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The relevance of the early years home and institutional learning environments for early mathematical competencies

Abstract

Mathematical competencies are a core prerequisite for educational success. In the present study, we therefore examine the relevance of the early years home and institutional learning environment at the age of two years on mathematical competencies at the age of four, while controlling for the later years home learning environment using the data of the starting cohort one of the NEPS study (N = 1170). Results show positive effects of global processual aspects of the home learning environment, conceptualized as the frequency of joint activities at home and domain-specific aspects, which are mathematical and language stimulation in parent-child interactions. The effects of parent-child interactions in the early years remains when control variables and joint activities at later ages are added. Processual aspects of institutional child care were analyzed on a subsample (N = 230) and showed only small associations with later mathematical competencies.

Keywords

Home learning environment; Institutional learning environment; Mathematical competencies; Parent-child interaction; Joint activities; Early childhood education and care

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Die Bedeutung frühkindlicher häuslicher und institutioneller Lernumwelten für frühe mathematische Kompetenzen

Zusammenfassung

Mathematische Kompetenzen sind eine Grundvoraussetzung für den Bildungserfolg. In der vorliegenden Studie untersuchen wir daher die Relevanz der häuslichen und institutionellen Lernumgebung von Kindern im Alter von zwei Jahren für mathematische Kompetenzen im Alter von vier Jahren anhand Daten der Startkohorte 1 des NEPS (N = 1170 Kinder) und kontrollieren die häusliche Lernumgebung zu späteren Zeitpunkten. Die Ergebnisse zeigen positive Effekte globaler prozessualer Merkmale der häuslichen Lernumgebung, wie der Häufigkeit gemeinsamer Aktivitäten zu Hause, sowie domänenspezifische Effekte der mathematischen und sprachlichen Anregung in Eltern-Kind-Interaktionen. Die Auswirkungen der frühen Eltern-Kind-Interaktion bleiben bestehen, wenn Kontrollvariablen und gemeinsame Aktivitäten aus späteren Wellen ergänzt werden. In einer Teilstichprobe (N = 230) wurden Aspekte der institutionellen Betreuung analysiert, hier zeigen sich nur geringe Zusammenhänge bezogen auf die späteren mathematischen Kompetenzen.

Schlagworte

Häusliche Lernumwelt; Institutionelle Lernumwelt; Mathematische Kompetenzen; Eltern-Kind-Interaktion; Gemeinsame Aktivitäten; Frühkindliche Erziehung Bildung und Betreuung

1. Introduction

The stimulation children experience in different learning environments are jointly responsible for the formation of inter-individual differences in various areas of competencies. In the early childhood phase, the family and institutional child care can be regarded as the central learning environments. Even though research shows that both environments play an important role in fostering competencies and for the general upbringing of children (for an overview: Lehrl, 2018; Melhuish et al., 2015), comparatively little is known about the effect of the home learning environment (HLE) and the institutional learning environment of early childhood education and care settings (ECEC) for children under the age of three. The focus on the very early years of a child's life seems essential not only for general child development but also for the development of mathematical competencies. First learning experiences, such as early numerical or mathematical activities like counting, comparing, or sorting, take place long before school entry. Accordingly, difficulties in dealing with mathematical phenomena are considered a cumulative process that can begin in the first years of life (Geary, Hamson, & Hoard, 2000). Mathematical competencies in particular are essential both for later education and for participation in social life (Duncan et al., 2007). Studies demonstrate that these early mathematical competencies, in the age range of three to six years, predict quite well the development of later mathematical competencies and also general school success, even when the intelligence of the child is taken into account (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Dornheim, 2008; Jordan, Kaplan, Locuniak, & Ramineni, 2007). The foundations for these competencies are already laid during the first four years of a child's life (Feigenson, Dehaene, & Spelke, 2004; Carey, 2009; Spelke, 2017). Based on inherent systems, such as the nonverbal systems of quantity representation (Feigenson et al., 2004), different mathematical skills develop further or emerge, like the perception of quantities, counting, or the idea of space and time (Krajewski, Grüßing, & Peter-Koop, 2009). The research landscape for the German early childhood educational system regarding very young children is characterized mostly by gaps. Additionally, conclusions from existing international studies have to be drawn from with caution because there are huge differences in maternal leave (International Labour Office, 2013), day care regulations (Waldfogel, 2001), and the early child care system itself (OECD, 2013). From a psychological-educational point of view, the emergence of the precursors of mathematical competencies and how they can be supported from early on are major research interests. Especially numerical or mathematical activities like counting, comparing, or sorting are supposed to foster the development of these competencies.

The present paper uses data from the starting cohort one of the German National Education Panel Study (NEPS; Blossfeld, Roßbach, & von Maurice, 2011) to analyze the relation between the experiences children have in their families as well as in institutional childcare under the age of three, and mathematical competencies at the age of four. The starting cohort one began as a nationally representative sample of 3481 children and their families in the year 2012. This period is of particular interest since daycare regulations, especially those for children under the age of three, have changed fundamentally. For example, since 2013, each child older than one year is entitled to a place in a childcare center or in family-based daycare. While only 15.7 % of German children attended institutional childcare in 2007, the attendance rate increased to 34.3 % in 2019 (German Federal Statistical Office, 2019). Thus, the NEPS includes one of the first cohorts of children and their parents exposed to the changed daycare situation in Germany.

For a better understanding, a short overview of the German ECEC-system will be provided. Usually, the German ECEC system is divided into two institutional settings: one for children aged 0 to 3 years and one for those aged 3 to 6. Besides this division, there is a mixed form, where all children age 0 to 6 are cared for. Note that these are age-mixed groups within the particular age range. Since 1996, each child aged 3 years or older has been entitled to a place in a German child day care centre. In 2013, this legal right was expanded to entitle each child older than 1 year to a place in a child care centre or in family-based day care. With an attendance rate for 3- to 6-year-olds of 93.0 %, almost every child in this age group has some ECEC experience, and the use of such services is highly accepted. The rate for the under-3s is 34.3 % (1.9 % for 0- to 1-year-olds, 37.1 % for 1- to 2-year-olds and 63.2 % for the 2- to 3-year-olds; German Federal Statistical Office, 2019). The lower attendance rates for the under-3s are partially due to the laws on parental benefits and parental leave. If parents decide to stay at home and care for their child after birth, the government will replace their income loss by 65 to 100 % for a maximum of 14 months. Since July 2015, an additional law called 'ElterngeldPlus' even allows a further 4 months of combining parental allowance and part-time work (Federal Ministry for Family Affairs, Senior Citizens, Women and Youth, 2015).

2. Theoretical framework and state of research

2.1 Conceptualizing early years learning environments

According to bio-ecological development theories (Bronfenbrenner & Morris, 2006), proximal processes, i.e. activities and interactions of the individual with his/her environment, are central to the acquisition of mathematical competencies (as well as other competencies). The research further differentiates these processes into domain-specific and global processes (Kluczniok, Lehrl, Kuger, & Roßbach, 2013; Lehrl, 2018). Domain-specific processes, like reading to the child or playing number board games, are supposed to stimulate specific developmental areas, such as language or mathematics (e.g. LeFevre, Polyzoi, Skwarchuk, Fast, & Sowinski, 2010; Lehrl, Ebert, Blaurock, Roßbach, & Weinert, 2020). Global processes, on the other hand, are defined as activities or interactions that cannot be assigned to specific developmental areas or in which individual content areas are classified in a global picture of the respective processes taking place (e.g., painting or pretend play; Lehrl, 2018). Another theoretical strand is represented by the interactionist assumptions of Wygotski, which stress the importance of interactions of the child with its immediate environment. To a certain extent, children acquire competences by dealing with the environment in which they grow up. Especially with regard to specific, culturally charged knowledge (like mathematics), the acquisition of knowledge requires mediation in co-constructive social interactions. Referring to the "zone of proximal development" which can be understood as the distance between the current child's stage of development and the potential stage of development, the interaction partners (here the parents) are of particular importance as they represent the knowledge before it can be internalized by the children (Leseman & de Jong, 1998). According to this, higher mental functions are acquired through the support of a more competent partner, by connecting to the current level of development and helping the learner to grow beyond his own abilities, which e.g., occurs in joint activities. Similar to this concept, Wood, Wood, and Middleton (1978) have already proposed the term "scaffolding" with reference to Wygotski's theory. Scaffolding refers to those strategies of the more competent partner that ensure a sensitive provision and sensitive withdrawal of support during a joint problem-solving process (Linberg, 2018).

In the period of early childhood, the family is certainly the first and central learning environment (Bronfenbrenner & Morris, 2006). With increasing age, other learning environments also become significant. In early childhood, institutional child care settings often represent another learning environment. Since the introduction of a legal entitlement to a place in child care from the age of one and the associated expansion, the care rate for children under three years has more than doubled in the last ten years in Germany. In this learning environment, mathematical support has also been established as a clear area of responsibility for educational work in the early years (Youth Ministers' Conference & Culture Ministers' Conference, 2004) and is anchored in most educational plans of the federal states.

2.2 State of research

2.2.1 Relationships between home learning environment and mathematical competencies

The term "home learning environment" comprises several aspects of the frequency and quality of stimulating activities between children and their primary caregivers as well as the availability of learning materials at home (Linberg, Lehrl, & Weinert, 2020; see Bradley & Corwyn, 2002 for review). Such proximal home learning experiences have been shown to be associated with mathematical competencies. For example, the global processes (e.g., parental responsiveness) that the child experiences at the age of three years or older are predictive of later mathematical abilities (Burchinal, Peisner-Feinberg, Pianta, & Howes, 2002; Bradley, Corwyn, McAdoo, & Coll, 2001). Results of the Effective Provision of Preschool Education (EPPE) study show long-term effects of global processes (measured as educationally relevant joint activities with the child) at the age of three years for mathematical competencies at the age of seven, and even showing effects up to 16 years (Melhuish et al., 2008; Sylva, Melhuish, Sammons, Siraj, & Taggart, 2014).

However, it is often pointed out that effects must be examined domain-specifically (Lehrl, et al., 2020; Sénéchal & LeFevre, 2002). Math-specific processes, such as engaging children in activities like counting, learning numbers and comparing sizes have proven to be important for the development of math competencies (e.g., Elliott & Bachman, 2018; Niklas & Schneider, 2012; Susperreguy, Di Lonardo Burr, Xu, Douglas, & LeFevre, 2020; Zippert & Rittle-Johnson, 2020). Studies also point to cross-domain effects, meaning that not only math-specific, but also language-specific processes are connected to math competencies (sometimes they are even more pronounced: Lehrl et al., 2020; LeFevre, Polyzoi et al., 2010; Napoli & Purpura, 2018). This might be the case because of the close relationship of domain-specific processes in the home learning environment, or it might be a result of the use of mathematical language ("Math talk") taking place during literacy activities (Lehrl, 2018; Lehrl et al., 2020) which is also connected to the development of mathematic competencies (Ramani, Rowe, Eason, & Leech, 2015; Eason & Ramani, 2018). However, a large body of research on the importance of (global and domain-specific) processes in the home learning environment focuses on children from three years onwards. Studies focusing on the importance of the home learning environment for children under the age of three are sparse and mainly focused on social and/or language outcomes (e.g., Lehrl, 2018; Mistry, Benner, Biesanz, Clark, & Howes, 2010; Rodriguez et al., 2009). One assumption is that the effects of the HLE during the preschool years might be an effect of former HLE-experiences in the toddler phase. Tamis-LeMonda, Luo, McFadden, Bandek, and Vallatton (2019) investigated the unique relation between quality of interactions and stimulating activities during the ages of one to three years on academic achievement in class five. They showed that early HLE effects were mainly mediated through its association with pre-academic skills and to a small degree (9 % of the variance) through its association with grade 5 HLE (Tamis-LeMonda et al., 2019). However, no mediating effects of consecutive HLE were found by Rodriguez et al. (2009) who investigated the effects of the home literacy environment at age 14, 24 and 36 months on children's language and literacy outcomes. They reported unique contributions of each HLE measure at each age for vocabulary development. Similarly, although focusing on preschool aged children, Lehrl et al. (2020) found that preschool HLE effects on reading and mathematical competencies at age 12 are mediated mainly through children's competencies at pre- and primary school, and only partly through primary school HLE. Likewise, Sammons et al. (2015) reported that primary school HLE adds to the effects of preschool HLE measures on child outcomes at age 16. Thus, regarding the addition or mediation of effects of consecutive HLE measures the findings are mixed.

2.2.2 Relationships between ECEC and mathematical competencies

A dramatic increase in childcare attendance in Germany has motivated our study to investigate whether the variations in attendance duration and the variation in indicators for process quality in the daycare-centers contribute to children's early differences in mathematical competencies. Referring to the structure-process model of quality (Bryant, Burchinal, & Zaslow, 2011; NICHD ECCRN, 2002a) we understand process quality as an umbrella term for all interaction processes between children and their educators (e.g., games, activities like shared picture book reading or dealing with numbers), their peers as well as the spatial-material environment.

Studies reveal positive effects of overall preschool attendance and the quality of the preschool for children's social and cognitive development, including mathematic knowledge (for an overview: Ulferts & Anders, 2016). Research from the German Studies Educational Processes, Competence Development and Selection

Decisions at Pre- and Elementary School Age (BiKS) and Preschool of the Future in Bavaria (KidZ) reveal that global but especially domain-specific processes children experienced in child care are important for explaining differences in early and later math development (Anders et al., 2012; Lehrl, Kluczniok, & Roßbach, 2016; Lehrl, Kluczniok, Roßbach, & Anders, 2017). Furthermore, early global and specific math intervention programs with preschoolers proved to be highly effective in terms of children's mathematical development (Clements & Sarama, 2007; Skillen, Berner, & Seitz-Stein, 2018; Hauser, Vogt, Stebler, & Rechsteiner, 2014). Again, results for children under the age of three are sparse: Loeb, Fuller, Kagan, and Carrol (2004) find that the attendance of child care at the age of two to three years is positively associated with the development of mathematical competencies at the age of five. Similarly, results from the Effective Provision of Preschool Education (EPPE) study also showed positive effects of attending child care before the age of 3 (e.g., Sylva, Stein, Leach, Barnes, & Malmberg, 2011). Wylie, Ferral, Hodgen, Thompson, and New Zealand Council for Educational Research (2006) point out that the overall duration of early child care is still connected to math skills at the age of 14 years. In a small Austrian sample Baumeister, Rindermann, and Barnett (2014) also found positive effects of crèche attendance on children's cognitive outcomes. However, Tietze et al. (2013), referring to a German sample, detected no attendance effects but did detect quality effects: Children attending high quality child care showed higher cognitive skills. Results from the National Institute of Child Health and Human Development Study of Early Child Care and Youth Development (NICHD SECCYD) also point in this direction: They measured quality in child care when children were six, 15, 24, 36, and 54 months old (NICHD ECCRN, 2002b). The results reveal that children receiving higher quality child care even under the age of three show better cognitive and social outcomes, including math outcomes at the age of 54 months (NICHD ECCRN, 2006; NICHD ECCRN & Duncan, 2003). Thus, whether attending a child care center at toddler age per se benefits children's development is not clearly documented (Jaffee, Van Hulle, & Rodgers, 2011), and might be moderated by child background variables (e.g., migrations background; Klein & Sonntag, 2017). However, the quality children experience in child care has consistently been shown to boost their development (Melhuish et al., 2015).

3. The present study

Only a few large-scale longitudinal studies directly assess both child development and HLE in the very early periods of a child's life. Developmental progress and child education do not result from experiences in one single learning environment. Applying this model, depicted by Bronfenbrenner and Morris (2006) to the very first years of life, a question arises regarding how HLE and ECEC are connected to children's competencies.

In particular, we address the following research questions:

1) Are there connections between global and domain-specific home learning environment at the age of two years and the time spent in ECEC under the age of three with mathematical competencies at the age of four years?
2) Does the effect of early HLE persist, when later HLE experiences at age 36 and 48 months are controlled for?
3) Within the group of children attending childcare under the age of three: Does the frequency of educational activities in ECEC add to the effects of HLE and ECEC duration on mathematical competencies at the age of four years?

The article is based on the following hypothesis: the early home learning environment children grow up in, plays an important role in fostering their competencies. For mathematical competencies, we suspect that especially domain-specific processes in the field of numeracy as well as the general HLE are connected to the child's mathematical competence. Regarding the addition or mediation of early and later HLE effects, the mixed research findings induce us to assume that effects of the early years home learning environment are at least partly mediated by later home learning environment.

With regard to the effects of institutional child care, we expect both positive effects for time spent in ECEC as well as extent of activities, as both can be seen as an enrichment in addition to the impact of the family. As described in the theoretical framework and the state of research, we suggest that the effect of institutional ECEC is smaller than the effect of the family a child grows up in, as it is the first and central learning environment.

4. Method

4.1 Sample

As already mentioned, the study draws on data of the Starting Cohort One of the German National Education Panel Study (NEPS[1]; Blossfeld & Roßbach, 2019), which started as a nationally representative sample of 3481 children born in 2012 and their families. From 2013 onwards, each child older than one year was entitled to a place in a child care center or in family-based day care, making this NEPS cohort one of the first to include children and their parents who have been exposed to the changed day care situation in Germany. We use the first five waves of this

1 This paper uses data from the National Educational Panel Study (NEPS): Starting Cohort Newborns, doi:10.5157/NEPS:SC1:6.0.0. From 2008 to 2013, NEPS data was collected as part of the Framework Program for the Promotion of Empirical Educational Research funded by the German Federal Ministry of Education and Research (BMBF). As of 2014, NEPS is carried out by the Leibniz Institute for Educational Trajectories (LIfBi) at the University of Bamberg in cooperation with a nationwide network.

cohort, in which the children were 7 months of age (wave 1), 13 months (wave 2), 27 months (wave 3), 38 months (wave 4), and 48 months (wave 5).

Information was gathered via computer-assisted interviews, videotaped and coded interactions of parents and their children, as well as competence tests of the children. By including data of the home learning environment, parent-child interactions and variables of institutional child care in wave three, it is possible to have information on different learning experiences in both central learning environments for children under the age of three. The panel design allows adding data of the HLE from later waves to prove whether the effects of early HLE remain. The mathematical competencies measured in the fifth wave of the NEPS were used in the study (children's age: 48 months).

Due to missing data in the central variables and drop-out over the five waves, the sample for the first research question is N = 1170. For the second research question, which examines activities in ECEC our sample size is reduced to N = 230. Note that the comparatively small sample size only includes children who were being cared for at wave three and the initial sample of the educators, which gives information on institutional child care from 560 educators, as information on ECEC activities were gained by a drop-off questionnaire for educators, which had a return rate of 31.6 %.

4.2 Measures

4.2.1 Dependent variable

Mathematical competencies of the children were assessed by using the standardized test "KiKi – Kieler Kindergartentest" (Grüßing et al., 2013). This test contains tasks referring to subareas like 'sets, numbers and operations', 'units and measuring' or 'space and shapes' (for more information on the theoretical background or validity-analyses: Neumann et al., 2013; Knopp et al., 2014). We used the weighted maximum likelihood estimates in our analysis (M = .08, SD = 1.00, Table 1).

4.2.2 Independent variables

Home learning environment (HLE). For information on the HLE we used two sets of different indicators (Table 1). One scale was formed to give information about *frequency of joint activities at home*. These indicators include activities like 'shared picture book reading' or 'dealing with numbers' (0 = never; 7 = several times a day). The indicator was computed for wave three (Cronbach's α = .53, seven items, M = 4.54, SD = .83), four (Cronbach's α = .55, six items, M = 4.36, SD = .89) and five (Cronbach's α = .59, six items, M = 4.21, SD = .91).

The second set of indicators gives information about parental stimulation in a semi-standardized play situation, which was videotaped and coded. The play situation (with a standardized toy set) lasted ten minutes and was conducted in the third wave at the home of the family. Trained coders using a system adapted from the NICHD study (NICHD Early Child Care Research Network, 1999) rated the parent-child interaction on a five point scale, indicating whether the described behavior was (1) not at all to (5) highly characteristic for the parent (see Linberg, Mann, Attig, Vogel, Weinert, & Roßbach, 2019 for a description of the procedure and instrument). As we focus on domain-specific stimulation, we used two variables in our analysis: *parent-child interaction: numeracy stimulation* (M = 1.43, SD = .60) and *parent-child interaction: language stimulation* (M = 3.41, SD = .75). Language stimulation "captures the amount and quality of verbal enrichment of the play situation, including prompting and expanding child's verbalizations, asking open ended questions, correcting mistakes, decontextualization / verbal distancing of subject matters. Numeracy stimulation covers inclusion of mathematical concepts in the play situation at a very basic level, e.g. counting, comparing, sorting, distinguishing patterns, in amount and variation" (Linberg et al., 2019, p. 7). Inter-rater reliability was checked by double-coding 20 % of randomly selected videos (inter-rater agreement for both scales > 90 %).

ECEC. For institutional child care we used the time a child spent in ECEC in his/her first three years (*duration* in months, M = 12.34, SD = 9.23, Table 1). Additionally, for the subsample we computed two variables, which give information about the frequency of activities as indicators for process quality. Here we followed a study of Linberg, Kluczniok, Burghardt, and Freund (2017) where observed quality (measured with the German version of the Infant/Toddler Environment Rating Scale, Harms, Cryer & Clifford, 2007) was linked to the NEPS-questionnaire. The goal of the study was to identify a small set of staff reported variables, which are linked to observed quality. For activities, two scales (0 = never; 7 = several times a day) were generated from data of the third wave: *Everyday activities* which include 'reading out loud/looking at picture books', 'making music/singing/dancing', 'playing with puppets and stuffed animals' and 'building blocks or stacking games' (Cronbach's α = .70, M = 6.15, SD = .85) and *extensive activities* which consists of three variables demanding more time and effort: 'moving outdoors', 'tinkering, painting, kneading' and 'playing in sand or in/with water' (Cronbach's α = .57, M = 5.54, SD = .87, Table 1). Linberg et al. (2017) showed that the extensive activities are especially linked to observed quality.

4.2.3 Control variables

As depicted in the theoretical model, it is important to investigate the effects of different learning environments, while considering the individual characteristics of the child, respective of the family. This seems especially important for children under the age of three in the context of German institutional child care. With regard to the theoretical approach of the economic consumer choice model, which mainly refers to the trade-off of returning to work through using child care (Boudon, 1974), as well as the state of research which shows that access to institutional child care is not accessible for all families in the same way (Burghardt, 2019), meaning that higher educated parents are more likely to return (earlier) to work and parents with a migration background are less likely, the following control variables (see table 1) are added to reduce the effects of selection into child care: migration background of the family (based on data on the first language spoken in the home, 0 = no migration background; 1 = migration background, 13 %) and mother's educational status (ISEI 08; Ganzeboom, 2010; M = 60.67, SD = 18.27). For the individual characteristics of the child, we used the child's age (at wave five, M = 50, SD = 1.56) and the child's gender (0 = girl; 1 = boy, 50 %).

Table 1: Descriptives

	N	*M*	*SD*	Min	Max
Mathematical competencies (wave 5)	1170	.08	1.00	-3.46	3.19
HLE (wave 3)					
Joint activities at home (0=never; 7=several times a day)	1170	4.54	.83	1.43	6.57
Parent-child interaction: mathematical stimulation (1=not at all characteristic; 5=very characteristic)	1170	1.43	.60	1	5
Parent-child interaction: language stimulation (1=not at all characteristic; 5=very characteristic)	1170	3.41	.75	1	4
ECEC					
Duration of time spent under the age of three (in months)	1170	12.34	9.23	0	30
Everyday activities (wave 3) (0=never; 7=several times a day)	230	6.15	.85	3.25	7
Extensive activities (wave 3) (0=never; 7=several times a day)	230	5.54	.87	2.00	7
Control variables: child and family					
Child's age at wave 5 (in months)	1170	50.00	1.56	46	54
Child's gender (0=girl, 1=boy)	1170	.50	.50	0	1
Migration background (0=no MB, 1=MB)	1170	.13	.34	0	1
Mother's educational status (ISEI 08)	1170	60.67	18.27	11.74	88.96
Control variables: HLE at wave 4 & 5					
Joint activities at home wave 4 (0=never; 7=several times a day)	1170	4.36	.89	1.67	6.5
Joint activities at home wave 5 (0=never; 7=several times a day)	1170	4.21	.91	0.83	6.5

4.3 Statistical analyses

To examine the impact of the early years home and institutional learning environment on children's mathematical competencies, a stepwise procedure was used. First, linear regression analyses were run where in Model 1 mathematical competencies were regressed on frequencies of joint activities at home as an indicator for global HLE. In Model 2, mathematical competencies were in addition to Model 1 regressed on the two domain-specific HLE indicators of parent-child interaction 'mathematical stimulation' and 'language stimulation' (Model 2). Third, in order to show if there is an effect of time spent in ECEC, the variable for duration was included. In the fourth model, control variables were added. To indicate whether the effect of the early years HLE (wave 3) and time spent in institutional child care under the age of three persist, we include joint activities at home from wave four and five (Model 5). To answer the last research question, we take a detailed look at those children who attended ECEC and analyze the additional effect of activities on mathematical competencies. Again, the first model includes the indicator for global HLE, the second model includes domain-specific HLE. The third model includes the duration and the scales for activities in institutional child care, before the control variables are added in the last two models. The analysis has been carried out using IBM SPSS 25.

5. Results

5.1 Relation between the early years HLE and time spent in ECEC with later mathematical competencies

The results for the effect of the early years home learning environment on mathematical competencies are shown in Table 2. Model one shows that there is a positive relationship between frequencies of joint activities at home and the outcome variable. However, the explained variance is quite small (adj. $R^2 = .01$). The second model reveals a positive effect of domain-specific HLE – language stimulation during parent-child interaction – on mathematical competencies. The time children spent in institutional child care reveals a positive tendency, meaning more time spent in ECEC is connected to higher mathematical competencies (Model 3). Note that the mathematical stimulation in parent-child interaction also reveals a positive tendency. By adding individual characteristics of the children and their families (Model 4), the explained variance increases to 11 %. Older children as well as children whose mother has a higher educational status reveal higher mathematical competencies. There is also a gender effect, displaying higher competencies in girls than in boys. At a significance level of $p < .10$, there is also an effect demonstrating lower mathematical skills in children with a migration background. Note that the effect of ECEC duration vanishes and the effects of joint HLE activities and lan-

Table 2: Regression of early years HLE and time spent in ECEC on later mathematical competencies

	Mathematical competencies at wave 5 (N = 1170)									
	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Step 1: global HLE (wave 3)										
Joint activities at home (0=never; 7=several times a day)	.09**	.04	.08**	.04	.09+	.04	.06+	.03	.01	.04
Step 2: domain-specific HLE (wave 3)										
Parent-child interaction: mathematical stimulation (1=not at all characteristic; 5=very characteristic)			.05	.05	.05+	.05	.07*	.05	.07*	.05
Parent-child interaction: language stimulation (1=not at all characteristic; 5=very characteristic)			.13***	.04	.13***	.04	.08**	.04	.08**	.04
Step 2: ECEC										
Duration of time spent under the age of three (in months)					.05+	.00	.02	.00	.03	.00
Step 3: Control variables: child and family										
Child's age (in months)							.22***	.02	.22***	.02
Child's gender (0=girl, 1=boy)							-.07**	.06	-.07*	.06
Migration background (0=no MB, 1=MB)							-.05+	.08	-.05+	.08
Mother's educational status (ISEI 08)							.18***	.00	.18***	.00
Step 4: Control variables: HLE at wave 4 & 5										
Joint activities at home wave 4 (0=never; 7=several times a day)									.06+	.04
Joint activities at home wave 5 (0=never; 7=several times a day)									.03	.04
***R*²**	**.01****		**.03*****		**.03*****		**.12*****		**.12*****	
adj. *R*²	**.01**		**.03**		**.03**		**.11**		**.12**	

+p < .10. *p < .05. **p < .01. ***p < .001. Significance of the ANOVA is indicated at R^2.

guage stimulation at home decrease while the effect of mathematical stimulation at home increases when adding the family background characteristics. In the final model (Model 5), the effects at the individual level remain the same. Even after controlling for joint HLE activities in the fourth and fifth wave, there are still significant effects of early parent-child interactions on mathematical competencies when the child was two years old but there are no effects for joint-activities at this early age. Overall, the explained variance rises to 12 %.

5.2 Relation between early years HLE, time spent and activities in ECEC on later mathematical competencies

To analyze the second research question, we used a subsample of our initial sample, which gives information about the group of children attending ECEC and the activities carried out in institutional child care at the age of two years. Like the analyses on the full sample, the first model includes HLE indicators, the second model includes the duration and the scales for activities in institutional child care, and in the final two models, the control variables were added (Table 3). In the comparatively small subsample, we do find a small tendency for global HLE (Model 1). In the second model, we do not find effects of either global or domain-specific HLE. The same is true when we add the duration and activities in ECEC (Model 3). When control variables are included, a positive tendency for mathematical stimulation in parent-child interaction ($\beta = .12$; $p < .10$) and for extensive activities in ECEC ($\beta = .12$; $p < .10$) arises. This model explains 6 % of the variance. Adding joint activities at home from wave four and five does not change the picture. All coefficients remain unchanged with the exception of mathematical stimulation, which decreases from $\beta = .12$ to $\beta = .11$.

6. Discussion

Based on the assumptions of ecological interactionist theory (Bronfenbrenner & Morris, 2006; Wygotski & Cole, 1978), our study explored the relevance of the early years home and institutional learning environments for early mathematical competencies. To get a better understanding of the results and also their validity, it seems necessary to point out the following limitations:

We described above, that we are using longitudinal data of the NEPS. As this is true for variables like 'joint activities at home' or 'duration of time spent in ECEC,' we could only refer to the mathematical competencies of the children in the fifth wave (age 4). As this is the first time it was assessed in the starting cohort one of the NEPS study, we were not able to analyze developmental progress but developmental status. However, we could not take previous competencies into account

Table 3: Regression of early years HLE and time spent in and activities in ECEC on later mathematical competencies

	Mathematical competencies at wave 5 (N = 230)									
	Model 1		Model 2		Model 3		Model 3		Model 4	
	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Step 1: global HLE (wave 3)										
Joint activities at home (0=never; 7=several times a day)	.11^{+}	.09	.10	.09	.11	.04	.10	.09	.06	.10
Step 2: domain-specific HLE (wave 3)										
Parent-child interaction: mathematical stimulation (1=not at all characteristic; 5=very characteristic)			.09	.13	.10	.05	.12^{+}	.13	.11^{+}	.13
Parent-child interaction: language stimulation (1=not at all characteristic; 5=very characteristic)			.04	.10	.04	04	-.01	.10	.00	.10
Step 3: ECEC										
Duration of time spent under the age of three (in months)					-.04	.01	-.06	.01	-.07	.01
Everyday activities (wave 3) (0=never; 7=several times a day)					-.09	.09	-.10	.09	-.11	.09
Extensive activities (wave 3) (0=never; 7=several times a day)					.12	.08	.12^{+}	.08	.12^{+}	.08
Step 4: Control variables: child and family										
Child's age (in months)							.19**	.04	.19**	.04
Child's gender (0=girl, 1=boy)							-.03	.14	-.02	.14
Migration background (0=no MB, 1=MB)							-.03	.22	-.03	.22
Mother's educational status (ISEI 08)							.15*	.00	-.15*	.00
Step 5: Control variables: HLE at wave 4 & 5										
Joint activities at home wave 4 (0=never; 7=several times a day)									.01	.10
Joint activities at home wave 5 (0=never; 7=several times a day)									.09	.09
R^2	**.01^{+}**		**.02**		**.04**		**.10***		**.10***	
adj. R^2	**.01**		**.01**		**.01**		**.06**		**.06**	

$+p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. Significance of the ANOVA is indicated at R^2.

which are known to contribute significantly to the prediction of later competencies (LeFevre, Fast et al., 2010; Nguyen et al., 2016).

The analysis of the first research question, to what extent the early home learning environment at the age of two years is associated with mathematical competencies at the age of four years, reveals positive effects of the separate HLE scales on mathematical competencies, irrespective of child and family background variables. Specifically, we find smaller effects of the global stimulation, as indicated in the frequency of joint activities at home, like frequency of shared book reading and singing songs, compared to the domain-specific stimulations, indicated through language and math stimulation during parent-child interactions. However, the significant relations of both parent-child interaction scales and mathematical competencies strengthen the hypothesis of cross-domain effects: Not only math-specific stimulation but also language-specific stimulation are connected to mathematical competencies (Lehrl et al., 2020; Napoli & Purpura, 2018). Such cross-domain effects could be explained by the fact that children's mathematical representations are built through language (Wiese, 2003). There is a well-documented relationship between language and mathematics (Peng et al., 2020). In their recent meta-analyses, Peng et al. (2020) conclude that language contributes to math performance via two pathways: through the medium function of language (i.e., using language as a tool for communicating mathematics knowledge with others and building and retrieving representations of mathematics knowledge from long-term memory) and the thinking functions of language (i.e., using language to think about abstract mathematical concepts). Whereas the medium function of language is especially important for foundational mathematics skills (e.g., numerical knowledge and simple calculations), the thinking function of language is particularly important for advanced mathematics. Thus, through high-quality language stimulation at home, parents might foster children's language skills, which in turn might be one pathway to the development of mathematical competencies. Although studies have shown that exposing children to mathematical language during interaction – the so called "math talk" – is highly relevant to mathematical development (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Ramani et al., 2015), it is still not clear, which language stimulation exactly contributes to mathematics learning.

But the interpretation of the results should take into account that the reliability of the quality indicators of the global HLE ranges from Cronbach's $\alpha = .53$ to $\alpha = .59$ and must be interpreted as quite low. Additionally it has to be mentioned that in wave three, the activity of pretend play was assessed, but this item was not assessed in the further waves. Therefore, the scale of wave three consists of seven items, and the scales of wave four and five consist of six items.

Concerning the question whether later HLE experiences add to or mediate early HLE effects (research question two), we found that the effect of the early joint activities at the child's age of two years vanished when we added the frequency of joint activities at age 3 and 4. As depicted in the research, effects of early years home learning environment are partly mediated by later home learning environment (e.g., Tamis-LeMonda et al., 2019). Our results point in the same direction.

Unfortunately, there was no data on later domain-specific measures of stimulation within the parent-child interaction, yet the global HLE indicator did not mediate the association between the domain-specific indicators and children's mathematical competencies. With regard to the effects of ECEC, we only find a small tendency of the duration of time spent in ECEC, when no control variables are added. The fact that this effect completely vanishes when child and family characteristics are added points to potential selection effects in ECEC. Research shows clear interrelations of parent's educational status or migration background with entry into ECEC, showing that especially parents with a migration background enter institutional child care rather late (Burghardt, 2018). While it was important to add these control variables for exactly this reason, these variables are mainly responsible for the vanishing of the duration-effect.

For the third research question regarding the effects of the frequency of activities in ECEC on children's math outcomes, we only find small effects of extensive activities in institutional child care. These results have to be interpreted with caution. As these tendencies only emerge in the models where control variables are added and were not related to (later) mathematical competencies on their own, the results point to a non-significant effect for frequency of activities in institutional child care. We ran several other statistical analyses as sensitivity analyses, where we included each activity on their own or used a different composite but did not find any significant effects on mathematical competencies. As depicted in the theoretical model, the quality of institutional child care has shown to be of high importance for a child's individual development. The frequency of activities within the whole group of children in institutional child care can only be seen as a rough indicator for the actual process quality, which an individual child experiences during its stay in the childcare-center. Additionally this scale of extensive activities in ECEC shows only small internal validity (Cronbach's $\alpha = .57$). Nonetheless, Linberg et al. (2017) showed that the extensive activities are linked to observed quality.

Furthermore, we do not have any information about whether or not the child was actually involved in the preschool teacher's stated activities nor do we have any information about the quality of the different activities. Additionally, even though the sample started as a nationally representative sample, our analysis sample is quite small; this is particularly true for the third research question regarding effects of the institutional setting. As explained above, this can be traced back to the relatively small sample size of $N = 230$ children, as information on ECEC activities was gained by a drop-off questionnaire for educators, which had a return rate of 31.6 %. Therefore, our results should not be generalized.

Our study contributes to filling research gaps by addressing the early years home and institutional learning environments for children under the age of three in Germany. In summary, we do find effects for global indicators like 'joint activities at home' as well as domain-specific stimulation in 'parent-child interaction'. Following Bronfenbrenner and Morris (2006), these aspects of the home learning environment can be characterized as the "prime engine" in child development. The rather rough indicators for the institutional learning environment calls for further research. As we could not include any information on stimulation quality or the enrollment of the child in the activities that were assessed in the NEPS, it would be important to conduct a study where process quality could be observed and not assessed in a questionnaire, as observation can be seen as the 'gold standard' (Bäumer & Roßbach, 2016). As we also do not know what part mathematical activities play in institutional child care for children under the age of three, even though it is in the educational plans of the federal states (Youth Ministers' Conference & Culture Ministers' Conference, 2004), further research should focus on the embedment of math-related processes. As some math intervention programs with preschoolers have been shown to be highly effective (for an overview: Lehrl, 2018), it should be examined which math-specific activities under which circumstances might be profitable for children under the age of three.

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Hybrid environments for universities

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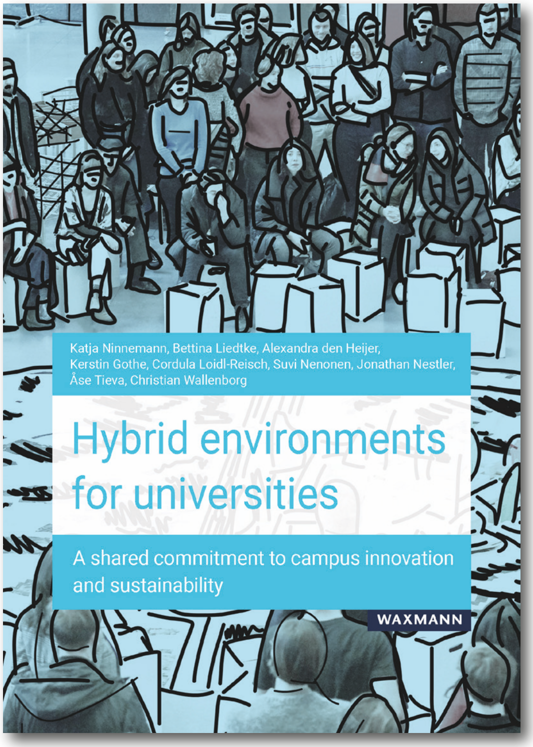

This publication is the result of an international and interdisciplinary expert meeting at Technische Universität Berlin, in March 2020. The aim of the expert meeting was to collaboratively write and publish a book, within five days, on the central question: Which organizational structures and processes at universities support a strategic as well as innovative campus development?

As experts with an interdisciplinary background including the social sciences, public real estate, urban planning, architecture and landscape architecture, we could examine the question from a holistic perspective and gain new insights.

The resulting manifesto states necessary steps and strategies to create innovative and sustainable hybrid environments for universities. It addresses all decision makers – executives, practitioners and contributors alike – as all of us face the challenge of limited resources and needing to do more with less.

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