items through subsequent exploratory and confirmatory factor analysis. The predictive validity of the scale was also tested by comparing scale scores against mathematics performance on a mathematics task to determine the relationship between scale and mathematics task scores. Exploratory factor analysis and associated parallel analysis indicated a 19-item scale solution with appropriate item loadings (> 0.45) and high internal consistency ($\alpha = 0.88$). A single factor model of Online Mathematics Anxiety was related to the experience of an entire mathematics lesson, from first entering the classroom to completing a task. A significant negative correlation was observed between the CMAS-UK and mathematics performance scores, suggesting that children who score high for mathematics anxiety tend to score to perform less well on a mathematics task. Subsequent confirmatory factor analysis was conducted to test a range of module structures; the shortened 19-item CMAS-UK was found to have similar model indices as the 26-item model, resulting in the maintenance of the revised scale. To conclude, the 19-item CMAS-UK provides a reliable assessment of children's mathematics anxiety and has been shown to predict mathematics performance. This research points towards the origins of mathematics anxiety occurring when number is first encountered and supports the utility of the CMAS-UK. Subsequent research in the area should consider and appropriately define an affective component that may underlie mathematics anxiety at older ages. Mathematics anxiety relates to more complex procedures that elude the experiences of younger children and may instead be the result of number-based experiences in the early years of education.

Keywords Mathematics anxiety · Factor analysis · Mathematics performance

1 A foundation phase of mathematics anxiety

Although well researched in adult populations, a definitive foundation for mathematics anxiety has yet to be identified (Harari, Vukovic, & Bailey, 2013). However, there is now emerging research that focuses on primary school education (Mizala, Martinez, & Martinez, 2015; Petronzi, Staples, Sheffield, Hunt, & Fitton-Wilde, 2017; Ramirez, Gunderson, Levine, & Beilock, 2013) and the influence of early negative experiences in the classroom is becoming accepted as a key factor in mathematics anxiety development.

Nicolaidou and Philippou (2003) considered that children are intrinsically motivated to learn mathematics with positive attitudes but begin to form attitudes that may be negative. Once mathematics anxiety develops, it can be viewed as cyclic (Ashcraft, 2002; Preis & Biggs, 2001) as negative attitudes relate to avoidance and poor performance which escalates negative feelings. This adverse consequence emphasises the importance of understanding and identifying the issue early in education. Indeed, psychologists (e.g., Rossnan, 2006) have posited that mathematics anxiety can develop at any age and is rooted within a child's first experience of school mathematics. Mazzocco, Hanich, and Noeder (2012) also suggest that efforts should begin in early childhood to steer children away from paths that lead towards negative outcomes. This is made more important by research findings showing that despite demonstrating normal performance in most thinking and reasoning tasks, mathematics anxious individuals demonstrate poor performance when solving mathematics problems (Maloney & Beilock, 2012). Anxiety is not exclusive to mathematics and exists in other subjects, particularly when performing in front of others, including foreign language learning, music performance, and literacy learning, particularly for those with dyslexia (Dowker, Sarkar, & Looi, 2016). Punaro and Reeve (2012) reported that whilst children aged 9 years had literacy and mathematics anxiety in relation to difficult problems in both subjects, mathematics caused more-intense worry related to performance. This suggests that whilst mathematics is not unique in causing anxiety, it may be the subject that produces the most intense responses.

Qualitative research conducted by Petronzi et al. (2017) explored and identified factors contributing to the development of mathematics anxiety in the early years of UK education. Mathematics anxiety in children aged 4–7 years refers to worrisome thoughts surrounding the manipulation of numbers in tasks that require basic mathematical skills. Within this educational context, children encounter number and place value, addition and subtraction, multiplication and division in accordance with the National Curriculum; multiplication and division skills are worked on and developed throughout year 1 and year 2 (UK Key Stage 1; ages 5–7 years) and at the end of this educational phase (UK year 2; age 7 years), children are expected to count in multiples of 2s, 5s and 10s, should know number bonds to 20 and be precise in using and understanding place value. Petronzi et al. identified themes that may have previously been underestimated or not considered as influencing mathematics-based attitudes in early education, for example, fear and stigma of failure, peer comparison/competition and awareness of a classroom hierarchy regarding mathematics ability. These findings highlight the importance of addressing the very early years of formal schooling to understand the development of mathematics anxiety. However, the construct of mathematics anxiety and the current, long-standing definition is grounded within adult research and is associated with more complex mathematical procedures; it does not address its origins in the early years of education. Indeed, mathematics anxiety in the early years has been considered as developing to the point of a rigid educational obstruction (Baptist, Minnie, Buksner, Kaye, & Morgan, 2007) and could be regarded as a pre-requisite phase of mathematics anxiety in later childhood and adulthood.

2 Quantifying mathematics anxiety: a new assessment scale for children

Traditionally, measurement scales using Likert-scale response formats have been developed and adapted to determine the underlying factors of mathematics anxiety in adult populations, such as the Revised Mathematics Anxiety Rating Scale (RMARS) with emerging factors of (a) mathematics course anxiety, (b) evaluation anxiety, and (c) arithmetic computation anxiety (Plake & Parker, 1982); the Short Mathematics Anxiety Rating Scale (sMARS) (a) mathematics test anxiety and (b) numerical test anxiety (Suinn & Winston, 2003); and the Mathematics Anxiety Scale UK, (MAS-UK) (a) mathematics evaluation anxiety, (b) everyday/social mathematics anxiety, and (c) mathematics observation anxiety (Hunt, Clark-Carter, & Sheffield, 2011). One notable exception is Dowker, Bennett, and Smith's (2012) measure of attitudes to mathematics for primary school children. This scale was developed with children aged 7–10 years and strayed from a typical Likert-scale response and instead adopted a face rating scale to ensure appropriateness for primary school-aged children. Children responding to images on questionnaires has previously been assessed by the Koala Fear Questionnaire (Muris et al., 2003), which was found to be a valuable instrument for clinicians and researchers when assessing fears and fearfulness in pre and primary school-aged children. More recently, the Modified Abbreviated Mathematics Anxiety Scale (Carey, Hill, Devine, & Szucs, 2017) has been developed for children aged 8–13 years with a sample of 1746 children and adolescents. This consists of 9-items and participants respond to a 5-point Likert scale, ranging from low anxiety (1) to high anxiety (5). Typically, mathematics anxiety scales have favoured a Likert-scale response, although it seems more appropriate for response formats to be adapted to support children's understanding. This was a core consideration during the development process of the Children's Mathematics Anxiety Rating Scale UK in the current and previous research (Petronzi, Staples, Sheffield, Hunt, & Fitton-Wilde, 2018).

Many existing mathematics anxiety scales are limited in their use with younger children in terms of content and format. For example, the sMARS (Suinn & Winston, 2003) comprises questions focussing on advanced concepts that might be difficult for younger children to comprehend. Other scales, including those for older children, e.g., the Mathematics Anxiety Rating Scale for Elementary children (MARS-E) (Suinn, Taylor, & Edwards, 1988), the Mathematics Anxiety Scale for Children (MASC) (Chiu & Henry, 1990), and the Child Mathematics Anxiety Questionnaire (CMAQ) (Ramirez et al., 2013) use a response format that include written labels pertaining to anxiety levels. Such a response format may not be appropriate for younger children in which comprehension of the labels may be compromised. Whilst the 26-item MARS-E was developed with 1119 fourth (U.K. age 9–10, year 5), fifth (U.K. age 10–11, year 6), and sixth graders (U.K. age 11–12, year 7) and the 22-item MASC is intended for use with children aged 9–14. A focus on older age ranges represents another limitation with existing scales. To address these points, the current study built on previous exploratory factor analysis of the CMAS-UK ($N = 307$) (Petronzi et al., 2018) and focused on the further development of this scale using simple emoticons with three response choices. Notably, both the MARS-E and MASC have the advantage of being applicable to a wider age range, unlike other scales, for example, the Scale for Early Mathematics Anxiety (ages 8–9 years) (Wu, Barth, Amin, Malcarne, & Menon, 2012).

In previous research (Petronzi et al., 2018), the CMAS-UK was implemented with children aged 4–7 years ($N = 307$). Factor analysis of 44 items resulted in the omission of 18 items and led to a 26-item iteration of the CMAS-UK. This produced a high internal consistency value ($\alpha = 0.89$). Two factors were identified: the first related to prospective mathematics task apprehension, e.g., seeing lots of numbers and walking into a mathematics lesson (and was thus termed *Prospective Mathematics Task Apprehension*), and the second was associated with apprehension when completing mathematics tasks, e.g., making mistakes and explaining a mathematics problem to the teacher (termed *Online Mathematics Anxiety*). A preliminary analysis was conducted to determine the extreme score discriminative power of the 26-items based on a median split (47). All *t* test results were significant, suggesting that each item could discriminate between extreme scores. Thus, our previous work suggested that the CMAS-UK is a valid tool for assessing mathematics anxiety in younger children, but further work was needed to validate the measure, particularly regarding the predictive validity of the scale in the context of mathematics performance.

3 Further validation of the Children's Mathematics Anxiety Scale UK (CMAS-UK)

In the current study, the 26-item CMAS-UK was completed by a new sample of children ($N = 163$) to further refine the scale items and to achieve a simple-to-administer scale for younger children. In conjunction with this, children also completed a mathematics task with a difficulty level that was relative to their year group. This was used as a measure of predictive validity to test whether the scale scores could predict mathematics performance. Predictive validity is typically established by presenting correlations between a measure of a predictive and other measures that should be associated with it. Suinn and Edwards (1982) determined the predictive validity of the MARS-A by comparing scale scores with grade averages. The results indicated an association between higher anxiety scores and lower mathematics grade averages. Similarly, Suinn et al. (1988) correlated children's Standardized Assessment Test scores (SATs) with their scores on the MARS-E. A relationship was found, supporting the predictive validity of the MARS-E. Chiu and Henry (1990) determined predictive validity of the MASC by comparing participants' scores against, for example, the shortened version of the MARS, their most recent mathematics results, and scores from completing the Test Anxiety Scale for Children (Wren & Benson, 2004). Participants who scored higher on the MASC had lower achievement in mathematics, higher test anxiety, and lower achievement motivation. Thus, the current study hypothesised that a higher score on the CMAS-UK would predict lower mathematics performance. Table 1 demonstrates the factor loadings and belonging of each of the items for the 26-item version of CMAS-UK following Exploratory Factor Analysis (Petronzi et al., 2018).

4 Method

4.1 Design and participants

The study employed a cross-sectional design to further determine the reliability and validity of a mathematics anxiety rating scale (CMAS-UK), in its 26-item iteration following factor analysis in previous research (Petronzi et al., 2018). Measurements of mathematics performance were also taken.

Participants for the research were recruited through opportunity sampling from two state primary schools across the East Midlands region in the UK. Active informed consent from

Table 1 Factor loadings of items for the CMAS-UK, 2-factor 26-item model ($N = 307$) (Petronzi et al., 2018)

Item	Prospective mathematics task anxiety	Online Mathematics Anxiety
[15] Listening to the teacher in a numeracy class makes me feel…	0.780	–
[26] Walking into the numeracy class makes me feel…	0.742	–
[6] When I read questions in numeracy, I feel…	0.673	–
[7] Starting a new topic in numeracy makes me feel…	0.592	–
[16] When I practise numeracy, I feel…	0.567	–
[5] If I have to do numeracy work in my head, I feel…	0.547	–
[21] When I watch or listen to my teacher explain a numeracy problem, I feel…	0.533	–
[25] When my teacher wants me to do numeracy at home, I feel…	0.533	–
[14] If I have to finish all my numeracy work in lesson, I feel…	0.487	–
[20] Thinking about numeracy outside of class makes me feel…	0.477	–
[24] When I explain how I got my answer to my teacher, I feel…	0.410	–
[2] When I am asked to do lots of numeracy in class, I feel…	0.393	–
[12] When I see lots of numbers, I feel…	0.381	
[13] When I have to explain a numeracy problem to my friends, I feel…	0.368	–
[3] If I am the last to finish numeracy work on my table, I feel…	–	0.711
[17] If I answer questions and get them wrong, I feel…	–	0.643
[11] If I think I cannot do my numeracy work, I feel…	–	0.640
[23] If other children finish their numeracy work very quickly, I feel…	–	0.618
[4] If I make a mistake in numeracy, I feel…	–	0.594
[22] If I do not finish my number work in class, I feel…	–	0.586
[8] When I cannot do my numeracy work, I feel…	–	0.577
[1] When my friends finish their numeracy before me, I feel…	–	0.551
[19] If other children know that I find numeracy hard, I feel…	–	0.501
[9] When I have someone watching me while I do my numeracy, I feel…	–	0.416
[18] If I have to tell the teacher that I do not understand my numeracy work, I feel…	0.397	
[10] When I have to explain a numeracy problem to my teacher, I feel…	0.390	–

parents was obtained via a question and answer information letter that was sent through the school administration system. Following conformation of parental consent, children verbally consented in response to an age-appropriate script. The demographics of the two schools were similar, with a catchment of predominantly white, middle class families. In total, 163 children between the ages of four and seven participated in the research. A total of 39 males (23.9%) and 36 females (22.1%) participated from school one, accounting for 46% of the overall sample size. In school two, 51 males (31.3%) and 37 females (22.7%) participated and accounted for a total of 54% of the sample size. The children in the research were pupils in either reception (age 4–5), year 1 (age 5–6), or year 2 (age 6–7). Seventy-five children participated from the first school (19 reception (25.3%); 36 year one (48%); 20 year two (26.7%)) and 88 participated from the second school (40 reception (45.4%); 21 year one (23.9%), and 27 year two (30.7%)). Across all schools, a total number of 59 children were in reception (36.2%), 57 children were in year one (35%) and 47 children were in year two (28.8%). Reflecting on the guidelines of Tinsley and Tinsley (1987) who suggest a ratio of 5 to 10 participants per item, the sample size of the research ($n = 163$) can be regarded as sufficient and acceptable for exploratory factor analysis, as this equates to 6.27 participants per item (26 items). Despite this, Comrey and Lee (1992) have previously stated 200 to be an adequate sample size for confirmatory factor analysis, and so a low variance could be explained by the relatively small sample size.

4.2 The Children's Mathematics Anxiety Scale UK

The 26 items from the CMAS-UK were randomly numbered and related to general thoughts and feelings about mathematics and typical day-to-day mathematics experiences, for example, teachers; peers and friends; difficulties with work; and receiving help or not. These items had been created in collaboration with teachers who advised on the term "numeracy" instead of "maths", "mathematics", or "sums". It was advised that children are more familiar with "numeracy" at this key stage and the National Curriculum in England predominantly refers to "mathematics" for Key Stage 2 (above the age range of the current research) and refers to "number" for Key Stage 1 (ages 4–7 years). Indeed, within the UK education system, children are familiar with the scheme "numeracy hour" (as well as "literacy hour") and so are accustomed to this consistently used terminology. Furthermore, our qualitative research reinforced UK children's understanding of "numeracy" (Petronzi et al., 2017)—the term is commonplace in the context of UK Key Stage 1 education. Following factor analysis (Petronzi et al., 2018), all items fell into either factor 1 (14-items; prospective mathematics task apprehension) or factor 2 (12-items; Online Mathematics Anxiety) ($\alpha = 0.89$). Children could respond to each item using an emoticon three-point Likert-scale, with one face representing "happy", another signified uncertainty and the final face representing "sad", for example "*If I have to finish all my mathematics work in lesson, I feel…*".

4.3 The mathematics task

Three primary school teachers in a single school (not teachers of the participating children) were asked to create a set of intermediate mathematics problems that were age appropriate for reception, year one and year two children and utilised teacher expertise and understanding of children's abilities in each year group. These mathematics problems were deemed acceptable by teachers in the participating schools. The mathematics task for reception children was more pictorial based and called upon knowledge of shapes (searching for these in a house structure), addition, subtraction, missing numbers and visual identification of more and less (in water beakers); these were ratified by other teachers (appendix Fig. 5). Examples include:

Fill in the missing numbers:

1, 2, _ 4, 5, _ 7

Add the two numbers together to find the answer:

$2 + 3 =$
$5 + 4 =$

For years one and two children, the mathematics task included longer addition (adding more than two numbers together), money, division, multiplication, and using numbers to make a specified value. In order for the tasks to be age appropriate, the year 2 task was of greater difficulty then the year 1 task (although tasks for each year group were set at medium ability). A time limit was not enforced when children were completing the mathematics task, as the intention was to measure their ability without pressure acting as a confounding variable. However, teachers typically allowed up to 15 min for task completion, although this was not stipulated to the children. The children were asked to work independently and to complete as much of the task as possible. To avoid children becoming too anxious when asked to do their own work, they were informed that the task was not a test and that the teacher would not see their answers. Reception children could achieve a maximum score of 18 (1 point for each correct answer), whilst years 1 and 2 children could achieve a maximum score of 20 (1 point per answer); all scores were converted to percentages to reflect accuracy, which was the outcome variable for mathematics performance.

4.4 Research procedure

For each research group, children in reception, year one and year two were taken to a separate and quiet area of the school to avoid distractions and to encourage concentration. For children in reception, the researcher again limited the group size to a maximum of three, as previous research experience had taught that, although emotionally aware, younger children can struggle to understand the response procedure for scales and may require assistance. A small group size enabled the researcher to ensure that all children responded to the appropriate statement after it had been read aloud to them twice. For children in years one and two, the maximum group size was eight, as children in these years were able to understand and follow the response procedure with minimal assistance. Once children had sat down in the research area of the school, introductions were made, and children were given time to talk generally. This time was used to record names, age, and year group. Following this, the researcher redirected the children's attention to the research. A standard introduction to the research that had been written at an age appropriate level was read to each group. Children also had the opportunity to ask any questions and raise any concerns and were informed that they could stop whenever they liked. Children in all groups were also kindly asked to not discuss their statement responses with each other, as the researcher's previous research experience had shown that some children can alter their responses if others are expressing more confidence. Measures were taken in terms of seating to avoid response copying, and avoid creating an anxiety evoking situation, similar to a test. All children were provided with the 26-item CMAS-UK and given a pencil for circling the appropriate emoticon that reflected their feelings. Each group was informed that the researcher would read each statement to the group and then time would be given for their response. For each scale statement, the researcher read the statement twice to ensure understanding. Once all children had responded, the researcher read the next statement. When the CMAS-UK had been completed, the children were thanked for their time and then returned to their class. The CMAS-UK was completed prior to the mathematics task to ensure that children were more inclined to respond generally rather than to the task. However, it is possible that children's mathematics task performance may have been influenced by a priming effect of the CMAS-UK and is an area of research interest.

Participating children completed the mathematics task in their classroom as a group the following day, to avoid fatigue. It was explained to the children that this was not a test and that they should complete as much of the task as possible. They were also informed that there was no time limit, and that they did not need to rush their work. The class teacher assisted in overseeing the completion of the mathematics task and to ensure that children completed their work independently, although they were given assistance in reading the questions, particularly children in reception. Children were not made aware of their mathematics anxiety scale or mathematics tasks scores and these were calculated off site.

5 Results

5.1 Internal consistency and exploratory factor analysis

An exploratory factor analysis on the 26-items was conducted using principal component analysis (PCA) and varimax rotation. Bartlett's test of sphericity was significant ($p < 0.01$), indicating that factor analysis was possible. The Kaiser-Meyer-Olkin (KMO) value was also sufficiently high (0.870) (Pallant, 2001). Considering the discrepancy between eigenvalues suggesting 5-factors and the scree plot suggesting 1-factor (Fig. 1) a parallel analysis (PA) was conducted simulating 1000 data files. According to Franklin, Gibson, Robertson, Pohlmann, and Fralish (1995), when comparing PA with the use of PCA in previous research, PCA alone was shown to have potentially resulted in over-extraction of components, and therefore potentially misleading results. Accordingly, Franklin et al. (1995) recommend the routine use of PA which creates a random dataset based on original data (comparing eigenvalues from a pre-rotated data set from a matrix of random values of the same dimensionality). Regarding interpretation of this test, when parallel analysis eigenvalues (based on the random data) exceed the eigenvalues from PCA, these can be ignored and the number of suggested components prior to intersect (if both PCA and PA eigenvalues and components were plotted on a graph) can be judged as the number of components to extract.

Our results suggested extraction of 1-factor explaining 31.26% of the variance as the second simulated eigenvalue (1.68) was higher than the empirical eigenvalue (1.37). A 1-factor solution with a loading threshold of more than .45 was forced, as the scale could be made more statistically robust by implementing a higher cut-off. Stevens (1992) suggests that factors should load above 0.5 for a sample of 100 and 0.3 for a sample of 200, the current study ($n = 163$) can be judged as between these values and thus > 0.45 was judged to be

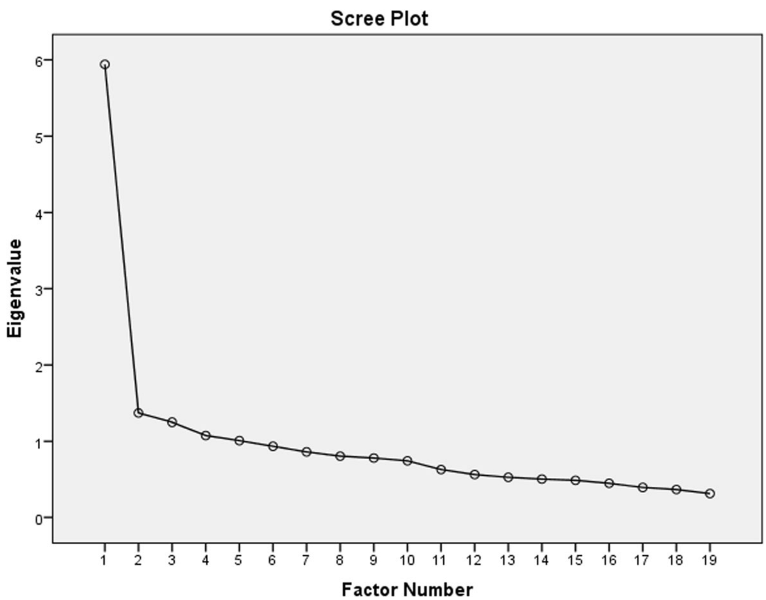


Fig. 1 Factor analysis scree plot suggesting 1-factor

acceptable. This resulted in the removal of seven items (2, 5, 6, 7, 9, 16, and 20), leaving a 19-item iteration of the CMAS-UK with high internal consistency ($\alpha = 0.88$). A subsequent analysis was conducted to determine the extreme score discriminative power of the 19-items based on a median split (33). All *t* test results were significant, suggesting that each item could discriminate between extreme scores.[1]

The current 19-item measure of mathematics anxiety corresponds to the 22-item MASC (Chiu & Henry, 1990) and 26-item MARS-E (Suinn et al., 1988) in terms of number of items and time to complete and should be more manageable for younger children. Future comparison against these validated scales is justified as, like the CMAS-UK, they were developed for use with children, albeit somewhat older. In terms of a practical application to classrooms, it is beneficial for the CMAS-UK to have fewer items due to its intended lower age range, with issues surrounding attention and fatigue in younger children, particularly those in reception. Table 2 shows the factor loadings of each item and the response frequencies, whilst Fig. 2 shows the range of CMAS-UK scores indicating a wide spread and normal distribution.

5.2 Factor labelling

Items that loaded onto the single observed factor appeared to have a strong association with feelings and situations during the moment-to-moment experience of performing a mathematics task, i.e., explaining an answer to the teacher, being the last to finish mathematics work, making mistakes and getting work wrong. This factor was thus named, "Online Mathematics Anxiety", maintaining the factor 2 name from the previous research (Petronzi et al., 2018). This factor consists of merged items from the initial factor 1 and factor 2. The entire mathematics lesson could be viewed as being an online task, as it requires the learner to not only complete work, but to observe and listen closely to instruction—something that high anxious children may find difficult.

5.3 Confirmatory factor analysis—2-factor 26-items

A series of confirmatory factor analyses was used to test the previous 26-item version of the CMAS-UK against the revised 19-item scale that emerged in this research. Testing the 2-factor model of the CMAS-UK identified in previous research (Petronzi et al., 2018), the fit indices showed that the data were not a perfect match to the model. The analysis of the 2-factor solution (Fig. 3) resulted in a large and highly significant chi square, $\chi^2(298) = 409.358$, $p < 0.001$ although this can be sensitive to sample size (Goffin & Jackson 1988, as cited in Kline (1994)). The comparative fit index (CFI) = 0.88 and the Tucker-Lewis Index (TLI) = 0.87 did not indicate a good model fit (< 0.95), although the root mean for approximation was acceptable (RMSEA = .05). Based on the CFI and TLI criteria (Table 3), the model did not indicate a good fit.

[1] When a 2-factor solution was forced on the data collected with 26-items ($N = 163$) with a loading threshold to replicate our previous study (0.35) (Petronzi et al. 2018), almost all of the same items were found to load on the same factors according to the Rotated Component Matrix. First factor items (2, 5, 6, 7, 12, 13, 14, 15, 16, 24, 26) and second factor items (1, 4, 8, 11, 17, 18, 19, 21, 22, 25). The only disparity was observed with items 3 (reverse direction loading), 10, and 23 (loaded onto both factors) although the same items were removed (9 & 20) due to insufficient loading (< 0.35) (see Table 1). This suggests reliability of the scale across our development studies, despite a 1 factor solution ultimately being indicated by more robust parallel analysis in the current research.

Table 2 Factor loadings and response frequencies of the 19-item CMAS-UK (> 0.45 threshold)

Item	Online number apprehension	Frequency—happy	Frequency—uncertain	Frequency—sad
Q1: When my friends finish their work before me, I feel…	0.540	73 44.8%	47 28.8%	43 26.4%
Q3: If I am the last to finish numeracy work on my table, I feel…	0.572	47 28.8%	52 31.9	64 39.3
Q4: If I make a mistake in numeracy, I feel…	0.565	48 29.4%	77 47.2%	38 23.3%
Q8: When I cannot do my numeracy work, I feel…	0.552	40 24.5%	50 30.7%	73 44.8%
Q10: When I have to explain a numeracy problem to my teacher, I feel…	0.540	74 45.4%	60 36.8%	29 17.8%
Q11: If I think I cannot do my numeracy work, I feel…	0.617	46 28.2%	56 34.4%	61 37.4%
Q12: When I see a lot of numbers, I feel…	0.520	105 64.4%	45 27.6%	13 8%
Q13: When I have to explain a numeracy problem to my friends, I feel…	0.520	89 54.6%	53 32.5%	21 12.9%
Q14: If I have to finish all my numeracy work in lesson, I feel…	0.583	78 47.9%	37 22.7%	48 29.4%
Q15: Listening to the teacher in my numeracy class makes me feel…	0.496	115 70.6%	35 21.5%	13 8%
Q17: If I answer questions and get them wrong, I feel…	0.624	41 25.2%	53 32.5%	69 42.3%
Q18: If I have to tell the teacher that I do not understand my numeracy work, I feel…	0.542	50 30.7%	70 42.9%	43 26.4%
Q19: If other children know that I find numeracy hard, I feel…	0.639	53 32.5%	46 28.2%	64 39.3%
Q21: When I watch or listen to my teacher explain a numeracy problem, I feel…	0.465	87 53.4%	55 33.7%	21 12.9%
Q22: If I do not finish my number work in class, I feel…	0.615	40 24.5%	62 38%	61 37.4%
Q23: If other children finish their numeracy work very quickly, I feel…	0.606	64 39.3%	49 30.1%	50 30.7%
Q24: When I explain how I got my answer to my teacher, I feel…	0.479	91 55.8%	45 27.6%	27 16.6%
Q25: When my teacher wants me to do numeracy at home, I feel…	0.515	92 56.4%	37 22.7%	34 20.9%
Q26: Walking into the numeracy class makes me feel…	0.567	98 60.1%	45 27.6%	20 12.3%

5.4 Confirmatory factor analysis—1-factor 26-items

A confirmatory factor analysis was used to further test a 1-factor model (Online Mathematics Anxiety) of the previous 26-item CMAS-UK to replicate the single factor identified in the current research. The fit indices showed that the data were not a perfect match to the model. The analysis of the 1-factor solution resulted in a large and highly significant chi square, $\chi^2(299) = 454.01$, $p < 0.001$ although this can be sensitive to sample size. The comparative fit index (CFI) = 0.84 and the Tucker-Lewis Index (TLI) = 0.82 did not indicate a good model fit (< 0.95), although the root mean for approximation was acceptable (RMSEA = 0.05). Based on the CFI and TLI criteria (Table 4), the model did not indicate a good fit.

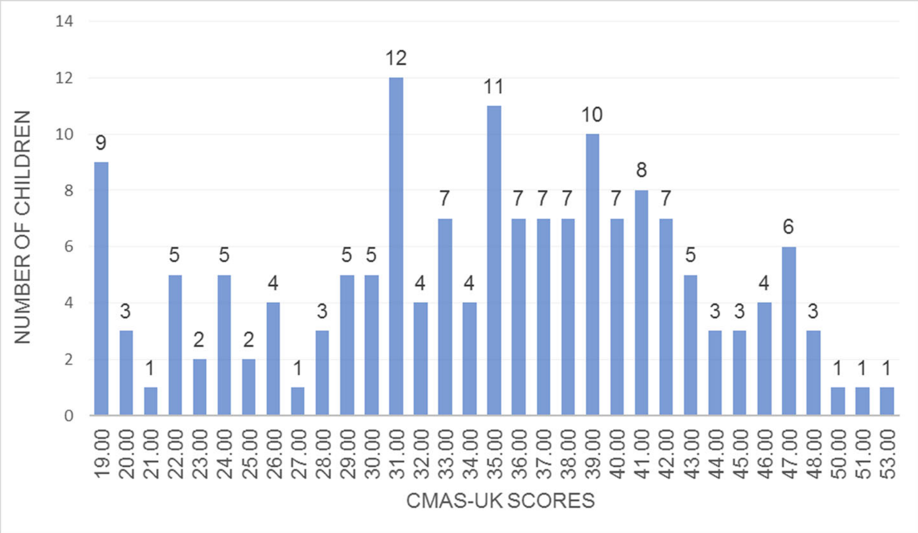


Fig. 2 The distribution of children's CMAS-UK Scores (19-items)

5.5 Confirmatory factor analysis of the current CMAS-UK: a 1-factor, 19-item model

A final confirmatory factor analysis was used to test the 1-factor model of the CMAS-UK. The analysis of the 1-factor solution (Fig. 4) resulted in a large and highly significant chi square, $\chi^2(152) = 244.860$, $p < 0.001$, although this can be sensitive to sample size. The comparative fit index (CFI) = 0.87 and the Tucker-Lewis Index (TLI) = 0.86 did not indicate a good model fit (< 0.95), although the root mean for approximation was acceptable (RMSEA = 0.06). In sum, the model fit indices (Table 5) matches the acceptable and non-acceptable parameters of the 2-factor 26-item CMAS-UK and the 1-factor 26-item model, indicating that a refined 19-item version of the scale—which will be more manageable for younger children—can be retained and subsequently tested using a larger sample size in future work.

The results show that CFA standardised regression weights are only marginally smaller than the EFA factor loadings. The standardised regression weights in the CFA are favourable as they closely link to the EFA, supporting the 19-item model and this is shown to be consistent across statistical tests. The small observed difference between regression weights and factor loadings exert no effects on the model that would lead to differential theoretical interpretations.

5.6 CMAS-UK scores and the mathematics task

As expected due to the age-appropriateness of the mathematics tasks for each year group, there was no significant effect of year group on mathematics task scores, $F(2,160) = 1.88$, $p = 0.16$; the means and standard deviations for each year group are shown in Table 6. There was no significant effect of primary school on mathematics performance $F(1,161) = 1.71$, $p = 0.19$, or mathematics anxiety $F(1,161) = 1.00$, $p = 0.32$. However, correlational analysis demonstrated a large, negative correlation between scores on the 19-item CMAS-UK and performance on the mathematics task (overall score accuracy), $r(163) = -0.620$, $p < 0.001$. This correlation can be seen by year group: (1) reception, $r(59) = -0.597$, $p < 0.01$, (2) year 1, $r(57) = -0.557$, $p < 0.01$, and (3) year 2, $r(47) = -0.807$, $p < 0.01$.

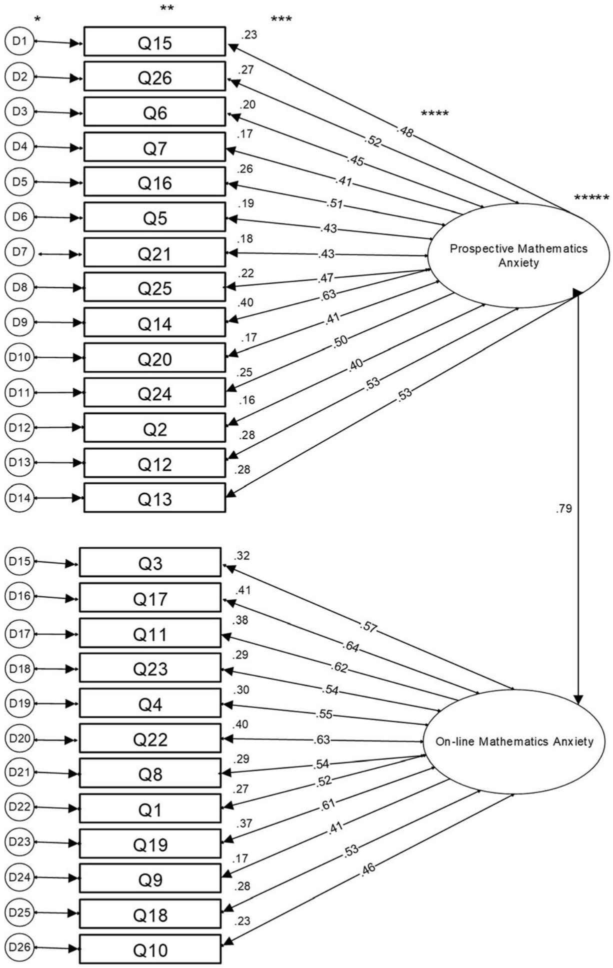


Fig. 3 CMAS-UK confirmatory factor analysis structure (2-factor 26-item model). *Measurement error. **Observed variables. ***Percent of variance explained. ****Standardised regression weights. *****Common factors

6 Discussion

The extant literature on mathematics anxiety has given limited attention to the early years of mathematics education. Knowledge has therefore been limited with regard to the onset of mathematics anxiety and whether factors in the early educational years have an

Table 3 Fit indices for the CMAS-UK (2-factor 26-items)

	X2	df	*p*	CFI	TLI	NFI	RMSEA	Pclose
M1	409.358	298	< 0.001	0.88	0.87	0.67	0.05	0.603
Cut off values (Hu & Bentler, 1999)	N/A	N/A	> 0.05	> 0.95	> 0.95	> 0.095	< 0.06	> 0.05

Table 4 Fit indices for the CMAS-UK (1-factor 26-items)

	X2	df	*p*	CFI	TLI	NFI	RMSEA	Pclose
M1	454.014	299	< 0.001	0.84	0.82	0.64	0.05	0.151
Cut off values (Hu & Bentler, 1999)	N/A	N/A	> 0.05	> 0.95	> 0.95	> 0.095	< 0.06	> 0.05

association with this. Consequently, the CMAS-UK was developed to measure mathematics anxiety in young children (4–7 years), younger than those targeted by other measures (Chiu & Henry, 1990; Dowker et al., 2012). The current study further validated the scale using exploratory and confirmatory factor analysis and demonstrated a negative relationship between mathematics anxiety and mathematics performance. The 19-item CMAS-UK was shown to have high internal consistency ($\alpha = 0.88$) (Lacobucci & Duhachek, 2003; Rattray & Jones, 2005) and is similar to that obtained in (Petronzi et al., 2018) ($\alpha = 0.89$).

Whilst the association between mathematics anxiety scores and mathematics performance scores was significant and large ($r = -0.620$), this should be viewed with a degree of caution. In some cases, children who obtained a high score on the mathematics task also obtained a high score on the CMAS-UK. Ashcraft (2002) also previously found that despite some children claiming a degree of mathematics anxiety, their competence scores

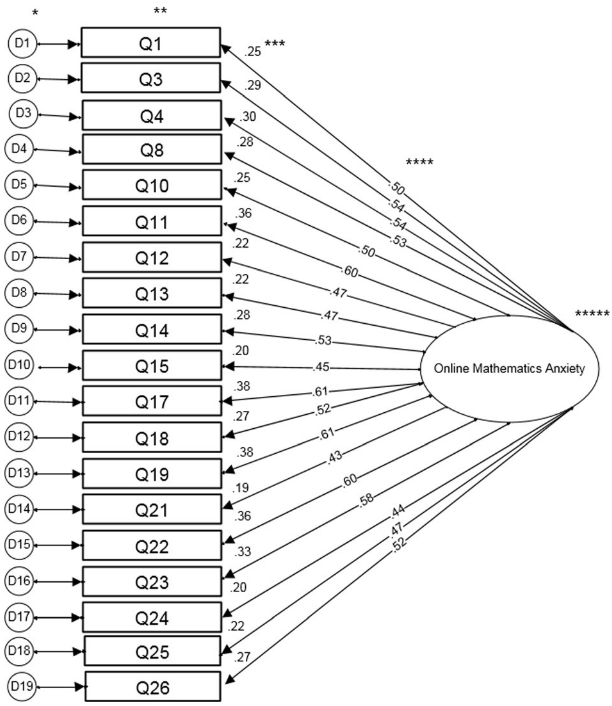


Fig. 4 CMAS-UK confirmatory factor analysis structure (1-factor 19-item model). *Measurement error. **Observed variables. ***Percent of variance explained. ****Standardised regression weights. *****Common factor

Table 5 Fit indices for the CMAS-UK (19-items)

	X2	df	*p*	CFI	TLI	NFI	RMSEA	Pclose
M1	244.860	152	< 0.001	0.87	0.86	0.72	0.06	0.095
Cut off values (Hu & Bentler, 1999)	N/A	N/A	> 0.05	> 0.95	> 0.95	> 0.095	< 0.06	> 0.05

remained unaffected. Previously, Ashcraft, Kirk, and Hopko (1998) found that the effects of anxiety were only apparent on certain mathematical concepts. Thus, it may be that the children were highly anxious, but were comfortable with the concepts on the mathematics task, and thus performance was unaffected. Ashcraft (2002) stated that researchers should always consider the competence-anxiety relationship, as those with higher anxiety may demonstrate increased competence in varying circumstances. However, for the most part our data demonstrates that children with low CMAS-UK scores performed better on the mathematics task whilst children with higher scores on the CMAS-UK generally had lower mathematics performance scores. This large correlation supports the use of items created following qualitative research with the target population (Petronzi et al., 2017) and suggests that the items are an accurate reflection of children's experiences. Indeed, it was also found that the items could discriminate extreme scores. In the current research, a range of anxiety scores was evident and there was a strong negative association between CMAS-UK scores and mathematics task scores; this addressed the aim of testing the predictive validity of the CMAS-UK and has shown that it can be an appropriate measure for early childhood difficulties in mathematics. Nevertheless, further research is required to assess the direction of causation. Previously, research by Ma and Xu (2004) used a longitudinal study with 3116 students from grade seven to twelve (UK age 12–17) to determine causal ordering. Throughout the 6 years, students completed achievement tests in mathematics and science and a questionnaire which covered a variety of measures, including mathematics anxiety, basic numeracy skills, algebra, geometry, and quantitative literacy. Results from the study indicated that lower mathematics achievement scores in earlier grades were associated with higher mathematics anxiety scores in the later grades, suggesting that mathematics achievement had a causal priority over mathematics anxiety.

The current analyses suggested a 19-item single factor solution was appropriate and contrasts to the previous 2-factor scale (Petronzi et al., 2018). Comparing the participation numbers from our previous work (reception = 82; year 1 = 108; year 2 = 117) to the current research's (reception = 59; year 1 = 57; year 2 = 47) suggests a possible explanation for the difference in model structure. In the previous research, the reception year group was considerably less represented than year one and two—whilst in the current research were similar across the year groups. Adding to this, the numbers of participating schools in the

Table 6 Means and standard deviations for year groups and mathematics performance scores

	N	Mean (SD)
Reception	59	72.46 (20.54)
Year 1	57	68.77 (25.60)
Year 2	47	77.23 (19.50)
Total	163	72.55 (22.29)

current research were less than in our previous scale development work; however, the schools were of similar socioeconomic status and ethnicity intake. The omission of an item relating to mental arithmetic is somewhat surprising as previous research, e.g., Ashcraft (2002) indicated that this is a particularly difficult aspect of mathematics and may act as a key differentiator between mathematics attitudes. Nevertheless, at the age of reception, children are learning and practising calculations, becoming familiar with numbers and strategies to facilitate their learning. Thus, there is less emphasis on mental arithmetic within this younger age group, which becomes a more essential skill as children progress through education. Therefore, the mental arithmetic item (and its low factor loading) has low saliency in this context for younger children. Again, this finding is a change in model structure from our previously observed 2-factor solution to the 1-factor solution in the current research. However, CFA results showed that a 1-factor 19-item scale had similar acceptable and non-acceptable parameters as a 2-factor 26-item version of the CMAS-UK, indicating that the change in model structure—whilst warranting further research—should not be considered concerning. Indeed, this shorter version is preferable and more manageable for younger children. Further to this, the current research also implemented a slightly increased and more robust loading threshold for items (> 0.45), although this had no impact on the factor solution of the CMAS-UK. It is also notable that a forced 2-factor solution on data for the 26-items with a loading threshold to replicate our previous study (0.35) indicated almost all the same items were found to load on the same factors according to Rotated Component Matrix. Although a 1-factor solution on the current data was advised by parallel analysis, the same items loading onto either of the two factors indicates reliability of the scale across our development studies, again suggesting that there should be little concern in the change of model structure.

Of the 19-items that remained from the previous 26-item version of the scale, 11 were maintained from the "Online Mathematics Anxiety" factor and it was thus preserved as the single dominant factor of the CMAS-UK. The additional 8 items were maintained from the "Prospective Mathematics Task" factors. The 19-items seemingly encapsulate a typical mathematics lesson, from feelings when walking into a mathematics lesson, to being unable or the last in a group to finish the work set and may explain the incorporation of "Prospective Mathematics Task" into the single factor solution. Other examples pertain to other children finishing their work quickly and having an awareness of someone struggling (failure and peer comparison); providing incorrect answers; making mistakes (failure and low self-efficacy); and holding the belief of being unable to complete work (low sense of ability and self-esteem). These items also identified in quantitative mathematics anxiety research with older populations, suggesting that the early years of education may somewhat contribute to later difficulties and negative attitudes, although this requires further investigation.

As a point of reflection, it can be argued that younger children may not have the capacity to accurately recall and rate their mathematics experiences. Young children's memories are still developing throughout earlier years and are therefore restricted in how much information and experiences they can store in their short-term memory (Croker, 2012). However, currently in the UK, children from 4 years are expected to engage in self-assessment and self-reflection of their learning and emotional state using school specific self-report measures (there is no standard measure). Yet in most cases children rate their learning-based feelings on a scale of 1–10 using emojis for visual support. Indeed, educational psychology services in the UK also implement and refer teachers and childcare workers to a test bank of scales for the measurement of children's emotional and mental well-being using quantitative measurement. In light of this, the CMAS-UK (with visual emoji support) aligns with the current UK practise.

The development of the CMAS-UK is a positive response to Ashcraft and Moore (2009) and Mazzocco (2007) who stated that the appropriate tools have not been developed to examine anxiety and those at risk of mathematics difficulties in early education. Rossnan (2006) argued that mathematics anxiety can develop at any age and the associated fear is deeply rooted within a child's first experience of school mathematics. The current study highlights an adverse relationship between young children's early mathematics experiences and performance that could potentially develop and progress into the later educational years. This relationship may be impacting performance much earlier than previously anticipated by research. Longitudinal studies may be beneficial to test the long-term consequences of worrisome thoughts about mathematics from the ages of 4–7 years. The results of this study support that the early years and experiences of working with numbers are critical. Mazzocco et al. (2012) further considered that mathematics anxiety in older children may be rooted within the early years of education and that efforts should be made in early childhood to steer them away from negative outcomes. This contention is supported by the current research and reinforces the utility of the CMAS-UK in identifying children at risk of developing mathematics anxiety.

Moreover, it is necessary for future researchers to consider the multitude of potential influences on the development of mathematics anxiety (Petronzi et al., 2018) including the use of negative mathematics-based language around children, using mathematics as a punishment and exposing children to evaluation and pressure from peers. These and other influences should be considered when using an assessment measure such as the CMAS-UK to quantify feelings and experiences. Further predictive and convergent validation work on the scale is needed with younger children, whilst the CMAS-UK can support projects evaluating intervention techniques that are known to be efficacious with older children. For example, Park, Ramirez, and Beilock (2014) that expressive writing following and prior to a mathematics task increases the mathematics performance of those with university students with higher mathematics anxiety.

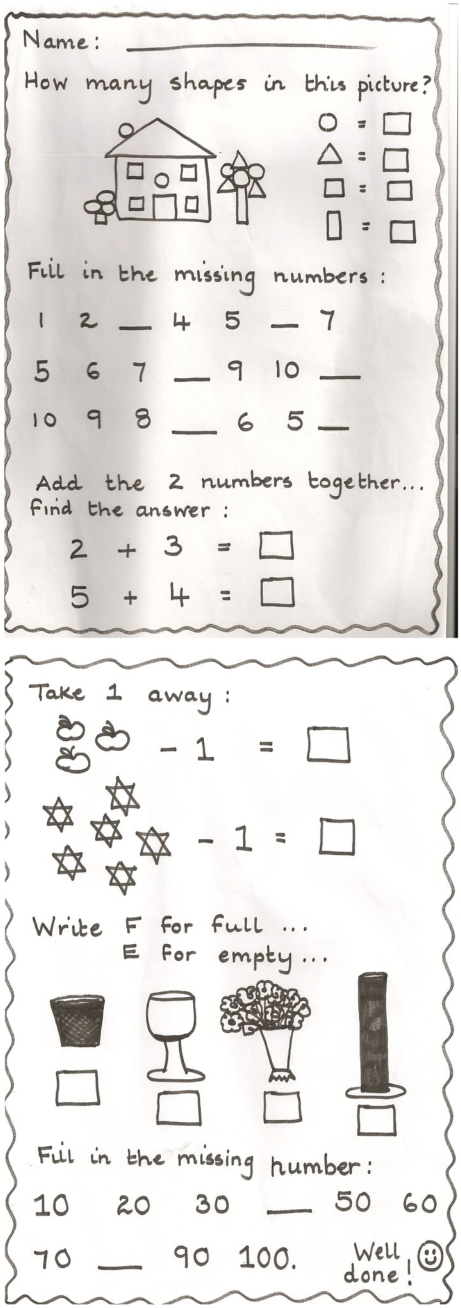
In sum, previous research has neglected the assessment of affect towards numbers among younger children. Our work has gone some way to address this shortfall by providing an easily administrable scale with a parsimonious factor structure. Previous attempts to measure mathematics anxiety among older children and adults have emphasised the multidimensionality of the construct whereas the current findings highlight the limited context in which young children are exposed to numbers. We demonstrate the importance of mathematics anxiety at a young age and the relation this has on mathematics performance. The current work should encourage further investigation into the developmental relations between mathematics anxiety and mathematics performance; improved theoretical understanding may inform educational practices and support the design of effective interventions that stop negative trajectories of mathematics anxiety and performance from a young age.

Compliance with ethical standards

Competing interests The authors declare that they have no conflict of interest.

Appendix 1

Fig. 5 Reception mathematics task



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