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Direct and indirect pathways from children's early self-regulation to academic achievement in fifth grade in Norway

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ABSTRACT

A large body of research has documented the role of self-regulation in academic skill development for young children. However, few studies have investigated longitudinal and indirect effects from kindergarten through later elementary school. In this longitudinal Norwegian study, we investigated pathways from children's self-regulation in kindergarten (M_{age} = 5.8; N = 243, 49% girls), to language and math skills in first grade (N = 240) and reading comprehension and math achievement in fifth grade (N = 160). Self-regulation was measured with direct and teacher-reported assessments. Path models showed that both directly assessed and teacher-reported self-regulation in kindergarten predicted math skills but not vocabulary and phonological awareness skills in first grade. Teacher-reported self-regulation indirectly predicted fifth grade reading comprehension through first grade teacher-reported self-regulation, and directly assessed self-regulation predicted fifth grade math achievement through math skills and directly assessed self-regulation in first grade. When controlling for kindergarten self-regulation, both self-regulation measures in first grade predicted fifth grade reading and directly assessed self-regulation predicted math achievement. Findings elucidate the foundational role of early self-regulation for later academic achievement and the differential effects of directly assessed versus teacher-reported self-regulation in a Norwegian sample.

1. Introduction

When children enter formal schooling, they often move from a relatively unstructured childcare setting to a more structured learning environment, with greater expectations for behaviors such as paying attention, cooperating, and following instructions. These behaviors depend on children's ability to self-regulate (McClelland & Cameron, 2012). Research has indicated that children's self-regulation provides a foundation for their academic skills because children need to demonstrate self-control to benefit from learning opportunities (Blair & Raver, 2015; McClelland & Cameron, 2019; Raver, Jones, Li-Grining, Bub, & Pressler, 2011). Although the literature on self-regulation and its relationship with academic outcomes is extensive, relatively few studies have examined the role of early self-regulation on academic achievement in the later elementary school years (G. J. Duncan et al., 2007; McClelland, Acock, & Morrison, 2006). Moreover, self-regulation may not only directly predict later outcomes, but also contribute to later academic achievement through its role in early academic skills (von Suchodoletz & Gunzenhauser, 2013). Understanding the indirect developmental pathways from self-regulation to later skills is important because academic skills are essential prerequisites for learning (G. J. Duncan et al., 2007; Gurlitt & Renkl, 2010). Finally, most studies have assessed self-regulation with either direct assessments (e.g., McClelland et al., 2014) or with teacher reports (e.g., McClelland et al., 2006). The additive contribution of direct assessments over teacher reports, and vice versa, remains less known.

The present study is conducted in the Norwegian context that includes generous welfare systems, low rates of poverty,

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and universal access to regulated and subsidized Early Childhood Education and Care (ECEC), which is based on a play-based pedagogical approach. In this setting, we investigate the longitudinal and unique effects from children's directly assessed and teacher-reported self-regulation in the spring of kindergarten[1] (5–6 years) to vocabulary, phonological awareness and, math skills in the spring of first grade (6–7 years). We also examine direct effects from children's self-regulation in kindergarten and first grade (controlling for kindergarten self-regulation) to reading comprehension and math achievement in fifth grade (9–10 years). Finally, we investigate indirect effects from self-regulation in kindergarten to reading comprehension and math achievement in fifth grade, through academic skills and self-regulation in first grade.

1.1. Conceptual and empirical understandings of self-regulation

Self-regulatory skills help children control their thoughts and behavior, solve problems, plan, and complete tasks (McClelland & Cameron, 2019), which in turn helps them to adapt to the demands and expectations in the classroom. Self-regulation is a multidimensional construct that broadly refers to the regulation of emotions, cognition, and behavior (McClelland, Ponitz, Messersmith, & Tominey, 2010), and it is understood to be composed of interrelated top-down and bottom-up components (Blair & Raver, 2012). The bottom-up components are automatic, stimulus-driven, rapid, and do not require mental capacity, while the top-down components are related to executive functioning (EF) (Blair & Raver, 2012; Nigg, 2017). EF, which is a term often used in cognitive disciplines (McClelland & Cameron, 2012), is a high-level set of processes that include attentional or cognitive flexibility, working memory, and inhibitory control (Blair, 2002).

EF is related to, but not synonymous with, self-regulation. Nigg (2017) suggests that EF is a set of cognitive capacities that, when implemented, enables self-regulation and self-regulated behavior. This is in line with research on the connection between EF and self-regulation, which argues that the components of EF subserve successful self-regulation and that temporary reductions in EF underlie many of the situational risk factors identified in the social psychological research on self-regulation (Hofmann, Schmeichel, & Baddeley, 2012).

1.1.1. Measuring self-regulation

Self-regulation can be measured with direct assessments, such as the Head-Toes-Knees-Shoulder task (HTKS; McClelland et al., 2014) used in the present study or ratings by teachers or caregivers. However, although direct assessments and questionnaire-based measures of self-regulation are significantly associated (Gestsdottir et al., 2014; Matthews, Cameron Ponitz, & Morrison, 2009; von Suchodoletz et al., 2013; Wanless et al., 2013), they are not synonymous.

Direct assessments of self-regulation can provide information about children's skills in highly structured one-to-one situations and are more likely to assess cognitive processes (e.g., EF components) involved in self-regulation (Allan, Hume, Allan, Farrington, & Lonigan, 2014). For example, the HTKS task has been found to be related to all three EF components (McClelland et al., 2014). However, direct assessments may not adequately reflect children's ability to regulate their behavior in a social classroom context over time (Toplak, West, & Stanovich, 2013). It is suggested that a child might score well on an individually administered self-regulation measure, such as the HTKS task, but he or she might not be able to pay attention in the classroom or work situation, which includes many distractions and extraneous situations (McClelland et al., 2010). Furthermore, direct assessments are typically used at one point in time, which only gives assessors a snapshot of a child's skills and may also capture factors unrelated to a child's self-regulation (e.g., time of testing, the test situation, child fatigue) (Allan et al., 2014).

In contrast, teacher ratings capture children's ability to apply their self-regulation in everyday tasks, across classroom contexts and over time (Campbell et al., 2016; Wanless et al., 2013), but they may be hampered by rater subjectivity and history between the child and the rater (Allan et al., 2014). Although teacher-reported measurements may target the cognitive processes included in EF, they may, to a larger degree, reflect the behavioral and social manifestations of these skills in the environment (Toplak et al., 2013). Thus, teacher-reports often focus on self-regulation more broadly and may not focus on specific processes such as inhibitory control, flexible attention, and working memory (Schmitt, Pratt, & McClelland, 2014).

Both methods of assessing self-regulation have been significantly related to academic achievement (e.g., Allan et al., 2014; Nathanson, Rimm-Kaufman, & Brock, 2009; Robson, Allen, & Howard, 2020; Wanless et al., 2011). In a recent meta-analysis, results showed no statistically significant differences in the associations between children's early self-regulation and later academic skills when self-regulation was measured using direct assessment or teacher-report (Robson et al., 2020). However, across both methods of assessing self-regulation, they found that self-regulation was more strongly associated with math skills than with early literacy skills. Some evidence suggests directly assessed self-regulation (using the HTKS task) to be an equal or better predictor of mathematics and literacy skills compared with teacher ratings (Matthews et al., 2009). Moreover, both methods of assessing self-regulation in preschool have been reported to predict reading comprehension two years later (Birgisdóttir, Gestsdóttir, & Thorsdóttir, 2015). Another study found that teacher-reported self-regulation was more strongly associated with early language, literacy, and reading skills, compared to directly assessed self-regulation (using the HTKS task), meanwhile, directly assessed self-regulation was the strongest predictor of math skills (Schmitt et al., 2014). These results provide some indications that direct assessments are more consistently related to children's math skills, and that both types of measurements are related to language skills and reading comprehension.

The two self-regulation assessments may represent different aspects of children's cognitive and behavioral functioning in different environments (Allan et al., 2014; Hofmann et al., 2012; Toplak et al., 2013). Thus, it may be useful to differentiate between these measurements as they may predict unique variance in academic outcomes.

1.2. Self-regulation, early language skills, and reading achievement

Self-regulation is related to knowledge acquisition more broadly but also to specific aspects of early language skills. For example, self-regulation facilitates the acquisition of phonological awareness and vocabulary knowledge in the early years by helping children focus, pay attention, and remember the meaning of sounds and words (Blair, Protzko, & Ursache, 2011; McClelland & Cameron, 2019). These early language skills, in turn, support the development of reading comprehension (Storch & Whitehurst, 2002).

Studies using direct assessment or teacher-report have demonstrated that early self-regulation predicts vocabulary (Bohlmann & Downer, 2016; Gestsdottir et al., 2014; Weiland, Barata, &

[1] In Norway, children attend Early Childhood Education and Care (ECEC) centers until they are six years old. Although Norwegian children do not attend kindergarten as it is known in the United States, for simplicity we use the name kindergarten as this study includes only the eldest children from the ECECs.

Yoshikawa, 2014), early literacy skills (Blair & Razza, 2007; Matthews et al., 2009; Schmitt et al., 2014; Welsh, Nix, Blair, Bierman, & Nelson, 2010), and early reading achievement (Birgisdóttir et al., 2015; Hernández et al., 2018; Welsh et al., 2010). However, others have not found effects from directly assessed self-regulation to vocabulary (Cameron Ponitz, McClelland, Matthews, & Morrison, 2009; Fuhs & Day, 2011), or early literacy skills (Cameron Ponitz et al., 2009; Hubert, Guimard, Florin, & Tracy, 2015; Schmitt, Geldhof, Purpura, Duncan, & McClelland, 2017), and nor from teacher-reported self-regulation to vocabulary (von Suchodoletz et al., 2013), or some early literacy skills (Blair & Razza, 2007). Thus, prior findings are inconsistent, which might be caused by study-specific factors such as choice of measurements, differences in aspects of early literacy, number and choice of control variables, and characteristics of the sample (e.g., age, socioeconomic background, and culture).

As children gain experience with reading in the early to mid-elementary grades, the cognitive demands, such as self-regulation, for reading words and sentences lessen as it is supported by already acquired and automated aspects of reading (e.g., vocabulary knowledge and phonological awareness) (Blair et al., 2011). However, to comprehend a series of sentences, hold the already-read text in short-term memory while drawing inferences for what may come next, may still, in addition to the acquired and automated aspects of reading require self-regulation (Blair & Razza, 2007; Blair et al., 2011; Sesma, Mahone, Levine, Eason, & Cutting, 2009). A few studies have found that teacher-reported self-regulation in kindergarten predicted reading achievement later in elementary school (G. J. Duncan et al., 2007; McClelland et al., 2006).

Considering that self-regulation may provide a foundation for learning vocabulary and phonological awareness skills, self-regulation may have an indirect effect on later reading comprehension through these skills (Blair & Razza, 2007; Bohlmann & Downer, 2016; G. J. Duncan et al., 2007; Gurlitt & Renkl, 2010; McClelland et al., 2014; Welsh et al., 2010). Some studies (ten Braak, Kleemans, Størksen, Verhoeven, & Segers, 2018; van de Sande, Segers, & Verhoeven, 2013) have found that phonological awareness mediated the relation between directly assessed self-regulation and later reading skills whereas others have not (e.g., Hubert et al., 2015).

Taken together, research points to a predictive role of early self-regulation for future vocabulary, phonological awareness skills, and reading achievement, but results from previous studies are mixed and may have depended on the type of task that has been used (direct vs. teacher-reported). Moreover, few studies have investigated the unique direct and indirect pathways from directly assessed and teacher-reported early self-regulation, to reading achievement measured later in elementary school.

1.3. Self-regulation, early math skills, and math achievement

Demonstrating proficiency in math achievement requires consistent and ongoing demands on self-regulation. For example, partial results must be stored in working memory and retrieved or replaced when necessary (Bull & Lee, 2014; Van der Ven, Kroesbergen, Boom, & Leseman, 2012). Further, inhibitory control may suppress inappropriate strategies, such as the use of addition when subtraction is required, and cognitive flexibility may help to shift between operations, solution strategies, quantity ranges, and notations (Bull & Lee, 2014). Neuro-scientific work has demonstrated that similar brain regions (e.g., prefrontal cortex) are important for solving math problems and completing self-regulation tasks (Blair & Razza, 2007).

Previous research found that various aspects of directly assessed self-regulation positively predicts children's math skills in preschool (McClelland et al., 2014), kindergarten (Blair & Razza, 2007; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Cameron Ponitz et al., 2009; McClelland et al., 2014; Welsh et al., 2010), and first grade (Hernández et al., 2018; ten Braak et al., 2018). Teacher-reported self-regulation has also been found to significantly predict math skills in kindergarten (Blair & Razza, 2007; Matthews et al., 2009) and first grade (Gestsdottir et al., 2014). A meta-analysis (Allan et al., 2014) showed that across all methods of measuring self-regulation, self-regulation was strongly associated with mathematics among children in preschool and kindergarten age. Moreover, studies using teacher-reported self-regulation, have demonstrated that self-regulation in kindergarten is a significant predictor of math achievement later in elementary school (G. J. Duncan et al., 2007; McClelland et al., 2006). Few studies, however, have investigated whether early self-regulation predicts math achievement more than four years after school entry and whether directly assessed and teacher-reported self-regulation shows unique associations over and above the other.

Self-regulation may also contribute to the development of later math achievement, partly through its initial effect on early math skills. Studies investigating indirect effects show contradictory findings. One study (ten Braak et al., 2018) found a direct effect from directly assessed self-regulation in kindergarten on mathematics in first grade, but no significant indirect effect via math skills in kindergarten. In contrast, another study only found an indirect effect from directly assessed self-regulation in preschool on first grade math skills through preschool math skills (Hubert et al., 2015). So although evidence for a direct pathway between self-regulation and mathematics has been found in previous research, results regarding indirect pathways are inconclusive.

1.4. The Norwegian context

Different cultural and educational settings may affect children's development and learning (Bronfenbrenner & Morris, 2006). Norway and other Nordic countries have a high priority on social welfare and education policies regarding childhood and early education. In Norway, children attend Early Childhood Education and Care (ECEC) centers from one-to-two years of age and stay until the year they turn six years old and enter first grade. All children have the right to attend ECEC from age one year, and in 2011, 97% of the five-year-olds were in ECEC centers for six to eight hours per day, five days a week (Statistics Norway, 2012).

Norwegian ECEC is regulated by the *Framework Plan for the Content and Tasks of Kindergartens* (Norwegian Ministry of Education & Research, 2011). The Framework Plan reflects a play-based approach, which emphasizes holistic learning and children's desire and curiosity for learning (OECD, 2006). Children spend considerable time in outdoor play, 70% during the summer, and 31% during the winter (Moser & Martinsen, 2010). There is little emphasis on formal preparation for academic learning or self-regulation. In fact, the Norwegian Framework plan does not mention self-regulation as a concept. These characteristics in the Norwegian ECEC create a fairly abrupt transition for children who move from a play-based and relatively unstructured environment to a highly structured learning environment in first grade (OECD, 2006). For example, when children enter first grade, they are faced with formal instructions and are expected to work independently, stay on tasks, follow instructions, focus on academic tasks, and have goal-directed behavior. When the structure and the expectations vary as much as they do between kindergarten and first grade, the transition to school may be particularly challenging (McClelland et al., 2010; OECD, 2006) and require stronger self-regulation compared to kindergarten.

There is little research in Norway on children's self-regulation and later academic achievement. A recent study (ten Braak, Størksen, Idsoe, & McClelland, 2019), assessing the direction of

relations between directly assessed self-regulation and academic skills, showed that self-regulation and mathematics were bidirectionally related across the transition from kindergarten to first grade. Another study (Backer-Grøndahl, Nærde, & Idsoe, 2018) found that directly assessed self-regulation at four years predicted academic competence (sum score of math and reading) in first grade (6.4 years) and second grade (7.4 years) (controlling for first grade academic competence and relevant background variables). Results also indicated indirect effects as early self-regulation predicted academic competence in second grade through first grade academic competence. However, these studies did not investigate the role of early self-regulation on academic achievement later in elementary school, and did not include teacher-reported self-regulation.

1.5. The present study

The present study focused on the following research questions:

1) Do directly assessed and teacher-reported measures of self-regulation at the end of kindergarten (age 5–6 years) uniquely predict vocabulary, phonological awareness, and early math at the end of first grade (6–7 years), and do these measures of self-regulation in kindergarten and first grade uniquely predict reading comprehension and math achievement in fifth grade (9–10 years)?
2) Do directly assessed and teacher-reported measures of self-regulation at the end of kindergarten have unique indirect effects on reading comprehension and math achievement in fifth grade through first grade academic skills and measures of self-regulation?

First, although prior research is mixed on relations between directly assessed and teacher-rated measures of self-regulation and early language skills, we expected that both types of measures would uniquely predict children's language skills and reading comprehension in first and fifth grade, respectively (e.g., Birgisdóttir et al., 2015; Blair & Razza, 2007; Gestsdottir et al., 2014). Based on prior studies showing that directly assessed self-regulation is often a stronger predictor of math skills, compared to teacher-reports we expected that directly assessed self-regulation would account for more unique variance in first and fifth grade mathematics (Matthews et al., 2009; Schmitt et al., 2014). Second, we expected that children's self-regulation in kindergarten would indirectly predict reading comprehension and math achievement in fifth grade through first grade achievement. We also expected both self-regulation measures in kindergarten to indirectly predict reading comprehension in fifth grade through first grade skills but only the direct assessment of self-regulation to indirectly predict math achievement in fifth grade.

2. Method

2.1. Participants

Data in this study derive from the Skoleklar [School readiness] research project. The project was approved by the Norwegian Centre for Research Data (NSD). All children (N = 287) who were in their last year of kindergarten in a municipality in the Norwegian west coast were invited to participate. A total of 243 children (84.7%) had parental consent to participate. Among these, there were 119 girls (49%) and 124 boys (51%), attending 19 kindergarten centers. For more details of this sample, see previous description (Størksen, Ellingsen, Wanless, & McClelland, 2015). The mean age of the children at the first data collection point (spring of the last year of kindergarten; 2012) was 5.8 years, ranging from 5.3 to 6.3 years (SD = 0.29). Mothers had a median education level of 3 at the first data collection point, which was one-to-two years of college/university. Mother's education was reported as follows: 1 = junior high school (2.9%), 2 = senior high school (40.0%), 3 = one-to-two years of college/university (8.8%), 4 = three years of college/university education (22.9%), 5 = more than three years of college/university education (25.4%). Nearly half (48.3%) of the mothers reported having three years of college/university education or more. About half of the women aged 25–39 in Norway have some higher education, which suggests that our sample was relatively representative of the Norwegian population (Statistics Norway, 2015). In this sample, parents were born in 21 different countries in addition to Norway. Thirteen children (5.3%) had a background where both parents were born in another country than Norway. These were coded as immigrants, and they included five children (2.0%), whose both parents were born in the EU/EEA, USA, Canada, Australia or New Zealand, and eight children (3.3%) whose both parents were born in either Asia, Africa, Latin-America, Oceania (except Australia and New Zealand), or from another country in Europe outside the EU/EEA. All children had attended kindergarten for at least one year and spoke Norwegian. Mothers with immigrant status had a mean education level of 2.46 compared to a mean level of 3.32 for the other mothers.

The present study had three time points of data collection. The first data collection was during the spring of kindergarten, the second was during the spring of first grade, and the third was during the fall of fifth grade. After the first data collection point, three children moved, leaving a sample of 240 children at the second data collection point. At the third data collection point, we collected new parental consents, which resulted in some attrition from the study and left a sample size of 160 (see attrition analyses below), attending eight different schools.

2.2. Missing data

In this study, there was a very close collaboration with the municipality, the kindergarten centers, and the schools in the first two data collection points. The close collaboration ensured that the rate of missing data was low, from 0.0 to 4.1 % for all variables from kindergarten to first grade. During fall 2016, we extended the dataset with National assessment scores in reading comprehension and math achievement from fifth grade. Reading comprehension in fifth grade had 34.6% missing data and math achievement 34.2%. The new parent consent before the fifth grade data collection explains most of this attrition. We separated the missing and complete cases, and we examined group means differences in all variables included in the models. The examination indicated some systematic attrition. Children with missing values in fifth grade had significantly lower mean scores in math skills and vocabulary in kindergarten and phonological awareness skills, vocabulary, and teacher-reported self-regulation in first grade. Furthermore, children were less likely to remain in the study if they had parents reporting immigrant status, partly because some of these children lived in a neighboring municipality. In the kindergarten data collection, there were 13 children with immigrant status, and in fifth grade, only three of them were left.

Attrition can lead to biased parameter estimates. Thus, to account for missing data and to produce estimates with less bias and greater power, variables that were related to attrition were included in the model as predictors, control variables, or as auxiliary variables. Based on this, missing data were assumed to be missing at random (MAR). Additionally, we used full information maximum likelihood estimators (FIML) (Enders, 2010).

2.3. Procedure

In the two first data collections points (spring kindergarten and spring first grade), the test battery was administered individually with the use of computer tablets. The testing was carried out by testers (trained in a two-day course), and all tests were conducted in Norwegian. The parents reported education level, immigrant status, child age, and gender on a questionnaire in spring in the last year of kindergarten. Teachers in kindergarten and first grade completed questionnaires for individual children, including the Survey of Early Schools Adjustment Difficulty (Rimm-Kaufman, 2005), that was used to assess children's self-regulation in the classroom. Scores in reading comprehension and math achievement in the third data collection point, derived from National assessments that were carried out by the schools in collaboration with The Norwegian Directorate for Education and Training.

2.4. Measures

2.4.1. Self-regulation in kindergarten and first grade

2.4.1.1. Directly assessed self-regulation. Self-regulation was directly assessed with the Head-Toes-Knees-Shoulders task (HTKS; McClelland et al., 2014). The test is a short game appropriate for children age 4–8 years and includes three parts, each with ten items. The first part requires children to touch the opposite body part of what is presented to the child. For example, when the instructor says, "touch your toes," the child must touch his or her head and vice versa. In the second part, knees and shoulders are added, and in the third part, the rules are switched. This task requires children to integrate several executive function skills, namely (1) paying attention to the instructions, (2) using working memory to remember and execute new rules, and (3) using inhibitory control through inhibiting the natural response to the instructor's command (McClelland et al., 2014). The scoring system is 2 points for a correct response, 1 point for a self-correct response, and 0 for an incorrect response. In the present study, we only had the sum scores of the three different parts; thus, it was not possible to calculate the reliability. However, the HTKS has shown good psychometric properties in previous studies conducted in the U.S., Asia, and Europe (Cameron Ponitz et al., 2009; von Suchodoletz et al., 2013; Wanless et al., 2013), with Cronbach's alpha reliability ranging from .92 to .94 (McClelland et al., 2014). It has also been used in a previous Norwegian study investigating the influence of parental socioeconomic background and gender on 5-year olds self-regulation (Størksen et al., 2015). Scores ranged from 0 to 60 (including 30 test questions and, each scored 0–2 points).

2.4.1.2. Teacher-reported self-regulation. Self-regulation was also assessed through teacher-report on the Survey of Early Schools Adjustment Difficulty (ESAD; Rimm-Kaufman, 2005). This scale contains 11 items and is designed to assess children's adjustment to the classroom environment. Thus, the survey is broadly focused on self-regulation in the classroom over time and does not explicitly focus on working memory, attention, and inhibitory control. Statement examples are; "this child has shown difficulty following directions," and "this child has shown difficulty taking turns or waiting until his/her turn to speak." Teachers responded to these statements for each child using a 5-point scale ranging from 1 (no, not at all true) to 3 (sometimes true) to 5 (yes, very true). The reliability (Cronbach's alpha) was .91 in kindergarten and .93 in first grade. In order to have a scale that reflected positive self-regulation in the classroom, we reversed all items after the data were entered. Teacher-reported self-regulation (ESAD) and directly assessed self-regulation (HTKS) correlated significantly in kindergarten (r = .32, p < .001) and first grade (r = .34, p < .001).

2.4.2. Academic skills in kindergarten and first grade

2.4.2.1. Vocabulary. Expressive vocabulary was tested with the Norwegian Vocabulary Test (NVT; Størksen, Ellingsen, Tvedt, & Idsøe, 2013) in kindergarten and first grade. NVT is a naming test where an illustration appeared on the tablet computer screen, and the child was subsequently asked to name it. The test has 45 items, and the reliability was α = .84 in kindergarten and α = .82 in first grade.

2.4.2.2. Phonological awareness. This skill was assessed in kindergarten and first grade using a blending test taken from the official screening battery from Norwegian Directorate for Education and Training (2012a). The test has 12 items of increasing difficulty and was automatically discontinued after three following errors. Children were required to blend separately pronounced phonemes into the corresponding whole word. For example, "here you see an illustration of /h u s/ - /m u r/ - /m u s/ - /p u s/ (house, wall, mouse, cat in English). Your task is to touch one of these illustrations after I tell you which one. I am going to say the word in a strange way because I pronounce one sound at a time. Listen carefully and touch the illustration that goes with /p/-/u/-/s/." Reliability (Cronbach's alpha) for this task is α = .75 (Solheim, Brønnvik, & Walgermo, 2013).

2.4.2.3. Early math. Math skills in kindergarten and first grade were assessed with the Ani Banani Math Test (ABMT; Størksen & Mosvold, 2013). The test is administered on a tablet and has 18 items, which include a little monkey called Ani Banani and his imagined everyday activities, such as counting toys, eating a certain amount of bananas, and doing a puzzle or copying a pattern with beads. It assesses three overlapping math areas: problem-solving, geometry, and numeracy. Reliability was satisfactory, with α = .73 in kindergarten and α = .68 in first grade. The task has shown strong psychometric properties (Størksen & Mosvold, 2013) and correlated r = .74 (unpublished data) with another validated early numeracy task, the Early Numeracy Test (Van Luit & Van De Rijt, 2009) in kindergarten and r = .69 (unpublished data) with an existing teacher administered math assessment in first grade (Norwegian Directorate for Education & Training, 2012b).

2.4.3. Academic achievement in fifth grade

2.4.3.1. Reading comprehension. Reading comprehension was assessed in fall 2016 by a mandatory National assessment of reading comprehension (Norwegian Directorate for Education & Training, 2016b). The test is conducted on a computer, and it is constructed to assess how students use reading in different academic contexts and everyday situations. Students are given ample time (90 min) to complete the assessment. The questions are designed to assess three different reading skills: (1) Find information in texts, (2) Interpret and compare information, and (3) Reflect on and evaluate the form and content of the texts. The test has five texts, and each text is followed by multiple-choice on a computer. There are five to seven items per text, with a total of 30 items.

2.4.3.2. Math achievement. Math achievement was assessed in fall 2016 by a mandatory National assessment (Norwegian Directorate for Education & Training, 2016a). This test has 45 items (90 min) and focuses on how students use math skills in academic and everyday contexts and assesses three different math aspects: (1) Numeracy, and how students manage to use the four arithmetical operations, (2) Measuring and geometry (e.g., length, area, volume, angle, mass, time, and scale), and (3) Statistics (e.g., ability to organize, analyze, present and evaluate data, tables, and charts.

Table 1
Descriptive statistics.

Measure	N	M	SD	Skewness	Kurtosis	Min	Max
Child age, years T1	242	5.79	0.29	.06	−1.16	5.29	6.30
Percent of male	241	50.2%					
Mother's education level	240	3.28	1.30	.09	−1.54	1	5
Percent of immigrants	237	5.3%					
Phonological awareness[a] T1	240	3.66	3.39	.59	−.91	0	12
Phonological awareness[a] T2	233	10.21	1.92	−1.75	3.98	1	12
Expressive vocabulary[b] T1	241	26.35	5.70	−.42	−.16	10	39
Expressive vocabulary[b] T2	239	30.72	4.97	−.63	.44	14	42
Mathematics[c] T1	241	10.62	3.13	−.32	−.19	2	18
Mathematics[c] T2	239	14.52	2.57	−1.01	1.18	5	18
Self-regulation, directly assessed[d] T1	241	34.46	15.67	−.62	−.40	0	60
Self-regulation, directly assessed[d] T2	239	47.48	9.83	−1.73	5.31	0	60
Self-regulation, teacher-reported[e] T1	243	4.32	.83	−1.35	.97	1.64	5.00
Self-regulation, teacher-reported[e] T2	240	4.39	.86	−1.57	1.84	1.18	5.00
Reading comprehension[f] T3	159	49.89	9.94	.13	−.65	26	74
Mathematical achievement[g] T3	160	50.88	9.75	.26	−.24	28	78

Note: T1 = kindergarten, T2 = first grade, T3 = fifth grade. Mother's education was coded: 1 = junior high school, 2 = senior high school, 3 = 1–2 years of college/university, 4 = 3 years of college/university education, 5 = more than 3 years of college/university education. Immigrant status was coded: 1 = children with both parents born in another country than Norway, and 0 = all other children.

[a] Norwegian Blending Test.
[b] Norwegian Vocabulary Test.
[c] Ani Banani Math Test.
[d] Head-Toes-Knees-Shoulder Task.
[e] Survey of Early School Adjustment Difficulty (reversed).
[f] National Assessment on Reading Comprehension.
[g] National Assessment on Mathematical achievement.

2.4.4. Demographics

2.4.4.1. Covariates and auxiliary variables. These variables included mother's education level, immigrant status, gender, and age reported through a parental questionnaire in kindergarten. The mean score of the mother's education level was 3.28 at the first data collection point. Immigrant status was used as an auxiliary variable and coded as 1 = children with both parents born in another country than Norway (5.3%), and 0 = all other children.

2.5. Analytic strategy

Children were nested in eight different schools, so we calculated intra-class coefficients (ICC). ICCs represent the proportion of the total variability in the outcome that is attributable to the classes (Geiser, 2013). Phonological awareness in first grade had an ICC of .06. For all other variables, the ICCs ranged between 0.00–0.04. As the ICC was not substantial (Hox, 2002), analyses adjusting for potential nested effects were not considered. We estimated path models using Mplus software Version 7.3 (Muthén & Muthén, 1998-2015Muthén & Muthén, 1998-2015). The path models included variables from all three data collection points, and separate models were conducted for the content areas of reading comprehension and math achievement. Because previous research (Hernández et al., 2018; McKinnon & Blair, 2018; ten Braak et al., 2019) suggests the possibility of bidirectional effects between self-regulation and early language and math skills across the transition from kindergarten to first grade, all variables were set as predictors of the outcome variables in first and fifth grade. Thus, initially, we estimated saturated path models in which all exogenous variables and covariates were allowed to affect one another and the outcome variables. Covariances between the exogenous variables, and residual covariances between the intermediate variables were included in model estimation. For the sake of parsimony, we eliminated one by one, all paths that were not statistically significant at the .05 probability level. We evaluated the fit of the models after the trimming, and the following fit indices and criteria were used: p-value $\chi^2 > .05$, CFI, and TLI $\geq .95$, RMSEA $\leq .06$ and SRMR $\leq .08$ (Hu & Bentler, 1999). The reduced path model was compared to the saturated model by using a chi-square difference test. The indirect effects were tested using the model indirect command in Mplus and bootstrapping process procedure (Hayes, 2012).

3. Results

The present study investigated pathways from children's early self-regulation to first grade and fifth grade academic achievement. Table 1 and Table 2 presents descriptive statistics and correlations, respectively, for all variables. As can be seen in Table 1, the shape of the distribution of the data was not severely non-normal (Kline, 2016). Robust maximum likelihood (MLR) was used to deal with outliers and non-normal distributions in the data in the further path analyses in Mplus (Muthén & Muthén, 1998-2015Muthén & Muthén, 1998-2015). The variance inflation factor values were all below ten, indicating that multicollinearity was not a problem within the data (Field, 2013).

The self-regulation measures in kindergarten were positively correlated with all first grade academic skills (Table 2). The weakest correlation was between teacher-reported self-regulation in kindergarten and phonological awareness in first grade (r = .28, p < .001), and the strongest was between directly assessed self-regulation in kindergarten and math scores in first grade (r = .48, p < .001). The self-regulation measures in kindergarten and first grade all correlated with fifth grade achievement, ranging from r = .32, p < .001 for the correlations between directly assessed self-regulation in kindergarten and fifth grade reading comprehension and math achievement, to r = .48, p < .001 for the correlation between directly assessed self-regulation in first grade and fifth grade math achievement.

3.1. Self-regulation, early language skills, and reading achievement

The fit of the trimmed model for reading comprehension (Fig. 1)[2] was good, χ^2 (22) = 19.74, p = .60, RMSEA = .000, CFI = 1.000, TLI =

[2] Nonsignificant paths are excluded and significant covariates are not displayed in Fig. 1 and Fig. 2

Table 2
Correlations for all study variables. N = 243.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Child age	–															
2. Gender	−.03	–														
3. Mother's education level	.04	−.07	–													
4. Immigrant status	−.01	.09	−.15*	–												
5. Phono. awareness[a] T1	.20**	−.28***	.20**	−.09	–											
6. Expressive voc.[b] T1	.14*	−.12	.28***	−.41***	.41***	–										
7. Mathematics[c] T1	.18**	−.17**	.29***	−.07	.40***	.46***	–									
8. SR, directly assessed[d] T1	.14*	−.23***	.13*	−.06	.38***	.33***	.48***	–								
9. SR, teacher-reported[e] T1	.13*	−.30***	.23***	−.12	.28***	.30***	.36***	.32***	–							
10. Phono. awareness[a] T2	.07	−.27***	.17*	−.14*	.40***	.40***	.35***	.31***	.23**	–						
11. Expressive voc.[b] T2	.12*	−.11	.31***	−.40***	.34***	.82***	.43***	.30***	.24***	.35***	–					
12. Mathematics[c] T2	.12	−.16*	.32***	−.05	.41***	.40***	.67***	.48***	.39***	.37***	.40***	–				
13. SR, directly assessed[d] T2	.06	−.08	.20***	.05	.20***	.32***	.44***	.38***	.30***	.31***	.30***	.46***	–			
14. SR, teacher-reported[e] T2	.11	−.30***	.22**	−.13	.23***	.24***	.41***	.32***	.70***	.24**	.19**	.43***	.34***	–		
15. Reading[f] T3	.03	−.14	.35***	−.23***	.34***	.50***	.51***	.32***	.36***	.27**	.44***	.50***	.38***	.40***	–	
16. Mathematics[g] T3	.01	−.07	.32***	.04	.26***	.37***	.61***	.32***	.39***	.27***	.35***	.62***	.48***	.36***	.67***	–

Note. T1 = kindergarten, T2 = first grade, T3 = fifth grade, SR = self-regulation. Gender was coded: 1 = girls, and 2 = boys. Immigrant status was coded: 1 = children with both parents born in another country than Norway, and 0 = all other children.

* $p < .05$.
** $p < .01$.
*** $p < .001$.
[a] Norwegian Blending Test.
[b] Norwegian Vocabulary Test.
[c] Ani Banani Math Test.
[d] Head-Toes-Knees-Shoulder Task.
[e] Survey of Early School Adjustment Difficulty (reversed).
[f] National Assessment on Reading Comprehension.
[g] National Assessment on Math achievement.

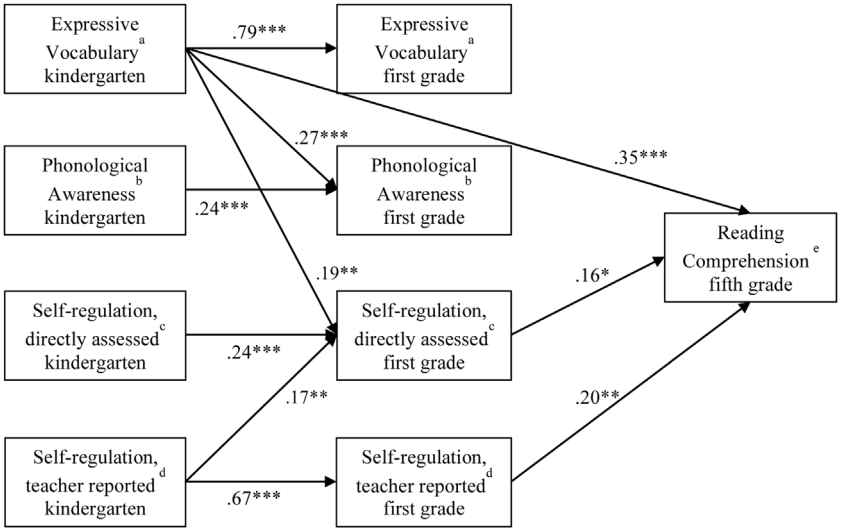

Fig. 1. Directly assessed and teacher-reported self-regulation predicting first grade vocabulary and phonological awareness, and fifth grade reading comprehension when accounted for all other factors in the model (including covariates). [a] Norwegian Vocabulary Test, [b] Norwegian Blending Test, [c] Head-Toes-Knees-Shoulder Task, [d] Survey of Early School Adjustment Difficulty (reversed), [e] National Assessment on Reading Comprehension. Covariates: age, gender, and mother's education are included in the model but are not displayed for reasons of clarity. Covariances between the exogenous variables and residual covariances between the intermediate variables were included in model estimation. All paths that were not statistically significant at the .05 probability level were eliminated from the model. Auxiliary variable: Immigrant status.

1.007, SRMR = .044. The chi-square difference test, using Satorra-Bentler correction due to the MLR estimator (Muthén & Muthén, 2018), showed that the trimmed model did not have a significantly worse fit compared to the saturated model, $\Delta\chi^2$ (22) = 19.74, p = .599. Directly assessed and teacher-reported self-regulation in kindergarten did not significantly predict first grade vocabulary or phonological awareness, and they had no significant direct effects on fifth grade reading comprehension. However, teacher-reported self-regulation in kindergarten had a significant indirect effect on fifth grade reading comprehension through teacher-reported self-regulation in first grade (β = .13, 95% CI [0.38, 2.91]). Finally, directly assessed (β = .16, p = .015) and teacher-reported self-regulation (β = .20, p = .004) in first grade were significant predictors of reading comprehension in fifth grade, while controlling for all other variables in the model.

Regarding covariates, child age did not significantly predict any of the variables and was therefore excluded from the model. Being a boy had significantly negative effect on kindergarten phonological awareness (β = −.24, p < .001), directly assessed (β = −.20, p = .001) and teacher-reported (β = −.27, p < .001) self-regulation, first grade phonological awareness (β = −.18, p < .001) and teacher-reported self-regulation (β = −.10, p = .028). Mother's education had a significant positive effect on kindergarten phonological awareness (β = .15, p = .010), vocabulary (β = .25, p < .001), teacher-reported self-

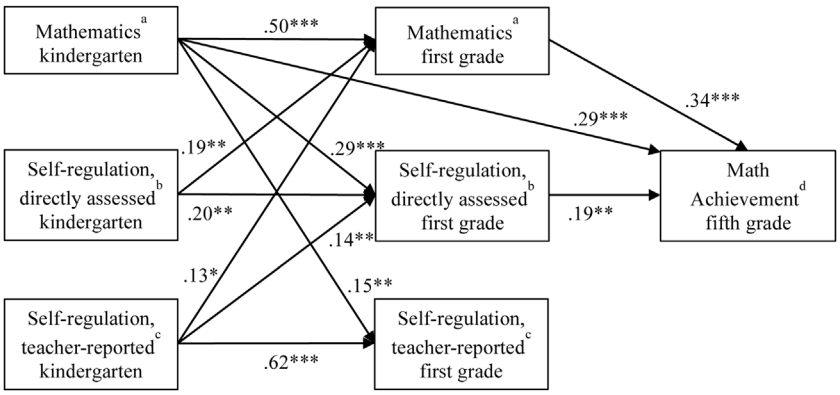

Fig. 2. Directly assessed and teacher-reported self-regulation predicting first grade math skills and fifth grade math achievement when accounted for all other factors in the model (including covariates). [a] Ani Banani Math Test, [b] Head-Toes-Knees-Shoulder Task, [c] Survey of Early School Adjustment Difficulty (reversed), [d] National Assessment on Math Achievement. Covariates: age, gender, and mother's education are included in the model but are not displayed for reasons of clarity. Covariances between the exogenous variables and residual covariances between the intermediate variables were included in model estimation. All paths that were not statistically significant at the .05 probability level were eliminated from the model. Auxiliary variable: Immigrant status.

regulation (β = .19, p < .001), first grade vocabulary (β = .09, p = .021) and fifth grade reading comprehension (β = .21, p = .002).

3.2. Self-regulation, early math skills, and math achievement

The fit of the trimmed model for math achievement (Fig. 2) was good, χ^2 (11) = 14.38, p = .21, RMSEA = .036, CFI = .995, TLI = .983, SRMR = .040. The trimmed model did not have a significantly worse fit compared to the saturated model, $\Delta\chi^2$ (11) = 14.38, p = .213 (Muthén & Muthén, 2018). Directly assessed (β = .19, p = .001) and teacher-reported self-regulation (β = .13, p = .019) in kindergarten significantly predicted first grade math skills, while controlling for kindergarten mathematics. None of the self-regulation measures in kindergarten had a significant direct effect on fifth grade math scores. However, directly assessed self-regulation in kindergarten had a significant indirect effect on math achievement in fifth grade, through math skills (β = .06, 95% CI [0.01, 0.07]), and directly assessed self-regulation (β = .04, 95% CI [0.00, 0.05]) in first grade. Moreover, directly assessed self-regulation in first grade (β = .19, p = .002), but not teacher-reported self-regulation, significantly predicted math achievement in fifth grade, while all other variables in the model were accounted for (Fig. 2).

After the trimming procedure, child age did not significantly predict any of the variables and thus, was excluded from the model. Boys had significantly lower math scores (β = −.15, p = .015), directly assessed (β = −.23, p < .001) and teacher-reported (β = −.29, p < .001) self-regulation in kindergarten, and teacher-reported self-regulation (β = −.09, p = .044) in first grade. Mother's education had a significant positive effect on kindergarten math skills (β = .24, p < .001), teacher-reported self-regulation (β = .19, p < .001), and on first grade math skills (β = .11, p = .024).

4. Discussion

The present study examined pathways from directly assessed and teacher-reported self-regulation to vocabulary, phonological awareness, and math skills in first grade, and reading comprehension and math achievement in fifth grade. The study was conducted in a society with a play-based pedagogical approach in kindergarten, where the transition to a structured learning environment in first grade may require strong demands on children's self-regulation. Path models showed that children's self-regulation in kindergarten significantly predicted math skills in first grade, and self-regulation in first grade predicted reading comprehension and math achievement in fifth grade. Indirect effects were also found where associations between self-regulation and academic skills were dependent on the type of self-regulation measure and outcome domain.

4.1. Self-regulation, early language skills, and reading achievement

Consistent with previous literature, we found that directly assessed, and teacher-reported self-regulation in first grade uniquely predicted fifth grade reading comprehension while controlling for prior self-regulation, background variables, and previous academic skills (Birgisdóttir et al., 2015; G. J. Duncan et al., 2007; McClelland et al., 2006). Although both self-regulation measures in kindergarten were significantly associated with fifth grade reading comprehension, there were no significant direct effects on reading comprehension in fifth grade. The inclusion of first grade self-regulation and academic skills in the path model may explain the lack of significant paths because previous research has shown that skills measured later are better predictors (G. J. Duncan et al., 2007; Welsh et al., 2010). However, we did find an indirect effect from teacher-reported self-regulation in kindergarten to reading comprehension through first grade teacher-reported self-regulation. Neither directly assessed nor teacher-reported self-regulation in kindergarten uniquely predicted vocabulary and phonological awareness in first grade, when controlling for prior language skills and covariates.

Regarding the indirect effect from teacher-reported self-regulation to reading comprehension through first grade teacher-reported self-regulation, one interpretation may be that children performing high on teacher-reported self-regulation in the play-based and less structured kindergartens adapted more easily to the structured learning environment in first grade. Children's ability to regulate their behavior in the first grade classroom context may, in turn, have led to higher teacher-reported self-regulation at the end of first grade, compared to their less self-regulated peers. It is also possible that children's early self-regulation predicted later self-regulation in a knowledge begets knowledge way. Thus, early self-regulation helped children do better on subsequent self-regulation. When children are highly regulated in the classroom, they, for example, work independently, execute goals and stay on tasks, and do not get distracted by peers. Thus, it is easier for children to focus and persist on reading tasks during subsequent school years, including doing better on reading comprehension in fifth grade. Prior research has reported that children low on teacher-reported self-regulation also had less school engagement, which in

turn led to lower academic outcomes (Portilla, Ballard, Adler, Boyce, & Obradović, 2014).

In line with prior research (Birgisdóttir et al., 2015) and our hypotheses, both self-regulation assessments in first grade uniquely predicted fifth grade reading comprehension. These results suggest that in addition to children's ability to regulate their behavior in the social classroom context over time, the cognitive demands of the HTKS task were likely needed for reading comprehension. These cognitive processes, including attentional or cognitive flexibility, working memory, and inhibitory control, may help children comprehend a sentence or series of sentences and draw inferences for what may come next (Blair et al., 2011; Sesma et al., 2009). For example, a recent review suggested that working memory supports the reader's comprehension by maintaining the activation of relevant information in working memory, inhibitory control supports it by suppressing the activation of irrelevant text information, and cognitive flexibility supports comprehension by flexible allocating attention to features of the text and reading strategies (Butterfuss & Kendeou, 2018).

Contrary to our expectations based on prior findings showing that both types of self-regulation assessments have predicted early language skills (Blair & Razza, 2007; Bohlmann & Downer, 2016; Gestsdottir et al., 2014; Matthews et al., 2009; Weiland et al., 2014), we found no significant effects from directly assessed and teacher-reported self-regulation in kindergarten to first grade vocabulary and phonological awareness. However, our results are in line with some prior studies (Fuhs & Day, 2011; McClelland et al., 2007), finding that the predictive role of self-regulation for vocabulary and early literacy skills became nonsignificant when controlling for prior achievement.

Our findings may suggest that children's vocabulary and phonological awareness become more automatized by the end of first grade and requires less self-regulation (Blair et al., 2011). However, the lack of significant paths from self-regulation in kindergarten to vocabulary in first grade may also reflect that children's vocabulary was highly stable from kindergarten to first grade, which left little variance to be accounted for by other variables, such as self-regulation. The strong stability between vocabulary in kindergarten and first grade means that the rank-order was already established in kindergarten, which may also explain why vocabulary in first grade (e.g., residual change) did not significantly predict reading comprehension in fifth grade over and above vocabulary in kindergarten. This was supported by further examinations showing that first grade vocabulary significantly predicted fifth grade reading comprehension without kindergarten vocabulary in the model.

In terms of phonological awareness, another possible explanation for the lack of significant paths is that the phonological awareness measure in first grade had a slight ceiling effect and a more restricted range. This may, in turn, lead to underestimated effects (Hessling, Traxel, & Schmidt, 2004). Moreover, we controlled for age, gender, and maternal education because previous research has shown that they are related to children's self-regulation and academic outcomes (McClelland et al., 2014; Størksen et al., 2015). However, controlling for these variables may have also controlled for true sources of variance in self-regulation. For example, controlling for gender may have attenuated the effect of self-regulation in kindergarten on first grade phonological awareness because girls have both better self-regulation in kindergarten and better phonological awareness in first grade. In line with recent research in Norway (ten Braak et al., 2019), the inclusion of vocabulary in the model may have attenuated how both types of self-regulation in kindergarten predicted phonological awareness in first grade. The models in the present study were based on previous research and a priori predictions, but these issues should be investigated in future research.

4.2. Self-regulation, early math skills, and math achievement

Consistent with prior research (Allan et al., 2014; Blair & Razza, 2007; Brock et al., 2009; Gestsdottir et al., 2014; Matthews et al., 2009), results showed that both measures of self-regulation in kindergarten were significant predictors of first grade math skills. The direct assessment of self-regulation also had an indirect effect on fifth grade math achievement through first grade mathematics and directly assessed self-regulation. Moreover, directly assessed self-regulation in first grade significantly predicted fifth grade math achievement while controlling for prior self-regulation, background variables, and previous math skills.

Contrary to the results for first grade language skills, both self-regulation assessments in kindergarten uniquely contributed to math skills in first grade. These results are consistent with prior research showing that self-regulation (both directly assessed and teacher-reported) is significantly more strongly associated with math skills than language skills in preschool and kindergarten age (Allan et al., 2014). The fact that both methods of assessing self-regulation predicted first grade mathematics over and above each other, may indicate that children's cognitive capacity, as well as their adjustment to the learning environment in first grade, are essential for acquiring math skills. The unique contribution from teacher-reported self-regulation, even when the direct assessment was included in the model, may be related to the structural changes and new social expectations that children experience in the transition from the play-based environment in kindergarten to the structured learning environment in first grade. Children with weak self-regulation may struggle to meet these new demands in school (e.g., to raise their hand, wait for a turn, and to be less physically active). In contrast, highly self-regulated children may adapt more easily to first grade, which in turn helps them take advantage of instruction in mathematics.

Having the cognitive self-regulatory abilities, as measured by the direct assessment, may be especially important in the transition from kindergarten to first grade in Norway since planned math activities are not highly prioritized in kindergarten (Østrem et al., 2009). Thus, the differences in academic focus in kindergarten and first grade may require high levels of the cognitive processes involved in self-regulation to cope with new math tasks and concepts introduced in first grade. It is critical to acquire math skills during first grade because these skills tend to be stable over time (G. J. Duncan et al., 2007).

In line with prior research (Hubert et al., 2015), we found that children with high scores on directly assessed self-regulation in kindergarten performed better on the math task and directly assessed self-regulation in first grade, which in turn led to higher scores in fifth grade mathematics. This supports other research suggesting the importance of early self-regulation for later achievement where self-regulation may give children the skills they need to be strong in math in first and fifth grade. For example, mathematics likely makes consistent, ongoing demands on higher-order reasoning ability where children cannot rely on automatized skills (Blair et al., 2011) and therefore require strong self-regulation (Bull & Scerif, 2001).

Our findings also support research reporting that links between self-regulation and mathematics were stronger for directly assessed self-regulation than for teacher-reported self-regulation (Schmitt et al., 2014). The lack of significant paths from children's teacher-reported self-regulation in the classroom on fifth grade mathematics suggests that the complex cognitive abilities (e.g., higher demands on working memory) tapped by the direct assessment were most related to later math achievement (Matthews et al., 2009; Schmitt et al., 2014). The complex cognitive skills, as measured in the HTKS task, are similar skills to what is needed to solve math problems, that is, to pay attention to the problem,

remember mathematical rules and concepts, keep information in mind, inhibit wrong strategies, and quickly switch to the right strategies (Bull & Scerif, 2001; Schmitt et al., 2014).

4.3. Unique contributions from directly assessed and teacher-reported self-regulation

The present study found that directly assessed and teacher-reported self-regulation uniquely predicted later academic outcomes. The unique contributions from the two self-regulation assessments may be related to the assessment contexts (Allan et al., 2014). Our results show that the direct assessment of self-regulation primarily captures the cognitive processes (EF) involved in self-regulation. In contrast, the teacher-report, to a greater extent, captures the multidimensional self-regulation construct that is needed when adjusting to a complex classroom context (Allan et al., 2014; McClelland et al., 2014; Toplak et al., 2013). Thus, it is essential to differentiate between these methods as they provide unique information about different aspects of children's self-regulation. However, further research is needed to extend the knowledge of the potential mechanisms related to how self-regulation assessments are related to different academic domains at different ages.

4.4. Practical implications

The present study indicates that promoting children's self-regulation in the Norwegian kindergarten and first grade, in addition to academic skills, may provide an important basis for the successful development of reading comprehension and math achievement throughout elementary school. Specifically, results from the present study suggest that it is essential to teach young children strategies to use their self-regulation in the social context of the classroom to promote their ability to benefit from math instructions in first grade and work independently and focus on reading tasks. Furthermore, children who struggle with mathematics and reading comprehension may benefit from a focus on working memory, inhibition, and shifting abilities as a means of improving their skills. Thus, teachers need knowledge and competence that enables them to enhance children's self-regulation in their classrooms, provide scaffolding for those who are less self-regulated, and organize engaging self-regulation games and activities (e.g., McClelland & Tominey, 2015). Prior research from samples with a school readiness approach has found that an intervention including games targeting self-regulation led to improvements in self-regulation and early academic outcomes in preschool children (R. J. Duncan, Schmitt, Burke, & McClelland, 2018; McClelland et al., 2019; Schmitt, McClelland, Tominey, & Acock, 2015; Tominey & McClelland, 2011).

The results of the present study are especially important in countries promoting play-based approaches like Norway because self-regulation is not highly emphasized in the Norwegian educational system. For example, The Framework Plan for Kindergartens in Norway (Norwegian Directorate for Education & Training, 2017; Norwegian Ministry of Education & Research, 2011) does not mention the concept of self-regulation. The plan has a child-directed approach and emphasizes free play, children's right to active participation, and their right to choose their activities, which are all essential factors for self-regulation (Center on the Developing Child at Harvard University, 2011; Engel, Barnett, Anders, & Taguma, 2015; Vygotsky, 1978). Still, this system may be most beneficial for highly self-regulated children because a certain level of self-regulation is needed to engage in meaningful learning activities and play with other children. Thus, it is essential to include the concept of self-regulation in guidelines to promote children's school success and encourage teacher education institutions to emphasize the importance of self-regulation.

It is also important, especially for children with weak self-regulation in kindergarten, and in countries with a play-based ECEC approach, that kindergartens and elementary schools collaborate to make the transition less challenging (Schleicher, 2019). One possibility is to develop early childhood curricula that emphasize school readiness skills, such as self-regulation and playful learning (Fisher, Hirsh-Pasek, Golinkoff, Dinger, & Berk, 2011; Lerkkanen et al., 2012; Rege et al., 2019). This can help bridge the gap from kindergarten to the first grade classrooms context, which is heavily based on teacher-directed practices.

4.5. Limitations and future directions

Overall, the present study extends existing research in several ways. First, it relies on a longitudinal data set spanning almost five years, with three assessment time points. This allows for the examination of long term direct and indirect associations between early self-regulation and later academic achievement. Second, the study includes two measures of self-regulation relying on two sources (direct assessment and teacher-report) that may capture different but related aspects of self-regulation. For example, the teacher-reported self-regulation was highly stable in the present study, even if it was rated by different teachers in kindergarten and first grade. This high stability suggests that the ability to regulate behaviors in complex real-life situations are relatively stable over time and across contexts. Finally, this study adds to our understanding of the role of self-regulation for later academic achievement in an educational system based on a play-based pedagogical approach in kindergarten.

There were, however, several limitations. First, although the longitudinal nature of the study was a strength, it led to some attrition, particularly between first and fifth grade. We accounted for missing data. Still, the results could be affected by attrition. Second, there were negatively skewed distributions on teacher-reported self-regulation in kindergarten and first grade and directly assessed self-regulation and phonological awareness in first grade. However, distributions were not severely skewed (skewness < 3), and robust methods were used to deal with violations of non-normality (Hessling et al., 2004).

Third, the stability of directly assessed self-regulation was relatively low compared to other studies using the same measurement on a similar age group (e.g., McClelland et al., 2014). However, the time elapsed from the first to second data collection point was 12 months, whereas it was six months in other studies (e.g., McClelland et al., 2014; Schmitt et al., 2017). The low stability could also reflect the inconsistent demand of children's self-regulation during a transition from an unstructured kindergarten environment to a much more structured first grade classroom.

Fourth, this study relied on a convenience sample. The sample was representative of the Norwegian population in terms of the mother's education level and children's academic skills in fifth grade. However, it was relatively homogenous in terms of ethnicity compared to many other western countries. It is important to keep this in mind as it may limit the generalizability of findings to more diverse populations. Finally, although our model represents causal pathways, it does not allow us to determine causality. We were interested in examining direct and indirect effects from early self-regulation to later academic skills. However, prior research (Bohlmann, Maier, & Palacios, 2015; Fuhs, Nesbitt, Farran, & Dong, 2014; Schmitt et al., 2017) and our recent work (ten Braak et al., 2019) has shown bidirectionality in self-regulation and certain academic skills across early childhood, and for this reason, we controlled for bidirectional pathways between kindergarten and first grade. In this study, self-regulation was not assessed in fifth grade,

and we can therefore not rule out the possibility that the association between self-regulation and academic skills may be bidirectional between first and fifth grade as well. Moreover, other factors not included in this study (e.g., listening comprehension) may account for some of the pathways between self-regulation and academic achievement. Research utilizing randomized control trials is needed to test the causal relationships between self-regulation and academic achievement.

4.6. Conclusion

Findings from the present study suggest that early self-regulation significantly predicts children's math skills in first grade, and their reading comprehension and math achievement in fifth grade. Our results indicate that the associations between self-regulation and academic skills were dependent on assessment timing, type of self-regulation measure, and outcome domain. The study highlights the importance of using both directly assessed and teacher-reported measures of self-regulation to better capture different aspects of self-regulation. Overall, our findings suggest that fostering the development of self-regulation in kindergarten and during first grade, in addition to early academic skills, can be important for later academic success.

Declaration of interest

None.

CRediT authorship contribution statement

Ragnhild Lenes: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Megan M. McClelland:** Writing - review & editing, Supervision. **Dieuwer ten Braak:** Investigation, Writing - review & editing. **Thormod Idsøe:** Methodology, Formal analysis, Writing - review & editing. **Ingunn Størksen:** Funding acquisition, Conceptualization, Investigation, Writing - review & editing, Software, Data curation, Supervision.

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