Missing numbers progress monitoring test level 5a. A mathematics curriculum-based measurement (CBM) on the online platform www.levumi.de

Anderson, S., Schurig, M., deVries, J.M., Gebhardt, M.

Sven Anderson, M.A.
Technische Universität Dortmund
sven.anderson@tu-dortmund.de
ORCID: https://orcid.org/0000-0002-2323-8543

Dr. Michael Schurig
Technische Universität Dortmund
michael.schurig@tu-dortmund.de
ORCID: https://orcid.org/0000-0002-7708-0593

Jeffrey M. DeVries
Technische Universität Dortmund
jeffrey.devries@tu-dortmund.de
ORCID: https://orcid.org/0000-0001-8923-6615

Prof. Dr. Markus Gebhardt
Technische Universität Dortmund
markus.gebhardt@tu-dortmund.de
ORCID: https://orcid.org/0000-0002-9122-0556

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Background

Progress Monitoring is a formative method of monitoring students learning development in different academic areas such as reading, writing and mathematics with the aim of identifying student's individual needs and evaluating current instructions in order to provide appropriate tasks in the future (Fuchs & Fuchs, 2001). One type of progress monitoring is curriculum-based measurement (CBM), which has a long tradition of research, particularly in the field of special education (Deno, 1985; Tindal, 2013). CBMs are short, high frequency and easy-to-use standardized tests that teachers can use during regular lessons. CBM tests enable long-term measurements of school performance through parallel test versions. After repeated measurements, CBM results enable the graphical representation of student's learning development (Deno, 2003). This data based feedback can support teachers in the early identfication of learning problems as well as in the evaluation of the learning development and the current instructions used in class (Stecker, Fuchs & Fuchs, 2005). In the design of CBM, Fuchs (2004) generally differentiates between the curriculum sampling approach and the robust indicator approach. The curriculum sampling approach includes representative samples of the mathematics curriculum of the school year, whereas the robust indicator approach uses measures that represent broadly defined mathematical skills. In this approach, effective measures are not necessarily representative of a specific curriculum.

CBM tests can be administered as paper and pencil and as computer or web-based version. Particularly computer or web-based CBM tests offer the opportunity to quickly and automatically evaluate and graphically visualize the results. In addition, computer and web-based methods can randomly select items from an item pool and thus automatically generate a very large number of potential parallel test versions (Mühling, Jungjohann & Gebhardt, 2019).

In mathematics, Hosp, Hosp and Howell (2016) differentiate progress monitoring with CBM between tests for numeracy concepts (early numeracy CBM), tests for computational skills (computation CBM) and tests for the application of mathematics such as interpreting measurements, tables or graphs (concept and application CBM). CBMs are developed in mathematics for students from pre-school to secondary school (Foegen, Jiban & Deno, 2007). The focus of the CBM test construction is on elementary mathematics, and so far, only few methods are available for secondary school (Tindal, 2013). CBM tasks in mathematics are designed using the robust indicator approach, the curriculum sampling approach, or a combination of both approaches (Foegen, Jiban & Den, 2007).

Previous research suggest that missing number tasks (also known as number series) are suitable for progress monitoring for students struggling with mathematics (Foegen, 2008; Gebhardt, Zehner & Hessels, 2014; Gebhardt, Oelkrug & Tretter, 2013). In an exploratory study by Gebhardt et al. (2014) on the development of basic mathematical skills in German special schools from the fifth to the ninth grade, students of all grades were able to improve in the missing numbers test over time. The missing numbers test requires mastery of numeracy concepts, which might be an adequate robust indicator of general mathematics competence (Foegen, 2008). The task is to identify the missing number from a pattern of four numbers, replacing one number with a blank space. The ability to recognize patterns is regarded as a fundamental algebraic competence and a thus a representation of number sense and ordinality (Foegen, 2008). Missing number tasks are used as CBM mainly for testing early numeracy skills in kindergarten or primary school (Hosp et al., 2016) and are only rarely used in secondary education (Foegen, 2008).

Item construction at level 5a

Missing number is a test on the web-based progress-monitoring platform Levumi (www.levumi.de; Jungjohann, DeVries, Gebhardt & Mühling, 2018). The test at level 5a consists of an item pool of 70 items. The test duration is currently 5 minutes (as of January 2020). On the Levumi platform, the tasks are selected randomly from the item pool during the test period, so that a large number of possible parallel test versions can be generated automatically. The appendix contains an exemplary paper and pencil test version. Table 1 is the Q-matrix for the missing number test at level 5a composed of 14 dichotomously scored items and hypothesized difficulty parameters (DP) based on the integrated theory of numerical development (Siegler, 2016). Siegler (2016) provides with the integrated theory of numerical development a combined model of the development of numerical competence. Within this theory, arithmetic follows from the expansion of the mental number line. Siegler's theory offers an explanation for a number of discoveries within research into the development of mathematical competence: size and distance effects, the learning of various mathematical operations and SNARC effects (spatial-numerical association of response codes).

The columns DP1 to DP 4 reflect the four construction rules covered by the test. The numbers 0 and 1 are the given difficulty values for each item. Based on Siegler's integrated theory of numerical development, the following elements were defined, which are expected to have an influence on the item difficulty:

- **DP 1:** the quantity of digits of a number. The item pool consists of five-digit (0) and six-digit numbers (1) shown in the column digits in table 1. This thesis corresponds to the size effect. The thesis is that tasks with more digits have a higher degree of difficulty.

- **DP 2:** the function. The item pool consists of ascending (0) and descending (1) pattern of numbers shown in the column function in table 1. The hypothesis is that ascending patterns could be less difficult (addition) than descending patterns (subtraction).

- **DP 3:** the position of the missing number. The item pool consists of blank column on position 3 and 4 (0) and blank column on position 1 and 2 (1) shown in the column position in table 1. The hypothesis is that blanks in the right column will be easier to solve than in the left. Solving the right blanks corresponds to the predominant reading direction, from left to right (e.g. a SNARC effect).

- **DP 4:** the step within the numeral in comparison to the previous number. The item pool consists of items with change in digit position in unit part and in ten part (1) or in hundreds part and in thousands part (0) shown in the column steps in table 1. This thesis corresponds to the distance effect, which suggests that increases in larger orders of magnitude should be easier than in smaller ones.

Table 1: Q-matrix for the Levumi missing number CBM level 5a with the four item difficulty parameters digits, function, position and steps

Item	DP 1 - digits	DP 2 - function	DP 3 - position	DP 4 - steps
1, 15, 29, 43, 57	0	1	0	1
2, 16, 30, 44, 58	1	0	1	0
3, 17, 31, 45, 59	0	0	1	0
4, 18, 32, 46, 60	1	1	0	1
5, 19, 33, 47, 61	0	0	0	1
6, 20, 34, 48. 62	1	1	0	0
7, 21, 35, 49, 63	1	0	1	1
8, 22, 36, 50 64	1	1	0	0
9, 23, 37, 51, 65	0	0	1	1
10, 24, 38, 52, 66	0	1	0	0
11, 25, 39, 53, 67	1	0	1	1
12, 26, 40, 54, 68	0	1	0	1
13, 27, 41, 55, 69	1	0	0	0
14, 28, 42, 56. 70	1	1	1	1

Procedure

As paper and pencil test the student receives several parallel test versions and works on them within the given test time. After the test, the examiner/teacher codes the correctly and incorrectly solved items and transfers them to a data sheet of a calculation program (e.g. Microsoft Excel).

The following materials are required to conduct the test as paper and pencil version (also see the information Hosp et al., 2016):

- sheets with different parallel test versions (student and teacher copies)
- a watch to stop the test time
- a quiet environment to test the students
- a calculation program to evaluate data and plot graphs to visualize the learning developemnt over time (for evaluating and visualizing data with Microsoft Excel also see Riley-Tilman & Burns, 2009).

Appendix Missing Numbers N5a

What number is missing?
Write it in the blank space!

1.	99 499	99 489	99 479	
2.		457 000	458 000	459 000
3.	89 485		89 685	89 785
4.	342 250	342 240	342 230	
5.	25 733	25 743		25 763
6.	227 760	226 760	225 760	
7.	238 350		238 370	238 380
8.	125 740	125 640	125 540	
9.		98 394	98 395	98 396
10.	74 754	74 654	74 554	
11.	475 643		475 645	475 646
12.	34 674	34 673		34 671
13.	239 280	239 380	239 480	
14.		365 153	365 152	365 151

Appendix Missing Numbers N5a

What number is missing?

Write it in the blank space!

15.	**77 374**	**77 364**	**77 354**	
16.		**643 000**	**644 000**	**645 000**
17.	**32 634**		**32 834**	**32 934**
18.	**748 950**	**748 940**	**748 930**	
19.	**39 424**	**39 434**		**39 454**
20.	**384 270**	**383 270**	**382 270**	
21.	**569 250**		**569 270**	**569 280**
22.	**477 470**	**477 370**	**477 270**	
23.		**29 884**	**29 885**	**29 886**
24.	**25 763**	**25 663**	**25 563**	
25.	**341 112**		**341 114**	**341 115**
26.	**86 626**	**86 625**		**86 623**
27.	**365 230**	**365 330**	**365 430**	
28.		**174 833**	**174 832**	**174 831**

Appendix Missing Numbers N5a

What number is missing?

Write it in the blank space!

29.	**59 572**	**59 562**	**59 552**	
30.		**317 000**	**318 000**	**319 000**
31.	**25 697**		**25 897**	**25 997**
32.	**123 570**	**123 560**	**123 550**	
33.	**43 924**	**43 934**		**43 954**
34.	**275 950**	**274 950**	**273 950**	
35.	**338 460**		**338 480**	**338 490**
36.	**788 590**	**788 490**	**788 390**	
37.		**39 657**	**39 658**	**39 659**
38.	**47 543**	**47 443**	**47 343**	
39.	**743 452**		**743 454**	**743 455**
40.	**37 177**	**37 176**		**37 174**
41.	**276 230**	**276 330**	**276 430**	
42.		**384 653**	**384 652**	**384 651**

Appendix Missing Numbers N5a

What number is missing?

Write it in the blank space!

43.	**63 644**	**63 634**	**63 624**	
44.		**952 000**	**953 000**	**954 000**
45.	**76 599**		**76 799**	**76 899**
46.	**987 990**	**987 980**	**987 970**	
47.	**54 632**	**54 642**		**54 662**
48.	**454 120**	**453 120**	**452 120**	
49.	**226 650**		**226 670**	**226 680**
50.	**244 860**	**244 760**	**244 660**	
51.		**89 882**	**89 883**	**89 884**
52.	**18 439**	**18 339**	**18 239**	
53.	**351 192**		**351 194**	**351 195**
54.	**49 896**	**49 895**		**49 893**
55.	**134 410**	**134 510**	**134 610**	
56.		**733 444**	**733 443**	**733 442**

Appendix Missing Numbers N5a

What number is missing?

Write it in the blank space!

57.	25 745	25 735	25 725	
58.		376 000	377 000	378 000
59.	12 346		12 546	12 646
60.	457 550	457 540	457 530	
61.	76 743	76 753		76 773
62.	477 210	476 210	475 210	
63.	112 930		112 950	112 960
64.	544 530	544 430	544 330	
65.		28 912	28 913	28 914
66.	77 443	77 343	77 243	
67.	984 563		984 565	984 566
68.	57 397	57 396		57 394
69.	157 310	157 410	157 510	
70.		528 813	528 812	528 811

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