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The Role of Executive Functions for Dyadic Literacy Learning in Kindergarten

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ABSTRACT
The current study used a dyadic and coconstructive approach to examine how to embed exercises that support executive functioning into early literacy instruction to empower its effects. Using a randomized controlled trial design with 100 children, we examined the effects of dyadic activities in which children scaffolded each other's learning and behavior through structured questioning procedures. This group was contrasted with a control group whose dyads observed each other while working with the same literacy exercises and with a business-as-usual control group. *Research Findings*: Results showed that the experimental group showed greater progress in letter knowledge. Further analyses indicated that these results were mainly driven by children with higher levels of executive functions. *Practice or Policy*: These results suggest that young children are able to regulate each other's learning behavior during preacademic exercises in dyadic contexts but may need more external control from a teacher when their executive function levels are low.

Executive functions (EF) have been shown to be essential for effective early academic instruction because they enhance learning and behavior. Higher EF manifest in better learning behavior, like better planning skills (Gathercole et al., 2007) and better problem solving (Van de Sande, Segers, & Verhoeven, 2015; Zelazo & Frye, 1997). Supporting EF can thus help young children to overcome learning difficulties and benefit more from academic instruction (Alloway & Alloway, 2010; Cartwright, 2012; Holmes, Gathercole, & Dunning, 2009; McClelland & Morrison, 2003; Van de Sande, Segers, & Verhoeven, 2016). A study by Diamond, Barnett, Thomas, and Munro (2007) provided first insights into how to support these capacities to help children in their academic development through embedded dyadic activities in the early curriculum: with scaffolding, monitoring, mediators, and role play. Being exploratory in nature, the current study examined to what extent such integrated EF activities have an additional effect on a dyadic intervention aimed at improving early literacy. Furthermore, we examined whether the effectiveness varied as a function of different EF levels of the children.

EF refer to a family of cognitive functions—inhibition, working memory, and cognitive flexibility—that control cognitive and behavioral processes and regulate them when necessary. Thus, these functions facilitate complex information processes and enable more engaged and efficient learning behavior during academic instruction from the early years of education onward (Alloway & Alloway, 2010; Diamond, 2013; McClelland et al., 2007). The strong cognitive interrelatedness between the development of EF and early academic abilities, like literacy, was shown by a recent review of neurocognitive studies (Ashkenazi, Black, Abrams, Hoeft, & Menon, 2013). Regarding early development of literacy, EF enable updating and flexible switching between visual, verbal,

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and spatial codes and help children to stay on task (Foy & Mann, 2013). Thus, they are an important precursor to set the preliteracy basis in phonological awareness and letter knowledge that enables more profound literacy development over time (Segers, Damhuis, Van de Sande, & Verhoeven, 2016; Van de Sande, Segers, & Verhoeven, in press).

It seems promising that helping young children to engage their EF will let them benefit more from preliteracy instruction. But the optimal way to provide this support is far from clear (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008). One approach is to train a single EF and to examine whether this transfers to better literacy development. However, such transfer effects have rarely been found (Bierman et al., 2008; Wass, 2015), likely because these trainings are too domain general. This was also evidenced by Cartwright (2002), who showed that a domain-general classification training to strengthen children's (7- to 11-year-olds') cognitive flexibility did not produce any effects on children's reading comprehension, whereas a domain-specific training that focused on the simultaneous classification of sounds and meanings to printed words did show effects. Similar effects of domain-specific EF trainings on early reading comprehension were evidenced for the use of reading strategies while thinking aloud (Gnaedinger, Hund, & Hesson-McInnis, 2016) in younger English-speaking children who were in first or second grade (Cartwright, Marshall, Dandy, & Isaac, 2010) and among children in a more transparent language than English (Colé, Duncan, & Blaye, 2014). Regarding interventions for preliteracy skills in kindergarten, to our knowledge no domain-specific and domain-general trainings have been compared yet, but Kroesbergen, van 't Noordende, and Kolkman (2014) investigated the effects of domain-general and domain-specific early numeracy trainings. They contrasted a domain-general working memory training with a specific working memory and numeracy training and a control group and found that kindergartners in the domain-specific training improved more on counting skills than those in the control group. Again, no transfer effects to numeracy development were found for the domain-general group.

In line with this domain-specific effect, focusing on EF alone might not be as beneficial for academic progress as supporting EF integral in instruction in the classroom (Wass, 2015). Recent insights suggest that constant and integral exercises with EF function as a hallmark for deep learning of early scholastic activities (e.g., Diamond, 2013). In such an embedded approach, children's learning becomes more effective, resulting in greater academic benefits (McClelland et al., 2007; Raver et al., 2011). Indeed, in an intervention study that related EF to progress from a preliteracy intervention, Kegel, Van der Kooy-Hofland, and Bus (2009) showed that kindergartners with lower EF had more off-task behavior and less problem solving, which resulted in lower learning gains from literacy software. A follow-up study evidenced that kindergartners low in EF benefitted more from the training when an integrated tutor reduced their executive load through scaffolding (Kegel & Bus, 2012). Furthermore, Van de Sande et al. (2016) showed that a combined stop-and-think procedure that used speech to structure thoughts as a form of EF support helped kindergartners to better stay on task and to benefit more from a short computer preliteracy intervention. These results show that EF help children to benefit from interventions in which they can boost their preliteracy skills in brief and relatively teacher-free interventions.

Dyadic learning can also provide such an autonomous learning context. It is a context that makes use of the most common naturalistic playful setting in kindergarten, in which children already play together and strengthen their own learning through interactions with their peers. During dyadic learning, children can help each other activate their EF through imitation and internalization via scaffolding, monitoring, and role play. In order to explain to each other what they are doing, they need to think before acting (i.e., stop and think) and formulate their thoughts well to explain them to their peer. Such other-regulatory activities thus help to structure the mind and promote task-focused behavior. Over time such other-regulation can be internalized to self-regulatory thoughts (Diamond et al., 2007; King, Staffieri, & Adelgais, 1998; Skibbe, Brophy-Herb, Philips, Day, & Connor, 2012; Vygotsky, 1978). These activities can be fostered through dyadic tutoring (Fernyhough & Fradley, 2005; Mathes, Torgesen, Allen, & Allor, 2001). In dyadic tutoring, children reinforce and coconstruct each other's learning by explaining and reflecting on tasks (King et al., 1998; Volpe, Young, Piana, & Zaslofsky, 2012). Moreover, they have to inhibit the tendency to think before acting, wait for their turn, and reflect on tasks. Dyadic tutoring can thus socially support children in keeping their EF engaged throughout the whole learning cycle of planning, performing, and reflecting (Perels, Merget-Kullman, Wende, Schmitz, & Buchbinder, 2009; Roscoe & Chi, 2007).

Young children can also benefit from dyadic tutoring but need more structured routines (King et al., 1998; Palmer & Wehmeyer, 2003). Diamond et al. (2007) tested a curriculum-wide intervention for preschoolers with an emphasis on EF for behavioral and preliteracy skills: Tools of the Mind (Bodrova & Leong, 2007). An important part of this curriculum was mutual dyadic learning, in which visual mediators, other-regulation, and role play activated children's reciprocal regulation. The mediators functioned as a reminder for the children to stay in their role, which resulted in stronger and longer engagement in peer storybook reading. A follow-up study by Barnett et al. (2008) included both pre- and posttests but could not establish stronger preliteracy progress in the Tools group. The questions thus remain what the causal effects of such dyadic scaffolding procedures are and also whether they can be fruitful in short interventions specifically aimed at literacy.

One short dyadic preliteracy intervention showed positive effects on phonological and decoding skills (Fuchs & Fuchs, 2005). Although not explicitly addressing EF, dyads assisted each other through structured step-by-step questioning after modeling by teachers. This group progressed more in phonological awareness compared to a business-as-usual control group. However, the teacher modeling involved phonological exercises, whereas the dyadic context targeted decoding. Moreover, similar effects on phonological awareness and letter knowledge were found for a teacher-mediated training when both of these groups were compared with a control group. It remains uncertain whether children were able to benefit from the dyadic scaffolding or benefitted most from the external control and guidance by the teacher.

These studies, to our knowledge, are the only ones that exist on dyadic learning to enhance preliteracy skills. Much information is lacking. For example, dyadic groups were only contrasted with control groups of individual children, which makes it difficult to discriminate between effects caused by the dyadic setting and mere training effects. Moreover, studies on dyadic literacy learning generally required (older) children to copy exactly what teachers modeled beforehand and matched a high-performing tutor with a lower performing tutee (Roscoe & Chi, 2007). In such dyadic learning, only half of the children will benefit.

The present exploratory study therefore examined the impact of EF support through dyadic learning that was embedded in preliteracy exercises. We designed tutoring activities that supported children's EF and embedded them in a short intervention that targeted phonological and letter skills. Peers with approximately same-ability preliteracy skills scaffolded each other's strategies, problem solving, and task-focused behavior through mediators and questioning routines. These routines were structured along the learning cycle of planning, performing, and reflecting and were designed to be applicable to new stimuli as well. We contrasted the preliteracy gains of this dyadic learning group with EF-supporting activities (EF-DL group) with those of an observing dyadic learning control group (O-DL group) and a business-as-usual control group. Furthermore, we examined whether different effects were found for different levels of EF.

We addressed the following research questions:

(1) *What are the effects of a dyadic preliteracy intervention with embedded EF-supporting activities?* Children in both intervention groups were expected to progress more in phonological awareness and letter knowledge compared to the business-as-usual control group. Moreover, children in the EF-DL group were expected to show higher preliteracy gains than those in the O-DL group.
(2) *To what extent do EF moderate the gains in preliteracy skills in the two intervention conditions?* We expected that, especially for children with higher EF, learning gains would be greater in the EF-DL group compared to the O-DL group.

Method

Participants

A total of 102 children participated, 42 girls and 60 boys. These children came from 11 kindergarten classrooms (three schools) and on average from middle to middle-high socioeconomic backgrounds (M = 5.31, SD = 1.00, range = 2–7). All children spoke Dutch as their first language. Parents gave active written consent for participation and video recordings. The children were approximately 5.5 years old (M = 5;7, SD = 0;4, range = 5;1–7;1) and in their second year of kindergarten.

Two participants dropped out of the study at pretest, one because of social phobia that led to an inability to speak to the experimenter and one because of a recent traumatic event.

Design

A randomized pretest–intervention–posttest design was used to examine the impact of the intervention. Multiple steps were taken to form dyads and randomly assign them to a group. In classrooms with an odd number of children, one child was first randomly assigned to the control group. Then we rank-ordered children within each classroom on their phonological awareness level and matched every third child on the list so that children would not be too close or far from each other's level. Next, dyads were assigned to one of three groups: one in which EF activities were embedded into the preliteracy intervention through structured dyadic learning with scaffolding and role play (EF-DL), one (control) dyadic intervention group in which children performed the same preliteracy intervention and only observed each other (O-DL), and one group that followed the regular school curriculum (control). Children in the intervention groups worked with the preliteracy games twice a week during 20-min sessions over five successive weeks, except for 1 week of holiday in between. Every dyad was randomly assigned to a group using an automatic randomization function.

Materials

Preliteracy program

We used a combined phonological awareness and letter knowledge program because interventions with instruction in letters and their underlying phonological structure have been shown to be more effective than instruction in phonological or letter knowledge alone (Hatcher, Hulme, & Ellis, 1994). We adopted an existing successful program to allow a valid context in which the self-designed EF support could be embedded. The *Leeslijn* (Literacy Line; De Baar (1992)) is a broad set of coherent (pre)literacy games designed by a team of education professionals. Teachers and clinicians use it for occasional extra practice for children in regular and special education. All games consist of plastic cards that present words, pictures, and/or letters. We selected games that targeted phonological awareness, word recognition, and letter knowledge. This resulted in 10 games of four different types: rhyming, segmentation, blending, and letter bingo. These 10 games were adapted slightly to fit the purpose of the current study. For example, the stimuli of each game were divided into two equal sets (hereafter "games") so that each child could play with a new version of that game in every session. Thus, in total we used 20 games of four types. The children had never seen the games before.

Rhyming game. Children matched cards that represented rhyming words. There were two types of cards: picture-word cards (e.g., a picture of the sun with the written word *sun* below the picture) and word-only cards. Children first had to recognize the written word on a picture-word card and match that card with the corresponding word-only card. Then they searched for the picture-word card that rhymed and connected it to the target word, again followed by the matching word-only card. There were four games, each of which consisted of four rhyming sets.

Phoneme segmentation game. Children saw a picture-letter card and connected two other picture-only cards that represented words starting with the same phoneme. Four games were included. Each part included three different phonemes divided over nine cards (e.g., *t, r, n: tas – ton – tak; rok – raam – riem; noot – net – neus*).

Phoneme blending game. Children selected three phoneme cards with matching pictures and had to place them in the order of the representing word. There were six games that together covered most available phonemes in Dutch. Each game on average included two vowels and eight consonants that together formed four words (e.g., *o, u; p, l, h, k, b, n, z, f; bot; vos; juf; bus*).

Letter bingo. Children threw a letter die and searched for the letter in a bunch of letter cards. This card was placed on a board with 12 pictures representing words that included the letters from that game (e.g., *m, aa [oo]*, and *n* could all be placed on a *maan [moon]* picture). Four games were provided that included a die with four vowels or six consonants.

EF-supporting activities

The EF-DL group performed the games with embedded dyadic EF-supporting activities through a combination of features that have been shown to enhance academic achievement. These features were scaffolding, monitoring, formulating strategies, stop and think, and role play (Bodrova & Leong, 2007; Diamond et al., 2007; Fuchs & Fuchs, 2005; King et al., 1998; Van de Sande et al., 2016).

There were two roles that the children played alternately within each session: schoolchild and schoolteacher (see Table 1). In the role of schoolchild, children initiated the game actions and explained step by step what they were doing. In the schoolteacher role, children scaffolded the task behavior of the schoolchild through protocolled questions along the learning cycle. In the planning phase, they helped the schoolchild to remember the goals and task demands. In the performance phase, the schoolteacher helped the schoolchild to define strategies via step-by-step questions. In the reflection phase, they reflected on the game performance of the schoolchild. Furthermore, the schoolteacher monitored the game when necessary, for example, when his or her peer stagnated in the game, had questions, or was distracted. The scaffolding protocols generally fit every game to enable internalization, but some questions during the performance phase were tailored to fit specific game demands.

Mediators were designed to help children remember their role. These mediators were placed in photo frames (6 × 8 in) so that children could place their visualized role in front of them. The role of schoolteacher was visualized through a funny-looking male or female teacher (see Figure 1). This picture was accompanied by three pictures that each visualized one step in the learning cycle. Because the children performed the intervention at school, we used a mirror as a playful mediator for the role of schoolchild.

Treatment fidelity

To check the treatment fidelity of the intervention, we annotated procedural aspects of both intervention groups. A strict observation protocol was designed for the purposes of the current study and was based on previous empirically observed behaviors in interventions that focused on EF

Table 1. Example of a scaffolding procedure: Letter bingo game.

Schoolteacher Scaffold	Schoolchild Response
"Okay, let's throw the die."	[Throws the die]
"Which letter is that?"	"That is the [names letter]." [Picks corresponding letter card]
"In which of these words can you find the letter [item]?"	"In [names one of the words on the bingo card]." [Points to the corresponding picture]
"Where in that word can you find the letter [. . .]?"	"At the [beginning/middle/end] of the word."
"Well done, you can now put the letter card on that word."	[Puts letter card on the corresponding word on the bingo card]

Figure 1. Mediators for the role of schoolteacher. The teacher was a reminder of the children's role. The boxes on the right visualize the different steps (from top to bottom) in the questioning routines: orientation, performance, and reflection.

during kindergarten interventions (e.g., De Koning-Veenstra, Timmerman, Van Geert, & Van Der Meulen, 2014; Kegel et al., 2009; Van de Sande et al., 2016). The annotation categories were off-task talking (i.e., talking that was irrelevant to the task at hand), off-task behaviors (e.g., looking away), number of literacy games played per session, mistakes (corrected for number of items), questions asked to the experimenter, and number of times the experimenter had to intervene to keep children engaged.

The observations were done by two independent observers who were intensively trained by the first author. Sessions 4 and 5 were selected for these observations. Thus, children would likely have had a similar amount of repeated play compared to other classroom instruction and would have had similar difficulty at times keeping engaged in the task. Every child was randomly selected for observations during the camera recordings of one of these two sessions, balanced across conditions. All children with written consent for camera recordings were observed (n = 50).

A random selection of 16% was observed by both observers. Two-way random intraclass correlation coefficients (ICCs) with consistency calculations all indicated good to high interrater reliability: procedural hints by experimenter: ICC = .97, $p < .001$; games played: ICC = 1.00, $p < .001$; off-task talking: ICC = .83, $p = .02$; off-task behaviors: ICC = .75, $p = .045$; mistakes: ICC = .94, $p = .001$. The ICC for questions asked to the experimenter was too low ($p = .24$) and was therefore omitted from the analysis.

Intervention procedure

Two dyads participated in each session. These four children gathered around a table with two trained undergraduates in educational science, who explained the preliteracy game of that day to them. Children were actively involved in the instruction through open questions and by having to repeat the game rules. Then the two games of the day were explained and modeled. After the modeling, the experimenters showed a large card with the pictures of the games and checked whether the children knew all of the words that the pictures represented. Instruction about the games took approximately 5 min.

In the EF-DL group, this instruction was followed by instruction about the scaffolding procedure related to the roles of schoolchild and schoolteacher. Instructors rehearsed the overall scaffolding procedure and game-specific adaptations of the overall scaffolding procedures with the children. This was followed by a modeled explanation in which the two experimenters played the preliteracy game together, one fixed teacher per role (i.e., schoolchild or schoolteacher) This was done in an interactive session in which children were asked to prompt the scaffolding questions that the schoolteacher should ask and prompt the answers to the preliteracy game (practice stimuli that were not included in the actual games) that the schoolchild should give.

If there were no further questions, the dyads sat at two desks with space in between. Peers sat next to each other so both children could look at the cards and mediators. There were four blocks within each session: two different games, 5 min per game. The games and types increased in difficulty over the course of the intervention, with one type per session.

Experimenters were intensively trained beforehand. They received a booklet with information about the literacy intervention (games, order of games, instruction to give) and EF-supporting activities (i.e., the mediators and procedural scripts for the roles of schoolteacher and schoolchild). After studying them independently, they participated in a collaborative training session in which the booklet was explained and the instruction that experimenters would give to the children was thoroughly practiced so that all children would receive the same instruction about the games, role play, and how to respond to children's questions. Then role play was performed in which all experimenters exercised both roles. Then questions were answered and the experimenters discussed which role they would represent in every session at the school. That is, every dyad had one fixed experimenter to monitor the children when necessary, through a strict protocol (i.e., two experimenters per school). Experimenters always represented the same role during the role-play modeling. Experimenters sat as out of sight as much as possible and at a right angle to one of the peers. In the EF-DL group this was always the schoolteacher's side, so that—only if strictly necessary—the experimenter could whisper in the schoolteacher's ear, for example, when the schoolchild asked a question about a stimulus that was unknown to the schoolteacher. The schoolchild always interacted with the schoolteacher only. To keep the intervention groups as comparable as possible, game performance was checked in the O-DL group as well. If children in the O-DL group finished the game, the experimenter corrected when necessary. No verbal response was given to maintain the observational nature of this group.

Measures

Executive functions

We assessed EF both on the level of information processing (i.e., cognitive control, attentional control) and on the level of behavior (i.e., action control, also called *behavioral inhibition*) using one computerized task for each level: Flanker Fish and Hearts & Flowers (Diamond, 2013; see also Van de Sande, Segers, & Verhoeven, 2013). Flanker Fish demanded inhibition, working memory, and cognitive flexibility to control attentional processing because children had to pay special attention to some features of the stimuli while inhibiting others and had to flexibly switch between game rules (Jäger, Schmidt, Conzelmann, & Roebers, 2014; Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2012; Rueda, Posner, & Rothbart, 2005). The Hearts & Flowers task assessed behavioral control. This task evoked a behavioral response of pressing a button that children had to inhibit and replace with a less salient response (Davidson, Amso, Anderson, & Diamond, 2006; Diamond et al., 2007). In both tasks, stimuli appeared on the right or left side of the computer screen and the children had to press one of two marked buttons on the keyboard according to the game rules. Both tasks had three blocks with different game rules. All items had a restricted presentation time: 2,000 ms for Flanker Fish and 1,500 ms for Hearts & Flowers. Items responded to in less than 200 ms were deleted because of the high risk of inhibitory failures (see Shing, Lindenberger, Diamond, Li, & Davidson, 2010). This resulted in the removal of 19.45% for Flanker Fish and 2.67% for Hearts & Flowers. All other stimuli that were correctly responded to within the allocated time frame were assigned 1 point.

Flanker Fish. Hungry fish had to be fed by pressing a button on the side that the hungry fish were facing. The middle fish was generally accompanied by five other fish that together could appear in three combinations. Either the middle fish swam on the opposite side of the flanker fish, all fish swam to the same side, or the stimulus fish swam alone. In the first block, the fish were blue and the hungry fish was in the middle. Children thus had to inhibit their tendency to pay attention to the flanker fish. In the second block, the fish were pink and the hungry fish were in the flankers. In the third block, blue and pink fish appeared by turns. There were 16 items in the first and second blocks and 44 items in the third block (Cronbach's α = .84).

Hearts & Flowers. A heart or flower appeared on the left or right side. In the first block, children saw hearts and had to press the button on the same side as the heart appeared. This block was removed from the analysis because of ceiling effects (M = 15.02, SD = 1.88). The second block included only flower trials. Children had to press the opposite button. In the third block, hearts and flowers were alternated. There were 14 items in the first and second blocks and 32 items in the third block (Cronbach's α for Blocks 2 and 3 = .87).

Aggregated EF measures. The z scores of the five blocks of the two tasks were included in a principal component analysis using oblimin rotation to allow the tasks to correlate. Two distinct factors were revealed. Factor 1 showed moderate to high loadings (.58–.78) on the items from the Flanker Fish task and explained 46.03% of the variance. Factor 2 showed high loadings (.85–.92) on the items from the Hearts & Flowers task and explained 18.89% of the variance in children's response on this task. Therefore, these tasks were analyzed as separate EF measures. The sum of scores per subtask was used for the analyses.

Preliteracy skills

Phonological awareness. The following tasks from the computerized Screeningsinstrument Beginnende Geletterdheid (Screening Instrument for Emerging Literacy) were assessed: rhyming, segmentation, blending, and deletion. Taken together, these tasks measure different aspects of children's early phonological awareness (Vloedgraven, Keuning, & Verhoeven, 2009; Vloedgraven & Verhoeven, 2007). Children saw pictures of stimuli and heard an accompanying word through the speakers. Children selected the answers using a computer mouse. Each task had 15 high-frequency monosyllabic items (Schrooten & Vermeer, 1994). In the rhyming task, the children were asked to select the response alternative that rhymed with the auditorily presented word. In the phoneme identification task, the target word was presented in its individual phonemes and the children were asked to indicate which of three alternatives on the computer screen corresponded to it. In the phoneme blending task, the children were asked to select the response alternative that began with the same phoneme as the one in the target word. In the phoneme deletion task, the children were asked to indicate the alternative from which a phoneme was deleted in the target item, resulting in another existing word (Cronbach's α >.90; Vloedgraven & Verhoeven, 2007).

Analysis of aggregated phonological awareness measures. A principal component analysis with oblimin rotation revealed a single underlying factor (phonological awareness) and explained 64.17% of the variance in children's responses on the four subtasks. The component loadings ranged from .75 to .84. The sum of the scores per subtask was used for the analyses.

Letter knowledge

Children were shown a card on which all 34 Dutch graphemes (including digraphs) were presented in three columns. All letters that were produced correctly received a score of 1 (Cronbach's α = .93; Verhoeven, 1995).

Nonverbal intelligence

Nonverbal intelligence was assessed with Raven's Colored Progressive Matrices (Raven, 1956). This task consisted of 36 items divided in three parts that increased in difficulty. Children had to complete patterns with small missing pieces by selecting one out of six pieces that were presented below the item. Overall raw scores were used for the analyses (Cronbach's α = .90; Van Bon, 1986).

Parental education level

We assessed the education level of the parent(s) as an indication of socioeconomic status on a scale from 1 (*no education*) to 7 (*university*). Average scores of both parents, or single scores if necessary, were used for the analyses.

Measurement procedure

Children were assessed directly before and after the intervention period. Testing was divided into two sessions of approximately 15 min: first the Flanker Fish and Hearts & Flowers and letter tasks, then the phonological awareness tasks. Nonverbal reasoning was assessed individually during the intervention period.

Results

Descriptive statistics and correlational analyses

Descriptive statistics for background measures, cognitive measures, and experimental measures at pretest are shown in Table 2. There were no differences among the three groups on cognitive and background measures (analysis of variance [ANOVA]). Moreover, the large standard deviations indicated a heterogeneous sample. Table 3 depicts the average pretest and posttest scores per group.

Table 4 shows the correlations between the measures at pretest. Because nonverbal intelligence correlated with preliteracy and EF, we controlled for this variable in all analyses. In none of the analyses were significant effects of this background measure found.

Table 2. Means (*SD*) for experimental and background variables for the control, O-DL, and EF-DL groups.

Variable	Control (n = 34)	O-DL (n = 32)	EF-DL (n = 34)	F(2, 88–97)
Phonological awareness	37.82 (10.96)	40.38 (8.43)	39.29 (8.09)	0.63
Letter knowledge	13.18 (9.07)	12.97 (7.57)	11.74 (7.20)	0.32
EF: Flanker Fish	46.88 (10.55)	48.81 (9.67)	50.12 (8.68)	0.96
EF: Hearts & Flowers	32.85 (8.15)	32.81 (7.17)	32.18 (7.26)	0.09
Age (in months)	69.18 (4.76)	64.44 (14.28)	68.42 (4.85)	2.53
Parental education level	5.25 (1.00)	5.53 (0.75)	5.16 (1.21)	1.15
Nonverbal intelligence	22.06 (4.84)	22.38 (4.38)	21.97 (3.90)	0.08

Note. No between-groups differences at $p < .05$ (analysis of variance) for any measure in the table. O-DL = observing dyadic learning group; EF-DL = EF-supporting dyadic learning group; EF = executive functions.

Table 3. Means (*SD*) for pretest and posttest measures for the three groups.

	Control		O-DL		EF-DL	
Variable (Min–Max)	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Phonological awareness (60)	37.82 (10.96)	42.32 (9.50)	40.38 (8.43)	44.16 (8.62)	39.29 (8.09)	43.91 (7.86)
Rhyming (15)	11.74 (2.77)	12.94 (2.35)	12.34 (2.04)	13.00 (2.26)	12.35 (2.15)	13.24 (1.94)
Phoneme identification (15)	9.79 (4.28)	11.56 (3.58)	10.13 (3.77)	11.78 (3.38)	10.21 (3.40)	11.76 (3.13)
Phoneme blending (15)	11.00 (3.84)	12.12 (3.98)	11.78 (3.53)	12.72 (3.13)	11.50 (3.21)	12.65 (3.15)
Phoneme deletion (15)	5.29 (2.29)	5.71 (2.49)	6.13 (1.91)	6.66 (2.36)	5.24 (2.36)	6.26 (2.81)
Letter knowledge (32)	13.18 (9.07)	16.71 (9.42)	12.97 (7.57)	17.75 (7.43)	11.74 (7.20)	17.76 (7.41)

Note. No between-groups differences at $p < .05$ (analysis of variance) for any measure in the table. O-DL = observing dyadic learning group; EF-DL = executive functions–supporting dyadic learning group.

Table 4. Correlations between measures of preliteracy skills, EF, and control variables at pretest ($N = 100$).

Variable	1	2	3	4	5	6	7
1. Phonological awareness	—						
2. Letter knowledge	.670**	—					
3. EF: Flanker Fish	.199*	.121	—				
4. EF: Hearts & Flowers	.172	.222*	.416**	—			
5. Age	.060	.060	.198	.096	—		
6. Parental education level	.008	.146	.069	.062	−.024	—	
7. Nonverbal intelligence	.390**	.387**	.504**	.434**	.180	.075	—

Note. EF = executive functions.
$^*p < .05$. $^{**}p < .01$.

Effects on preliteracy skills

We first examined the effects of the preliteracy intervention and how the embedded EF-supporting activities strengthened its learning effects. Repeated measures ANOVAs were undertaken with time (pretest, posttest) as the within-subjects factor and group (EF-DL, O-DL, control; $N = 100$) as the between-subjects factor.

For phonological awareness, there was a main effect of time but no effect of group: time, $F(1, 96) = 5.22$, $p = .02$, $\eta^2 = .05$, power = .62; group, $F < 1$. For letter knowledge, we found a main effect of time and a significant interaction effect of group: time, $F(1, 96) = 9.39$, $p = .003$, $\eta_p^2 = .09$, observed power = .86; group, $F(2, 96) = 3.14$, $p = .048$, $\eta_p^2 = .06$, observed power = .59, 95% confidence intervals (CIs) [12.51, 17.47], [12.64, 17.76], [12.38, 17.34].

Further analysis of the learning effect through Bonferroni post hoc analysis showed that the interaction was caused by the EF-DL group making more progress than the control group ($p = .041$,

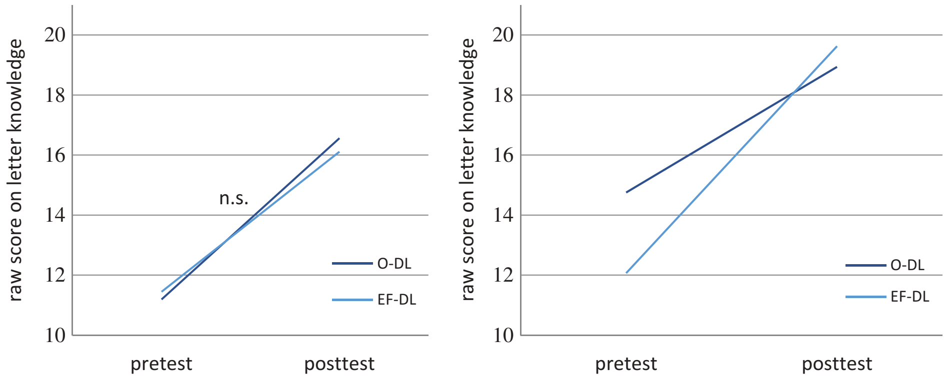

Figure 2. Differential effects for learning gains in letter knowledge for children with lower (left) and higher (right) levels of EF. No differences were found in pretest scores for the contrasted groups (*p*s = .30–.92). EF = executive functions; EF-DL = EF-supporting dyadic learning group; O-DL = observing dyadic learning group.

CI [–4.92, –0.079]). Treatment fidelity analyses showed that children in the EF-DL group played fewer games and had more procedural hints, but these measures did not correlate with the learning effect ($p > .67$): games, $t(30.33) = 8.50$, $p < .001$, observed power = 1.00, 95% CI [4.53, 7.79]; procedural hints, $t(48) = 2.42$, $p < .05$, observed power = .73, 95% CI [–2.70, –0.25].

Differential effects of the preliteracy intervention for different EF levels

To examine to what extent the level of EF moderated the effectiveness of the intervention for letter knowledge gains, we created two equal groups based on scores on the EF measure that correlated with preliteracy (i.e., Hearts & Flowers; see Table 4): those children who scored among the lowest 50% EF levels and those children who scored among the highest 50%. Repeated measures ANOVAs were undertaken with time (pretest, posttest) as the within-subjects factor and group (EF-DL, O-DL) and EF (high, low) as between-subjects factors.

We found a main effect of time between the intervention group and the intervention control group, $F(1, 62) = 122.59$, $p < .001$, $\eta_p^2 = .66$, observed power = 1.00, 95% CIs [10.54, 14.18], [15.99, 19.63]. No intervention effect was found when we compared the two intervention groups for all children, with varying EF levels, together, $F(1, 96) = 1.84$, $p = .18$. However, the analyses showed a three-way Time × Group × EF effect, $F(1, 62) = 4.30$, $p = .04$, $\eta_p^2 = .06$, observed power = .53, 95% CIs for O-DL [7.50, 14.88], [12.88, 20.25], [11.06, 18.44], [15.25, 22.62]; 95% CIs for EF-DL [7.96, 14.93], [12.64, 19.59], [8.37, 15.75], [15.94, 23.31] (see Figure 2). Independent-samples *t* tests between the two groups showed that children with higher EF benefitted more from the EF-DL intervention than from the O-DL intervention, $t(30) = 2.26$, $p = .03$, $d = .83$, observed power = .63, 95% CI [–6.42, –0.33]. No intervention effects were found for learning letters among children with lower EF, $t(32) < 1$.

Discussion

The present exploratory study examined whether embedding EF-supporting activities could reinforce the gains of a preliteracy intervention in kindergarten. Role play, mediators, and strategy formulation were integrated into a dyadic learning context to continuously activate EF. A group of children who received this intervention was contrasted with a dyadic control group that worked with the same preliteracy intervention in a dyadic setting but without the explicit EF activities, as well as with a business-as-usual control group. For phonological awareness, children in all groups showed equal development over time. For letter knowledge, however, children in the dyadic context with EF activities showed the greatest progress. This effect was driven by children with higher levels of EF.

Children in the dyadic control group did not progress more than those in the business-as-usual-control group in literacy skills. The fact that no effects were found for this unstructured dyadic setting might indicate that children had more difficulty actively participating in the preliteracy games when simply put in a collaborative setting in which they had to find their way without guided instruction.

These findings relate to the naturalistic preschool setting in which children learn from and with each other. It is important to note that the results suggest that children indeed can tutor one another's learning even at a very young age—but only when their EF are actively supported. To our knowledge, these results are the first on the effects of embedded dyadic EF exercises in a specific preacademic intervention in kindergarten. The curriculum-wide intervention Tools of the Mind used dyadic regulation though scaffolding and mediators in preschool and showed some correlations with school-based preliteracy assessments at posttest as well (Diamond et al., 2007). However, a follow-up study that assessed literacy at pretest and posttest could not confirm direct effects on preacademic gains (Barnett et al., 2008). Moreover, the Tools intervention generally lasted 2 years, in which EF were addressed about 80% of the school time throughout the curriculum. This placed a high load on the teacher's time (Imholz & Petrosino, 2012). The current study was aimed at a short and domain-specific intervention. Moreover, we compared the active dyadic learning context to a dyadic control group to control for overall dyadic effects.

Unexpectedly, no effects of the intervention were found for phonological awareness. Fuchs and Fuchs (2005) did find effects for phonological awareness when using dyad-assisted learning strategies. However, they contrasted a dyadic literacy group only to an individual control group that received less than half of the phonological exercises that the experimental group did. Moreover, phonological awareness was targeted during teacher modeling, whereas the dyadic exercises targeted decoding skills. Although the current study also made use of adult modeling during practice items, the children had to independently transfer these modeled steps and apply them to the task items. An explanation for the lack of phonological gains therefore more likely lies in the nature of the preliteracy exercises. As our intervention addressed four types of phonological abilities, children only practiced with each ability for about two sessions, which might have been too incidental for deep learning. Likewise, it might have been too incidental for transfer effects of the domain-specific aspects in the EF supporting activities. A setup in which children practice more with the modeling procedure and gradually receive more responsibility may lead to better transfer. Letter stimuli, in contrast, were involved in all games, and positive results of the intervention were found for this aspect of preliteracy. Despite the fact that fewer games were played in the EF-DL group compared to the intervention control (O-DL) group, children showed greater learning benefits when playing the games with the embedded activities. This shows that not the quantity but the quality of learning is important to benefit from an intervention.

As expected, children with higher EF levels benefitted most from the intervention. This result seems to contradict studies that have suggested that children with lower EF will gain most from explicit EF support (e.g., Diamond, 2013). However, generally such studies have considered interventions individually guided by teachers and directly aimed at stimulating specific EF. Our intervention aimed to reduce high EF loads to help children gain from an autonomous preliteracy intervention. Such a learning context places high demands on children's EF due to the complexity of the learning environment and to lower external teacher control. The higher demands on children's own control might have been too demanding for children with lower EF. This tentative conclusion allies with recent studies that have shown that children with higher EF are better able to overcome distracted behavior when working independently and show more verbal responsiveness in formulating strategies (De Koning-Veenstra et al., 2014; Van de Sande et al., 2015).

Several limitations should be acknowledged. The results should be interpreted with caution. This was an exploratory study, and some of the analyses had less power than the recommended .80 level (Cohen, 1988). Replication studies with larger sample sizes are therefore advised. Furthermore, dyadic or multilevel analyses could have better controlled for the intervention setting, but our sample size as well as the classwide control group did not allow us to use these techniques.

Another option for disentangling the individual contributions would have been to give children fixed instead of reciprocal roles, but that would have resulted in a situation in which only half of the children would have had the opportunity to practice preliteracy skills. Furthermore, retention measures would have enabled examination of intervention effects over time. Last, to enable internalization and to ensure treatment fidelity, strict procedural scripts were designed, but these provided less space for children's own scaffolding initiatives.

Many ideas for future studies can be generated. First, the current dyadic scaffolding activities could be embedded into other scholastic domains to further disentangle the benefits of this type of EF support. Second, observing children's task behavior and relating it to the EF measures could enrich knowledge about the ongoing effectiveness of the activities. Third, although EF support in a brief intervention is not sufficient to directly promote EF, research with more repetition across multiple academic domains might reveal whether the current activities might ameliorate EF development over time as well.

To summarize, the present study shows that young children of the same age with higher EF can scaffold one another's academic learning through tutoring within their zone of proximal development even without prior expertise—when offered embedded EF-supporting activities to do so. The benefits of peer scaffolding is an important finding, because previous research has emphasized that the regulation of others (either adults or peers) is a crucial step before children can internalize such regulatory mechanisms (Diamond et al., 2007; King et al., 1998; Vygotsky, 1978). From a theoretical point of view, this is the first study to demonstrate how to embed EF-supporting activities into a coconstructive and peer-based academic intervention in kindergarten. As such, it strengthens previous longitudinal findings on the causal role of EF for early literacy development (e.g., Foy & Mann, 2013; Segers et al., 2016; Van de Sande et al., 2013) and also may speak to the need for assessing, supporting, and teaching EF through embedded EF-supporting exercises in the classroom (see also Diamond et al., 2007; Van De Sande et al., 2016). This study also adds to the very limited knowledge about the influence of peer EF on children's own literacy development (Skibbe et al., 2012). From an educational practice point of view, the results show that the intervention can strengthen the effects of instruction within the naturalistic educational setting of kindergarten. This novel approach provides guidelines for exercises that can be implemented in small groups without expensive equipment or much time on the part of teachers and could, in an adaptive format, strengthen self-regulated learning within the existing natural peer-based context in preschool settings (see Gnaedinger et al., 2016; Röthlisberger et al., 2012). Thus, young children can be provided with baseline skills to promote their school readiness.

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