
Developmental Neuropsychology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/hdvn20

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DEVELOPMENTAL NEUROPSYCHOLOGY
2021, VOL. 46, NO. 1, 54–69
https://doi.org/10.1080/87565641.2020.1858421

Routledge
Taylor & Francis Group

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# Development of Cognitive Functions and Academic Skills in 9- to 10-year-old Children with Borderline Intellectual Functioning

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**ABSTRACT**

This longitudinal study examined whether the cognitive and academic development of children ($M_{age}$ = 10.52 years) with Borderline Intellectual Functioning (BIF), is characterized by developmental delay or atypical development. Cognitive tasks, arithmetic tasks, and reading tasks were administrated during three succeeding years to the BIF group and a Chronological Age-Matched Comparison (CAMC) group. The BIF children displayed weaknesses in relation to all tasks, and slower developmental rates on four arithmetic tasks and word reading. The results provide evidence in support of the developmental delay model as the BIF children overall displayed similar developmental growth and trends as the CAMC group.

**ARTICLE HISTORY**

Received 4 July 2020
Revised 26 November 2020
Accepted 28 November 2020

## Introduction

During the last 20-years an increasing number of studies have focused on individuals with Borderline Intellectual Functioning (BIF), defined as individuals with an IQ score between one and two standard deviations below the mean of the typical general population (Peltopuro, Ahonen, Kaartinen, Seppälä, & Närhi, 2014). This trend of increased research interest is much needed because our knowledge about this population is still sparse. Based on their systematic literature review, Peltopuro et al. (2014) concluded that individuals with BIF encounters a multitude of neurocognitive, academic, social, economic and mental health problems across their life courses. Furthermore, as almost all research on children with BIF have used designs with chronological age-matched controls (CA) or both mental age-matched controls (MA) and CA controls, they emphasized the need for longitudinal studies in order to further map out the nature of BIF.

With this in mind, the purpose of the current study was to examine, using a three-year longitudinal design, the development of cognitive abilities and academic skills in children with BIF. The main advantage of using a longitudinal design, instead of a combined MA and CA control groups design, is that it enables an examination of the BIF children's development of cognitive abilities and academic skills. This design will thereby make it possible to determine whether the BIF children's cognitive and academic difficulties reflect a developmental delay or an atypical development. The longitudinal design will also allow an examination of how far behind children with BIF are in their cognitive and academic development. The main advantage of using a combined MA and CA control groups design, in contrast to a longitudinal design with only a CA control group, is that it allows a direct test of the assumption that children with BIF suffer from neurocognitive deficits. That is, if the BIF group displays poorer cognitive performance (e.g., working memory) than the MA control group.

### *Developmental delay or atypical development?*

Akin to a few previous studies, the aim of the present longitudinal study was to determine whether the academic and cognitive weaknesses of children with BIF are due to a developmental delay or an

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atypical development (e.g., Schuchardt, Gebhardt, & Mäehler, 2010). The atypical development model or different model claims that children with BIF suffer from neuro-cognitive deficits, and thus follow a qualitatively different developmental path and reach a much lower asymptotic level of cognitive capacity than children with average intellectual ability. The developmental delay model states that children with BIF follow the same developmental path as children with average intellectual ability but more slowly, and that they reach a lower asymptotic cognitive level (Bennett-Gates & Zigler, 1998; Weiss, Weisz, & Bromfield, 1986; Zigler & Balla, 1982). That is, children with BIF display a quantitatively different developmental path, not a qualitatively different one.

Carroll's model of school learning (Carroll, 1989) is relevant in relation to the current study. It states that school learning is made up of five factors; aptitude, perseverance, ability to understand instruction, opportunity to learn, and quality of instruction. Aptitude consists of cognitive abilities (e.g., logical reasoning) that determine the child's potential to learn and thereby the amount of time he/she needs to learn a given task. Perseverance concerns the child's motivation for learning, that is, the amount of time on task she/he is willing to spend on learning the task. The ability to understand instruction is the third individual characteristic and refers to the child's capability to grasp on their own what the task is and how to learn it. Low ability to understand instruction increases the time needed to learn a given task. The factors opportunity to learn and quality of instruction are connected to circumstance in the school environment (i.e., classroom, schedule; teaching, didactics). Opportunity to learn refers at the theoretical level to the amount of teaching time stipulated in the school schedule/program for each specific school subject, but more important the amount of teaching time the child actually receives in school. The factor quality of instruction concerns the question "How to teach in order to help the child to learn as easy and quickly as possible?" (Carroll, 1989). The model states that it is important for the child to be clearly aware of the learning objectives for each lesson. Furthermore, each step in the learning/teaching process needs to be thoroughly organized and ordered, and when teaching materials are used, the child must be given ample opportunity to learn about the material, and how to use it.

Applying the model (Carroll, 1989) on to children with BIF, it is clear that they should have problems with the aptitude and ability to understand instruction factors as these factors involve different types of cognitive functions known to be problematic for this population of children (Peltopuro et al., 2014). The children with BIF may also display low perseverance, as their willingness to spend time on learning might be low, due to consistent slow progress in learning, which in turn is the result of their low aptitude and low ability to understand instruction. Given these problems, the two school related factors, opportunity to learn and quality of instruction, are very important for this population of children. More specifically, low aptitude and low ability to understand instruction increases the teaching time the children with BIF need in order to learn. Thus, the school must provide extra teaching time to these children as well as provide instructions that matches these children's aptitude and ability to understand instruction and also enhance their motivation for learning.

### *Cognitive functions in children with BIF*

The majority of studies focusing on cognitive functions in individuals with BIF have studied working memory functions in view of the three-component model developed by Baddeley (Baddeley, 1990, 1997; Baddeley & Hitch, 1974). This model's key component is the central executive which is a control–attention system responsible for functions such as the coordination of simultaneous operations, switching between operations, selective attention, the inhibition of irrelevant information, and retrieval of information from long-term memory. The phonological loop and the visuospatial sketchpad sub-serve this central executive by providing short-term storage for verbal and visuospatial information, respectively (Baddeley, 1990, 1997).

The available evidence clearly demonstrates that children with BIF have lower capacity in all components of working memory compared to chronological age-matched children of average intelligence (Alloway, 2010; Schuchardt et al., 2010; Stefanelli & Alloway, 2018). However, as most studies have only featured chronological age-matched controls it is not possible to conclude whether the lower working memory capacity of children with BIF reflects a developmental delay or an atypical development. In two studies, Schuchardt and colleagues (Schuchardt et al., 2010; Schuchardt, Mäehler, & Hasselhorn, 2011) addressed this shortcoming by including an additional control group consisting of mental age-matched children. In Schuchardt et al. (2010) the children with BIF displayed lower capacity in all three components compared to the chronological age-matched children, but only lower capacity in the phonological loop compared to the younger mental age-matched children (see also Hasselhorn & Mäehler, 2007). These findings suggest that children with BIF have developmental lags concerning the central executive and visuospatial sketchpad but an atypical development concerning the phonological loop. However, this conclusion was not supported by Schuchardt et al's (Schuchardt et al., 2011) study focusing on the phonological loop component, in which the children with BIF performed equally with the younger mental age-matched children. In conclusion, the overall empirical picture concerning working memory functions in eight-to-fifteen years-old children with BIF strongly favors the developmental delay model.

Two prior studies have examined executive functions, which are related to working memory functions, in children with BIF (Alloway, 2010; Hartman, Houwen, Scherder, & Visscher, 2010). Hartman et al. (2010) used the Tower of London tasks to assess planning skills. They found that the BIF children were outperformed on this task by the chronological age-matched children. Alloway (2010) focused on five different executive functions; shifting attention (Trail-making test), cognitive inhibition (Color–Word Interference test), problem solving (Sorting test), planning (Tower test.), and response inhibition (Walk–Don't Walk test). The children with BIF performed worse than the chronological age-matched control children in all five executive functions. Thus, there is some evidence that children with BIF are marked by weaknesses in executive functioning.

Similar to executive functions, children with BIF have also been found to display weaknesses in processing speed when compared to chronological age-matched children with average IQ (Bonifacci & Snowling, 2008; Napora-Nulton, 2003). Bonifacci and Snowling (2008) examined four different aspects of processing speed; simple reaction time, choice reaction time, number scanning, and symbol scanning. On all four processing speed tasks, children with BIF performed more slowly than the chronological age-matched children suggesting that they have a general weakness in processing speed.

In summary, more longitudinal research, or research featuring both chronological age-matched and mental age-matched comparison groups is required to determine whether the cognitive weaknesses of children with BIF are due to a developmental delay or an atypical development.

### *Academic performance and development in children with BIF*

It is widely known that children with BIF are slow learners and as such experience a number of academic difficulties during the course of schooling (Kaznowski, 2004; Peltopuro et al., 2014). More specifically, compared to chronological age-matched children with average IQ, children with BIF have poorer reading, spelling and mathematical skills (Bonifacci & Snowling, 2008; Claypool, Marusiak, & Janzen, 2008; Di Blasi, Buono, Cantagallo, Di Filippo, & Zoccolotti, 2019; MacMillan, Gresham, Bocian, & Lambros, 1998).

So far, few studies featuring children with BIF have included tasks assessing mathematical skills. Kortteinen, Närhi, and Ahonen (Kortteinen, Narhi, & Ahonen, 2009) used a standardized test of arithmetic skills (basic addition and subtraction; Räsänen, 2004) on a sample of 33 eighth graders. It was found that the BIF group showed poorer arithmetic skills than age-matched children with an average IQ. In a recent study, Stefanelli and Alloway (2018), extended Kortteinen et al.'s (Kortteinen et al., 2009) results when they observed that children with BIF scored lower than age-matched controls on the numerical operation subtest and the mathematical reasoning subtest of the Wechsler Objective Numerical Dimensions (Wechsler, 1996). The combined results of Kortteinen et al. (2009) and Stefanelli and Alloway (2018) indicate that children with BIF probably have weaknesses in many domains of basic mathematics.

As with mathematics, only a limited number of studies have examined reading skills in children with BIF. Bonifacci and Snowling (2008) and Claypool et al. (2008) focused on word–reading skills and found that children with BIF performed worse than age-matched controls. In contrast, Kortteinen et al. (2009), who examined different aspects of reading skills, found that the eighth graders with BIF but no reading difficulties only displayed weaker skills in reading comprehension than age-matched children with an average IQ. Thus, their word reading and pseudo-word reading skills as well as text reading skills were equal to those of the age-matched controls.

The findings reported by Bonifacci and Snowling (2008), Claypool et al. (2008) and Kortteinen et al.'s (2009) were corroborated and extended by a cross-sectional study on second to eighth graders performed by Di Blasi et al. (2019). These researchers based their study on the dual-route cascaded (DRC) model developed by Coltheart, Rastle, Perry, Langdon, and Ziegler (2001), and they found that the BIF group showed weak reading comprehension skills across all grades (cf. Kortteinen et al., 2009). Furthermore, the BIF group read real-words and pseudo-words more slowly and less accurately than the norm (cf. Bonifacci & Snowling, 2008; Claypool et al., 2008). Slowness in real-word reading was particularly marked in later grades. An important theoretical finding was that the BIF children displayed a less marked lexical effect on word reading, that is, faster and more accurate reading of real words compared to pseudo-word. This reduced lexical effect indicates that the BIF children use the immature grapheme-to-phoneme conversion routine (sub-lexical route) as their primary word-decoding strategy and continue to do so in higher grades. The lack of a shift in word-decoding strategy from grapheme-to-phoneme conversion to the more effective orthographic-lexical strategy (lexical route) could explain why the BIF children appeared to fall behind in word–reading fluency (speed). Moreover, Di Blasi et al. (2019) proposed that the BIF children's continuous use of a grapheme-to-phoneme conversion strategy during word reading may be due to their inability to develop orthographic lexical representations.

All in all, due to the very limited amount of research focusing on academic skills in children with BIF no firm conclusions can be drawn about these children's academic skills profiles. The only conclusion that can be drawn is that children with BIF have academic difficulties. Thus, more longitudinal research focusing on different aspects of mathematics and reading is needed in order to expand our knowledge concerning academic skills development in children with BIF. Such research will also enable us to determine whether their academic difficulties reflect developmental delay or atypical development.

### *The current study*

The aim of the current longitudinal study was to expand our knowledge concerning cognitive development and academic skill development in children with BIF, and to determine whether their cognitive and academic weaknesses are due to developmental delay or atypical development (Bennett-Gates & Zigler, 1998; Zigler & Balla, 1982).

Both models state that the children with BIF will display overall weaker academic skills and cognitive abilities than the CAMC children. However, according to the developmental delay model, children with BIF should follow the same developmental trend (e.g., linear) as the chronological age-matched controls. Moreover, the developmental growth rate of the children with BIF should be similar or slightly slower compared to the CAMC children (Bennett-Gates & Zigler, 1998; Weiss et al., 1986; Zigler & Balla, 1982).

The atypical developmental model, on the other hand, states that children with BIF will display a qualitatively different developmental trend (e.g., quadratic), and considerable slower developmental growth rate compared to the CAMC children (Bennett-Gates & Zigler, 1998; Weiss et al., 1986; Zigler & Balla, 1982).

Thanks to its longitudinal design, the study also addressed the important research question: how far behind are children with BIF in their cognitive and academic development.

To address the aim of this study a comprehensive test battery featuring four cognitive tasks, six arithmetic tasks, and two reading tasks was administrated on one occasion in each of three successive years.

## Materials and methods

### Participants

Written consent to participate in the study was obtained from each child's caregiver prior to testing by means of a letter of consent that the children took home to their parents from school. A total of 310 children from 30 regular schools agreed to participate in the study. All participating children had Swedish as their native language, normal or corrected-to-normal visual acuity and no hearing loss. All children were screened using *Raven's Standard Progressive Matrices test* (Raven, 1976) and Järpsten and Taube's word ability test (Järpsten & Taube, 1997) to obtain indices of nonverbal and verbal IQ. Each participating child's raw scores on *Raven's Standard Progressive Matrices* and Järpsten and Taube's word ability test (1997) were transformed into a percentile scores according to the test manuals (Järpsten & Taube, 1997; Raven, Court, & Raven, 1996).

*Children with BIF*. Twenty-seven children (10 boys) aged 9–11 ($M_{\text{age in years}}$ = 10.52, SD = 0.60) were identified with BIF. All 27 children with BIF attended regular school. In order to be classified as having borderline Intellectual functioning the child's percentile scores on *Raven's Standard Progressive Matrices* and the word ability test had to be between the 2.3$^{th}$ and 15$^{th}$ percentile, that is, between one and two standard deviations below the norm mean (see Table 1).

*Chronological Age-Matched Comparison group* (CAMC). The CAMC group consisted of 28 typical children (12 boys) with average intellectual functioning ($M_{\text{age in years}}$ = 10.58, SD = 0.59). In order to be included in this group, the child's percentile score on *Raven's Standard Progressive Matrices* and the word ability test had to be between the 17$^{th}$ and 75$^{th}$ percentile.

Background information and results from the Raven's Progressive Matrices test and the verbal ability test, are displayed for each group in Table 1.

This research project has been approved by the Regional Ethics Committee in Linköping, Sweden (Protocol Number 2011/58-31).

### General procedure

All instructions were given orally, read aloud from a printed manuscript to ensure that all participants were given the same instructions. The child was also informed that she/he could ask for a break in testing, as well as withdraw from the study completely, whenever she/he wanted to with no questions asked. The same test order was used for all children and all the children were tested in familiar rooms at their respective schools. The testing was performed between February and May each year. The following tasks were administered during the group session (in order of presentation): Multi-digit calculation (horizontal), Nonverbal arithmetic problem solving, Raven's progressive matrices, Reading comprehension, Word reading, and Verbal ability. The following tasks were administered individually to each child: Mental arithmetic fluency, Visual-spatial WM, Semantic and phonological fluency, Processing speed (digit matching), One-step arithmetic problem–solving, Multi-step word problem–solving, Shifting (Trail-making B–A), and Multi-digit calculation (vertical).

**Table 1.** Background information for the children in the BIF group and the CAMC group.

| | BIF group | | | CAMC group | | |
|---|---|---|---|---|---|---|
| | M | SD | Min/Max | M | SD | Min/Max |
| Age (in month) | 126 | 7.23 | 113/143 | 127 | 7.12 | 114/137 |
| N (Number of boys) | 27 (10) | | | 28 (12) | | |
| Grade 3/4 | 12/15 | | | 13/15 | | |
| Special instructions in Math/Reading/ Both math and reading | 9/8/10 | | | 0/0/0 | | |
| Raven's Progressive Matrices (percentiles) | 10.63 | 3.34 | 5/15 | 49.77 | 9.64 | 23/75 |
| Verbal ability (percentiles) | 10.34 | 3.33 | 3/15 | 50.05 | 14.24 | 17/75 |

BIF = Children with borderline intellectual functioning
CAMC group = Chronological Age-Matched Comparison group with average intellectual functioning

### Experimental task and procedure

*Processing speed*. A digit matching task was used to assess the child's processing speed (cf. Bonifacci & Snowling, 2008). The material consisted of a sheet of paper with 30 rows of digits, each row consisting of seven digits, with two identical digits. The task was to cross out the two identical digits on each row as fast as possible. The time needed to complete the task was used as an index of processing speed. Test-retest reliability of.71 was established by calculating the correlation between years 1 and 2.

*Accessing long-term memory information*. Two verbal fluency tasks were used to tap the retrieval of semantic and phonological information from long-term memory (Hodges & Patterson, 1995). The tasks involved generating as many words as possible from two semantic categories (animals, food) and two initial phoneme categories (/f/,/s/). Sixty seconds were allowed for each category. The total numbers of words retrieved within 60 seconds in the two semantic categories and the two phoneme categories were used as two dependent measures. Split-half reliabilities calculated between the two semantic categories, and the two phoneme categories in year 1 were $r_{sh}$ = .79, and $r_{sh}$ = .87, respectively.

*Shifting ability*. The Trail-making task was used to tax the ability to shift between operations or retrieval strategies, which is an important executive function (Baddeley, 1996). The task involved two conditions: In the A condition, the material consisted of 25 circled digits on a sheet of paper. The task was to connect the 25 circles in numerical order as quickly and as accurately as possible. In the B condition, half of the circles had a digit (1–13) and half had a letter (A–L) in the center. The child was asked to start at 1 and make a trail with a pencil so that each digit alternated with its corresponding letter (i.e., 1–A–2–B…12–L–13). The difference in response time between the two conditions was used as the dependent measure. The test-retest reliability established by calculating the correlation between years 1 and 2 turned out to be rather low, $r$ = .42. However, the Trail-making task is a well-established measure of the executive function, shifting, with reported reliabilities between .60 and .90 (Lezak, 1995).

*Visual-spatial working memory*. In this complex task, tapping the central executive and the visuospatial sketchpad, the child was presented with a number of dots in a matrix (Swanson, 1992). The task was to remember the location of these dots in the matrix. A matrix was displayed on a sheet of paper for 5 seconds, after which it was removed. The child was then asked a process question: ("Were there any dots in the first column?") After answering, the child marked with a pen on an identical empty matrix where he/she remembered the dots were located. The first matrix had nine squares (3 x 3) and included two dots (level 1). The matrices on the next level (2) had nine squares (3 x 3) and three dots. The third level had twelve squares (3 x 4) and included three dots. The complexity of the matrices increased for each new level either by increasing the size of the matrix or increasing the number of dots. The most complex matrix had 42 squares and nine dots (level 14). Two trials were presented for each level. The number of trials presented to the children varied as testing proceeded as long as the child succeeded in reproducing one of the two trials of the same span size. Thus, testing stopped when the child failed both trials. The dependent variable was measured as the most complex matrix remembered correctly, plus 0.5 points if the child could remember both trials in her/his most complex matrix. The maximum score (highest level) was 14.5. For example, a child that correctly reproduced both trials on level three (see above), but failed both trials on level four, received a score of 3.50. Test-retest reliability of $r$ = .70 was established by calculating the correlation between years 1 and 2.

*Multi-digit calculation*. In this task, the child was asked to solve and answer in writing horizontally presented addition and subtraction calculation problems. The calculation problems became increasingly more difficult (568 + 421; 658–437; 56 + 47; 65–29; 545 + 96; 384 + 278; 824–488; 4203 + 5825; 8010–914; 11305–5786; 123.50 + 17.85; 30.7–15.65; 98–76.58; 34.7 + 24.6 + 88.24). The child was allowed eight minutes to perform the task and the maximum score was 14. Test–retest reliability of $r$ = .83 was established by calculating the correlation between years 1 and 2.

*Multi-digit calculation (vertical)*. In this task, the child was asked to solve and answer in writing vertically presented arithmetic calculation problems. The task included 24 multi-digit calculation problems (e.g., 258 + 341; 1295 + 5437; 26856 + 14249; 647–566; 9566–978; 12405–7748) that became successively more difficult. All but two problems involved regrouping. Ten minutes was the maximum performance time. The maximum score was 24, and test–retest reliability of $r = .75$ was obtained by computing the correlation between performance in years 1 and 2.

*Mental arithmetic fluency*. The task was to solve, in order, twelve addition (5 + 4; 8 + 5; 7 + 4; 9 + 5; 3 + 8; 7 + 9; 4 + 6; 3 + 9; 7 + 8; 8 + 4; 3 + 6; 6 + 5), twelve subtraction 9–4; 7–4; 9–5; 7–5; 8–4; 9–7; 6–3; 8–3; 6–2; 9–3; 9–6; 7–3,), and twelve multiplication (4 x 5; 2 x 7; 9 x 4; 9 x 10; 7 x 5; 6 x 3; 9 x 2; 7 x 3; 6 x 6; 4 x 6; 3 x 4; 5 × 6) single-digit arithmetic problems, which were presented in a single column on three separate sheets of paper. The children were instructed to provide their oral answer right away and encouraged to guess if the answer was not available right away. A stopwatch was used to measure the total response time. The total number of correctly solved arithmetic problems and total response time (all 36 problems) were used as the dependent measures. These two measures were combined into an efficiency measure by dividing the total number of correctly solved arithmetic problems by the total response time. Test–retest reliability of $r = .89$ was established by calculating the correlation between years 1 and 2.

*One-step word problem-solving*. The material consisted of 20 written arithmetic word problems (e.g., Fredric has 145. USD If he had 166 USD more, he could buy a bike. How much does the bike cost?). The problems were only one to four sentences long but became successively more difficult. The child was allowed 15 minutes to perform the task. Eighteen of the 20 problems featured multi-digit calculations. During testing the experimenter read out the individual problems while the child followed along on the paper. The problems were reread if requested by the child and the child responded in writing. The maximum score was 20, and a test–retest reliability of $r = .77$ was established by calculating the correlation between years 1 and 2.

*Multi-step word problem-solving*. The material consisted of 14 written arithmetic word problems (e.g., Bill has 70. USD Sandra has 10 USD more. Simon has half as much as Sandra. How much do they have altogether?) that required at least two solution steps in order to solve them. All problems included multi-digit calculation and became successively more difficult. The problems were two to four sentences long. The same administration procedure as for the one-step problems was used. The maximum score was 14, and a test–retest reliability of $r = .78$ was established by calculating the correlation between years 1 and 2.

*Non-verbal arithmetic problem-solving*. In this paper-and-pencil tasks, the child had to solve twelve problems (27, 113 = 140; 11, 26 = 15; 5, 8, 9 = 12; 10, 50, 90 = 30; 11, 19, 25 = 33; 4, 16, 4 = 0; 25, 19, 11 = 5; 4, 2, 5, 9 = 9; 2, 5, 30, 60 = 100; 1, 3, 8, 25 = 0; 5, 5, 6, 12 = 13; 7, 8, 65, 3 = 15) consisting of an answer and two to four numbers that had to be combined with one to three operations (addition, subtraction, multiplication) in order to obtain the predetermined answer. For example, if the four numbers were 4, 2, 5, 9 and the answer was 9, a correct solution would be (9 x 2) – 4 – 5. Prior to the actual testing, the child solved three practice problems with help from the experimenter if needed. Five minutes was the maximum performance time. The maximum score was 12, and a test–retest reliability of $r = .71$ was established by calculating the correlation between years 1 and 2.

*Word reading*. The test material consisted of strings of two to four words (e.g., horsecitytree; horse-city-tree; Jacobson, 1993). The child had to read and identify the separate words in the string by drawing lines between the words. Three minutes was the maximum performance time. The total number of correctly completed word strings was used as an index of word reading. A test–retest reliability of $r = .81$ was established by calculating the correlation between years 1 and 2.

*Reading comprehension*. The child had to read short stories (20–150 words) as fast and accurately as possible and then answer one to four multiple-choice comprehension questions in relation to each story (Malmquist, 1977). Four minutes was the maximum performance time to read a total of 12 short stories and answer a total of 33 questions. The number of correctly answered questions was used as the dependent measure. A test–retest reliability of $r = .83$ was established by calculating the correlation between years 1 and 2.

## Results

Descriptive statistics for the cognitive and academic tasks by group and time are displayed in Tables 2 and 3. A number of mixed factorial ANOVAs were computed to examine group differences, effects of time, and

**Table 2.** Mean achievement (SD) on the cognitive tasks by group and time.

| | BIF group | | | CAMC group | | |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T1 | T2 | T3 |
| Measures | M (SD) | M (SD) | M (SD) | M (SD) | M (SD) | M (SD) |
| Processing speed (digit matching) | 161 (51) | 135 (45) | 116 (34) | 117 (35) | 102 (31) | 92 (35) |
| Executive function | | | | | | |
| Shifting (Trail-making) | 94 (51) | 85 (41) | 68 (39) | 74 (54) | 45 (23) | 35 (18) |
| Semantic fluency | 23.48 (7.39) | 25.00 (6.21) | 27.04 (7.25) | 31.39 (7.15) | 31.93 (6.30) | 32.46 (9.65) |
| Phonological fluency | 13.93 (5.64) | 14.89 (6.50) | 16.41 (5.15) | 19.11 (8.33) | 21.00 (7.12) | 21.64 (6.37) |
| Visual-spatial WM | 4.26 (1.56) | 5.11 (2.34) | 5.93 (2.00) | 6.38 (2.40) | 7.27 (2.43) | 8.62 (1.29) |

BIF = Children with borderline intellectual functioning
CAMC group = Chronological Age-Matched Comparison group with average intellectual functioning

**Table 3.** Mean achievement (SD) on the academic tasks by group and time.

| | BIF group | | | CAMC group | | |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T1 | T2 | T3 |
| Measures | M (SD) | M (SD) | M (SD) | M (SD) | M (SD) | M (SD) |
| Multi-digit calculation (horizontal) | 2.63 (1.82) | 3.93 (2.27) | 5.22 (2.49) | 6.00 (2.32) | 7.64 (2.34) | 9.96 (2.96) |
| Multi-digit calculation (vertical) | 4.37 (3.62) | 6.04 (4.37) | 8.22 (5.27) | 8.93 (3.60) | 13.54 (5.22) | 16.43 (5.39) |
| Mental arithmetic fluency | 0.15 (0.08) | 0.19 (0.08) | 0.25 (0.11) | 0.32 (0.12) | 0.43 (0.15) | 0.49 (0.18) |
| One-step word problem-solving | 4.26 (2.54) | 5.74 (2.78) | 7.41 (2.65) | 8.36 (2.90) | 11.29 (2.42) | 12.79 (2.78) |
| Multi-step word problem-solving | 0.59 (0.97) | 1.74 (1.77) | 2.30 (1.61) | 3.25 (1.94) | 4.93 (1.86) | 6.25 (2.01) |
| Non-verbal arithmetic problem-solving | 2.85 (1.59) | 3.15 (1.92) | 3.74 (1.85) | 4.68 (2.50) | 6.25 (2.14) | 7.07 (2.12) |
| Word reading | 5.70 (3.80) | 9.19 (4.84) | 11.93 (5.75) | 11.86 (5.64) | 19.39 (6.77) | 24.50 (8.94) |
| Reading comprehension | 9.44 (3.19) | 12.11 (4.37) | 13.85 (3.67) | 16.68 (4.75) | 19.54 (5.22) | 22.32 (4.47) |

BIF = Children with borderline intellectual functioning
CAMC group = Chronological Age-Matched Comparison group with average intellectual functioning

interaction effects between group and time. Partial eta square values $\eta_p^2$were used as a measure of effect sizes (Cohen, 1988). A $\eta_p^2$ of .25 or larger represents a large effect, whereas a $\eta_p^2$ between .10 and .24 is of medium size. A $\eta_p^2$ of .09 or less is considered small. As the main effects of time were of minor interest, they were reported but not discussed further.

## Cognitive tasks

*Processing speed*. The CAMC group (M = 103) performed faster on the speed processing task than the BIF group (M = 137), $F(1, 53) = 12.755$, $MSE = 3606.696$, $p = .001$, $\eta_p^2 =.194$. A large time effect emerged, $F(2, 106) = 35.952$, $MSE = 474.149$, $p < .001$, $\eta_p^2 = .404$, but no time by group interaction, $F(2, 106) = 3.042$, $MSE = 474.149$, $p = .052$, $\eta_p^2 = .054$.

*Shifting (trail-making)*. The BIF group's (M = 82) performance on the shifting task was slower than the CAMC group's performance (M = 51), $F(1, 53) = 14.179$, $MSE = 831.469$, $p = .001$, $\eta_p^2 =.211$. A main effect of time was obtained, $F(2, 106) = 14.917$, $MSE = 1001.687$, $p < .001$, $\eta_p^2 = .220$, but no time by group interaction, $F(2, 106) = 1.382$, $MSE = 1001.687$, $p = .256$, $\eta_p^2 = .025$.

*Accessing semantic long-term memory information*. The ANOVA showed that the BIF group's mean score (M = 25.17) on the sematic fluency task was lower than the CAMC group's mean score (M = 31.93), $F(1, 53) = 15.960$, $MSE = 117.921$, $p < .001$, $\eta_p^2 =.231$. A small effect of time, $F(2, 106) = 3.313$, $MSE = 23.598$, $p = .048$, $\eta_p^2 = .056$, emerged, but no time by group interaction, $F(2, 106) = 0.912$, $MSE = 23.598$, $p = .405$, $\eta_p^2 = .017$.

*Accessing phonological long-term memory information*. The BIF group (M = 15.07) produced fewer words when performing the phonological fluency task compared to the CAMC group (M = 20.58), $F(1, 53) = 12.688$, $MSE = 98.641$, $p = .001$, $\eta_p^2 =.193$. The effect of time was small but significant, $F(2,$

106) = 5.346, $MSE$ = 16.285, $p$ = .006, $\eta_p^2$ = .092, but the time by group interaction was non-significant, $F$(2, 106) = 0.230, $MSE$ = 16.285, $p$ = .795, $\eta_p^2$ = .004.

*Visual-spatial WM*. The ANOVA performed on the WM task revealed lower capacity in the BIF group (M = 5.10) compared to the CAMC group (M = 7.42), $F$(1, 53) = 30.954, $MSE$ = 7.194, $p$ < .001, $\eta_p^2$ =.369. The effect of time was large, $F$(2, 106) = 19.460, $MSE$ = 2.720, $p$ < .001, $\eta_p^2$ = .269, but the time by group interaction was non-significant, $F$(2, 106) = 0.536, $MSE$ = 2.720, $p$ = .587, $\eta_p^2$ = .010.

## Academic tasks

*Multi-digit calculation (horizontal)*. A 2 (groups) x 3 (time points) mixed ANOVA revealed a large group effect, $F$(1, 53) = 51.608, $MSE$ = 12.424, $p$ < .001, $\eta_p^2$ =.493, a large time effect, $F$(2, 106) = 61.933, $MSE$ = 2.394, $p$ < .001, $\eta_p^2$ = .539, but no time by group interaction, $F$(2, 106) = 2.921, $MSE$ = 2.394, $p$ = .058, $\eta_p^2$ = .052. The BIF group (M = 3.93 obtained lower score than the CAMC group (M = 7.87).

*Multi-digit calculation (vertical)*. The mixed ANOVA performed on this task displayed a large time effect, $F$(2, 106) = 51.890, $MSE$ = 8.566, $p$ < .001, $\eta_p^2$ = .495, and a large group effect, $F$(1, 53) = 39.509, $MSE$ = 47.616, $p$ < .001, $\eta_p^2$ =.427. Again, the BIF group (M = 6.21) was outperformed by the CAMC group (M = 12.96). A medium-sized time by group interaction, $F$(2, 106) = 6.006, $MSE$ = 8.566, $p$ = .003, $\eta_p^2$ = .102, were also obtained, showing that the BIF group progressed at a slower rate than the CAMC group. The BIF group increased by 3.85 points from time point 1 to 3, while the CAMC group increased by 7.50 points. The time by group interaction effect followed a linear trend, $F$(1, 53) = 8.384, $MSE$ = 10.910, $p$ = .005, $\eta_p^2$ = .137. Thus, both participant groups displayed a linear developmental trend, and the differences between the group means increased linearly over the three measurement points (Time point 1: $M_{diff}$ = 4.56; Time point 2: $M_{diff}$ = 7.50; Time point 3: $M_{diff}$ = 8.21).

*Mental arithmetic fluency*. The mixed ANOVA revealed a large group effect, $F$(1, 53) = 50.839, $MSE$ = 0.039, $p$ < .001, $\eta_p^2$ =.490, a large time effect, $F$(2, 106) = 66.365, $MSE$ = 0.004, $p$ < .001, $\eta_p^2$ = .556, and a medium-sized time by group interaction, $F$(2, 106) = 5.909, $MSE$ = 0.004, $p$ = .004, $\eta_p^2$ = .100. The BIF group (M = 0.19) was outperformed by the CAMC group (M = 0.41). The interaction effect was due to the BIF group's mean score increasing by 0.10 while the corresponding increase for the CAMC group was 0.17 over the three measurement points. The interaction effect followed a linear trend, $F$(1, 53) = 6.863, $MSE$ = 0.005, $p$ = .011, $\eta_p^2$ = .115. Thus, the differences between the group means increased linearly over the three measurement points (Time point 1: $M_{diff}$ = 0.17; Time point 2: $M_{diff}$ = 0.24; Time point 3: $M_{diff}$ = 0.24). However, the developmental trend of the time by group interaction also revealed a small quadratic trend, $F$(1, 53) = 4.093, $MSE$ = 0.003, $p$ = .048, $\eta_p^2$ = .072. This trend was related to the CAMC group as they increased their mean score from year 1 to year 2 by 0.11, while the increase from year 2 to year 3 was only 0.06. The corresponding scores for the BIF group were 0.04 and 0.06. Thus, it is possible that that the control group was starting to reach a plateau in the development of mental arithmetic fluency.

*One-step word problem-solving*. The ANOVA showed that the BIF group's mean score (M = 5.80) was lower than the CAMC group's mean score (M = 10.81), $F$(1, 53) = 65.715, $MSE$ = 15.732, $p$ < .001, $\eta_p^2$ =.554. Also a large effect of time, $F$(2, 106) = 68.069, $MSE$ = 2.924, $p$ < .001, $\eta_p^2$ = .562, emerged on the one-step word problem-solving task, but no time by group interaction, $F$(2, 106) = 2.947, $MSE$ = 2.924, $p$ = .057, $\eta_p^2$ = .053.

*Multi-step word problem-solving*. The CAMC group (M = 4.81) performed more accurately than the BIF group (M = 1.54) on the multi-step word problem-solving task, $F$(1, 53) = 74.010, $MSE$ = 5.944, $p$ < .001, $\eta_p^2$ =.583. The ANOVA also displayed a large time effect, $F$(2, 106) = 50.225, $MSE$ = 1.534, $p$ < .001, $\eta_p^2$ = .487, and a small time by group interaction, $F$(2, 106) = 3.805, $MSE$ = 1.534, $p$ = .029, $\eta_p^2$ = .067. The time by group interaction followed a linear trend, $F$(1, 53) = 6.071, $MSE$ = 1.902, $p$ = .017, $\eta_p^2$ = .103, showing that the performance gap between the groups increased linearly over the three measure points (Time point 1: $M_{diff}$ = 2.66; Time point 2: $M_{diff}$ = 3.19; Time point 3: $M_{diff}$ = 3.95).

*Non-verbal arithmetic problem solving*. On this task, an effect of time emerged, $F(2, 106) = 20.690$, $MSE = 1.800$, $p < .001$, $\eta_p^2 = .281$, with the BIF group (M = 3.25) obtaining lower scores than the control group (M = 6.00), $F(1, 53) = 35.066$, $MSE = 8.913$, $p < .001$, $\eta_p^2 = .398$. Furthermore, a small interaction effect emerged between time and group, $F(2, 106) = 5.014$, $MSE = 1.800$, $p = .009$, $\eta_p^2 = .086$, showing that the BIF group progressed at a slower rate than the CAMC group. The BIF group increased by 0.89 points from year 1 to year 3, while the CAMC group increased by 2.39 points. The time by group interaction effect followed a linear trend, $F(1, 53) = 7.002$, $MSE = 2.220$, $p = .011$, $\eta_p^2 = .117$. Thus, both groups displayed a linear developmental trend, and the differences between the group means increased linearly over the three measurement points (Time point 1: $M_{diff} = 1.83$; Time point 2: $M_{diff} = 3.10$; Time point 3: $M_{diff} = 3.33$).

*Word reading*. The ANOVA performed on the word-reading task yielded a significant group effect, $F(1, 53) = 40.665$, $MSE = 94.335$, $p < .001$, $\eta_p^2 = .434$, as the BIF group (M = 8.94) scored lower than the CAMC group (M = 18.58). A time effect was obtained, $F(2, 106) = 119.079$, $MSE = 10.367$, $p < .001$, $\eta_p^2 = .692$, as well as a medium-sized time by group interaction, $F(2, 106) = 13.980$, $MSE = 10.367$, $p < .001$, $\eta_p^2 = .209$. The interaction effect emerged as the BIF group progressed at a slower rate than the CAMC group over the three measure points, +6.23 points, and +12.64 points, respectively. The time by group interaction effect followed a linear trend, $F(1, 53) = 21.589$, $MSE = 13.124$, $p < .001$, $\eta_p^2 = .289$, indicating that the group mean differences increased linearly across the three measurement points (Time point 1: $M_{diff} = 6.16$; Time point 2: $M_{diff} = 10.20$; Time point 3: $M_{diff} = 12.57$).

*Reading comprehension*. The BIF group (M = 11.80) was outperformed by the CAMC group (M = 19.51) on the reading comprehension task, $F(1, 53) = 54.598$, $MSE = 44.890$, $p < .001$, $\eta_p^2 = .507$. A main effect of time was obtained, $F(2, 106) = 59.851$, $MSE = 5.818$, $p < .001$, $\eta_p^2 = .530$, but no time by group interaction, $F(2, 106) = 1.045$, $MSE = 5.818$, $p = .355$, $\eta_p^2 = .019$.

### How far behind are children with BIF in their cognitive and academic development?

To address this question, the BIF children's scores on the third time point were compared to the CAMC children's scores on the second and first time points. These comparisons were performed by means of one-way ANOVAs with pooled error terms and corrected alpha-levels (1%).

*Cognitive tasks*. The ANOVAs revealed that the BIF children's mean score on the processing speed task, $F(1, 159) = 1.702$, $MSE = 1518.330$, $p > .01$, the shifting task, $F(1, 159) = 4.553$, $MSE = 1586.407$, $p > .01$, the semantic fluency task, $F(1, 159) = 5.976$, $MSE = 55.039$, $p > .01$, the phonological fluency task, $F(1, 159) = 6.629$, $MSE = 43.737$, $p > .01$, and the visual-spatial WM task, $F(1, 159) = 5.878$, $MSE = 4.211$, $p > .01$, at the third time point were comparable to the CAMC children's mean scores at the second time point.

*Academic tasks*. The BIF children's performance on the horizontal multi-digit calculation task, $F(1, 159) = 14.039$, $MSE = 5.737$, $p < .01$, the vertical multi-digit calculation task, $F(1, 159) = 17.983$, $MSE = 21.580$, $p < .01$, the mental arithmetic fluency task, $F(1, 159) = 29.084$, $MSE = 0.016$, $p < .01$, the one-step word problem-solving task, $F(1, 159) = 28.755$, $MSE = 7.193$, $p < .01$, the multi-step word problem-solving task, $F(1, 159) = 31.705$, $MSE = 3.004$, $p < .01$, the non-verbal arithmetic problem solving task, $F(1, 159) = 20.750$, $MSE = 4.171$, $p < .01$, the word reading task, $F(1, 159) = 19.981$, $MSE = 38.356$, $p < .01$, and the reading comprehension task, $F(1, 159) = 23.570$, $MSE = 18.842$, $p < .01$, at the third time point were significantly lower than the CAMC children's performances at the second time point. However, the BIF children's mean scores on the horizontal multi-digit calculation task, $F(1, 159) = 1.449$, $MSE = 5.737$, $p > .01$, the vertical multi-digit calculation task, $F(1, 159) = 0.318$, $MSE = 21.580$, $p > .01$, the mental arithmetic fluency task, $F(1, 159) = 4.292$, $MSE = 0.016$, $p > .01$, the one-step word problem-solving task, $F(1, 159) = 1.724$, $MSE = 7.193$, $p > .01$, the multi-step word problem-solving task, $F(1, 159) = 4.162$, $MSE = 3.004$, $p > .01$, the non-verbal arithmetic problem solving task, $F(1, 159) = 2.898$, $MSE = 4.171$, $p > .01$, the word reading task, $F(1, 159) = 0.002$, $MSE = 38.356$, $p > .01$, and the reading comprehension task, $F(1, 159) = 5.829$, $MSE = 18.842$, $p > .01$, at the third time point were comparable to the CAMC children's performances at the first time point.

## Discussion

The aim of this longitudinal study was to examine cognitive development and academic skill development in children with BIF, and to determine whether their academic and cognitive weaknesses are due to developmental delay or atypical development (Bennett-Gates & Zigler, 1998; Zigler & Balla, 1982). Before discussing the findings in relation to these contrasting models, the main findings will be summarized.

As predicted by both models and consistent with a number of prior studies, the children with BIF obtained lower scores compared to the CAMC group on all academic tasks (Bonifacci & Snowling, 2008; Claypool et al., 2008; Di Blasi et al., 2019; Kortteinen et al., 2009; MacMillan et al., 1998) and all cognitive tasks (Alloway, 2010; Bonifacci & Snowling, 2008; Hartman et al., 2010; Schuchardt et al., 2010; Stefanelli & Alloway, 2018). More important, the group with BIF developed at a slower rate than the CAMC group in the four arithmetic tasks; calculation (vertical), mental arithmetic fluency; multi-step word problem-solving; non-verbal arithmetic problem-solving, and the word reading task across the three measurement points. In contrast, the children with BIF progressed at the same rate as the CAMC group in all cognitive tasks.

### *Cognitive functioning in children with BIF – developmental delay or atypical developmental?*

The present findings concerning cognitive functions in children with BIF provide strong support for the developmental delay model because they displayed similar rates of cognitive development as their age-matched peers (see Schuchardt et al., 2010, 2011 for similar findings). However, their levels of cognitive performance were considerably lower than those in the CAMC group as indicated by the large group effects obtained on all cognitive tasks. Even so, the BIF children's development in relation to the different cognitive abilities appears to lag less than a year behind their age-matched peers, as their cognitive performance at time point three was comparable to the cognitive performance of their age-matched peers at time point two.

Consistent with prior studies, a large group difference was observed in the complex visual-spatial working memory task, which is assumed to tax the central executive and the visuospatial sketchpad components of the model developed by Baddeley and Hitch (0, 1974, 2010, 2018)). As well as their weakness in visual-spatial working memory, the BIF group also displayed difficulties with the executive function shifting (Trail-making), as previously found by Alloway (2010). An important and novel finding is that the children with BIF were also less efficient at retrieving semantic and phonological information from long-term memory (semantic and phonological fluency). The combined results of the visual-spatial working memory task, the trail-making task, and the semantic and phonological fluency tasks provide additional evidence that children with BIF have weaknesses in several executive functions. These weaknesses are unsurprising given that research has repeatedly found associations between executive functioning and IQ (Conway, Kane, & Engle, 2003; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008). Some researchers even argue that executive functioning is one aspect of the intelligence construct (see Ackerman, Beier, & Boyle, 2005; Jaeggi et al., 2008).

In addition to their weaknesses in executive functioning, the present study corroborates prior studies showing that children with BIF have a weakness in processing speed (Bonifacci & Snowling, 2008; Napora-Nulton, 2003). Basic processing speed, according to some researchers, is a fundamental cognitive resource in relation to children's general cognitive development, and a critical aspect of intelligence (e.g., Anderson, 1992; Jensen, 1998; Nettlebeck, 1987).

All in all, the present longitudinal findings demonstrate that children with BIF are marked by a number of persistent cognitive weaknesses in areas that are critical for acquiring and developing academic skills (Christopher et al., 2012: Träff, Olsson, Skagerlund, & Östergren, 2020).

### *Academic skills in children with BIF – developmental delay or atypical developmental?*

The present study provides a number of novel and important findings concerning arithmetic skills in children with BIF. Consistent with Kortteinen et al. (2009) and Stefanelli and Alloway (2018), the BIF children displayed lower multi-digit calculation skills, both when the problems were presented horizontally and when they were presented vertically. The results of the two arithmetic word problem-solving tasks corroborate Stefanelli and Alloway (2018) finding that mathematical problem-solving/reasoning represents another major challenge for children with BIF. Furthermore, the severe arithmetic problem-solving difficulties of children with BIF appear not to be restricted to word problems, as they also showed serious difficulties when performing the non-verbal arithmetic problem-solving task.

The BIF children's severe difficulties with multi-digit calculation and arithmetic problem-solving are logical because IQ, especially logical reasoning, is a key cognitive resource for acquiring these two aspects of arithmetic (see Träff et al., 2020). However, the children with BIF also displayed serious difficulties when performing the simpler mental arithmetic fluency task which in the present age group should not draw heavily on logical reasoning ability (Geary, Nicholas, Li, & Sun, 2017; Lee & Bull, 2016).

Taken together, the results of the arithmetic tasks provide clear evidence that children with BIF have severe difficulties with three fundamental aspects of arithmetic: arithmetic fluency, multi-digit calculation and arithmetic problem-solving. Furthermore, findings observed in relation to multi-digit calculation, mental arithmetic fluency, multi-step word problem-solving, and non-verbal arithmetic problem-solving indicate that the children with BIF progressed at somewhat slower rates than the CAMC group. However, it should be noted that the group by time interaction effect sizes were small (6.7%; 8.6%) or just above small (10.2%; 10.0%), that all developmental trends were linear, and that all group by time interaction effects were linear suggesting that both groups followed a similar linear developmental trend. These findings are essentially in line with the developmental delay model because the children with BIF displayed similar developmental growth trends as the CAMC group. The fact that the BIF children exhibited a slightly slower rate of development on some tasks suggests that their developmental path is quantitatively but not qualitatively different from the age-matched typical children's developmental path. However, it cannot be ruled out that the BIF children's slightly slower growth rates might reflect an atypical developmental disposition that eventually results into qualitatively different developmental paths.

Akin to arithmetic, the present results indicate that reading is a problematic academic domain for children with BIF. The BIF children's poor word reading and reading comprehension skills corresponds with the findings of prior studies, which show weak word reading and reading comprehension abilities in this population (Bonifacci & Snowling, 2008; Claypool et al., 2008; Di Blasi et al., 2019; Kortteinen et al., 2009).

A novel and more important result is that the BIF children displayed a much slower rate of word-reading development than the CAMC children. This result corroborates and extends Di Blasi et al.'s (2019) cross-sectional finding that slowness in real-word reading was particularly marked in later grades. The way in which the present BIF children fall behind in word-reading fluency is in line with Di Blasi et al.'s (2019) suggestion that these children have difficulties in developing and utilizing an orthographic-lexical strategy when reading real words. This might in turn be due to their inability to develop orthographic lexical representations. This account is reasonable given the design of the present word-reading task (see the method section) which emphasized the use of an orthographic-lexical strategy. Although, the children with BIF displayed a much slower rate of word-reading development, they exhibited a linear developmental trend, as did the CAMC children.

Contrary to reading comprehension, the results regarding word-reading are less straightforward in relation to the two models, as different aspects of the results support different models. The fact that the BIF children exhibited the same developmental trend as the CAMC children is consistent with the developmental delay model. In contrast, their considerable slower, and not just slightly slower, developmental growth rate is more in line with the atypical developmental model. Thus, it is possible that the children with BIF suffer from a neuro-cognitive deficit that impair their ability to develop orthographic lexical representations which is required in order to use an orthographic-lexical reading strategy (cf. Di Blasi et al., 2019). This deficit could eventually entail that the BIF children exhibit atypical reading developmental paths.

This study provides important findings showing that the arithmetic and reading skills of children with BIF at time point three matched the skills of their age-matched peers at time point one and were lower than their age-matched peers' skills at time point two. These longitudinal findings constitute important evidence that children with BIF suffer from a two-year academic developmental lag in relation to arithmetic and reading skills. As their cognitive developmental lag is less than one year, it appears that their teachers may not be managing to fully take into consideration their cognitive weaknesses during mathematics and reading classes.

## Limitations section

One methodological limitation of this study, is the relatively low number of participants, leading to issues of generalizability of the results. Thus, future studies should replicate and extend the present study by using larger samples. They should also use four measurement points, which would allow for other statistical analyses (e.g., growth curve modeling) to be used. Another limitation is that a number of theoretically interesting and critical cognitive measures were not included in this study. By including measures of verbal working memory, inhibition control, and non-word reading, a more comprehensive picture of cognitive and academic development in children with BIF could be obtained. Thus, future longitudinal studies should also feature these measures in the test battery, if possible.

## Conclusions

The present longitudinal study provides clear evidence in support of the developmental delay model because the children with BIF displayed similar cognitive developmental growth and trends as their age-matched peers. They also demonstrated similar developmental trends as their age-matched peers on the academic tasks, even though they progressed at a slower rate on five academic tasks. Children with BIF appear to experience less than one-year cognitive developmental lag, while their academic developmental lag amount to two years. Thus, it is possible that the BIF children's persistent cognitive weaknesses are not fully considered at school, when they struggle to acquire age-appropriate arithmetic and reading skills.

## Educational implications

The main finding from an educational point of view is that the BIF children experienced less than one-year cognitive developmental lag, while they experienced a two-year academic developmental lag. Prior research on 9–10 years old children with BIF that has included mental-age matched controls has observed that the BIF children show a mental/cognitive developmental lag of three years (Hasselhorn & Mäehler, 2007; Schuchardt et al., 2010, 2011). In the present study, a much smaller cognitive developmental lag of one year was observed. However, the two-year academic developmental lag displayed by the children with BIF is closer to the three-year developmental lag that have been found in prior studies.

The present findings are interesting in view of the model of school learning (Carroll, 1989). The BIF children's persistent cognitive weaknesses suggest that they have difficulties with the factors; aptitude and ability to understand instruction, which emphasize the need to adapt the teaching to these children's learning potential. That is, they must be provided extra teaching time as well as individually tailored high-quality instructions that matches their aptitude and ability to understand instruction and also may enhance their motivation for learning.

According to the model (Carroll, 1989), are high-quality instructions characterized by clearly stated learning objectives, careful organization and order of each step in the teaching process, and all teaching materials must be well-known to the child. However, the observed lack of parallel between cognitive and academic developmental indicates that the children with BIF have not fully receive the required individually tailored high-quality instructions and training in basic arithmetic and reading skills.

The academic skill examined in the present study are considered important prerequisites for future school success (Cirino, Tolar, Fuchs, & Huston-Warren, 2016; Duncan et al., 2007; Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010; Träff et al., 2020). Thus, if children with BIF do not receive the necessary help in school they are at risk of encounter even more severe future academic problems. They may also eventually encounter many of the social, economic and mental health problems reported by Peltopuro et al. (2014).

## Disclosure statement

The authors report no conflict of interest.

## Funding

This work was supported by the Swedish Council for Working Life and Social Research under Grant 2010-0078

## Ethics

This research project has been approved by the Regional Ethics Committee in Linköping, Sweden (Protocol Number 2011/58-31)

## Data Availability Statement

The main and corresponding author has full access to all the data used in this study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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