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Differential Efficacy of Digital Scaffolding of Numeracy Skills in Kindergartners With Mild Perinatal Aversities

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Introduction: Children who experienced mild perinatal adversity (i.e., born late preterm or small for gestational age) are at increased risk for delays in early numeracy and literacy, which increases inequality in educational opportunities. However, this group showed increased susceptibility to the characteristics of their educational environment for literacy, especially for those born late preterm. Intervening in this group may thus be particularly beneficial, provided that their educational environment is highly structured. Delays in numeracy and mathematics are most firmly acknowledged in these children. It remains unclear if these children are also more susceptible to their educational numeracy environment. We test the hypothesis of increased susceptibility to characteristics of their educational environment in the field of numeracy.

Methods: We tested the efficacy of a digital intervention of two to 3 months, which focused on visual spatial skills in a large randomized controlled trial in a sample of five-to-six-year-old kindergarten pupils from 140 elementary schools. About 45% of all participants showed delays in numeracy, of whom n = 67 (11%) were born late preterm, n = 157 (26%) were born small for gestational age, and n = 389 (63%) had no mild perinatal adversities. Pupils were assigned to a guiding and structured intervention focused on visual spatial skills (n = 294) or a control program (n = 319), targeting literacy skills. *Results:* The intervention did not show a main effect. The program was not effective in children small for gestational age, but it was for children born late preterm (Cohen's *d* = .71, CI = .07–1.36), showing stronger numeracy skills compared to term-born peers in the intervention condition. Early numeracy skills in children born late preterm fell behind compared to term-born peers in the control condition.

Conclusion: A highly structured educational numeracy environment, using repetition and adaptive feedback benefited early numeracy skills of late preterm children. These children outperformed their peers in early numeracy skills, while those in the control condition fell behind. Findings align with earlier findings on promoting early literacy in this group through an equivalent literacy intervention. A relatively simple and cost-effective intervention thus may help reduce the risk of educational inequality for children born late pre-term.

Keywords: late preterm, scaffolding, differential susceptibility to educational environment, academic skills in kindergarten, digital intervention, RCT—randomized controlled trial

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INTRODUCTION

Children who experienced mild perinatal adversity (i.e., born late preterm or small for gestational age) are at increased risk for delays in early numeracy and for literacy delays, increasing inequality in educational opportunities. However, in literacy research children born late preterm, but not the group small for gestational age showed increased susceptibility to the characteristics of the educational environment (Merkelbach et al., 2018). This suggests that intervening is particularly beneficial for the late preterm group provided that the educational environment is highly structured. Moreover, delays in numeracy and mathematics are most firmly acknowledged in this group of children. However, it remains unclear if this group is more susceptible to their educational numeracy environment. Therefore, in the current study we aimed to test the hypothesis of increased susceptibility to the characteristics of their educational environment in the field of numeracy. In early childhood numeracy develops long before formal education starts. Delays in early numeracy skills can however have long lasting effects on the development of mathematical abilities (Desoete et al., 2010). Fortunately, mathematical performance is particularly susceptible to intervention effects (e.g., Gervasoni, 2001), especially when implemented at an early age. Identification of children falling behind in early numeracy could thus prevent serious problems in mathematical performance later in life. In this paper we use the term numeracy to denote the field of numbers, such as understanding numbers, amounts and spatial relations (e.g. bigger, more, less, smaller), in line with Reid and Andrews (2016). Mathematics in this paper refers to learning arithmetic more formally.

Developmental Challenges in Children Born Late Preterm

Children born late preterm (born between 34 and 37 weeks into pregnancy) may have been subject to altered stress responses (Windhorst et al., 2017), or to neural variations that involve many neurocognitive systems. Walsh and colleagues showed for instance that late preterm children had smaller brain size, less-developed myelination of the posterior limb of the internal capsule, and more immature gyral folding than their full-term peers (Walsh et al., 2014). Even though late preterm birth is considered "merely" a *mild* perinatal adversity (Van der Kooy-Hofland et al., 2012), these children consistently show higher levels of cognitive problems (Shah et al., 2016; Searle et al., 2017) compared to their peers. The experienced cognitive problems are diverse (e.g. Chyi et al., 2008; Woythaler et al., 2015; Martínez-Nadal and Bosch, 2021), but problems in numeracy and mathematics are highly pronounced (e.g. Poulsen, et al., 2013). Mathematics involves many domains (e.g., numbers, quantity, operations, measurement, fractions, geometry, modeling etc.) and is hierarchical in nature, making it a complex skill, especially for children with less well-developed brains (Barnes and Raghubar, 2014).

Developmental Challenges in Children Born Small for Gestational Age

Similar general outcomes are found in children born small for gestational age (below the 10th percentile), also considered a mild perinatal adversity associated with changes in stress response (Windhorst et al., 2017) and alterations in brain size and maturity (Thompson et al., 2019). In childhood and adolescence this group too, is at risk for experiencing a range of cognitive problems (e.g., Sommerfelt et al., 2000; Ido et al., 1995), such as more frequent as well as more severe learning disabilities (O'Keeffe et al., 2003) and poorer school performance (Larroque et al., 2001). Acknowledged is that adverse perinatal factors can influence brain development throughout childhood (Gonzalez et al., 2020), causing problems at all domains of cognitive functioning. However, the link with math and numeracy problems seems to be more firmly established in the late preterm group than in the small for gestational age group.

Differential Susceptibility

These biological alterations associated with mild perinatal adversities interact with environmental factors, culminating in either positive or very negative outcomes: Labayru et al. (2021) for instance show that mild developmental problems in toddlers might develop into clinical problems at school age. Increasing environmental demands at school age compared to toddler age could add to the difficulties these children encounter with executive skills, sustained attention, and memory (Ho, 2018; Jin et al., 2019). Although both these mild perinatal adversities are generally associated with increased chances of negative cognitive outcomes, considering mild perinatal adversities as a mere vulnerability factor might be short-sighted. People who have experienced mild perinatal adversities might be more susceptible to qualities of their environment, for better *and* for worse as described in the differential susceptibility model (Belsky and Pluess, 2009). Indications of such increased susceptibility have already been identified in studies into the effects of the rearing environment (Windhorst et al., 2017), as well as in studies into the effect of characteristics of the educational environment (Van der Kooy-Hofland et al., 2012; Merkelbach et al., 2018).

Importance of Targeting the Learning Environment

High-quality early childhood education for disadvantaged children, improves their early-life environments which in turn boost a variety of early-life skills and later-life achievements (Elango et al., 2016). Identification of effective (digital) programs for this group is therefore crucial to improve early-life opportunities for disadvantaged children. Mild perinatal adversities are more common in groups already at risk for educational problems, such as low-SES populations (Gardosi and Francis, 2005; Kelly and Li, 2019). Adversities of mild perinatal nature might put children at risk for educational disadvantage lasting well into adult life (Larroque et al., 2001; Labayru et al., 2021). To reduce educational inequality, it is of great societal importance that methods are found to offer educational guidance and tutoring to children with mild perinatal problems.

Susceptibility to the Effects of Scaffolding

Some evidence points towards a possible increased susceptibility to scaffolding in an educational setting in children with mild perinatal adversities. In a small-scale experiment, kindergartners who have experienced mild perinatal adversities were shown to be more susceptible to a digital early literacy intervention. This digital program, *Living Letters*, characterized by scaffolding offering structure, repetition, and adaptive feedback promoted a phonological awareness and alphabetical knowledge (Van der Kooy-Hofland et al., 2012). For children without perinatal adversities Living Letters had no effect on phonological awareness and alphabetical knowledge. However, children with mild perinatal adversities outperformed their peers after working with Living Letters whereas they fell behind even further after working with a digital control program. This control program was highly similar in terms of scaffolding (i.e., offering structure and adaptive feedback), but did not target letter knowledge.

In the study by Van der Kooy-Hofland et al. (2012), children with mild perinatal adversities were treated as a homogenous group, whereas Merkelbach et al. (2018) showed in their large-scale replication study that only children born late preterm were susceptible to Living Letters, while children born small for gestational age showed similar results as their peers without perinatal adversity. Acknowledging subgroups in children with mild perinatal adversity was shown to be crucial: it seems that children with mild perinatal adversities are a heterogeneous group with different educational needs. Based on current evidence discussed above, it is likely that the scaffolding features of the literacy intervention used by Merkelbach et al. (2018) meet the educational needs of children born late preterm particularly well, but not those of children small for gestational age. Vollmer and Edmonds (2019) showed in their review that children small for gestational age are at greater risk of difficulties with attentional control compared to their late preterm peers. As a result, they may need more scaffolding and guidance than was offered by the digital intervention.

Present Study

The current study was part of a larger research project which focused on promoting literacy. In the current study, to test these hypotheses, we opted for a digital program with similar scaffolding characteristics (structure, repetition etc.) but now in the domain of numeracy; a domain of vulnerability for children with mild perinatal adversities (e.g., Labayru et al., 2021; Poulsen, et al., 2013). This digital program is mainly focused on visual spatial skills. However, in the context of the larger project, children were selected for participation by their teachers based on delays in literacy.

Longitudinal studies have shown that visual spatial abilities (such as encoding and mental manipulation of spatial information) are important for mathematical performance in children (Assel et al., 2003; Bull et al., 2008; Raghubar et al., 2010). A robust finding is that spatial visualization contributes to arithmetic performance via basic number knowledge (LeFevre et al., 2010; Cirino, 2011; Zhang et al., 2017; Yang et al., 2021). That is, the ability of spatial visualization might function as a cognitive tool used by young children to learn basic numerical relations and thus contributes to higher-level mathematics. Also, numeracy and mathematical problems are more prevalent in children born late preterm than in their full-term peers (Nepomnyaschy et al., 2012), and such problems are generally susceptible to the effects of early interventions (e.g., Gervasoni, 2001). Therefore, our research questions are 1) if an early digital numeracy intervention, *Clever Together*, is beneficial for children, and 2) whether intervention efficacy differs for children born small for gestational age and for children born late preterm, compared to children with normal weight for their gestational age and children born at term. In line with Merkelbach et al. (2018), we hypothesized that children born small for gestational age would not benefit exceptionally more from this digital early numeracy intervention compared to their late preterm peers and in comparison, to their normal weight and term-born peers.

We assessed the efficacy of a digital early numeracy program promoting visual spatial skill: Clever Together in children born late preterm, children small for gestational age, and children without mild perinatal adversities. In Clever Together, in accordance with Living Letters, scaffolding is used to teach basic academic skills. Clever Together consists of short early numeracy or visual spatial ability games which are repeated several times creating a highly structured digital learning environment for children in the same way as Living Letters. In addition, Clever Together includes digital tutors that offer the child continuous and adaptive feedback, and high levels of guidance and explanation. Clever Together highly resembles Living Letters in terms of substantive features, as well as in design (e.g., the same digital tutors), duration and dosage (10 minutes, once a week for two to 3 months). Duration, dosage, and teacher involvement were thus also limited in Clever Together, thereby offering a possible time- and cost-effective solution for supporting vulnerable children. In addition, in some schools there is a high concentration of students with learning difficulties. Those schools are more likely to experience teacher shortages, which can lead to a decline in the quality of education in those schools, increasing inequality in education opportunities. A well-designed digital intervention that helps students with learning difficulties has the potential to have a large reach and can thus contribute to reducing differences (Dondorp and Pijpers, 2020).

MATERIALS AND METHODS

Design

We evaluated the benefits of a digital program targeting visual spatial skill, Clever Together using an experimental design. The experiment was based on an intervention which took place in two separate cohorts (2012/2013 and 2013/2014). Kindergartners were preselected by their teachers for showing early numeracy delays. After receiving parental consent these children were randomly assigned to either the experimental condition (Clever Together) or to the control condition which consisted of a digital book-reading program (Living Books). Pre- and post-testing of early numeracy skills took place as part of the regular monitoring system applied in Dutch kindergarten classrooms, with a standardized numeracy test (national Cito evaluation) administered group wise by the teacher, blind for the hypotheses of the study, in January/February of the second kindergarten year and in May/June, just preceding first grade of primary school. Testing in January/February preceded the intervention. The test in May/June was administered directly after the intervention. The design was evaluated and approved by the Ethics Committee of the Institute of Education and Child Studies at Leiden University (file ID: ECPW-2012/044).

Procedure

A total of 1750 randomly selected schools throughout the Netherlands received an email about the study and were invited to participate. Additional information about the educational computer programs was provided through a website, leaflets, letters and personal contact. Schools were offered 3 months of free access to educational computer programs that normally require a paid subscription (http://www.bereslim.nl) for all pupils, after completion of the intervention. A final set of 140 schools signed up for participation.

Parents provided informed written consent and their email address. Parents received a link to a website with information and frequently asked questions about the project. In case of further questions, they could directly contact the researchers (via phone or email). In the first cohort, parental consent for retrieving perinatal information was not a condition for participating in the study and parents were asked for this specific consent after the intervention was completed. This largely (67.7%) explains the high rate of missing perinatal data in this wave. In the second cohort, in effort to counter the high rates of missing data, consent for perinatal information was included as a condition for participation in the study. This resulted in a much lower total rate (31.7%) of missing data, of which a large part (20.1 out of 31.7%) was due to matching errors between the registry and the research database.

Children worked with the assigned program once a week during two to 3 months. Variability in intervention duration was the result of the number of days off or holidays that fell in the intervention period. Also, the adaptive nature of the program resulted in small differences in the number of sessions offered to the child. The program was completed when children finished all offered games. Children were offered a maximum amount of games each week, making sure, the amount of games were spread out equally and could not be completed in a short period of time. Children who made no mistakes worked faster to consecutive levels of the program than children who made one or more mistakes. The "dosage" in the current study was the same as was used in previous studies (e.g. Van der Kooy-Hofland et al., 2012; Plak et al., 2016). Children independently played the games in a classroom setting only

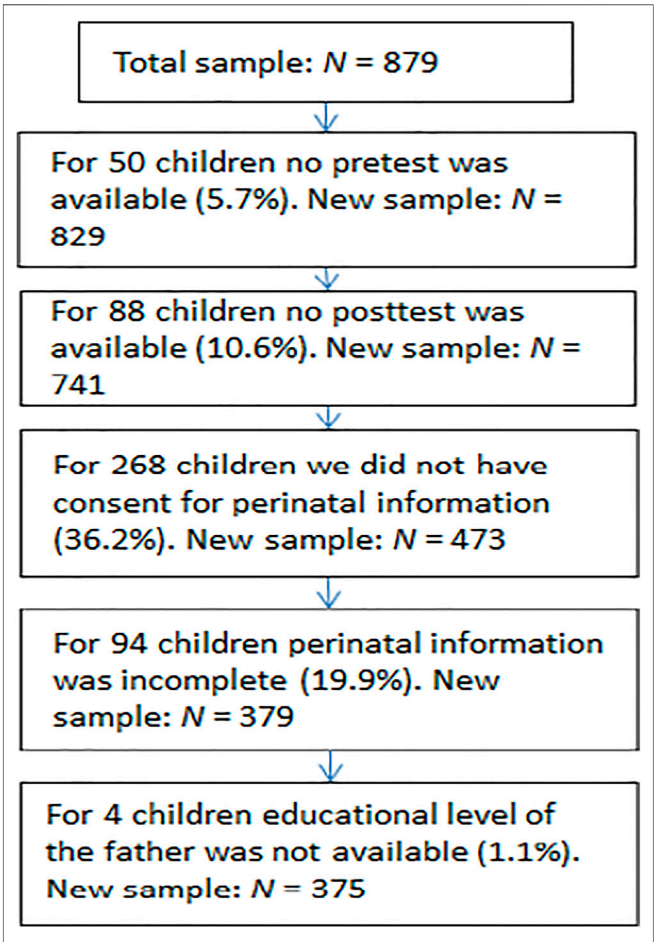


FIGURE 1 | Flowchart from initial to final participant inclusion.

receiving adult assistance for logging in. They wore headphones to prevent that the program would attract and distract other children. Teachers merely logged children on, and hence could not influence the assignment procedure.

Participants

A total of 879 children from kindergarten classrooms of 140 elementary schools, both urban and rural, located across the Netherlands, were initially included in the trial. Children were on average 67.02 months old (*SD* = 4.46).

Children's age (in months), gender, and the educational level of the father were assessed. Following the rationale of Van der Kooy-Hofland et al. (2012) on the strong association between educational level of the father and mild perinatal adversities (as compared to educational level of the mother–also in this study the association was stronger), we used father's educational level instead of that of the mother. The gender and the date of birth of the child were reported by the teacher of the child. The educational level of the father was reported by the parent(s) on a 7-point scale (ranging from no education to university degree or higher).

Children were excluded when there was no consent from the mother to retrieve perinatal information from the national perinatal

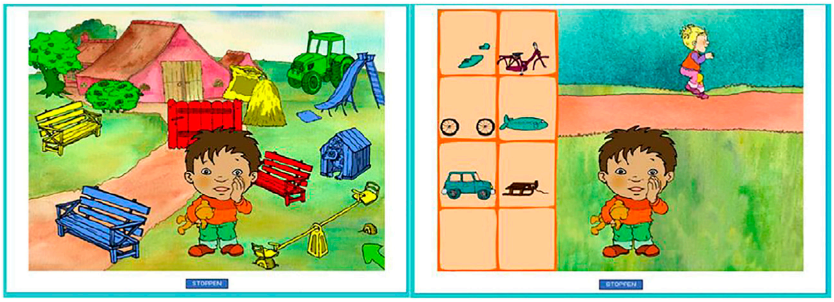


FIGURE 2 | Clever Together games: Find Sanne who is hiding behind one of the objects (left) or assemble an object from different parts (right).

registry (n = 266), in case of missing data on the numeracy pretest (n = 50) or numeracy posttest (n = 88), or if the information provided by parents (home address and date of birth of the mother) was incomplete and we were therefore unable to retrieve perinatal information from the registry (n = 96). Lastly, children were excluded when information about the educational level of the father (n = 4) was lacking, for all other covariates data were complete. The final sample for whom data on all study variables were available therefore consisted of 375 children (**Figure 1**). Given the large final sample (N = 375) and the stability of the percentage of perinatal adversities, it was reasonable to assume that random assignment by the researcher would result in a comparable number of children born late preterm and small for gestational age between conditions (Late preterm: Experimental = 10.1%, Control = 11.2%, Small for gestational age: Experimental = 27.4%, Control = 23.0%).

In the final complete case sample of N = 375, n = 179 children were in the experimental condition and n = 196 in the control condition. In the incomplete sample of N = 613 with consent there were n = 294 children were in the experimental condition and n = 319 in the control condition. For explicit comparison, analyses were performed on both the final listwise complete sample (n = 375) and the maximum incomplete sample for whom consent was available (n = 613), after multiple imputation.

Intervention Programs

Clever Together The program mainly targets visual spatial skills–e.g., recognizing shapes, positions, and measures-, problem solving -e.g., hide and seek games in different situations (the park, the living room and at the farm)- strategies for task approach (Sanne depicts an action -e.g., scootering-in which the right objects have to be searched for by the child), and -although to a lesser extent-numbers -e.g., counting from one to ten. In line with the literature we expect these skills to be foundational for the development of numeracy and mathematics (Kyttälä et al., 2003; Bower et al., 2020; Nahdi et al., 2020). The program Clever Together requires children to mentally visualize, transform, and manipulate objects or scenes with the help of spatial mathematical language (e.g., "in," "behind"). Sim, one of the main characters in the game, asked the child for help in finding Sanne who is hiding behind one of the objects in the illustration (e.g., "I am going to hide behind the blue tree"). In the other 30 games (**Figure 2**), children had to assemble objects (e.g., a bike) from their parts (e.g., tires, frame, steering wheel), and select attributes for an activity (e.g., taking a shower), thereby practicing with spatial prepositions (e.g., "in," "behind").

In the program, a tutor in the form of a teddy bear provided adaptive feedback in a positive and supportive manner. In case of errors a hierarchical set of replies dependent on the child's response was provided including spatial language feedback when giving hints or explaining the correct answer (see **Figure 3**). Spatial language feedback has been shown to help young children attend to and encode spatial information (Pruden et al., 2011). Moreover, assignments that were not answered correctly at a first try were repeated in later sessions followed by similar adaptive feedback loops to create several opportunities for practicing difficult assignments. When children made many mistakes, this could result in them having to complete one or more extra sessions. This way we offered all children comparable learning opportunities, focusing on equity instead of equality (that is practice until they mastered the skill at hand). However, because assignments were of a basic level, addition of extra practice sessions was highly exceptional.

Control condition The control program Living Books not aimed at promoting numeracy skills, consisted of eight digital, age-appropriate, multimedia storybooks with oral text, each read twice. In each individual digital storybook the story text matched the nonverbal, film-like information including animated pictures, music, and sounds. Each storybook was interrupted four times by digital tutors for questions about difficult words that appeared in the text or about story events, followed by a similar set of hierarchical replies as is offered in Clever Together. However, in this program the questions and answers section only occupied a small part of the session, about 10% of the total duration, while in Clever Together assignments were the main part of the program. The questions and answers did not contain spatial language.

Measures

Cito Numeracy Skills

The Cito Numeracy Test for Kindergarten Pupils (CNT) is a group-administered standardized numeracy test for kindergarten children orally presented by the teachers in January/February and May/June in the senior year of kindergarten when children were five to 6 years of age (Koerhuis and Keuning, 2011). The psychometric properties of the test has been judged satisfactory by a national independent committee that evaluates test construction, quality of materials, norms, reliability and construct validity (COTAN, 2011). The test

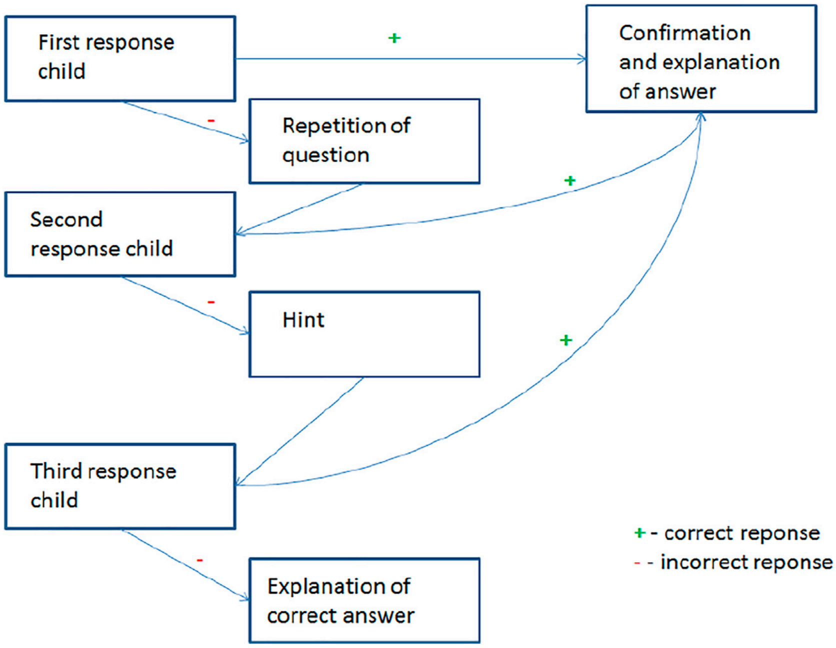


FIGURE 3 | Feedback circle in Clever Together.

targets three domains of emergent numeracy and consists of 48 multiple-choice items consisting of three or four answer options in picture-format to choose from: 1. Numbers (i.e. non- and symbolic number knowledge, counting-, organizing-, comparing skills, nonverbal addition and subtraction), 2. Measurement (length, circumference, content, area, time, weight), and 3. Geometry (shape identification, rotation, shape assembly). Teachers scored the test by counting the number of correct responses which were then translated into normative scores, as described in (Frans et al., 2021). Based on these normative scores, the pretest score of the CNT January/ February was dichotomized and coded into the 40th percentile or lower (i.e., below average, raw score <78), and average and above (raw score ≥78). At posttest the full range of scores on the CNT May/June was used. Versions of the CNT administered in January/February and the CNT administered in May/June were similar in content and design (derived and matched from the same item pool), but included different items to prevent learning effects (48 items in each version of the test).

Perinatal Data

Netherlands Perinatal Registry (Centraal Bureau voor de Statistiek, 2013) combines data about duration of pregnancy and weight of the child at birth from three registries: the national obstetric database by midwives, the national obstetric database by gynecologists, and the national neonatal/pediatric database (Méray et al., 2007) and covers about 96% of all pregnancies in the Netherlands.

Duration of pregnancy was dichotomized into being born full term (0) or being born late preterm 1) which was defined as a gestational age at birth of 34–37 weeks +6 days, in concurrence with Van der Kooy-Hofland et al. (2012). Our target sample did not include children born very preterm. Small for gestational age was dichotomized into "not small for gestational age at birth" (0) and "small for gestational age at birth" (1), which was defined as lower than the 10th percentile of birth weight for gestational age, considering gender and parity.

Statistical Analyses

Scores on the Cito Numeracy Test at posttest as a dependent measure were regressed on the intervention status, late preterm birth and small for gestational age (coded as dummy variables), and the interactions between late preterm birth and intervention, and small for gestational age and intervention. For both susceptibility markers a dummy variable was created. Children could thus be in both groups, as was the case for two children. Group variance imbalances was evaluated through inspection of the residual distribution across the full predictor and outcome range; normality and homoscedasticity.

All main variables were compared between the experimental and control group using *t*-tests and χ^2 tests. As the total amount of missing data was high (57.3%) we followed Little (1986) MCAR χ^2 test procedure to see if data are presumably Missing Completely At Random by testing if the missingness (*missing* = 0 vs *present* = 1) was unrelated to characteristics on other variables and therefore allowing for complete cases analyses. To answer the research questions, multilevel regression models were estimated, twice. First, the model was estimated using the selected complete cases. The second estimation was based on datasets resulting from multiple imputation (MI) approach (Enders et al., 2020). Using MI, missing values were imputed (m = 100 sets) via chained equations. Imputation methods were specified separately

TABLE 1 | Percentages, means and standard deviations for all main variables, presented for the complete group of children with complete cases and for the experimental (Clever Together) and control conditions (Living Books); *p*-values for χ^2 or Student's t-test.

	Total complete group (*N* = 375)	Experimental condition (*n* = 179)	Control condition (*n* = 196)	*p*-value
Male[a]	54.9%	55.3%	54.6%	.889
Age (in months)	67.12 (*4.50*)	67.58 (*4.64*)	66.70 (*4.33*)	.060
Father's education[b]	3.74 (*1.50*)	3.72 (*1.50*)	3.77 (*1.51*)	.774
Late preterm (1)[c]	10.7%	10.1%	11.2%	.714
Late preterm (2)[d]	3.7%	3.9%	3.6%	.863
SfGA[e]	25.1%	27.4%	23.0%	.324
CNT pretest[f]	78.67 (*10.30*)	79.54 (*11.44*)	77.88 (*9.09*)	.123
CNT posttest[f]	87.09 (12.03)	88.05 (12.87)	86.22 (11.18)	.145
Delayed children	45.3%	40.8%	49.5%	.091

Note: presentation in means (standard deviation) or percetage (%).
[a]Male compared to Female.
[b]Maximum level of 6
[c]VDK, 2012: Defiition according to Van der Kooy-Hofland et al. (2012).
[D]WHO: World health organization.
[e]SfGA: small for gestational age.
[f]CNT: cito numeracy test.

per variable, including predictive mean matching, linear and logistic regression and random forests where appropriate. The imputation scheme includes all model variables and appropriate two-way interactions. In this second set, estimates of parameters and standard errors from the multilevel regression model were pooled over imputed datasets to obtain robust parameter point estimates, with potentially increased standard errors to account for multiple estimation of missing information (Van Ginkel et al., 2020). Lastly, to assess robustness of results, estimates and standard errors obtained from the multilevel regression model were compared between the two approaches (complete case and MI). Considerable differences could signal that results derived from complete case analysis might have been biased.

RESULTS

Missing Data

Based on Little's MCAR test (1986), we could not reject the null hypothesis, which means that data were missing completely at random (χ^2 (9) = .08, p = .777). Complete case analysis can thus be assumed to lead to unbiased results under a correctly specified model.

Sample Characteristics

Sample characteristics for the complete case selection (N = 375) are presented in **Table 1** (see **Supplementary Table S1** for the full consenting sample with incomplete information). A small majority of children was male (54.9%), in accordance with the general finding that more boys than girls are delayed in the early years of schooling (Gurian, 2010). Following the definition of late preterm birth by Van der Kooy-Hofland et al. (2012), 40 children (10.7%) were born late preterm. Following the WHO definition of late preterm birth between 34 and 36 weeks and 6 days, 13 children (3.7%) were born late preterm. In total 94 children were born small for gestational age (25.1%).

Table 2 shows the mean Cito Numeracy Test scores at posttest, standardized on the full sample, presented per experimental condition. Scores are presented separately for late versus full term children, small for gestational age versus normal for gestational age, and for the final sample as a whole.

TABLE 2 | Means and Standard Deviations for standardized numeracy post-tests by condition and mild perinatal adversities, based on the complete final sample (n = 375).

Cito numeracy posttest (standardized)						
Group	Experimental condition[a]			Control condition[b]		
	Mean	*SD*	*n*	*Mean*	*SD*	*n*
Full term	.04	1.05	161	-.04	.93	174
Late Preterm (VDK 2012)[c]	.43	1.26	18	-.33	.88	22
Late Preterm (WHO)[d]	.23	1.93	7	-.23	1.93	7
Not SfGA[e]	.05	.97	130	-.11	.87	151
SfGA	.16	1.30	49	.04	1.11	45
Total	.08	1.07	179	-.07	.93	196

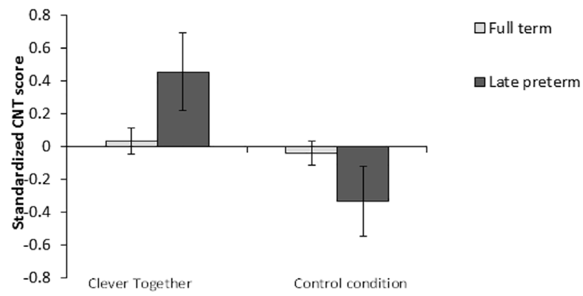
[a]Experimental condition: Clever Together.
[b]Control condition: Living Books.
[c]VDK, 2012: Defiition according to Van der Kooy-Hofland et al. (2012).
[d]WHO: World health organization.
[e]SfGA: small for gestational age.
Effects of Clever Together.

The Cito Numeracy posttest scores (June) were regressed on dichotomized Cito Numeracy pretest scores, preterm status (late preterm versus full term), size for gestational age (small versus normal), and the two-way interactions: late preterm * condition, and small for gestational age * condition. Variance Inflation Factors for all predictors ranged between 1.01 and 2.45. This is widely considered as low inflation (Akinwande et al., 2015), and thus strongly suggests absence of multicollinearity. Therefore, no further action was taken in the model estimations. Next, we tested if it was necessary to allow the intercept and slope to differ between schools in the regression model (Bickel, 2007). The Intra Class Coefficient of the intercept-only model was .12. The difference between the -2log likelihood of the model with a random intercept and the -2log likelihood of the model without a random intercept equaled .94. Following a χ^2 distribution with one

TABLE 3 | Cito Numeracy scores at posttest, regressed on Cito numeracy scores pretest, experimental condition, preterm status, size for gestational age, and interactions between conditions and mild perinatal adversities. Results are presented for complete cases (N = 375), nested in 140 schools.

Measure*	β	SE	p-value
Intercept (fixed effect)	78.94	(1.9053)	<.001
Intercept variance (random effect)	1.39	1.179	*NA*
Random effect residual variance	97.31	9.87	*NA*
Main effects (fixed)			
Cohort[a]	-1.55	1.14	.175
Cito Numeracy pretest[b]	13.45	1.04	<.001
Experimental condition[c]	.15	1.24	.902
Preterm status[d]	-3.29	2.27	.148
Size for gestational age[e]	.95	1.71	.577
Two-way interaction			
Late preterm* Condition	7.83	3.35	.019
Small for gestational age* Condition	-1.44	2.38	.547

**Fixed effects after adjustment for random intercept at school level. No random slopes were estimated.*
[a]*Cohort 2012/2013 compared to 2013/2014.*
[b]*Cohort 2012/2013 compared to 2013/2014.*
[c]*Control (0) compared to Intervention (1).*
[d]*Term born (0) compared to Late Preterm born.*
[e]*Normal (0) compared to Small for Gestational Age.*



$N_{full\ term/Clever\ Together} = 161$; $N_{preterm/Clever\ Together} = 18$; $N_{full\ term/Control} = 174$; $N_{preterm/Control} = 22$.

FIGURE 4 | Adjusted, standardized mean scores on the standardized CNT posttest for children born late preterm versus full term assigned to the experimental condition or the control condition.

degree of freedom, this difference was not significant ($p > .10$). This indicates that variability in scores on the numeracy test administered after the intervention was similar across schools and intervention slopes are similar across as well, therefore we fitted a multilevel model with nesting within schools for increased precision, but we do not interpret the variance at the school level any further. The fixed effects are interpreted as non-hierarchical ordinary least squares (OLS). All main analyses were performed using the definition for late preterm birth by Van der Kooy-Hofland et al. (2012). Group assignment based on the WHO definition yielded insufficient power to perform the current statistical significance tests. Explicit adjustment for group size imbalance was not performed, even though group sizes for gestational age groups and preterm birth groups are imbalanced, since the assumptions of residual normality was not violated, which is an indication of nonbiased estimations. Furthermore, the assumption of residual homoscedasticity was not violated, indicating equivalent precision in all groups.

Results are presented in **Table 3**. The CNT pretest (t (373) = 12.89, p <.001) showed a main effect, children with an average or above score on the pretest scored higher than children with a below average score on the pretest. No main effects were found for late preterm birth (t (373) = −1.45, p = .148) and small for gestational age (t (373) = 0.558, p = .577). There was no significant interaction between small for gestational age * condition (t (373) = −0.06, p = .547), however the interaction, born late preterm * condition was significant (t (373) = 2.34), p = .019). Children born late preterm scored higher on the posttest than their peers when working with Clever Together but lagged further behind with Living Books, the control condition (see **Figure 4**). Four CLT scores were outliers (more than three SDs above the sample mean). The variance of the random intercept at school level ($\sigma^2_{\text{intercept}}$ = 1.39) was not significant ($SD_{\text{random intercept variance}}$ = 1.18).

Repetition of the analysis using MI yielded highly similar results and thus similar substantive conclusions indicating that results derived from complete case analysis were not biased. Estimates were highly comparable across all parameters (**Supplementary Table S2**). The nonsignificant effect for cohort remained non-significant, but was less negative (closer to zero). The adjustment effect for pretest provided the same estimate and remained significant. The effect of the experimental condition switched direction from positive to slightly negative, which showed that the intervention was not effective in the larger sample after imputation either. The estimate for preterm status became less negative but remained nonsignificant. The estimate for gestational age * condition became less negative, and also remained nonsignificant. The estimate for the interaction between preterm status and condition became slightly smaller (from 7.83 to 6.52) but remained significant. As the multiply imputed datasets are generally less biased compared to complete case analysis (van Ginkel et al., 2020), but models fitted on both types of datasets yielded exactly the same interpretations, we conclude that the results and interpretations are robust.

Estimates obtained using the late preterm birth definition by WHO yielded equivalent point estimates and direction for the association but were underpowered and thus yielded nonsignificant results. For completeness, these results are presented in **Supplementary Table S3** (complete cases) and S4 (multiply imputed data).

Effect sizes of the intervention were calculated for the group as a whole and separately for children born late preterm and children born full term (**Table 4**). For the group as a whole, a small, non-significant, positive effect of Clever Together on numeracy skills at the end of senior kindergarten year was found (Cohen's d = .15, CI = −.05/.35). In the group born full term, the effect size was close to zero (Cohen's d = .08, CI = −.13/.30). However, Clever Together produced a large effect in the late preterm group (Cohen's d = .71, CI = .07/1.36).

DISCUSSION

We investigated if children with mild perinatal adversities were susceptible to a digital intervention in the domain of numeracy. A

TABLE 4 | Effect sizes of Clever Together for the complete group, children born late preterm and children born full term separately.

Cito numeracy posttest				
Dataset	**Group**	***n***	**Cohen's *d***	**95% CI**
Complete sample*(*N* = 375)	Full term	335	.08	-.13/.30
	Late preterm	40	.71	.07/1.36
	Total group	375	.15	-.05/.35

scaffolding and adaptive approach characterized the mainly visual spatial skills' training offered by the program. Late preterm children attending kindergarten, are generally at risk for developing academic delays (Chyi et al., 2008), but on the other hand were found to be highly susceptible to a digital early literacy intervention with the same scaffolding and adaptive approach (Living Letters) (Merkelbach et al., 2018). In line with these results we expected late preterm children also to benefit when the same didactic approach was applied in an intervention in the numeracy domain, another known area of difficulty for this group. We thus tested the hypothesis that children born late preterm need structured scaffolding, that is characterized by repetition, adaptive feedback and guidance irrespective of the domain of learning (literacy or numeracy). Children born small for gestational age and children without mild perinatal adversities were however not expected to benefit. In some studies increased susceptibility in the entire group with mild perinatal adversities is suggested (Van der Kooy-Hofland et al., 2012). However, in later research only the late preterm group is identified as susceptible (Merkelbach et al., 2018), while there was no difference in response between the children small for gestational age and the children without perinatal adversities.

Results offer support for our hypotheses: neither a main effect nor an interaction between small for gestational age and condition was found, while late preterm children clearly benefitted from working with the program (Cohen's d = .71, CI = .07/1.36). Consistent with the differential susceptibility model (Belsky and Pluess, 2009), when assigned to the control condition, late preterm children fell behind as compared to their peers, while they outperformed their peers after having worked with Clever Together.

Key scaffolding characteristics (repetition, structure, guidance, and adaptive feedback) of both Clever Together and Living Letters seem to meet the educational needs of late preterm children particularly well. We hypothesize that these key scaffolding characteristics facilitate learning in late preterm children. A positive effect of these scaffolding characteristics on especially late preterm as compared to small for gestational size children could be explained by the association between specifically preterm birth and increased levels of maternal stress during pregnancy (Mulder et al., 2002; Dole et al., 2003), which in turn is predictive for increased levels of fearfulness (Pike, 2005) and stress reactivity (Meaney, 2001) in offspring. These characteristics could be expressed as performance- and test anxiety, which are known to have detrimental effects on school performance (McDonald, 2001). In schools differentiated instruction by the teacher that meets the needs of all children is challenging (Suprayogi et al., 2017). Late preterm children might fall behind, possibly due to increased levels of stress reactivity which might cause children to shut themselves from learning experiences (Van der Kooy-Hofland et al., 2012). In the digital program Clever Together however, the scaffolding given through repetition, structure, feedback, and guidance central to the program help clarify the task at hand. Task clarity lowers levels of experienced stress (Richter and Gendolla, 2006). The key scaffolding characteristics of Clever Together (and Living Letters) could thus result in lower levels of stress through providing high levels of clarity and predictability, thereby facilitating learning. In addition, since late preterm birth is associated with for example lower SES (Gardosi and Francis, 2005), these adaptive and supportive educational programs may compensate for a possibly suboptimal learning environment in the home setting. Lack of resources in the home environment interfere with the development of academic skills (Aalders et al., 2020). More research is needed to identify which exact features support the learning of late preterm children as well as through which mechanisms.

We replicated the finding by Merkelbach et al. (2018) that children with mild perinatal adversities are a heterogeneous population with different educational needs; children small for gestational age did not benefit from the intervention. In their review Vollmer and Edmonds (2019) conclude that although they may experience problems with attention, children term born small for gestational age are not hugely impacted by the fact that they are born small for gestational age. Late preterm birth seems to contribute more consistently to the presence of educational delays. Children small for gestational age might not have specific educational needs that need to be addressed in order to thrive. Perhaps they might benefit from different interventions, not specifically targeting scaffolding and potential stress reduction.

Strengths and Limitations

Unavoidably, this study has some limitations. It should be noted that the studies looking into effects of Living Letters (Merkelbach et al., 2018) and Clever Together (current study) are not completely independent. This could be seen as limitation, since in both studies the same control condition was used, thus including largely the same sample of children. However, this approach also allowed for the evaluation of scaffolding in different domains in the same children.

Additionally, teachers selected children based on early literacy delays instead of numeracy problems. Children with literacy delays, thus experience problems in both domains. In line with the literature (e.g., see Davidse et al., 2014; Peng et al., 2020; Purpura et al., 2011) literacy- and numeracy skills of children in this study were highly correlated (in total sample: r = .589, p <.001). However, children might differ from children who only experience problems in the field of numeracy. Additionally, we can only speculate about effective functionalities in Clever Together and mechanisms explaining this effectivity.

Interestingly, although using the late preterm birth definition (34–37 weeks + 6) as in Van der Kooy-Hofland et al. (2012) study yielded a larger number of children classified as born late preterm, compared to the WHO definition (34–36 weeks + 6), the magnitude of the associated parameter estimates was equivalent in both definitions. Since the WHO classification yielded a smaller group, thus lower power, the parameters were not indicated as statistically significant. However, the equivalence of both sets of parameter estimates could be interpreted as evidence for a robust differentially susceptible mechanism via late preterm birth, regardless of its precise definition.

Although details of the Clever Together numeracy intervention require further study, we can conclude that children born late preterm, a vulnerable group, can benefit from this intervention, preventing them from falling behind further in a cost- and time-effective fashion. Findings confirm that intervening in this group is crucial to reduce inequality in education opportunities.

Future Directions

This study offers strong evidence of increased susceptibility to the educational environment in children born late preterm. Future research should focus on unraveling mechanisms underlying this increased susceptibility. Insight into underlying mechanisms leads to opportunities to adapt existing interventions to the needs of different target groups. Additionally, future research might benefit from the identification of more vulnerable subgroups showing increased susceptibility to the learning environment.

CONCLUSION

Merkelbach et al. (2018) showed that kindergartners born late preterm are more susceptible to their educational environment than term born control children when learning literacy skills. With the current study these results are expanded to the domain of numeracy. The digital intervention Clever Together boosted the early numeracy performance of kindergartners born late preterm, while children born small for gestational age, or born at term, do not benefit from this intervention. On the other hand, late preterm children fall behind when assigned to a control condition, following the pattern as described by the differential susceptibility model. This pattern does not hold for children born small for gestational age, and aligns with the findings in this group when offering a digital literacy intervention as was done by Merkelbach et al. (2018). As a possible explanation for the effectivity of Clever Together in preterm children we expect that scaffolding via structure, guidance, and feedback provided by this program offer an optimal learning environment for this group. The findings also underline the importance of well-designed early interventions not only to reduce inequality in education achievement but to give susceptible children a head start.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, upon request, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee Institute of Education and Child Studies—Leiden University file ID: ECPW-2012/044. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

IM, RP, and RR were involved in the study design. IM and RR were involved in the statistical analyses. IM, RP, MS-dJ, and RR were involved in the discussion on the manuscript and in writing the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2022.709809/full#supplementary-material

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