Influences of training length on the effectiveness of a number board intervention for 6-year-old German kindergartners

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ABSTRACT

Game-based learning approaches are an effective way of facilitating mathematical learning in early childhood. Considering constraints on staff and time resources in early childhood education, this study evaluated whether a four-session intervention using a linear number board game, designed to foster early mathematical development in preschool children aged around 6 years would lead to significantly more pronounced early mathematical development compared to a business as usual control group und thus behave similarly to a longer six-session intervention using the same game. Mathematical development was considered in terms of progressions, stagnations, and regressions across levels of early mathematical development as assessed by a standardized test of early mathematical skills. Results indicated that changes from pre- to post-test differed significantly across groups with both, the groups completing four or six game sessions presenting with significantly more pronounced mathematical development compared to the control group. In particular, the six-session group yielded the most progressions, followed by the four-session group, and the control group. At the same time, significantly more stagnations were observed for the control group, while regressions to lower levels of mathematical development were minimal for all three groups. These results substantiate that regular engagement with linear number board games can effectively facilitate early mathematical development before school entry, offering a practical and accessible educational tool in early childhood education.

Game-based approaches, and especially board games seem promising in promoting the development of mathematical skills in early childhood (e.g., Gasteiger & Moeller, 2021; Herzog & Fritz, 2022). For instance, Berner et al. (2024) found that playing a linear number board game six times over a period of two weeks facilitated the development of early mathematical skills significantly. Others reported similar effects for similarly intense (six sessions, e.g., Elofsson et al., 2016; Ramani et al., 2012), but also longer (27 sessions e.g., Lange et al., 2020), or shorter game-based interventions (four sessions e.g., Skillen et al., 2018; Whyte & Bull, 2008). Considering constraints on staff, time, and other resources in early childhood education, it would thus be interesting to know more about whether a shortened intervention may be similarly effective. Accordingly, we evaluated whether a shortened four-session version of the number board game, as used by Berner et al. (2024) over six sessions, would still have a significantly positive effect on the development of 6-year-olds' early mathematical skills compared to a business-as-usual control group. In the following, we first introduce the relevance of early mathematical skills and how these can be promoted using game-based approaches, before we describe aims and details of this study.

Early mathematical skills, such as counting and cardinality understanding, were repeatedly found to significantly predict later mathematical achievement (e.g., Gashaj et al., 2023; Koponen et al., 2019). This means that these early mathematical skills serve as

building blocks of later more complex mathematical skills such as basic arithmetic (e.g., Hirsch et al., 2018; Jordan et al., 2009), but also fraction understanding (e.g., Wortha et al., 2023). This hierarchical development is reflected in current models of the development of mathematical skills. For instance, Fritz and colleagues' *model of numerical concept development* (2013; 2018) outlines six developmental levels. Starting at around age 4 with basic *counting skills* (Level 1), development then advances to developing a *mental number line* (Level 2) and grasping *cardinality and decomposability* of numbers (Level 3). Subsequently, children acquire the concept of *class inclusion and embeddedness* (Level 4), which involves understanding part-whole relations (Resnick, 1983), before they understand differences and thus *relationality* between numbers (Level 5). Finally, children master *bundling and unbundling* of numbers (Level 6) thereby understanding that numbers can be composed of equally large subsets as a starting point for multiplicative reasoning about numbers (Fritz et al., 2013).

As suggested by Fritz et al. (2018), the majority of children should have developed to Level 2 around 6 months before starting first grade. In Germany, this corresponds to an age of around 6 years, when children typically attend childcare facilities referred to as 'Kindergarten' before they start primary school. Failing to master the respective early mathematical skills before starting school may lead to difficulties with acquiring more complex mathematical skills or even to the development of mathematical learning difficulties (e.g., Krajewski, 2008). Furthermore, when no specific intervention is provided, inter-individual differences observed at school entry were found to remain stable or even increase over subsequent school years (Bakker et al., 2023; Morgan et al., 2011; Stern, 2009; Watts et al., 2014). Taken together, this highlights the need to promote early mathematical skills effectively even before school entry, for example through game-based approaches.

Game-based approaches to promote early mathematical skills before school entry have repeatedly been proven effective and to have significantly positive effects (e.g., Cohrssen & Niklas, 2019; Herzog & Fritz, 2022; Jörns et al., 2014; Laski & Siegler, 2014; Seeger et al., 2018). Importantly, previous game-based interventions were implemented in very different ways. Some studies created or modified existing games (Hauser et al., 2014; Jörns et al., 2013; Lange et al., 2020; Ramani et al., 2012), while others incorporated picture books (Seeger et al., 2018) or used commercially available games (e.g., Gasteiger & Moeller, 2021). In particular, recent evidence identified playing *linear number board games* as being effective (Elofsson et al., 2016; Lange et al., 2020; Laski & Siegler, 2014; Ramani et al., 2012; Skillen et al., 2018; Whyte & Bull, 2008). These games typically resemble commercial board games like Snakes and Ladders that also use a linear layout of the game board. That is, they have squares of uniform size arranged in a continuous and consecutive way, reflecting a physical realization of the mental number line (Siegler & Ramani, 2009). This way, they provide opportunities to practice early mathematical skills such as counting and cardinality understanding.

One such game is *House of Numbers-20,* which consists of a board with 20 numbered squares, called "doors" because they represent the doors to the houses the respective numbers live in. The goal of the game is for each player to role a 10-sided die (marked with the Arabic digits 1 to 5, each appearing twice) during their turn, move their pawn along the board according to the number shown on the die face and reach the finish first. To move the pawn, players use the count-on rule (Laski & Siegler, 2014). For example, when a player's pawn is standing on the square number 3 and they roll a 2, they say: "I have rolled a 2. I can therefore walk past door four to door five. So, I walked on two doors from door three". The game also features action cards children need to draw when their pawn stands on specific squares. These cards provide additional tasks, which target specific early mathematical skills (e.g., players have to count fish shown on the card). Berner et al. (2024) found that playing this game for six game sessions led to significant increases in early mathematical skills of 6-year-olds - in particular related to early mathematical skills associated with Level 3 of the model by Fritz et al., (2013; 2018) described above.

However, a closer look at the constraints of early childhood education indicates that childcare facilities often have limited staff and time resources (Bock-Famulla et al., 2023a; 2023b), which may restrict the implementation of lengthy intervention programmes. Accordingly, there is interest in and need for effective and resource-efficient interventions to facilitate early mathematical development. Previous game-based interventions for early mathematical skills differed considerably with respect to their time demands in particular, ranging from four (e.g., Skillen et al., 2018; Whyte & Bull, 2008) to 27 (e.g., Lange et al., 2020) small-group sessions lasting between 10 and 30 minutes (Elofsson et al., 2016; Gasteiger & Moeller, 2021; Lange et al., 2020; Laski & Siegler, 2014; Ramani et al., 2012; Skillen et al., 2018; Whyte & Bull, 2008). Nevertheless, to our knowledge, there is hardly any evidence evaluating the effectiveness of successful game-based interventions when reduced in length. For instance, it is unclear whether a shorter intervention using *House of Numbers-20* would still facilitate the development of early mathematical skills. Therefore, the present study aimed to evaluate whether playing *House of Numbers-20* only four instead of six sessions would still lead to significantly more pronounced development of early mathematical skills compared to a business-as-usual control group and thus yield similar positive effect as previously observed for the six-session intervention. Additionally, most previous studies compared the development of early mathematical skills in terms of differences based on pre- and post-intervention scores on selected mathematical skills (e.g., counting in Elofsson et al., 2016; Lange 2020; Ramani et al., 2012; Skillen et al., 2018; Whyte & Bull, 2008 or magnitude understanding in Lange et al., 2020; Ramani et al., 2012; Skillen et al., 2018; Whyte & Bull, 2008). However, this was mostly not aligned with or did reflect progression through levels of a model of early mathematical development such as the one described above by Fritz et al., (2013; 2018). Therefore, we were specifically interested in evaluating whether children completing a shorter game-based intervention showed a similar or differing pattern of progression to the next level, stagnation on the same level or regression to an earlier level of early mathematical development compared to children completing a longer game-based intervention and a business-as-usual control group.

1. The present study

In particular, this study set off to evaluate whether completing four game sessions with the number board game *House of Numbers-20*, would yield a different patterns of progression, stagnation, and regression of children's level of early mathematical development

according to the model of Fritz et al., (2013; 2018) when contrasted to a business-as-usual control group similar to what would be expected for completing six game sessions of the same game. In case a shorter intervention with *House of Numbers-20* would also be effective in promoting children's early mathematical development, we would expect a significant difference of the pattern of progressions, stagnations and regressions across levels of early mathematical development (with more progression in particular) compared to the control group.

2. Method

2.1. Sample

The sample consisted of 208 German-speaking children (109 girls, 99 boys, mean age 6.04 years, $SD_{age} = 0.38$, in the year before school entry) recruited from 31 childcare facilities in southern Germany. The study was approved by the research university ethics committee. Participation was voluntary. Parents provided written informed consent and demographic data before the start of the study. Children had to give verbal assent to participate in each session of the study.

All children were randomly assigned to one of three groups. The six-game-session group included $n = 56$ children (28 girls, 28 boys, mean age 6.01 years, $SD_{age} = 0.37$ months), the four-game-session group $n = 79$ children (40 girls, 39 boys, mean age 6.07 years, $SD_{age} = 0.40$), and the control group $n = 73$ children (41 girls, 32 boys, mean age 6.03 years, $SD_{age} = 0.37$). We aimed for comparable group sizes, but organizational matters, such as illness, led to fewer participants in the six-session group.

2.2. Materials

2.2.1. Assessment of early mathematical skills

The standardized, commercially available test *Mathematik- und Rechenkonzepte im Vorschulalter-Diagnose* [Preschool mathematics and numeracy concepts – Diagnosis] (MARKO-D; Garrote & Opitz, 2021; Ricken et al., 2013) was used to assess children's early mathematical skills. This test is available in German, Englisch, Spanish, and several South African languages. It includes 55 items assessing the first five levels of the model by Fritz et al., (2013; 2018), which describe typical early mathematical development before school entry. The experimenter marks each test item as correct or incorrect and awards one point for each correctly solved item. Cronbach's alpha for the total score, calculated from the sum of correct answers, was excellent at both measurement times (.90 at pre-test and .91 at post-test). According to the test manual, the total score can be used to assign children to their respective developmental levels according to the model. That means, for instance, when a child is placed on Level 3, it is assumed that they already mastered all lower levels.

2.2.2. Game-based training of early mathematical skills

The number board game *House of Numbers-20* (Berner et al., 2024; Berner et al., 2021) was used to train early mathematical skills. During game sessions, an experimenter played the game with a small group of two to three children for about 20 minutes. This study used a version of the game based on the model by Fritz et al., (2013; 2018). Specific early mathematical skills matching the levels of this model were addressed through the interaction of children with various game elements. For instance, children practiced counting by naming the squares their pawn stepped on using the count-on rule (Level 1). Their number line representation was addressed by interacting with the linear layout of numbers on the board (Level 2). Moreover, children had to associate magnitudes with the respective Arabic digit on the die and the verbal number word when moving their pawn (Level 3). Aspects of part whole relations were addressed when children considered the squares left to reach the target number in relation to those already reached (Level 4) thus fostering understanding of the relationality of numbers (Level 5). Additionally, tasks provided on the action cards were specifically designed to target the first three levels of the model.

2.3. Procedure

Data was collected in three waves from 2022 to 2024, starting each spring. Each wave included two intervention groups and a business-as-usual control group. Six as well as four game sessions with the *House of Numbers-20* were completed within a period of approximately two weeks. During the same time, the control group received no intervention beyond activities done in their respective childcare facility. Individual mathematical skills of all participating children were assessed before (pre-test) and after (post-test) the game sessions. Testing and game sessions were conducted in separate rooms during regular operating hours at their childcare facilities.

2.4. Analytic strategy

To compare mathematical development between the three groups, we first computed total scores for the MARKO-D as described in the test manual. Through their total score each child (at pre- and at post-test) was assigned to one of the five developmental levels assessed by the MARKO-D. We then ran a chi-squared test using SPSS 29.0.2.0 (IBM Corp, 2023) to evaluate whether patterns of level changes (i.e., progressions vs. stagnations vs. regressions) between measurement points were distributed evenly between the three groups.

3. Results

At pre-test, most of the children had already achieved Levels 3, 4, and 5 according to the developmental model of Fritz et al., (2013; 2018; see Fig. 1).

Overall, all groups showed an increase in their math performance over time (see Table 1). The chi-squared test indicated a significant association between change patterns (progression vs. stagnation vs. regression) and groups (six-session vs. four-session vs. control), $\chi^2 (4) = 24.32, p < .001$, reflecting a medium-size effect, Cramér's V = .24. In particular, and as evident from the contingency table (see Table 2), 69.6 % of the children within the group participating in six game sessions advanced to a higher developmental level according to the model of Fritz et al., (2013; 2018). By contrast, 50.6 % of the children completing four game sessions and only 27.4 % of children in the control group advanced to a higher level. As Table 2 indicates, most stagnations were noticed within the control group, whereas, there were only few regressions across all three groups.

To evaluate potential associations between the patterns of progressions, stagnations, and regressions between either two groups (i. e., six-session vs. control, four-session vs. control, and six-session vs. four-session) more directly, we reran the chi-squared test for each of these pairwise combinations. Results showed a significant association between patterns of change and group when differentiating between the six-game-session and the control group $\chi^2 (2) = 23.88, p < .001$, reflecting a large-size effect Cramér's V = .43, as well as between the four-game-session and the control group $\chi^2 (2) = 8.57, p = .014$, with a medium-size effect Cramér's V = .24. In both cases, significantly more progressions were observed for the group completing the game-based training. In contrast, there was no significant association between patterns of change and the two intervention groups $\chi^2 (2) = 5.95, p = .051$, Cramér's V = .21, although there was a tendency towards more progressions in the six-game-session group.

4. Discussion

The aim of this study was to evaluate whether a shortened game-based intervention using *House of Numbers-20* would still yield significantly more pronounced facilitation of early mathematical development compared to a business-as-usual control group and thus behave similarly to a longer intervention using the same game (e.g., Berner et al., 2024). If so, this should be reflected by more progressions to higher levels of early mathematical development according to the model by Fritz et al., (2013; 2018) - instead of stagnations at the same level or regressions to an earlier level of mathematical development.

Our results substantiated that patterns of changes in developmental levels between pre- and post-test were not independent from participant group. In particular, they clearly indicated significantly more progressions for the six-session and four-session group compared to the control group. At the same time, most stagnations at the same level were observed within the control group while the number of regressions to earlier levels of mathematical development were only minimal in all three groups.

Our findings thus reflect that children who completed four game sessions still showed significantly more progressions than the control group but in tendency less compared to the group completing six game sessions. At the same time, the six-game-sessions group showed a clear developing advantage, compared to the control group. This suggests that playing even just four times with a linear number board game, such as *House of Numbers-20*, still led to a significant advantage for early mathematical development compared to not playing at all. However, presumably, spending more time (six times) playing the game allowed children to benefit more from its features (e.g., linear board, count-on rule), as well as from the collaborative learning atmosphere with their peers and the adult facilitator. Nevertheless, it is worth noting that children generally benefitted from receiving more training.

4.1. Limitations and future directions

Certain limitations should be considered when interpreting these results. First, there was no follow-up assessment to evaluate the sustainability of effects of the game-based training. In fact, children who participated in the game-based intervention may continue to benefit from it beyond the end of the intervention itself. As such, future studies employing longitudinal design are needed to better understand this aspect. Additionally, larger sample sizes of the individual groups would improve reliability and generalizability of the
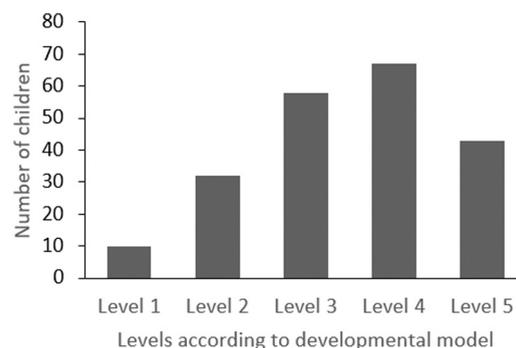

Fig. 1. Distribution of Children Across Developmental Levels at Pre-test.

Table 1
Level assignment at pre- and post-test.

Group	Assignment	Pre-test		Post-test	
		n	%	n	%
Six sessions	Level 1	4	7.14	0	0.00
	Level 2	7	12.50	8	14.29
	Level 3	21	37.50	9	16.07
	Level 4	22	39.29	18	32.14
	Level 5	2	3.57	21	37.50
Four sessions	Level 1	2	2.53	2	2.53
	Level 2	13	16.46	7	8.86
	Level 3	21	26.58	15	18.99
	Level 4	25	31.65	16	20.25
	Level 5	18	22.78	39	49.37
Control	Level 1	4	5.48	2	2.74
	Level 2	10	13.70	10	13.70
	Level 3	16	21.92	12	16.44
	Level 4	20	27.40	20	27.40
	Level 5	23	31.51	29	39.73
Full sample	Level 1	10	4.81	4	1.92
	Level 2	30	14.42	25	12.02
	Level 3	58	27.88	36	17.31
	Level 4	67	32.21	54	25.96
	Level 5	43	20.67	89	42.79

Table 2
Contingency table of change patterns between pre-test and post-test for each group.

	Six sessions			Four sessions			Control			Total sample		
	n	%	Exp. n	n	%	Exp. n	n	%	Exp. n	n	%	Exp. n
Progression	39	69.6	26.7	40	50.6	37.6	20	27.4	34.8	99	47.6	99.0
Stagnation	14	25.0	26.7	36	45.6	37.6	49	67.1	34.8	99	47.6	99.0
Regression	3	5.4	2.7	3	3.8	3.8	4	5.5	3.5	10	4.8	10.0
Total	56	100	56	79	100	79	73	100	73	208	100	208

Note. Exp. n = Expected n

findings. Furthermore, individual variables, such as general cognitive abilities, phonological awareness, working memory and others which were not considered in the current study, may also affect the development of early mathematical skills (Amland et al., 2025; De Vita et al., 2022; Träff et al., 2020). Future studies should therefore include these when possible to allow a more comprehensive evaluation.

A general limitation of group activities, such as playing board games, is the variability in individual experiences. While *House of Numbers-20* allows comparable participation through turn-taking, some children may nevertheless experience different degrees of benefit, which is challenging to control for. Additionally, this study utilized an analog board game. In light of the need for time- and resource-efficient ways to support early mathematical development and given the availability, effectiveness and ease of access to numerous digital interventions aimed at facilitating early mathematical development (e.g., Kiili et al., 2018; Niklas et al., 2025; Papadakis et al., 2018), it would be interesting to evaluate effects of digital number games, such as the digital *House of Numbers-20* (Berner et al., 2022), with different training length compared to analogue board games.

5. Conclusion

Taken together, latest research emphasizes the importance of fostering early mathematical skills even before school entry (Gashaj et al., 2023; Koponen et al., 2019). Game-based approaches such as linear board games have been found to be an effective way of promoting these skills (Berner et al., 2024; Berner et al., 2021; Gasteiger & Moeller, 2021; Siegler & Ramani, 2009). However, constraints on time and staff resources make short, time-efficient interventions preferable. Therefore, we evaluated whether a shortened version of the effective *House of Numbers-20* intervention (Berner et al., 2024) still yields significantly more pronounced facilitation of early mathematical development regarding patterns of progressions, stagnations, and regressions across levels of the model of Fritz et al., (2013; 2018). Our results substantiated the effectiveness of the game in terms of eliciting significantly more progressions to higher levels of early mathematical development: more children progressed to higher levels of early mathematical development the more they played *House of Numbers-20*. These findings substantiate that playing linear board games, such as *House of Numbers-20*, regularly may be a low threshold approach to facilitating early mathematical skills in early childhood education.

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CRediT authorship contribution statement

Maria-Aikaterini Chatzaki: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Valérie-D. Berner:** Conceptualization, Methodology, Investigation, Project administration, Supervision, Writing – review & editing. **Korbinian Moeller:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known conflict of interest to disclose.

Data availability

Data will be made available on request.

References

Amland, T., Grande, G., Scherer, R., Lervåg, A., & Melby-Lervåg, M. (2025). Cognitive factors underlying mathematical skills: A systematic review and meta-analysis. *Psychological Bulletin, 151*(1), 88–129. https://doi.org/10.1037/bul0000457

Bakker, M., Torbeyns, J., Verschaffel, L., & DeSmedt, B. (2023). Longitudinal pathways of numerical abilities in preschool: Cognitive and environmental correlates and relation to primary school mathematics achievement. *Developmental Psychology, 59*(3), 442–459. https://doi.org/10.1037/dev0001491

Berner, V.-D., Liebermann, L., & Seitz-Stein, K. (2022). Promoting mathematical skills with an app-based number game. *Enzyklopädie Erziehungswissenschaft Online*. https://doi.org/10.3262/EEO21220453

Berner, V.-D., Niklas, F., Chatzaki, M.-A., & Seitz-Stein, K. (2024). Play-integrated fostering of basic mathematical skills: Findings of two experiments. *Educational Psychology, 44*(2), 247–264. https://doi.org/10.1080/01443410.2024.2329638

Berner, V.-D., Seitz-Stein, K., Segerer, R., Oesterlen, E., & Niklas, F. (2021). 'Good' or 'well calculated'? Effects of feedback on performance and self-concept of 5- to 7-year-old children in math. *Educational Psychology, 42*(3), 296–315. https://doi.org/10.1080/01443410.2021.2001790

Bock-Famulla, K., Berg, E., Girndt, A., Akko, D. P., Krause, M., & Schütz, J. (2023a). *Länderreport Frühkindliche Bildungssysteme 2023 - Bayern: Transparenz schaffen - Governance stärken*. Verlag Bertelsmann Stiftung: Federal state report on early childhood education systems 2023 - Bavaria: Creating transparency - Strengthening governance.

Bock-Famulla, K., Berg, E., Girndt, A., Akko, D. P., Krause, M., & Schütz, J. (2023b). *Länderreport Frühkindliche Bildungssysteme 2023 - Hamburg: Transparenz schaffen - Governance stärken*. Verlag Bertelsmann Stiftung: Federal state report on early childhood education systems 2023 - Hamburg: Creating transparency - Strengthening governance.

Cohrssen, C., & Niklas, F. (2019). Using mathematics games in preschool settings to support the development of children's numeracy skills. *International Journal of Early Years Education, 27*(3), 322–339. https://doi.org/10.1080/09669760.2019.1629882

De Vita, C., Costa, H. M., Tomasetto, C., & Passolunghi, M. C. (2022). The contributions of working memory domains and processes to early mathematical knowledge between preschool and first grade. *Psychological Research, 86*(2), 497–511. https://doi.org/10.1007/s00426-021-01496-4

Elofsson, J., Gustafson, S., Samuelsson, J., & Träff, U. (2016). Playing number board games supports 5-year-old children's early mathematical development. *The Journal of Mathematical Behavior, 43*, 134–147. https://doi.org/10.1016/j.jmathb.2016.07.003

Fritz, A., Ehlert, A., & Balzer, L. (2013). Development of mathematical concepts as basis for an elaborated mathematical understanding. *South African Journal of Childhood Education, 3*(1), 38–67. https://doi.org/10.4102/sajce.v3i1.31

Fritz, A., Ehlert, A., & Leutner, D. (2018). Arithmetische Konzepte aus kognitiv-entwicklungspsychologischer Sicht [Arithmetic concepts from a cognitive-developmental psychological perspective]. *Journal Für Mathematik-Didaktik, 39*(1), 7–41. https://doi.org/10.1007/s13138-018-0131-6

Garrote, A., & Opitz, E. M. (2021). Erfassung von mathematischen Kompetenzen im Vorschulalter mit MARKO-D: Erprobung des Tests MARKO-D an einer Schweizer Stichprobe und Überprüfung des Instruments für Messwiederholungen [Assessment of mathematical competencies in preschool age with MARKO-D]. *Diagnostica, 67*(1), 13–23. https://doi.org/10.1026/0012-1924/a000258

Gashaj, V., Thaqi, Q., Mast, F. W., & Roebers, C. M. (2023). Foundations for future math achievement: Early numeracy, home learning environment, and the absence of math anxiety. *Trends in Neuroscience and Education, 33*, Article 100217. https://doi.org/10.1016/j.tine.2023.100217

Gasteiger, H., & Moeller, K. (2021). Fostering early numerical competencies by playing conventional board games. *Journal of Experimental Child Psychology, 204*, Article 105060. https://doi.org/10.1016/j.jecp.2020.105060

Hauser, B., Vogt, F., Stebler, R., & Rechsteiner, K. (2014). Förderung früher mathematischer Kompetenzen: Spielintegriert oder trainingsbasiert [Promotion of early mathematical competences: Game-integrated or training-based]. *Frühe Bildung, 3*(3), 139–145. https://doi.org/10.1026/2191-9186/a000144

Herzog, M., & Fritz, A. (2022). Entwicklungs- und spielbasierte Förderung früher arithmetischer Konzepte [Developmental and game-based promotion of early arithmetic concepts]. *Lernen und Lernstörungen, 11*(1), 5–17. https://doi.org/10.1024/2235-0977/a000358

Hirsch, S., Lambert, K., Coppens, K., & Moeller, K. (2018). Basic numerical competences in large-scale assessment data: Structure and long-term relevance. *Journal of Experimental Child Psychology, 167*, 32–48. https://doi.org/10.1016/j.jecp.2017.09.015

IBM Corp. (2023). *IBM SPSS Statistics (Version 29.0.2.0) [Computer software]*. IBM Corp. https://www.ibm.com/de-de/products/spss-statistics.

Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45*(3), 850–867. https://doi.org/10.1037/a0014939

Jörns, C., Schuchardt, K., Grube, D., & Mähler, C. (2014). Spielorientierte Förderung numerischer Kompetenzen im Vorschulalter und deren Eignung zur Prävention von Rechenschwierigeiten [Playful training of numerical skills in preschool for prevention of mathematical disability]. *Empirische Sonderpädagogik, 3*, 243–259. https://doi.org/10.25656/01:9933

Jörns, C., Schuchardt, K., Mähler, C., & Grube, D. (2013). Alltagsintegrierte Förderung numerischer Kompetenzen im Kindergarten [Everyday integrated promotion of numerical competences in kindergarten]. *Frühe Bildung, 2*(2), 84–91. https://doi.org/10.1026/2191-9186/a000088

Kiili, K., Moeller, K., & Ninaus, M. (2018). Evaluating the effectiveness of a game-based rational number training - In-game metrics as learning indicators. *Computers Education, 120*, 13–28. https://doi.org/10.1016/j.compedu.2018.01.012

Koponen, T., Aunola, K., & Nurmi, J.-E. (2019). Verbal counting skill predicts later math performance and difficulties in middle school. *Contemporary Educational Psychology, 59*, Article 101803. https://doi.org/10.1016/j.cedpsych.2019.101803

Krajewski, K. (2008). Vorhersage von Rechenschwäche in der Grundschule [Predicting dyscalculia in primary school] (2nd ed.). Studien zur Kindheits- und Jugendforschung: Vol. 29. Dr. Kovač.

Lange, A. A., Brenneman, K., & Sareh, N. (2020). Using number games to support mathematical learning in preschool and home environments. *Early Education and Development, 32*(3), 459–479. https://doi.org/10.1080/10409289.2020.1778386

Laski, E. V., & Siegler, R. S. (2014). Learning from number board games: You learn what you encode. *Developmental Psychology, 50*(3), 853–864. https://doi.org/10.1037/a0034321

Morgan, P. L., Farkas, G., & Wu, Q. (2011). Kindergarten children's growth trajectories in reading and mathematics: Who falls increasingly behind? *Journal of Learning Disabilities, 44*(5), 472–488. https://doi.org/10.1177/0022219411414010

Niklas, F., Birtwistle, E., Mues, A., & Wirth, A. (2025). Learning apps at home prepare children for school. *Child Development, 96*(2), 577–590. https://doi.org/10.1111/cdev.14184

Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2018). The effectiveness of computer and tablet assisted intervention in early childhood students' understanding of numbers: An empirical study conducted in Greece. *Education and Information Technologies, 23*(5), 1849–1871. https://doi.org/10.1007/s10639-018-9693-7

Ramani, G. B., Siegler, R. S., & Hitti, A. (2012). Taking it to the classroom: Number board games as a small group learning activity. *Journal of Educational Psychology, 104*(3), 661–672. https://doi.org/10.1037/a0028995

Resnick, L. B. (1983). A developmental theory of number understanding. In H. P. Ginsburg (Ed.), *The development of mathematical thinking* (pp. 109–151). Academic Press, Inc.

Ricken, G., Fritz, A., & Balzer, L. (2013). Mathematik- und Rechenkonzepte im Vorschulalter – Diagnose (MARKO-D) [Preschool mathematics and numeracy concepts - Diagnosis (MARKO-D)] (1st ed.). Hogrefe.

Seeger, D., Holodynski, M., & Roth, M. (2018). BIKO-Mathekiste: Spielbasierte Förderung für 4- bis 6-jährige Kinder mit einem Entwicklungsrisiko im Bereich numerischer Basiskompetenz [BIKO math box: Play-based support for 4- to 6-year-old children with a developmental risk in the area of basic numerical skills]. *Frühe Bildung, 7*(3), 135–143. https://doi.org/10.1026/2191-9186/a000369

Siegler, R. S., & Ramani, G. B. (2009). Playing linear number board games—but not circular ones—improves low-income preschoolers' numerical understanding. *Journal of Educational Psychology, 101*(3), 545–560. https://doi.org/10.1037/a0014239

Skillen, J., Berner, V.-D., Ricken, G., & Seitz-Stein, K. (2018). Förderung basisnumerischer Kompetenzen mit einem regelbasierten Spiel im Einzel- und Gruppensetting [Promoting basic numerical skills with a rule-based game in individual and group settings]. *Frühe Bildung, 7*(3), 144–151. https://doi.org/10.1026/2191-9186/a000381

Stern, E. (2009). The development of mathematical competencies: Sources of individual differences and their developmental trajectories. In W. Schneider, & M. Bullock (Eds.), *Human Development from Early Childhood to Early Adulthood* (pp. 221–237). https://doi.org/10.4324/9780203888544-15

Träff, U., Olsson, L., Skagerlund, K., & Östergren, R. (2020). Kindergarten domain-specific and domain-general cognitive precursors of hierarchical mathematical development: A longitudinal study. *Journal of Educational Psychology, 112*(1), 93–109. https://doi.org/10.1037/edu0000369

Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher, 43*(7), 352–360. https://doi.org/10.3102/0013189X14553660

Whyte, J. C., & Bull, R. (2008). Number games, magnitude representation, and basic number skills in preschoolers. *Developmental Psychology, 44*(2), 588–596. https://doi.org/10.1037/0012-1649.44.2.588

Wortha, S. M., Klein, E., Lambert, K., Dackermann, T., & Moeller, K. (2023). The relevance of basic numerical skills for fraction processing: Evidence from cross-sectional data. *Plos One, 18*(1), Article e0281241. https://doi.org/10.1371/journal.pone.0281241