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Monika Szczygiel*

How to measure math anxiety in young children? Psychometric properties of the modified Abbreviated Math Anxiety Scale for Elementary Children (mAMAS-E)

Abstract: Starting in the early years of education, math anxiety is negatively related to mathematic outcomes, therefore there is a need for its adequate measurement in young children. This study presents the psychometric properties of the modified Abbreviated Math Anxiety Scale for Elementary Children (mAMAS-E) for first- to third-grade children based on mAMAS. The validity of mAMAS-E was determined by a series of tests. The analysis confirmed its two-factor structure (Testing and Learning), positive relationships between mAMAS-E and math, general, and test anxiety, and a negative relationship with mathematical achievement. Children with a high level of math self-esteem and math self-confidence (but not Polish language self-esteem and self-confidence) have lower math anxiety in comparison to those with a moderate level. The results also indicate that girls have a higher level of math anxiety than boys. The validity and internal consistency of mAMAS-E are satisfactory; therefore, mAMAS-E may be a recommendable questionnaire for measuring math anxiety in young children.

Keywords: math anxiety, mAMAS-E, mAMAS, assessment, early school age

Introduction

Correlates of math anxiety

Math anxiety is a negative emotional state that accompanies contact with mathematics (Ashcraft & Ridley, 2005) and which negatively affects the domains related to the mathematics of many children, teenagers, and adults (Dowker, Sarkar, & Looi, 2016). A higher level of math anxiety is related to lower performance in mathematical tasks (Carey, Hill, Devine, & Szűcs, 2017; Dowker, 2019), negative attitudes to mathematics ((Dowker, 2019; Pinxten, Marsh, De Fraine, Vane den Noortgate, & Van Danne, 2014; Van der Beek, Van der Ven, Kroesbergen, & Leseman, 2017), lower math self-confidence (Bursal & Paznokas, 2010), lower math self-esteem (Goetz, Cronjaeger, Frenzel, Ludtke, & Hall, 2010), and lower math self-concept (Isiksal, Curran, Koc, & Askun, 2009; Justicia-Galiano, Martin-Puga, Linares, & Pelegrina, 2017). The results of many studies suggest that gender is an important factor in differentiating the level of math anxiety among children, adolescents, and adults. It is generally found that females report a higher level of math anxiety

than males (Dowker, 2019), but some studies indicate no gender differences (Harari, Vukovic, & Bailey, 2013).

Math anxiety is considered a specific type of anxiety that cannot be explained by referring only to anxiety (Hembree, 1990). Its specificity has been confirmed by results indicating that math anxiety correlates weakly or moderately with general anxiety and test anxiety (Ganley & McGraw, 2016; Hembree, 1990; Wu, Barth, Amin, Melcarne, & Menon, 2012) and strongly with other measures of math anxiety (Hembree, 1990; Hopko, Mahadevan, Bare, & Hunt, 2003). Although much is known about the characteristics of math anxiety in school children, adolescents, and adults, research into this issue among young children has only started relatively recently. However, according to what is described below, many characteristics of this anxiety are probably similar to those in older learners (Ganley & McGraw, 2016).

Gender

Many research results indicate a higher level of math anxiety in secondary school girls than in boys (Devine et al., 2012; OECD, 2015), but there are also results which

* Institute of Psychology, Pedagogical University of Krakow

Corresponding author: e-mail: monika.szczygiel@up.krakow.pl

did not demonstrate such differences (Ma & Cartwright, 2013; OECD, 2015). Fewer studies have been conducted on gender differences among children in primary school but they indicate a similar pattern of results as among the older age groups. Some results reveal a lack of gender differences (Gierl & Bisanz, 1995; Harari et al., 2013; Newstead, 1998; Punaro & Reeve, 2012; Ramirez, Gunderson, Levine, & Beilock, 2013; Young, Wu, & Menon, 2012), but others confirm that girls exceed boys in the intensity of math anxiety (Griggs, Rimm-Kaufman, Merritt, & Patton, 2013; Hill et al., 2016; Schleepen & Mier, 2016).

General and test anxiety

General anxiety concerns an individual's disposition to worry about a number of different things, events, behaviors, and competences (Spence, 1997), whereas test anxiety relates to apprehension in evaluative settings (Putwain & Daniels, 2010). Although many studies among secondary children and adults confirm the specificity of math anxiety (Hembree, 1990), the relationships between math anxiety, general anxiety, and test anxiety among primary children have been rarely tested and are not obvious. Most studies indicate that such relationships exist (Carey et al., 2017; Cargnelutti, Tomasetto, & Pasolunghi, 2017; Ganley & McGraw, 2016; Gierl & Bisanz, 1995; Hill et al., 2016); however, a lack of a correlation between math and general anxiety has been observed by others (Wu et al., 2012).

Math self-esteem and math self-confidence

Math self-esteem is an aspect of self-concepts and is the basis of actions and behaviors performed in relation to mathematics (Reyna, 2000); mathematics confidence is the perception of one's own ability to obtain good results and belief about one's own ability to handle difficulties in mathematics (Pierce & Stacey, 2004). Math self-esteem and math self-confidence (Ganley & McGraw, 2016) are already moderately to strongly correlated with math anxiety in early childhood, and these relationships persist in later years (Eden, Heine, & Jacobs, 2013; Hembree, 1990). Children, adolescents, and adults who feel comfortable in relation to mathematics and assess their ability to perform tasks well have lower math anxiety than their counterparts who have low math self-esteem and low math self-confidence.

Math achievement

Undertaking research on math anxiety among children in early school age is justified by the fact that a high level of math anxiety in children is related to their low mathematical achievement. Although some studies indicate no such relationship (Krinzinger, Kaufmann, & Willmes, 2009; Thomas & Dowker, 2000), other studies confirm a decrease in mathematical achievement with an increase in math anxiety (Ramirez et al., 2013; Wu et al., 2012; Vukovic, Kieffer, Bailey, & Harari, 2013 – among children with high working memory capacity). The detrimental effect of math anxiety on mathematical outcomes of children in primary school may be weak, but it develops over time and is more intense among secondary school

children (Devine et al., 2012) and adults (Cipora, Szczygiel, Willmes, & Nuerk, 2015).

Problems with measurement of children's math anxiety

Appropriate and reliable measurement of math anxiety is important when designing means of prevention of its negative impact on results in mathematics; therefore, increased interest in developing appropriate research tasks by researchers has been observed recently. Proposed methods of math anxiety measurement in primary school children include the following:

- (1) Questionnaires based on a popular measurement of math anxiety: *The Abbreviated Math Anxiety Scale* (AMAS; Caviola, Primi, Chiesi, & Mammarella, 2017; Hill et al., 2016; Hopko et al., 2003); *Mathematics Anxiety Scale UK* (MAS-UK; Hunt, Clark-Carter, & Sheffield, 2011).
- (2) Modifications of AMAS and MAS: *modified Abbreviated Math Anxiety Scale* (mAMAS; Carey et al., 2017); *Children Mathematics Anxiety Scale UK* (CMAS-UK; Petronzi, Staples, Sheffield, Hunt, & Fitton-Wilde, 2019).
- (3) New research scales especially designed to assess math anxiety of primary school children: *Mathematics Anxiety Survey* (MAX; Gierl & Bisanz, 1995); *Math Anxiety Questionnaire* (MAQ; Krinzinger et al., 2009; Thomas & Dowker, 2000); *Mathematics Anxiety Scale for Young Children* (MASYC; Harari et al., 2013; Vukovic et al., 2013); *Scale for Early Math Anxiety* (SEMA; Cargnelutti et al., 2017; Wu et al., 2012; Young et al., 2012); *Children's Anxiety in Math Scale* (CAMS; Jameson, 2013, 2014).
- (4) Modified versions of the above: *Child Math Anxiety Questionnaire* (CMAQ; Ramirez et al., 2013); *Revised Child Math Anxiety Questionnaire* (CMAQ-R; Ramirez, Chang, Maloney, Levine, & Beilock, 2016); *Revised Version of the Math Anxiety Scale for Young Children* (MASYC-R; Ganley & McGraw, 2016).

Ganley & McGraw (2016) and Cipora, Artemenko, & Nuerk (2019) provided a detailed summary of the characteristics of most of the research scales listed above. The number of questionnaires developed so far for primary-school children is substantial but stems from the many difficulties in assessing math anxiety and the search by investigators for the best measurement method among young children.

Although an increase in research interest in the assessment of math anxiety in young children has recently been observed, the problems with measurements of children's emotions are common and hard to solve (Carey et al., 2017; Ganley & McGraw, 2016). One problem is the theoretical and ecological validity of math anxiety questionnaires; another problem concerns the reliability of the scales.

There is still no consensus about the number and type of dimensions of math anxiety and their unchangeability throughout life (Carey et al., 2017). The available scales assume the existence of different areas of anxiety related to mathematics: MAX – mathematics test anxiety, mathematics problem-solving anxiety (Gierl & Bisanz, 1995); SEMA –

numerical processing anxiety, situational and performance anxiety (Wu et al., 2012); MASYC, MASYC-R – negative reactions, numerical confidence, worry (Ganley & McGraw, 2016; Harari et al., 2013); CAMS – general math anxiety, math performance anxiety, math error anxiety (Jameson, 2013); AMAS, mAMAS – testing and learning math anxiety (Carey et al., 2017; Caviola et al., 2018; Hill et al., 2016). However, in other studies (MASYC, Vukovic et al., 2013; CAMS, Jameson, 2014; SEMA, Cargnelutti et al., 2016; Wu et al., 2012) and in other questionnaires (MAQ, CMAQ, CMAQ-R, CMAS; Krinzinger et al., 2009; Petronzi et al., 2019; Ramirez et al., 2013; 2016; Thomas & Dowker, 2000) such dimensions have not been found. The problem is more general and concerns the nature of math anxiety, its development, and ways of preventing it. Another problem is that some scales contain questions related to specific mathematical tasks that cause problems when using them in different classes, educational systems, or cultural contexts and which make it impossible to track the development of math anxiety, both individually and between classes (Ganley & McGraw, 2016).

Analysis of various scales indicates problems with the ecological validity of the questions, especially if they do not apply to children's experiences or contain a description of physiological responses that are inadequate to the level of the children's language development. Additionally, some of the questions suggest that mathematics causes anxiety, fear, worry, and sadness, so children who do not feel negative emotions may feel obliged to report such feelings according to what they think the researchers expect.

Beyond the problems with the content of the items, consideration should also be given to the difficulties associated with the response scale (Ganley & McGraw, 2016). Researchers use pictorial (CMAQ, Ramirez et al., 2013; CMAQ-R, Ramirez et al., 2016; MAQ, Krinzinger et al., 2009; Thomas & Dowker, 2000) or Likert scales (MAX, Gierl & Bisanz, 1995; MASYC, Harari et al., 2013; MASYC-R, Ganley & McGraw, 2016; AMAS, Hill et al., 2016; mAMAS, Carey et al., 2017), but both of them have limitations. The pictorial scales are child-friendly but their use is burdened with individual differences between children in assessing the meanings of cartoon expressions of emotion; also, their scale construction is often more categorical than continuous (although they are usually treated as continuous scales). From the statistical point of view, the Likert scale is better, especially if it contains many response points, but when considering children's skills in accurately estimating emotions the problem becomes complex. When there are many possibilities of slightly different answers, young children have problems with reliable estimation of their own feelings, especially when the scale is numerical, not verbal (Ganley & McGraw, 2016). It seems that the best idea is to replace the numerical scale with a verbal description (CAMS, Jameson, 2013; SEMA, Wu et al., 2012) and replace the questionnaire study with a structured interview if the tested children cannot yet read. Interviews may take longer to conduct but they allow more friendly (due to the individual approach) and accurate (due to the possibility of confirming what the child means and

eliminating interpretation errors) measuring of math anxiety among the youngest children.

The last important problem is the varying reliability of measurement (Cronbach's alpha 0.55–0.91; Ganley & McGraw, 2016). The more questions there are, the more accurate the measurement is; however, a larger number of questions is also associated with greater fatigue of children. The math anxiety questionnaire is often used with a battery of other tests, so it is important to use a relatively short scale with questions that are highly reliable (Carey et al., 2017; Ganley & McGraw, 2016).

It seems that problems with the accuracy and reliability of all the scales are associated with the age of the tested children. In searching for the sources of math anxiety, researchers are trying to adapt the scales to the age of primary-school children, but this age varies from country to country. For this reason, it is important to measure math anxiety by using a highly reliable scale consisting of a relatively small number of questions, a short answer scale, and instructions and questions that are simple and clear for children. A scale that meets most of these criteria is mAMAS, which was designed to measure math anxiety in children from 8 to 13 years old. The present study introduced several modifications to this scale in order to extend its use to studying younger children. The advantages and weaknesses of the scale that needed revision in order to conduct a study among children from 6 to 11 years old are presented in the materials description.

Present study

Measurement of math anxiety in early school-age children is important because it allows screening of the first symptoms of negative emotions related to mathematics and prevention of the development of math anxiety. Considering the importance of the proper measurement of math anxiety, the main objective of the study is to analyze the validity and reliability of mAMAS-E, which is designed for early school-age children. mAMAS-E is based on mAMAS, which in turn is a modified version of AMAS. AMAS is characterized by very good psychometric properties and universality of use in different cultures, educational systems, and age ranges, as was also confirmed in the Polish adaptation (Cipora et al., 2015). According to Carey et al. (2017), the validity and reliability of mAMAS are as good as any language version of AMAS, which suggests that it should also be adequate for use in the Polish cultural context. While Carey et al. (2017) used the scale among fourth-, seventh- and eighth-grade children (8–13 years), the present study expands its usefulness into younger first- to third-grade children (6–11 years). The advantages of mAMAS that influenced its selection are the universal factor structure that is confirmed in many studies, its shortness, its well-known high reliability, and its proper validity.

In the study, the two-factor structure (Testing and Learning) of mAMAS-E was tested. It was assumed that if mAMAS-E is a valid measurement of young children's math anxiety, its score should correlate positively and strongly with other measures of math anxiety, positively and weakly or moderately with test and general anxiety,

and negatively (from weakly to moderately) with math achievement. In addition, one might expect that children with various levels of math self-esteem and self-confidence differ in the level of math anxiety, whereas the various levels of Polish language self-esteem and self-confidence should not differentiate children's math anxiety. It could also be expected that girls have a higher level of math anxiety than boys.

Method

Participants

The presented results are part of two cross-sectional and longitudinal research projects regarding the predictors of math anxiety and mathematical achievement in early school-age children. The cross-sectional research involved measurement at the end of the first, second, and third grade, whereas the longitudinal study consisted of four measurement points (at the beginning, middle and end of first grade as well as the end of second grade). The presented data are combined from two studies and include all the results from cross-sectional research (the end of the first, second and third grade) and the results from the two last measurements of the longitudinal study (the end of the first and second grade). The participants were children from public primary schools in Krakow (Poland) whose parents allowed them to participate in the project. The schools are at various places in the ranking of schools in the city (at the top, middle, and bottom of the scale). Most children's families were characterized by a relatively moderate or high socio-economic status (including the level of income, education, and occupation).

The cross-sectional research was conducted in nine primary public schools. 241 pupils took part in the research: 46 children (23 girls) from the first grade (mean age 7 years and 3 months, range 6.1–8.3 years); 101 children (60 girls) from the second grade (mean age 8 years and 2 months, range 7.1–9.3 years); 94 children (51 girls) from the third grade (mean age 9 years and 4 months, range 8.0–11.2 years). The longitudinal study was carried out among children who attended twenty-eight different classes across twelve schools. Among the 369 participating children, there were 205 girls and 164 boys. The mean age of the children at the end of the first class was 7 years 8 months (range 6.6–8.7 years). Children were one year older when the second measurement was performed.

Materials

Math anxiety

mAMAS-E. The modified Abbreviated Math Anxiety Scale (mAMAS) proposed by Carey et al. (2017) for children aged 8–13 years is a 9-item, self-report, 5-point Likert scale. mAMAS contains two subscales, Evaluation and Learning math anxiety, but according to Cipora et al. (2015) and Caviola et al. (2018) the decision about changing the label 'Evaluation' to 'Testing' was made on the basis of the items' content. mAMAS was translated into Polish and back-translated, improved, and tested in pilot sessions. To adapt the scale for early

school-aged children, it was necessary to make a few changes in comparison to the original version. The data were collected during individual meetings with children; the instructions and statements were read aloud by the researcher to eliminate the differences between children in the level of reading skills. The children's answers were marked on the response card by the interviewer. The pilot sessions showed that children had problems assessing their emotions on the five-point scale, so the range of answers was modified to three possibilities. After each statement was read, children were asked 'Do you feel anxiety in such a situation? Yes, A little, or No?'. The proper explanations about the meaning of 'anxiety' were given for every child ('Anxiety means feelings of worry, nervousness, or fear'). The answers were rated 2, 1, and 0 points, respectively. Therefore, the minimum and maximum scores in modified Abbreviated Math Anxiety Scale for Elementary Children (mAMAS-E) are in the range 0–18 for Total score, 0–10 for Learning score, and 0–8 for Testing score. Additionally, before the testing session, to make sure that the children understood how to respond to the questions, an example was given: 'Do you like chocolate? Yes, A little, or No?' (scale used in the study, instruction, and test hints are included in the Appendix). In addition to the change in the response scale due to the capabilities of children, the substantive justification is worth emphasizing. The answer scale in AMAS and mAMAS includes the assumption that a person experiences some intensity of math anxiety because the scale encompasses a level of anxiety from low to high. Thus, a low score is often interpreted as a low intensity of anxiety, while it is not known whether or not it should be interpreted as a complete absence. This problem is especially valid when proper math anxiety preventions are planned because it matters whether children feel weak math anxiety or do not feel math anxiety at all.

MAQC. The Math Anxiety Questionnaire for Children was constructed based on two scales: The Mathematics Anxiety Scale in Young Children (MASYC; Harari et al., 2013) and the Scale for Early Mathematics Anxiety (SEMA; Wu et al., 2012). The results of the pilot sessions in the Polish educational context using MASYC and SEMA revealed that many changes were needed (manuscript under review). Firstly, the questions were not adapted to the level of language of very young children (especially the physiological dimension). Secondly, the mathematics curriculum in Poland differs from the US curriculum, so math-related questions were not valid and were removed. Finally, the response scale was simplified to three levels because of children's problems estimating their own feelings on the standard Likert scale. The final version of the scale consists of twelve items and a 3-point scale was employed (2 – Yes, 1 – A little, 0 – No). The range of possible scores was from 0 to 24; the higher the score of the MAQC, the higher the level of math anxiety. The results of exploratory and confirmatory factor analysis revealed that the scale is one-dimensional. In the present study, MAQC correlates moderately with trait anxiety (RCMAS $r = .47$, $p < .001$, $N = 119$) and test anxiety (CTAS-T $r = .48$, $p < .001$, $N = 127$). The reliability calculated by Cronbach's

alpha was $\alpha = .77$ ($N = 368$) and the test-retest reliability established in the pilot studies equaled $r = .56$, $p < .001$, $N = 55$.

General anxiety

RCMAS. The Revised Children's Manifest Anxiety Scale (Reynolds & Richmond, 1978) is a popular 37-item measurement of general anxiety with a Yes/No answer scale. Originally, the scale consisted of a Lies scale and three subscales: Physiological anxiety (RCMAS-P), Worry/Oversensitivity (RCMAS-W), and Social concerns/Concentrations (RCMAS-S). The Polish language version of RCMAS was prepared in accordance with the principles of back-translation. In the present study, the reliability of RCMAS was calculated using Cronbach's $\alpha = .88$ for Total score, $\alpha = .69$ for Physiological anxiety, $\alpha = .69$ for Worry, and $\alpha = .75$ for Social anxiety ($N = 57$).

sRCMAS. General anxiety was also measured by items that were extracted by Stark and Laurent (2001) from the Revised Children's Manifest Anxiety Scale (RCMAS; Reynolds & Richmond, 1978) as uniquely measuring children's anxiety (in comparison with the Children's Depression Inventory; CDI; Kovacs, 1980/1981). The short version of RCMAS (sRCMAS) was translated into Polish, back-translated, improved in the Polish language, and tested in a pilot study. This 7-item questionnaire with a Yes/No answer scale is unidimensional (as was confirmed by exploratory factor analysis). The reliability in the present study is $\alpha = .70$ ($N = 203$).

Test anxiety

CTAS. One of the scales that measures test anxiety among children is the Children's Test Anxiety Scale (Wren & Benson, 2004). It is designed for children 8–12 years old and consists of 30 items and three subscales: Thoughts (13 items), Off-Task Behaviors (8 items), and Autonomic reactions (9 items). In the present study, the Thoughts subscale (CTAS-T) was used and the rating was given by four response options (1 – almost never, 2 – some of the time, 3 – most of the time, 4 – almost always). The Polish language version was prepared in accordance with the principles of back-translations and has a very satisfactory reliability calculated by Cronbach's $\alpha = .86$ ($N = 249$).

Math and Polish self-evaluation

Math self-esteem (MSE) and Polish self-esteem (PSE). Children were asked about their math self-esteem in one question: 'Are you good at math? Yes, a little or no?'. In the same way, their Polish self-esteem was assessed: 'Are you good at the Polish language? Yes, a little or no?'. The results were coded as 2, 1, and 0 points, respectively. Children who answered 'Yes' were categorized as high self-esteem subjects, 'A little' as having moderate self-esteem, and 'No' as having low math or Polish self-esteem.

Math self-confidence (MSC) and Polish self-confidence (PSC). To distinguish children who assess their chances of completing math problems as low, medium, and high, one question was asked: 'When you do math, do you think that you do it well? Yes, a little or no?'. In a similar

manner, self-confidence in Polish language was investigated. Children were asked 'When you learn the Polish language, do you think that you do it well? Yes, a little or no?'. The answers were awarded 2, 1 or 0 points. Children that answered 'Yes', 'A little', and 'No' were classified as having high, moderate, and low math or Polish self-confidence.

Mathematical achievement

MATH. The mathematical achievement of children in the two studies was measured by tasks prepared by a mathematician in accordance with the core curriculum for elementary schools and mathematics education materials recommended by the Ministry of Education in Poland. Because of the different research plans and grades, various mathematical tasks were prepared for each class. The MATH-1, MATH-2, MATH-3 tasks were directed to first- to third-grade children in the cross-sectional research plan, and MATH-I and MATH-II tasks were targeted at first- and second-grade children in the longitudinal study, respectively.

The tests in the cross-sectional and longitudinal study examined the practical application of mathematical knowledge in the following areas: MATH-1 and MATH-I – knowledge of numbers, counting, addition and subtraction, discovering rules, knowledge of money, knowledge of geometric figures, reading a tape measure; MATH-2 and MATH-II – addition and subtraction, multiplication and division, reading a tape measure, spatial orientation, discovering rules, clock reading; MATH-3 – addition and subtraction, multiplication and division, reading a tape measure, discovering rules, clock reading, knowledge of dates and money.

Mathematical tasks were performed by the children themselves. The tasks were presented on an A4 sheet in written form; however, to eliminate differences in the level of reading skills between children, instructions were read aloud by the researcher. Each task consisted of instructions, space for calculations and space for answers. The tasks had no time limit. The number of tasks was selected so that children who needed more time to solve the tasks were able to complete them in less than 40 minutes. The tasks had various levels of difficulty: very easy, easy, moderately difficult, difficult, and very difficult. The maximum points score that could be obtained in each class in the cross-sectional study was 36 and in the longitudinal measurements was 62.

Procedure

The studies were carried out in public schools after prior approval was given by the head of each school and the children's parents. Ethical permission was obtained from the Scientific Research Ethic Committee of the Institute of Psychology of Jagiellonian University of Krakow. The cross-sectional study was conducted by a researcher in two meetings (first between April–May; second between May–June) in 2017 among children from first, second, and third grade. The data from the longitudinal study is from two meetings with children at the end of the first and second grade and was collected by research assistants between May and June 2018 and May and June 2019.

Table 1. The materials used in the studies

	Cross sectional study <i>N</i>				Longitudinal study <i>N</i>			
	Order	1 st grade	2 nd grade	3 rd grade	Order	1 st grade	Order	2 nd grade
mAMAS-E	2	29	70	58	1	317	5	263
MAQC	3	46	101	94	–	–	7	127
RCMAS	4	15	16	26	–	–	–	–
sRCMAS	–	–	–	–	3	316	9	204
CTAS-T	–	–	–	–	–	–	8	255
MSE	1	40	94	86	–	–	1	263
MSC	–	–	–	–	–	–	2	263
PSE	–	–	–	–	–	–	3	263
PSC	–	–	–	–	–	–	4	263
MATH-1	–	46	–	–	–	–	–	–
MATH-2	5	–	101	–	–	–	–	–
MATH-3	–	–	–	93	–	–	–	–
MATH-I	–	–	–	–	2	317	–	–
MATH-II	–	–	–	–	–	–	6	263

Note. Math anxiety – mAMAS-E, MAQC; general anxiety – RCMAS, sRCMAS; test anxiety – CTAS-T; math and Polish self-esteem – MSE, PSE; math and Polish self-confidence – MSC, PSC; math achievement – MATH-1, MATH-2, MATH-3, MATH-I, MATH-II.

In the two studies, individual meetings with children were conducted in a room adapted to the needs of children. The children were asked about their agreement to participate; they also were informed that they could withdraw from the study at any time, could choose not to answer any question they wanted, or should say if something was not clear to them. Instructions for all the tasks were read aloud by the researcher. The children's answers about math, general, and test anxiety and math and Polish self-esteem and confidence were written down by the researcher on the answer card; the mathematical problem solutions were written on the test cards by the children themselves. Each meeting with the children lasted 20 to 45 minutes and was dependent on the individual pace of the children's work. Because children in various studies, measurements, and grades answered different questions and performed varied mathematical tasks, Table 1 presents a list of the materials used and the order in which the measurements were performed.

Analysis

The analysis was prepared in PS IMAGO PRO 5.1. and *R* (*lavaan* and *ggplot* packages; Rosseel, 2012; Wickham, 2016). The data from the two studies were combined to better assess the psychometric properties of mAMAS-E. Firstly, the descriptive statistics and results of the confirmatory factor analysis of mAMAS-E were calculated in the *R* program. Then, the divergent and convergent validity was assessed using correlation analysis (mAMAS-E, MAQC, RCMAS, sRCMAS, CTAS-T, MATH-1, MATH-2, MATH-3, MATH-I, and MATH-II)

and group comparison in mAMAS-E score (gender, MSE, PSE, MSC, PSC). Finally, the reliability of mAMAS-E was calculated using Cronbach's alpha. Validity and reliability tests were conducted in PS IMAGO PRO 5.1.

Results

Descriptive statistics and structure of mAMAS-E

The data from the cross-sectional study and measurement among second-grade students from the longitudinal study were used to test the structure of mAMAS-E. Because the results in mAMAS-E among pupils from the longitudinal study are correlated, the decision to include observation from only one measurement is well-founded.

First of all, the intercorrelations between items were calculated (see Table 2). Most results indicate that the strengths of the relationships between items are weak to moderate.

In the second step, the structure of mAMAS-E was checked. In accordance with the assumptions of the construction of AMAS and mAMAS, a model with two factors was tested (Model 1): Learning (items 1, 3, 6, 7, 9) and Testing (items 2, 4, 5, 8). The assumption of multivariate normality was checked using Mardia's test, which revealed multivariate nonnormality (skewness 2473.19, $p < .001$, kurtosis 37.81, $p < .001$). Therefore, Maximum Likelihood Estimation with Robust (MLR) was applied. The model, similarly to the model described by Carey et al. (2017), did not obtain the required Chi² value ($\chi^2_{(26)} = 46.11$, $p = .01$, $N = 419$), but other indices of

Table 2. Item intercorrelations of mAMAS-E

	1	2	3	4	5	6	7	8
mAMAS-E 1								
mAMAS-E 2	.31***							
mAMAS-E 3	.25***	.19***						
mAMAS-E 4	.35***	.50***	.25***					
mAMAS-E 5	.30**	.29***	.14***	.32***				
mAMAS-E 6	.34***	.18***	.18***	.26***	.25***			
mAMAS-E 7	.16**	.15**	.14**	.20***	.14**	.38***		
mAMAS-E 8	.30***	.50***	.24***	.39***	.34***	.22***	.13**	
mAMAS-E 9	.22***	.24***	.24***	.26***	.18***	.29***	.02	.17**

Note. $N = 419-420$; *** $p < .001$; ** $p < .01$.

fitting the model to the data were satisfactory: CFI = .94, TLI = .92 (Hu & Bentler, 1999), robust RMSEA = .06 [$CI = .029, .084$] (Browne & Cudeck, 1993), SRMR = .049 (Kline, 2016). All factor loadings in the two-factor model were significant and their values varied from .36 to .70. The Total result correlates strongly with the Learning subscale ($r = .82, p < .001$; $r = .38-.62, p < .001$ for individual items) and the Testing subscale ($r = .91, p < .001$; $r = .62-.69, p < .001$ for individual items). The Learning and Testing subscales correlate moderately ($r = .50, p < .001$). The Learning scale correlates $r = .21$ to $.43, p < .001$ with individual items; the Testing scale correlates $r = .35$ to $.43, p < .001$ with individual items (see Table 3).

Better fitting of items to the factors was noted in the Testing compared to the Learning subscale. The sixth statement about listening to another child in the class who was explaining a math problem (.36), the third item about watching the teacher solve a math problem (.41) and the ninth statement concerning starting a new topic in math (.42) had especially relatively weak loadings for the Learning subscale. Learning score correlates with Testing score positively and moderately ($r = .50,$

$p < .001$). Learning and Testing scores are strongly correlated with Total score ($r = .82, p < .001$ and $r = .91, p < .001$, respectively, $N = 420$). Correlations between items, the whole scale and the two subscales confirm the consistency of mAMAS-E. In summary, the two-factor structure of mAMAS-E among children from first to third grades was validated; however, the properties of the scale structure are slightly worse than those reported by Carey et al. (2017).

To ensure that the two-factor model (M1) proposed by many authors is a better solution than the one-factor model (M2) and the split-halves two-factor model (M3), the additional analyses were conducted in similar way to Vahendi & Farrokhi (2011). First, M1 and M2 were compared by one-way analysis of variance (ANOVA). The results indicate that the two-factor model (M1) fits the data significantly better than a model with a single latent factor (M2) for math anxiety ($\chi^2_{(1)} = 9.21, p = .002$). While M1 and M3 are nested models and ANOVA can be used to compare two non-nested models, the confirmatory factor analysis was performed for M3. It enables comparison of the properties of fitting models to the data between M1 and M3. The model with two split-halves

Table 3. Descriptive statistics, item-scale correlations and CFA of mAMAS-E

Subscale	Items	Mean (SD)	Skewness	Kurtosis	Correlations item-scale			CFA results (β)	
					mAMAS-E Total	mAMAS-E Learning	mAMAS-E Testing	mAMAS-E Learning	mAMAS-E Testing
Learning	1	.32 (.63)	1.76	1.78	.62***	.70***	.43***	.60	
	3	.14 (.43)	3.29	10.18	.45***	.55***	.27***	.41	
	6	.21 (.53)	2.50	5.08	.56***	.72***	.31***	.57	
	7	.13 (.42)	3.34	10.62	.38***	.50***	.21***	.36	
	9	.24 (.53)	2.18	3.76	.48***	.59***	.28***	.42	
Testing	2	.50 (.70)	1.05	-.25	.68***	.35***	.77***		.70
	4	.50 (.67)	.99	-.21	.69***	.43***	.73***		.68
	5	.68 (.78)	.63	-1.10	.62***	.34***	.68***		.49
	8	.56 (.75)	.93	-.63	.68***	.35***	.76***		.65

Note. $N = 420$; *** $p < .001$. In the table are presented the results of Model 1.

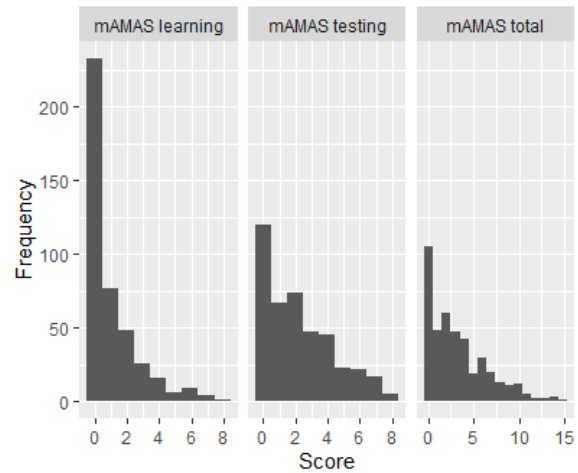
items was specified in the following way: Factor 1 – items 1, 2, 3, 4, 5; Factor 2 – items 6, 7, 8, 9. The results indicate that M3 is not very well fitted to the data, and the value of χ^2 ($\chi^2_{(26)} = 63.15, p < .001, N = 419$) is greater than for M1. Other indices of fitting the model to the data also were worse than the analogical indices for M1 (M3: CFI = .89, TLI = .85, robust RMSEA = .08 [CI = .055, .104], SRMR = .059). All factor loadings in M3 were significant and their value varied from .29 to .66, which means that factor loadings in M1 were a little better. Therefore, it may be concluded that the two-factor structure of mAMAS-E proposed by many authors is better than the one-factor model and the two-factor model when the items are divided into two halves.

Finally, the descriptive statistics for mAMAS-E (M1) are presented. The mean level of math anxiety ($N = 420$) for Total score is 3.28 ($SD = 3.23$; range 0–15), for Learning score it is 1.04 ($SD = 1.58$; range 0–8), and for Testing score it is 2.24 ($SD = 2.14$; range 0–8). The Shapiro-Wilk tests showed a significant deviation from normality in Total ($W = .88, p < .001$), Learning ($W = .70, p < .001$), and Testing ($W = .88, p < .001$) scales. Skewness was 1.07, 1.86, and .78; kurtosis was .60, 3.20, and $-.30$ for Total, Learning and Testing scales, respectively.

The results indicate that most early-school-age children are not math-anxious or feel weak math anxiety. Figure 1 additionally presents the distribution of Learning, Testing, and Total scores of mAMAS-E, which confirmed that both subscales and Total score are characterized by right-skewed distribution.

Based on the descriptive statistics for all items that are presented in Table 3, it should be noted that the mean level of intensity of the testing items in comparison to learning items is stronger. The comparison between Learning

Figure 1. Distribution of mAMAS-E Learning, Testing, and Total scores



and Testing subscales ($t_{(419)} = 12.90, p < .001, N = 420$) indicates that children feel stronger math anxiety when they are tested in math ($M = 2.24, SD = 2.14$) in comparison to learning math ($M = 1.04, SD = 1.56$).

Validity of mAMAS-E

The convergent and divergent validity of mAMAS-E was checked by a series of correlation analyses (see Table 4) and group comparisons (see Table 5). Firstly, the relationship between mAMAS-E and other measures of math anxiety was tested (see Table 4).

According to expectations, the MAQC result positively and strongly correlated with mAMAS-E Total, Learning, and Testing. Subsequently, the relationships

Table 4. Convergent and discriminant correlations of mAMAS-E

		<i>N</i>	Mean (<i>SD</i>)	mAMAS-E Total	mAMAS-E Learning	mAMAS-E Testing
Math anxiety	MAQC	284	.39 (.34)	.66***	.59***	.56***
	RCMAS	44	.36 (.23)	.44 **	.28; $p = .07$.45*
	RCMAS-P	44	.37 (.24)	.21	.15	.19
General anxiety	RCMAS-W	44	.36 (.26)	.55***	.36*	.54***
	RCMAS-S	44	.33 (.30)	.35*	.18	.40*
	sRCMAS	204	.74 (.50)	.41***	.33***	.37***
Test anxiety	CTAS-T	255	1.99 (.63)	.54***	.43***	.51***
	MATH-1	29	27.75 (4.98)	.06	.14	-.12
Mathematical achievement	MATH-2	70	25.66 (6.55)	-.42***	-.29*	-.39*
	MATH-3	58	25.13 (8.14)	-.39*	-.32*	-.35*
	MATH-I	317	40.47 (17.91)	-.09	-.02	-.12*
	MATH-II	263	30.29 (21.00)	-.30***	-.27***	-.25***

Note. * $p < .05$; ** $p < .01$; *** $p < .001$.

Math anxiety – MAQC; general anxiety – RCMAS, RCMAS-P, RCMAS-W, RCMAS-S, sRCMAS; test anxiety – CTAS-T; Math achievement – MATH-1, MATH-2, MATH-3, MATH-I, MATH-II.

The data of sRCMAS was used in the analysis of second-grade children.

between mAMAS-E and general and test anxiety were examined. The correlations between RCMAS score and mAMAS-E Total and Testing were positive and moderate. In the case of RCMAS and mAMAS-E Learning, a weaker relationship was observed that was on the border of statistical significance. Analyses of the RCMAS subscales indicate that math anxiety is positively and moderately related to Worry, Social anxiety is positively and moderately related to mAMAS-E Total and Testing, and there is no relationship between Physiological anxiety and math anxiety. The relationship between general and math anxiety in a larger group of children shows that sRCMAS is positively and moderately related to the scores of mAMAS-E. The obtained results confirm that mAMAS-E measures a specific kind of anxiety and should not be considered a measure of general or test anxiety. Additionally, more evidence indicating this has been gathered.

In the next step of the analysis, the relationships between math anxiety and mathematical achievement were tested. Mathematical achievement among second- and third-grade children is negatively and moderately related to math anxiety. Among first grade children, a lack of such a relationship was generally observed. MATH-1 score was not correlated with math anxiety and MATH-I score was not related to mAMAS-E Total and Learning; however, MATH-I was negatively and weakly related with mAMAS-E Testing.

The series of independent samples *t* Tests was then conducted and effect size was calculated (see Table 5).

Firstly, gender differences were checked. The results indicate that girls in comparison to boys have a higher level of math anxiety in the Total and Testing scores, but not in the Learning score. The size of effects calculated by Cohen's *d* indicates that the differences are moderate.

In the next step of the analysis, the number of children in the groups of high, moderate, and low MSE, PSE, MSC, and PSC was checked. It turned out that only a few children assessed their own math and Polish self-efficacy and self-confidence as low. Moreover, the number of children that had high self-efficacy and self-confidence in math and the Polish language was definitely higher than those who were characterized by a moderate level. For these reasons, a comparative analyses was performed after selecting at random the appropriate number of children from the whole group using the Random Number Generator (Furey, 2019). In this way, 'High' and 'Moderate' groups were created.

The results indicate that children with high math self-esteem have lower math anxiety than their counterparts with a medium level of math anxiety in Total, Learning, and Testing score. The differences in mean results are large. Similar results were observed when comparing children with high and medium math self-confidence. In the Testing subscales, the result is on the border of statistical significance, but the compared groups are small. When analyzing the effect size, it should be pointed out that the differences between Total, Learning, and Testing scores are large. Children with moderate and high Polish language self-esteem and self-confidence do not differ in the level of math anxiety. These results are in accordance with the

Table 5. Convergent and discriminant comparison of mAMAS-E in groups

	<i>N</i>	mAMAS-E Total	mAMAS-E Learning	mAMAS-E Testing
		Mean (<i>SD</i>)	Mean (<i>SD</i>)	Mean (<i>SD</i>)
Gender	Girls = 213	.42 (.37)	.23 (.34)	.66 (.56)
	Boys = 207	.31 (.34)	.18 (.29)	.46 (.49)
		$t_{(418)} = -3.26; p < .001; d = .31$	$t_{(418)} = -1.51; p = .13; d = .16$	$t_{(418)} = -3.82; p < .001; d = .38$
MSE	M = 98	5.08 (3.42)	1.69 (1.80)	3.39 (2.21)
	H = 98	2.82 (3.11)	.93 (1.52)	1.89 (2.03)
		$t_{(194)} = 4.85; p < .001; d = .69$	$t_{(194)} = 3.22; p < .01; d = .46$	$t_{(194)} = 4.95; p < .001; d = .71$
PSE	M = 87	3.67 (3.18)	1.11 (1.58)	2.55 (2.16)
	H = 87	3.83 (3.52)	1.33 (1.74)	2.49 (2.20)
		$t_{(172)} = -.32; p = .75; d = -.05$	$t_{(172)} = -.87; p = .39; d = -.13$	$t_{(172)} = .17; p = .86; d = .03$
MSC	M = 32	5.91 (3.26)	2.44 (2.23)	3.47 (1.69)
	H = 32	3.76 (3.77)	1.24 (1.89)	2.52 (2.41)
		$t_{(63)} = 2.46; p < .05; d = .61$	$t_{(63)} = 2.34; p < .05; d = .58$	$t_{(63)} = 1.84; p = .07; d = .46$
PSC	M = 37	3.62 (2.86)	1.30 (1.58)	2.32 (1.78)
	H = 37	3.49 (3.80)	1.16 (1.69)	2.32 (2.48)
		$t_{(72)} = .17; p = .86; d = .04$	$t_{(72)} = .36; p = .72; d = .09$	$t_{(72)} = .00; p = 1.00; d = 0$

Note. MSE – math self-esteem; PSE – Polish self-esteem; MSC – math self-confidence; PSC – Polish self-confidence; M – 'medium' level group; H – 'high' level group; *t* – independent sample *t* Test; *d* – Cohen's *d*.

expectations and confirm the convergent and divergent validity of mAMAS-E.

Reliability of mAMAS-E

The internal consistency of mAMAS-E (whole scale and two subscales) was checked by Cronbach's α coefficient. The internal consistency for the Total score was $\alpha = .75$ ($N = 419$), for Learning score $\alpha = .59$ ($N = 419$), and for Testing score $\alpha = .71$ ($N = 420$). The reliability for Total and Testing score is satisfactory, but the reliability of the Learning subscale is insufficient.

Discussion

Structure, distribution, and reliability of mAMAS-E

AMAS (Hopko et al., 2003) is one of the most valid and reliable assessments of math anxiety among various groups of people. The modified version, mAMAS, was adapted to assess math anxiety in children in fourth grade of primary school and seventh and eighth grade of secondary school (Carey et al., 2017). The study was conducted to check whether mAMAS-E may be used among even younger children from the first to third grade of elementary school. Despite the changes made to mAMAS, the study validated the solution with two factors (Testing and Learning) and undermined the validity of a one-factor or two-factor solution in a different configuration (split in half). This implies that anxiety related to testing and learning mathematics situations is universal throughout an individual's lifespan. However, some deficiencies of mAMAS-E were also observed.

Relatively low correlations were observed between items. This indicates that the scale is not as consistent as was expected and the items describe various not very related math situations. Low factor loadings and the rather low reliability of the Learning scale were especially noted. The reliability of mAMAS-E for Total and Testing score are satisfactory, but for the Learning subscale it is generally low. This is surprising because in most studies in which AMAS and mAMAS were used the reliability of the whole scale and its subscales was sufficient. This low reliability may be explained by the small number of questions and the homogeneity of the group of children that was characterized by a low level or lack of math anxiety in learning situations. The fact that the response scale had only three points may also have influenced the results. It may be concluded that there is a problem that is difficult to solve concerning the compromise between statistical correctness and the ecological relevance of a study of early school-age children, as was also observed in other studies (Carey et al., 2017; Ganley & McGraw, 2016).

Considering other scale properties, mAMAS-E may be recommended as a math anxiety screener scale. Such a diagnosis at an early stage of education is justified because math anxiety develops over time and in early school age is already associated negatively with mathematics achievement (Ramirez et al., 2013; Vukovic et al., 2013; Wu et al., 2012). Most children have a low level of math anxiety, but there are also children with moderate and strong math anxiety, especially with regard to testing in math. Similarly to

other research (Carey et al., 2017; Cipora et al., 2015), the comparison between Testing and Learning scores indicates that learning of mathematics is less anxiety inducing than testing of it. The pattern of distribution of all mAMAS-E scores is right-skewness, which may be characteristic of children starting math education. The math anxiety characteristic among older children and early adolescents (Carey et al., 2017) indicates a similar pattern of results in Learning score and is definitely platykurtic in Evaluation and Total score. The results among adults indicate right-skewness in Learning, whereas Testing and Total scores are close to normal distribution (Cipora et al., 2015). Differences in variable distributions are probably a result of the age of the subjects. Children starting school experience a lack of or weak math anxiety, while some older children and adults who have more experience with mathematics experience a stronger level of this anxiety. The results indicate that math anxiety develops over time, which suggests that anxiety related to test situations increases in the population more than anxiety accompanying learning math. However, the answer to the question of how math anxiety develops may be provided only when the same research tool is used in various stages of education (Carey et al., 2017).

The convergent and discriminant validity of mAMAS-E

Despite some doubts concerning the internal consistency of the scale, mAMAS-E is characterized by very satisfactory theoretical validity. In accordance with expectations, the scores of mAMAS-E were positively related to the MAQC result and these relationships were stronger than the correlations between mAMAS-E and general and test anxiety. This indicates that mAMAS-E measures a specific kind of anxiety and cannot be reduced to general or test anxiety as early as in early school age. The significance and strength of the relationship between mAMAS-E and RCMAS is dependent on the subscales of the scales, but the results are quite consistent and explainable. The relationship between Learning and general anxiety is on the border of statistical significance, but it should be pointed out that unlike the other statistics, this one was obtained from a relatively small group of children. The lack of a relationship between the social aspect of general anxiety and Learning may be explained by the lack of pressure regarding results in a math learning situation. Children that understand math and feel comfortable in math class may not experience negative effects in response to their peers' reactions. The lack of relationships between mAMAS-E scores and the physiological aspect of anxiety may be explained by the low level of math anxiety among children. If children do not experience high math anxiety, they also do not observe typical symptoms of stress like stomach squeeze, heart palpitation, sweaty hands, etc. Moreover, the lack of a relationship between the physiological and the questionnaire surveys has been observed in other studies (see Avancini & Szűcs, 2019). In line with expectations, a positive and moderate correlation was observed between worry and math anxiety. Math-anxious children may worry about their learning outcomes; conversely, children that are generally worried may feel more stress when faced with mathematical problems. The undisputed importance of a common field

between general anxiety, test anxiety, and math anxiety was confirmed when the tests were carried out among a larger group of children. The Testing score is moderately related with testing and general anxiety, which is also consistent with the observations of other researchers among children (Carey et al., 2017) and older learners (Devine et al., 2012; Kazelskis et al., 2000). It is not surprising that people who feel anxiety in general testing situations are also more anxious when facing mathematics situations.

The validity of mAMAS-E was also acknowledged through its relationship with mathematics achievement. Although the associations between math anxiety and math achievement among young children are not obvious (Krinzinger et al., 2009; Ramirez et al., 2013; Vukovic et al., 2013; Wu et al., 2012), it is expected that there should be negative and low or moderate correlations between these variables. Indeed, such relationships were observed among second- and third-grade children, while the lack of such a dependence was mostly revealed in first-grade children. It is reasonable that the effects of math anxiety on mathematical achievement may be revealed only after some time of math education. First-grade children are rarely tested in math in comparison with older children, but a low and negative relationship between math outcomes and math anxiety was observed among a large group of pupils in Testing score. An alternative explanation for the difference in correlations between first-, second- and third grade children relates the types of mathematical tasks that were used in this study, which differ in content and the level of difficulty and therefore may affect the obtained results.

Moderate gender differences were noted in mAMAS-E Total and Testing but not in learning situations. Girls were more anxious than boys, which is in line with many previous studies (Griggs et al., 2013; Hill et al., 2016; Schleepen & Mier, 2016) and may be explained by the fact that girls more than boys are exposed to the gender math stereotype from early years of math education (Belilock, Gunderson, Ramirez, & Levine, 2010; Cheryan, Matser, & Meltzoff, 2015). An alternative explanation of the gender difference in the level of math anxiety might be that girls can feel more comfortable when talking about their emotions than boys (Ashcraft, 2002). Children in general had high self-esteem and self-confidence, which is very optimistic but it is a challenge for teachers to uphold this belief. This is especially important because the findings indicate that children with medium and high self-esteem and self-confidence in mathematics are differentiated in the level of math anxiety but do not differ in the intensity of math anxiety when the Polish language self-assessment was taken into consideration. This is another piece of evidence that mAMAS-E is a specific measure of math anxiety, not school subject anxiety, but also such results indicate the importance of more general factors in explaining the sources of math anxiety such as self-awareness of one's own skills and capabilities. The study of Seema & Kumar (2017) confirmed this hypothesis by demonstrating that children with a higher level of self-esteem tend to have better math self-proficiency, motivation, and understanding of math, which in turn may be related to low math anxiety.

Conclusion

The findings of the validation study indicate that the usefulness of mAMAS may be expanded to children in early school age. mAMAS-E is characterized by sensible convergent and divergent validity and acceptable reliability, therefore its application in future studies may be recommended. Early diagnosis of math anxiety can allow the timely detection of children with a high level of this anxiety in order to take the appropriate action to prevent its development. In combination with mAMAS-E as a complementary measure, existing measurements such as AMAS and mAMAS can also be used to track changes in math anxiety and to better understand its nature and determinants throughout an individual's life.

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Appendix**Table 6. The modified Abbreviated Math Anxiety Scale for Elementary Children**

[The test is conducted in the form of a structured interview. Instructions and questions are read aloud by the researcher. Children's responses are marked by the researcher on the answer sheet.]

Instruction: I will ask you about your feelings about math, but first I will give you an example: Please, tell me 'Do you like chocolate? Yes, A little, or No?'. I will ask you more questions in a similar way. So please, tell me now do you feel anxiety in some situation. Anxiety means the feelings of worry, nervousness, or fear. 'Do you feel anxiety in such a situation [item]. Yes, A little, or No?'

1 L	Having to complete a worksheet by yourself	Yes	A little	No
2 T	Thinking about a maths test the day before you take it	Yes	A little	No
3 L	Watching the teacher work out a maths problem on the board	Yes	A little	No
4 T	Taking a maths test	Yes	A little	No
5 T	Being given maths homework with lots of difficult questions that you have to hand in the next day	Yes	A little	No
6 L	Listening to the teacher talk for a long time in maths	Yes	A little	No
7 L	Listening to another child in your class explain a maths problem	Yes	A little	No
8 T	Finding out that you are going to have a surprise maths quiz when you start your maths lesson	Yes	A little	No
9 L	Starting a new topic in maths	Yes	A little	No

L – Learning subscale; T – Testing subscale.