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Relations between motor skills and language skills in toddlers and preschool-aged children

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Abstract
The purpose of this longitudinal study is to (1) examine the relations between language and motor-life skills in toddlers and preschool-aged children (n = 646) in real-life situations; and (2) to explore how the level of motor-life skills in toddlers (2 years and 9 months, T1) is related to language skills at preschool age (4 years and 9 months, T2). Data were collected through structured observation during play and daily life activities (authentic assessment) by staff in Norwegian Early Childhood Education and Care institutions. The correlations between motor-life skills and language skills at T1 were significant but small (r = .12 to .29) and were somewhat stronger at T2 (r = .18 to .46). The correlation between motor-life skills at T1 and language skills at T2 (total score) was small (rho = .25) but significant. However, the subgroups with weak and strong motor-life skills at T1 differed significantly in language skills at T2 (effect size: .40). These findings support and complement previous research, which indicates significant relations between the level of motor-life skills in toddler age and language skills in preschool age.

Keywords: *early childhood education; skill development; prediction; authentic assessment*

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Introduction

The importance of early language learning for the development of language and literacy in later years is frequently emphasised in the literature (see, for example, Aukrust, 2005; Kuhl, 2011; Rogde et al., 2016). The specific importance of speech-, oro- or verbal-motor skills for language development is widely accepted (Dodd & McIntosh, 2010; Hotulainen et al., 2010; Nip, et al., 2011). However, the need for a deeper understanding of the relationship between general motor skills and language skills has been highlighted in the literature (Iverson, 2010; Leonard & Hill, 2014; Son & Meisels, 2006). We agree with Iverson's (2010) characterization of the relations

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between motor and language development as 'complex and multi-faceted rather than simple and directional' (p. 258).

This study aims to examine the relations between motor-life skills and language skills in a group of children at ages 2 years and 9 months (2;9, T1) and 4 years and 9 months (4;9, T2) and to explore how the level of motor skills in toddlers is related to language skills in preschool. Beyond that, we provide a more in-depth investigation by scrutinising various subdimensions that constitute the motor and language domain. Our particular focus is the opportunity for staff in Early Childhood Education and Care institutions (ECECs) to assess children's motor and language development from a functional angle by applying structured observation tools implemented by the staff at these institutions.

The relations between motor and language skills

There is some evidence that motor skills and experiences from motor activities are related to language already at an early age (Cameron et al., 2012; Dodd & McIntosh, 2010; Leonard & Hill, 2014; Oja & Jurimae, 2002; Wang et al., 2014; Webster et al., 2005). According to Iverson (2010), 'Studying the ways in which motor achievements contribute to the development of language may not only yield a more comprehensive picture of the emerging language system; it may also provide fundamental insights into the processes underlying this emergence' (p. 258).

Ionesco and Ilie (2018) have recently shown that embodied learning processes in early language development may be superior to learning processes that do not involve the child's body. One possible explanation for this is that the ability to (inter) act intentionally with the environment requires sensory, physical and motor skills that are continuously developing throughout childhood. For instance, one of the earliest motor milestones, the onset of walking, affects how young children share objects with their mothers and, in turn, mothers' verbal responses to their children (Karasik et al., 2014); this underscores the close, mutual relationship between motor behaviour and verbal and non-verbal communication.

Becker, McClelland, Loprinzi, and Trost (2014) observed that a higher level of physically active play in preschool age was positively related to self-regulation, which in turn increased literacy and mathematics scores. This improvement only emerged when self-regulation also improved, not as a direct consequence of more play activity by itself. These findings suggest that the positive outcomes of physically active play on literacy and mathematical skills may be engendered by reinforcing and integrating executive functions such as memory, attention and inhibitory control. Movement training and physically active play stimulate the development of motor skills (Logan et al., 2012; Wick et al., 2017) and, through this, can contribute to strengthening children's language skills. The importance of physically active play is also supported from a neuroscientific perspective. Kuhl (2011) emphasises that language performance is strongly related to children's experiences and brain development. Although results from brain research are still mostly correlational, the connection can be considered 'potentially causal and [...] further research will allow us to develop causal explanations' (Kuhl, 2011, p. 13).

Peer interactions and, to some degree, adult-child interactions rely heavily on motor skills (Leonard & Hill, 2014). Participating in play, playful activities and playful relationships with others requires sufficiently developed motor skills. Successful participation in play contributes to the physical mastery of play tasks, inclusion and appreciation in the peer group, as well as to being perceived as an attractive playmate for others. Since language learning is a highly social process, social settings that provide opportunities to experience and acquire complex language skills are one of the key demands for high-quality early childhood education, both within families and ECECs. Thus, an environment that provides affordances and opportunities to relate properly to peers and adults is of particular importance. This is consistent with the findings in a systematic review of the literature conducted by Leonard and Hill (2014), who explored the connections among motor development, social cognition and language. They concluded, 'It is evident from these studies that developing motor skills can influence the number and types of opportunities that infants and children have to interact with others, and the consequent development of social relations' (Leonard & Hill, 2014, p. 167).

The comorbidity between impaired motor skills and challenges in other domains of development has been frequently stated (Gillberg & Kadesjo, 2003; Hill, 2001; Iverson, & Braddock, 2011; Visser, 2003) in regard to developmental and learning problems at a young age. Son and Meisels (2006) revealed that weak motor-life skills at ages 5 to 6 can be a marker for the risk of weak development of academic skills. Hill (2010) emphasised that a large proportion of children with specific language impairment (40%–91%) show weak motor skills similar to developmental coordination disorders.

Poor or atypical motor development could be considered a possible moderating factor related to problems with language, communication and social interaction that arise in several neurodevelopmental disorders (Leonard & Hill, 2014, p. 167). However, the causality of the relationship has not yet been adequately clarified. Deficient motor skills might compromise preschool-aged children's participation and enjoyment (Bart et al., 2011) and thereby limit their opportunities for communication as the basis for language development. Another explanation suggested by Adi-Japha, Strulovich-Schwartz, and Julius (2011) could be that deficient skill acquisition in language might not be exclusively linked to the language system but could be tied to the procedural memory system, which may affect both the language and motor domains. This is in line with Webster et al. (2005), who concluded that factors causing weak motor performance may lead to language deficits as well. Assuming that multiple approaches to understanding comorbidity may be more relevant than single explanations, Carpenter and Drabick (2011) called for longitudinal studies that focus on specific subgroups of children and provide relevant knowledge of the predictors of developmental outcomes in these subgroups. Thus, in this study, we aim to contribute longitudinal data pertinent to educational practice regarding all children of toddler and preschool ages.

Assessing children's motor-life skills and language skills from a functional perspective

In characterising requirements for individual professional competence among ECEC staff, Urban, Vandebroek, Lazzari, Van Laere and Peeters (2012, p. 35) identified the following as core elements of educational practice: 'Observing children in order to identify their developmental needs', 'Documenting children's progress systematically in order to constantly redefine educational practices' and 'Identifying children with special educational needs and elaborating strategies for their inclusion'. Our specific interest lies in the relationships between the motor and language domains in children's natural environment in Norwegian kindergartens. In this way, we hope to promote knowledge that is especially relevant to employees' professional work with and for children. Professionals' educational and pedagogical activities are based on daily observations of interactions with children. In this study, we thus build on the information professionals themselves can generate in their work and support them with observation instruments that centre on children's actions and expressions in everyday life.

The term 'functional perspective' denotes an understanding of assessment that is closely related to, and could potentially benefit to, the field of educational practice, particularly regarding the professional work carried out by staff in ECECs. From a sociocultural and ecological understanding of learning and development (Vygotsky, 1997), according to Säljö (2009, p. 207), a major area of interest lies in 'the study of how human skills—be they bodily, cognitive, perceptual or a mix of these dimensions—are appropriated by individuals'. Hence, we assume that knowledge relevant to educational decisions and actions requires observations of children in natural interactions with their social and physical environments.

The Norwegian Framework Plan for Kindergartens (Norwegian Directorate for Education and Training, 2017) and the national regulation of preschool teacher education (at the bachelor's level) are highly process- and resource-oriented (see summary in Engel et al., 2015). Therefore, in this study, we are particularly interested in the opportunity for ECEC staff to implement the obtained knowledge in their pedagogical practice in ECECs. In line with Iverson (2010), we consider knowledge about the relations between motor and language skills, and the development of these skills, to be highly relevant for practitioners working with young children. Systematic observations of children's skills in everyday life in ECECs have a direct bearing on educational practice and practitioners. Adapted support for individual children by the staff requires reliable, valid observations of children's functional skills in their everyday activities and play.

Thus, our methodology to assess functional skills among toddlers and preschool-aged children is consistent with the authentic assessment approach (Bagnato et al., 2010; Macy & Bagnato, 2010). In this approach, toddlers' and preschool-aged children's interactions with their natural physical and social environments become the core objects of observation, and functional skills are understood as important prerequisites for meeting the challenges of daily life.

Research questions

The purpose of this study is to examine the relations between language and everyday motor-life skills in toddlers and preschool-aged children in real-life situations, as well as the association between these skills from toddler to preschool age (i.e., how the level of motor skills in toddler age is related to language skills in preschool age). The research questions are as follows: (1) (a) What is the relation between language skills and motor-life skills at age 2;9 and at age 4;9 respectively, (2) How are motor-life skills in toddler age related to language skills in preschool age?

Design and method

This study is part of the longitudinal, interdisciplinary *Stavanger Project – The Learning Child* following children's development from 2 ½ to 10 years of age (Reikerås et al., 2012).

Instruments

As discussed above, data generation is based on authentic assessment as a presumed reliable, valid and non-intrusive way of assessing children's skills in their play and everyday life activities in ECECs (Bagnato et al., 2014). The children's *language skills* were assessed using the observation material *TRAS – Tidlig registrering av språkutvikling* (Early registration of language development) (Espenakk, 2003). The TRAS consists of eight sections, including nine items in each section (for a total of 72 items): *Language comprehension*, *Linguistic awareness*, *Attention*, *Communication*, *Interaction*, *Sentence production*, *Word production*, and *Pronunciation*. There are three levels of difficulty within each section, with level 1 as the easiest and level 3 as the most difficult. The interrater reliability for the sections in TRAS varied from .69 to .83 (Espenakk, 2003).

The material was developed in Norway for children between two and five years old and was constructed for use in ECECs. Natural situations and children's play activities are the main observational arenas. To make the observations easier for the staff in the ECECs and to strengthen the quality of the data, a detailed description of each item and guidelines for scoring were developed for the project (Helvig & Løge, 2006). The 3-point response scale ranges from 0 (proficiency not yet observed) to 1 (partial proficiency for the given task) to 2 (the child possesses competence in the given task).

Motor-life skills were assessed by ECEC staff who applied the Early Years Movement Skills Checklist (EYMSC, Chambers & Sugden, 2002, 2006). Moser and Reikerås (2016) reported the adaptation of the material to fit the Norwegian context. The EYMSC provides information about motor skills in natural surroundings for children from three to five years old (Chambers & Sugden, 2006). The interrater reliability was .96 ($p<.01$), and the test-rest reliability was .95 ($p<. 01$). A validation of the EYMSC (Chambers & Sugden, 2002) against the Movement Assessment Battery for Children (Henderson & Sugden, 1992) revealed a correlation of $r = .76$ ($p<.01$).

The material is divided into four sections: *Self-help skills* (six items); *Desk skills* (five items); *General classroom skills* (five items); *Recreational and playground skills* (seven items). Each of the 23 items is scored on a four-point scale to register how well a child has mastered the particular skills. First, the teachers must decide whether the child can or cannot perform the task. Subsequently, the teachers concretize their choice by using two further subcategories: for children who can perform the task, the subcategories are (1) can do this task well or (2) can just do this task; for children who cannot perform the task, the subcategories are (3) can almost perform this task (4) or not close to performing this task. After the observation period, the scores for the items in each section are summed, and the sum of these section scores becomes the EYMSC total score. The lower the total score is, the larger the number of items that are well-performed or mastered by the child. The EYMSC was developed for children between 3 and 5 years of age (Chambers & Sudgen, 2002); the age group at T1 in the current study lies somewhat outside this range. However, a study comparing the same sample as in the current study at T1 with 3-year-old British children revealed relatively high motor competence in the Norwegian sample compared to the slightly older British sample (Moser & Reikerås, 2016). This indicates that the EYMSC can be used for the participants in our study, although they are slightly younger than the age span for which the material is designed. Notwithstanding, we must interpret the findings cautiously.

Since both TRAS and the EYMSC are thought to identify developmental difficulties in children up to 5 years old, we expected ceiling effects at preschool age within a sample containing a majority of children assumed to not have such difficulties. Such ceiling effects at T2 are expected to reduce the information regarding average and high-performing children's skills at T2.

A detailed description of each item and guidelines for scoring the EYMSC were developed (Iversen & Larsen, 2007) to help the staff gather the data, thereby strengthening the comparability of the assessments and increasing the reliability of the data collection. During the first round of data analysis, the response categories were re-coded so that high scores represented a better level of motor-life skills, while lower scores represented a weaker level. The recoded values are as follows: 1 = not close to performing this task; 2 = can almost perform this task; 3 = can just do this task; 4 = can do this task well. This was done essentially for convenience; it is easier to understand and communicate the results when a higher numerical score expresses a higher level of motor skills.

Recruitment, participants and dropout rate

All public (61) and 50% of the private ECECs (25) of Stavanger municipality accepted the invitation to participate in the study. The parents of children born between July 1st, 2005, and December 31st, 2005, who attended one of the participating ECECs received oral and written information about the project and were asked for written consent for their child to participate in the study. Apart from this period of birth, no other criteria excluded a child from participating in the study.

We consider the city of Stavanger to be representative of other Norwegian cities and urban settlements of a certain size in terms of ECEC services. The law nationally regulates ECEC, and the national curriculum guidelines for ECEC must be applied all over the country. The proportion of private and public ECECs in Stavanger corresponds to the national average. Because only half of the private institutions participated in the study, this could be a source of error. On the other hand, most national studies carried out in ECECs have usually not revealed any significant differences between private and public institutions. Nevertheless, due to the presence of the oil-related industry, the residents of Stavanger had higher average incomes during the data collection period (approximately 24% higher than the national average according to Kommunefakta, 2017). Nevertheless, we assume that the results are transferable to other Norwegian cities and urban settlements.

At baseline (T1), we gathered data on language skills and motor-life skills for 1,077 children (529 girls, 548 boys). All children had been enrolled before they were 2;6 years of age. Between the first round of data collection (T1) and the second round (T2), 200 children moved out of the municipality, and two consent forms were withdrawn. In addition, some ECECs had not returned results from either TRAS or the EYMSC at T2 for 219 children. These ECECs did not observe the children in the proper time intervals, forgot where they had stored their observation schemes, or the children had been absent because of holiday or illness. Finally, for 10 of the children, we identified failures in the registration of data at T2. Thus, the study had a dropout of 431 children, equivalent to 40% of the baseline group at T1. For the remaining 646 children (323 girls, 323 boys), data on motor-life and language skills were available for T1 and T2.

A dropout analysis using an independent-sample t-test identified no significant differences in motor-life skills (EYMSC total at T1) between the dropout group ($M = 75.52$, $SD = 9.33$) and the remaining group (participants) ($M = 75.11$, $SD = 8.33$); $t\ (849.29) = -.75$, $p = .45$ (two-tailed). The magnitude of the differences in the means was quite small (mean difference = –.42, CI: –1.51 to .67; eta squared = .001). For TRAS, the independent-sample t-test between the dropout group ($M = 66.96$, $SD = 23.95$) and the remaining group ($M = 70.68$, $SD = 22.86$) revealed a significant difference at T1 ($t\ (1075) = 2.57$, $p = .01$; two-tailed). However, the effect of the mean difference was quite small (mean difference = 3.72, CI: .88 to 6.57; eta squared = .006).

Compared to the remaining group, there was a slightly larger proportion of boys (225) than girls (206) in the dropout group. In addition, 15.3% of the children in the dropout group were multilingual, which is somewhat less than those in the remaining group (19%). On the basis of these analyses, we assume that dropouts do not seriously affect the findings.

Socioeconomic status (SES) was measured by parents' education levels. In a questionnaire, both parents were asked to indicate their highest level of education achieved by choosing one of four levels (upper secondary school; high school; college/university education [1 to 3 years], and college/university education [>3 years]). Even though all parents received the questionnaire, not all of them returned a completed questionnaire. SES data are therefore only available for 269 (41.6%) of the participants, of which 263 contained answers for both the mother's and father's education level, five for only the mother's education level and one for only the father's education level (see Table 1).

Table 1. Parents' levels of education compared with the average education level for the entire municipality of Stavanger and for all of Norway

Level of education	**Mother's education level (n = 268)**	**Father's education level (n = 264)**	**All of Stavanger**	**All of Norway**
Upper secondary school	2.2%	.8%	21.5%	25.8%
High school	12.7%	23.1%	35.2%	40.1%
College/university (1 to 3 years)	22.8%	22.0%	27.1%	24.1%
College/university degree (>3 years)	62.3%	54.2%	16.2%	10.0%

As shown in Table 1, the SES level for the participants is considerably higher than the educational level in all of Stavanger and in all of Norway. This difference in SES, possibly based on selection effects, may affect the results. Families with a higher level of parental education may have a better understanding of the study's relevance and/or may be more generally interested in educational issues regarding their children. The proportion of parents of multilingual children who answered the questionnaire was 39.8%, which was similar to the proportion of parents of children who are living in a monolingual Norwegian environment at home. Thus, there were no differences in the response rates between multilingual families and monolingual Norwegian-speaking families.

Although the limitations of the study, due to the high share of missing SES data, should be noted when generalising the findings, t-tests between the groups with and without available SES data did not reveal any significant differences between the scores in the dependent variables (two-tailed, $p<.05$; see Table 2).

Table 2. Comparison of motor (ETMSC) and language (TRAS) skills between the groups with and without SES data[a] (t-test) at age 2;9 (T1) and 4;9 (T2), respectively

	Group with SES data n = 269 Mean (SD)	**Group without SES data n = 377 Mean (SD)**	**t (644)**	**p**
TRAS T1	71.97 (22.28)	69.76 (23.25)	1.21	.23
TRAS T2	136.19 (10.88)	134.60 (13.06)	1.63	.10
EYMSC T1	75.14 (7.94)	75.08 (8.61)	.08	.94
EYMSC T2	89.72 (3.34)	89.52 (4.29)	.66	.51

[a]Levene's test for equality of variance was not significant for any of the tests; equal variance in the groups could be assumed.

Whether parental SES data were available apparently did not interfere with the children's scores for the dependent variables.

Procedure

Data were collected through structured observation of the children's motor and language competencies during play and daily life activities by the staff in the ECECs when the toddlers were between 30 and 33 months (T1) and when the children were between 54 and 57 months (T2).

Two of the staff independently had to observe whether the children had partially or fully mastered the various items for both the EYMSC and TRAS. In addition, before the observation started, the staff in the ECECs received updated information on young children's language development and training to rehearse how to use the EYMSC and TRAS.

Data analysis

The Statistical Package for the Social Science (SPSS), Version 21.0 (IBM Corporation, 2013), was used for all statistical analyses. Two research assistants entered the data into an SPSS file. Alternately, one entered the data while the second controlled the results of the data input. After data entry, two other research assistants re-entered the data for a randomly selected 10% of the participants to compare the degree of deviation. The outcomes of this control procedure showed good consistency (nearly 100%) between the datasets. Furthermore, frequency analyses were conducted for all variables in the whole sample to check whether the values were within the range of possible values. The few deviations discovered in this control procedure were corrected in the data set.

On an item level, the observations in the EYMSC and TRAS produced data on an ordinal scale. There is a ceiling effect for the data at T2; thus, nonparametric analysis was applied. The association between motor-life and language skills within and between T1 and T2 was analysed by Spearman-Brown correlations. To explore how the level of motor skills at T1 was related to language skills at T2, nonparametric group comparisons (the Kruskal-Wallis test) were used. We established three groups, with two groups representing toddlers with the weakest and strongest levels of motor skills and a middle group. The first two groups were defined by the 15% of children with the weakest and strongest motor-life skills, respectively, at T1. The middle group encompassed 15% of children who scored closest to the mean EYMSC total score at T1.

Ethical considerations

The study was approved by the Norwegian Social Science Data Services and was conducted in accordance with the ethical regulations for research in Norway. Participation was based on the parents' voluntary and written consent. Applying authentic assessment as a respectful methodological approach is considered to provide low strain for the participating children. In general, children's participation in the study did not notably affect their everyday lives in the ECECs.

Results

The *first research question* addresses the relations between language and motor-life skills at age 2;9 and 4;9. Table 3 provides an overview of the correlations between motor-life skills, including the four EYMSC section scores and the eight TRAS section scores, and the total scores at 2;9 years of age (T1).

Table 3. The relations between motor-life and language skills at age 2;9 (T1); TRAS and EYMSC section and total scores; means, standard deviations (SDs), medians and Spearman's rho (n = 646)

			Motor-life skills EYMSC section scores Age 2;9 (T1)				
Language skills TRAS section scores Age 2;9 (T1)			**Self-help skills**	**Desk skills**	**General classroom skills**	**Recreation/ playground skills**	**EYMSC total score T1**
	Mean (SD)		16.92 (3.61)	15.02 (2.67)	18.51 (1.90)	24.65 (2.96)	75.11 (8.33)
		Median	17.00	15.00	19.00	25.00	76.00
Interaction	9.23 (3.46)	9.00	.20**	.19**	.17**	.22**	.26**
Communication	9.68 (3.46)	10.00	.20**	.21**	.17**	.20**	.25**
Attention	9.79 (3.46)	10.00	.17**	.14**	.17**	.20**	.23**
Language comprehension	8.25 (3.00)	8.00	.19**	.28**	.17**	.17**	.26**
Linguistic awareness	8.03 (2.52)	8.00	.28**	.18**	.17**	.19**	.29**
Pronunciation	9.07 (4.48)	9.00	.14**	.19**	.12**	.16**	.20**
Word production	8.46 (3.30)	8.00	.23**	.23**	.12**	.15**	.25**
Sentence production	8.17 (3.08)	8.00	.20**	.25**	.19**	.15**	.25**
TRAS total score T1	70.68 (22.86)	72.00	.23**	.24**	.19**	.22**	.29**

**Correlation is significant at the 0.01 level (2-tailed)

All the correlation coefficients are significant (p<.01) and vary between .12 and .29; they are thus considered small (Cohen, 1988). There are small variations in the correlation coefficients between the EYMSC total score and each of the TRAS section scores, as well as the EYMSC section scores and the TRAS total score.

Table 4 presents an overview of the correlations between motor-life skills, including the four EYMSC section scores and the eight TRAS section scores, and the total scores for the EYMSC and TRAS at 4;9 years of age (T2).

Table 4. The relations between motor-life and language skills at age 4;9 (T2); TRAS and EYMSC section and total scores; means, standard deviations (SDs), medians and Spearman's rho (n = 646)

			Motor-life skills EYMSC section scores Age 4;9 (T2)				
Language Skills TRAS section scores Age 4;9 (T2)			**Self-help skills**	**Desk skills**	**General classroom skills**	**Recreation/ playground skills**	**EYMSC total score T2**
	Mean (SD)		22.85 (1.96)	19.49 (1.16)	19.74 (.86)	27.53 (1.20)	89.60 (3.92)
		Median	24.00	20.00	20.00	28.00	91.00
Interaction	17.36 (1.49)	18.00	.27**	.35**	.26**	.26**	.32**
Communication	16.54 (1.67)	17.00	.26**	.26**	.20**	.28**	.33**
Attention	17.22 (1.72)	18.00	.23**	.30**	.18**	.18**	.27**
Language comprehension	17.08 (1.97)	18.00	.27**	.32**	.24**	.31**	.35**
Linguistic awareness	15.60 (2.82)	17.00	.35**	.41**	.27**	.30**	.44**
Pronunciation	17.06 (2.25)	18.00	.19**	.27**	.18**	.20**	.25**
Word production	17.24 (1.78)	18.00	.21**	.33**	.25**	.24**	.32**
Sentence production	17.16 (1.93)	18.00	.20**	.29**	.21**	.29**	.31**
TRAS total score T2	135.26 (12.22)	140.00	.35**	.42**	.27**	.32**	.46**

**Correlation is significant at the 0.01 level (2-tailed)

Table 4 reveals considerably higher correlations between motor-life skills and language skills at age 4;9 (T2) compared to age 2;9 (T1). All correlations at the section and sum score levels are statistically significant (p<.01). Eighteen of these 45 correlation coefficients are of moderate size (Cohen, 1988), with the highest correlation between TRAS and the EYMSC total score (.46). In general, there are larger differences between the intersectional correlations at age 4;9 than at age 2;9. Among all TRAS sections, *Linguistic awareness* had the strongest overall association with motor-life skills, while *Attention* and *Pronunciation* had the weakest relations with the EYMSC total score. Among the EYMSC sections, *Desk skills* were the most strongly related, while *General Classroom skills* were weakly related to the TRAS total score.

The *second research question* asks to what degree the level of motor-life skills at age 2;9 is related to language skills at age 4;9. To explore this relation—which is of particular interest for children with weak motor-life skills—we examined the degree to which the groups with the lowest, highest and middle scores of motor-life skills at 2;9 years of age (T1) differed in language skills at 4;9 years of age (T2).

Table 5 shows the results of the Kruskal-Wallis test analysing the differences in language skills at T2 between the three groups with different motor-life skill levels at T1.

Table 5. Differences in language skills (TRAS total score) at age 4;9 (T2) between groups with weak (n = 109), middle (n = 116) and strong (n = 99) motor-life skills at age 2;9 (T1; EYMSC Total score); Kruskal-Wallis test

	Language skills at T2			
Motor-life skills groups at T1	**Mean (SD)**	**Median**	**Mean Rank**	$\chi^2_{(2,312)}$
Strong	139.25 (7.23)	141.00	198.35	35.37**
Middle	134.53 (13.12)	139.00	153.30	
Weak	128.46 (17.75)	135.00	123.92	

** p<.01.

There were significant differences (p<.01) at T2 in the total TRAS score between groups with weak, middle and strong motor-life skills at T1. Mann-Whitney U tests were used to examine which groups significantly differed from one another, and effect sizes were calculated to estimate the effects of grouping for the total TRAS score at T2. To prevent a Type 1 error due to a three-way group analysis, a Bonferroni correction was applied. The significance level of .05 was divided by three; thus, the significance level was adjusted to .017. Table 6 shows the findings of these analyses.

Table 6. Differences in language skills (TRAS total score) at age 4;9 (T2) between the groups with weak (n = 109), middle (n = 116) and strong (n = 99) motor-life skills at age 2;9 (T1); Mann-Whitney U tests; R = effect size)

	Between weak and middle				**Between middle and strong**				**Between weak and strong**			
	U	**Z**	**p**	**R[1)]**	**U**	**Z**	**p**	**R[1)]**	**U**	**Z**	**p**	**R[1)]**
TRAS Total score	4302.00	–2.43	.015*	.16	4280.50	–3.77	.00*	.26	3016.00	–5.74	.00*	.40

Effect size: ≥.1 = small, ≥.3 = medium, ≥.5 = large (Cohen, 1988); * p<.017

Based on the measurement at T1, the three motor-life skill groups differed substantially in their TRAS total score at T2. Significant differences were found between all three groups. The difference between the groups with weak and strong motor-life skills at age 2;9 was of medium strength, whereas the differences between the middle group and the two other groups were of small effect size.

Discussion

Regarding the *first research question* on the relations between language and motor-life skills at age 2;9 and at age 4;9 respectively, we discuss the findings for toddlers and preschool-aged children separately. In the discussion, we will apply the term *gross motor skills*, including the sections *General classroom skills* and *Recreational/playground skills,* and the term *fine motor skills*, including the EYMSC sections *Self-help skills* and *Desk skills*.

For toddlers (T1; 2;9 years), only the correlation between the total EYMSC and TRAS total score reached a moderate level (.31). The association between EYMSC total scores and the eight TRAS section scores varied between .20 and .29, indicating that the relations between motor-life skills and language skills is rather weak in this age group. Neither of the correlations between the EYMSC sections and the TRAS total score reached moderate size, even though all correlations were still statistically significant ($p<.01$). Only a few studies have examined these associations in a comparable young age group. Houwen, Visser, van Der Putten and Vlaskamp (2016) found somewhat higher correlations (.27 to .46) for children 0;3 to 3;6 years of age; the somewhat younger average age of their sample (1;10 years) may have caused the differences. Additionally, Wang, Lekhal, Aarø, and Schjølberg (2014) found a high correlation (.72) at the very young toddler age of 1;6 but considerably lower correlations at age 3 (.29). Thus, the results at T1 in our study (.29) are comparable to the Norwegian sample of Wang et al., at age 3.

The relations between the sections in TRAS and the EYMSC provide a more differentiated picture. The highest correlation between motor-life skills (EYMSC total score) and language skills for toddlers was in *Linguistic awareness* (.29). This section involves reflecting on language and includes items regarding children's skills in drawing attention to sound structure (phonological awareness), as well as their participation in language awareness activities (Frost, 2003). Prior research has shown (Stangeland et al., 2018) that participation in language awareness activities are the skills in this section that is most commonly mastered by toddlers. The strongest correlation between the TRAS and EYMSC sections at T1 was between *Self-help Skills* and *Linguistic awareness*. Mastering self-help skills requires a substantial amount of practice in terms of active participation in everyday life. Likewise, to develop language awareness skills, the child must take part actively and extensively in various activities that stimulate and require language awareness activities over time (Frost, 2003). Hence, the associations between these skills may mirror the toddler's level of participation in different activities. Participation therefore seems to be highly important as a prerequisite to developing skills in several developmental areas simultaneously, as emphasised by Leonard and Hill (2014).

Further, the correlations between *Language comprehension* and *Desk skills* in toddlers are among the largest in the present study. However, the findings of Houwen et al. (2016) revealed a considerably higher correlation (.46) between the fine motor subscale in their instrument and receptive language. Additionally, our study indicates lower correlations between the EYMSC fine motor skills (the sections *Self-help skills* and *Desk skills*) and expressive language skills than those found by Houwen et al. (2016). These divergent findings can be explained by the different age spans, languages or scales applied. Differences in the children's development of motor skills between countries may also influence the results; for example, toddlers in Norway generally have a higher level of motor skills than British children of the same age (Moser & Reikerås, 2016).

The correlations between EYMSC gross motor skills (*General classroom skills* and *Recreational/playground skills*) and the three sections characterising expressive language skills (*Pronunciation*, *Word production* and *Sentence production*) in toddlers are among the lowest in our study, though they are at the same level as those recently found by Houwen et al. (2016). The weak associations between gross motor skills and expressive language suggests that for toddlers, expressive language still might not be as important for their physically active play. In addition, the rather low correlations imply that the onset of the most prominent development of motor skills in early childhood has not yet begun (Williams et al., 2008).

The relations between motor skills and the TRAS sections *Interaction, Communication* and *Attention* in our study are in line with the results of Giske et al. (2018) and Stangeland (2017), who found comparable relations between motor skills, social skills and language in toddlers. The strongest correlation appears between *Interaction* and *Recreational/playground skills*. This is commensurate with findings from Leonard and Hill (2014), showing that interactions between peers at a young age rely heavily on motor skills.

In regard to preschool-aged children (T2, 4;9 years), the associations between motor-life skills and language skills become considerably more salient. All correlations are statistically significant (see Table 4; $p<.01$); the TRAS and EYMSC total scores correlated on a moderate level (.46), while the correlations between the EYMSC total score and the eight TRAS section scores varied between .25 and .44. Only *Pronunciation* and *Attention* were weakly related to motor-life skills, while the correlations in the other six sections achieved moderate strength. Three of the EYMSC sections correlated on a moderate level with the TRAS total score; only the correlation with *General classroom skills* was weak. It is striking that the two fine motor skill sections were moderately correlated with five of the language sections, four of which belong to *Desk skills* and one to *Self-help skills*. Only two correlations with gross motor skills were of moderate size, both belonging to *Recreational/playground skills*.

Our findings of clearly stronger associations between motor-life skills and language skills in preschool-aged children compared to toddlers contrast with those of Wang, Lekhal, Aarø, Holte, and Schjølberg (2014), who found stronger relations between motor-life skills and language skills at age three than at age five. A methodological explanation could be the ceiling effect at T2 for both TRAS and EYMSC in the present study, which reduces the spread of the scores. More suitable instruments may contribute more information regarding high-performing children at age 4;9, possibly leading to other results.

The strongest correlations at preschool age emerge between *Linguistic Awareness* and the two sections *Self-help skills* (.35) and *Desk skills* (.41). This association indicates that activities that demand fine motor skills create space for verbal communication, play and reflections on language between children, as well as between staff and children (Frost, 2003).

At preschool age, *Desk skills* also correlate with a medium strength with the remaining four of seven language sections: *Interaction* (.35), *Word production* (.33), *Language comprehension* (.32) and *Attention* (.30). This is in line with the conclusions of a review study (Van der Fels et al., 2015) on the relations between the motor and cognitive domains in children aged 4 to 16, which showed that fine motor skills had the strongest relations with higher-order cognitive skills such as language. Attention, as a core component of self-regulation, has been proven in several studies to be related to motor skills (McClelland et al., 2016; Robinson et al., 2016). Becker et al. (2014) emphasised self-regulation as a moderating factor between motor and language skills.

The moderate correlation between *Recreational/playground skills* and *Linguistic Awareness* in preschool age (.30) corresponds with the findings of Becker et al. (2014), Stangeland (2017), and Stangeland, Lundetræ and Reikerås (2018), which underscore the significance of participation in play for language development, as well as the findings of Bar-Haim and Bart (2006) and Giske et al. (2018), who confirmed the relations between social competence and motor skills. Play in early age builds heavily on motor skills and communication with peers; children's play both requires and strengthens language (Dickinson & Porche, 2011). This also appears to be a plausible explanation for the high correlations between *Language comprehension* and *Recreational/playground skills*.

In addition, the correlation between *Recreational/playground skills* and *Sentence production* (.29) is one of the strongest in the gross motor domain in preschool age, indicating that expressive language plays a major role in children's gross motor play. Children use more words and apply more complex sentences in play situations compared to other classroom activities, as shown by Cohen and Uhry (2007) and Fekonja, Marjanovič Umek and Kranjc (2005).

The *second research question* examines the degree to which the level of motor-life skills at age 2;9 is related to language skills at age 4;9. Weak, middle and strong motor skills groups based on the EYMSC scores at T1 were created, each comprising 15% of the total sample (see the method section). The Kruskal-Wallis test reveal significant grouping effects for the TRAS total score at T2 (Table 5). The largest effect size was between the strong and weak groups (.45; Table 6). Additionally, the differences between the weak and middle groups, as well as between the middle and strong groups, were significant but only indicated small effect sizes (.20 and .27, respectively; Table 6).

These findings are in accordance with other Norwegian (Wang et al., 2014) and international (Leonard & Hill, 2014) studies. To some extent, the rather weak association between motor-life and language skills at age 2;9 speaks against the alleged comorbidity between the areas (Hill, 2010; Webster et al., 2005). However, the clear differences in language skills between children with weak and strong motor skills at age 4;9 indicate that the two developmental domains are related from a longitudinal perspective. According to Williams et al. (2008), the most prominent changes in height, muscle strength, body mass and proportion appear between 3 and 5 years of age. These bodily changes allow children to achieve much more complex, well-coordinated movements by boosting their motor skills. Our assumption is that the baseline in motor skills at a young age to some degree determines the developmental track for motor skills and thereby affects children's opportunities to communicate with their social and physical environment (Bart et al., 2011; Kuhl, 2011) as a prerequisite for developing language skills. This implies that motor and language development are closely intertwined from 2;9 to 4;9 years of age and that motor development could be a driving force (Ionesco & Illie, 2018; Leonard & Hill, 2014).

However, there are considerable dynamics and discontinuities in early motor skill development (WHO, 2006), and neither delayed nor advanced motor development in toddler age fully determines later motor development (Moser et al., 2018). Thus, an overall effect size of .45 in language differences between the weak and strong motor skill groups may be substantial.

Summarising discussion and implications

The present study contributes to the body of knowledge on the relations between motor-life skills and language skills, which are crucial for educational praxis in ECECs (Iverson, 2010). The findings in the present study support the conclusion of Leonard and Hill (2014) that motor development at an early age is not an independent process, but it has diverse, complex connections to several cognitive domains. In summarising the findings for our first research question, there are low to moderate correlations between everyday motor-life skills and language skills; these correlations are more prominent for preschool-aged children than toddlers.

Although our study does not address causal relations, the results advocate for an embodied approach to language learning as appropriate for young children (Ionescu & Ilie, 2018). Promoting an activity- and movement-oriented pedagogy can strengthen children's motor competency and may simultaneously support development in other domains. An adequate level of motor skills may efficiently contribute to placing children in a position to better experience, understand and cope with demands and challenges that involve their own body, as well as the physical and social environment. These experiences are crucial for general cognitive development and learning, including language. Motor skills are not only a matter of bodily and physical development; they should also be thoroughly integrated in a holistic educational approach that addresses all developmental domains.

To determine whether the observed associations between the two domains in the present study are based on a causal relationship or whether other factors create a purely correlative relation, further studies using appropriate experimental designs are needed. As Carpenter and Drabick (2011) underlined, processes from multiple domains are necessary to understand how risk and protective factors translate into different patterns of children's language functioning.

Although this study does not allow for causal explanations, we assume that the development of language and motor-life skills mutually influence each other, and that they presuppose and stimulate one another. Young children's interactions rely on motor skills; it is through such interactions that language skills develop (Leonard & Hill, 2014). Children with sufficient language skills are attractive playmates and have a higher participation rate in play with their peers (Stangeland, 2017). Such participation in play is necessary to cultivate vital motor skills. This means that children who have difficulties in one or both areas may end up in a vicious cycle. Due to a lower level of development, they might not be included in play to the same degree as others, and thus have fewer opportunities to develop their skills and to catch up.

Knowledge of the relations between the level of motor-life skills in toddler age and language skills in preschool age, may be useful for staff in ECECs in terms of identifying children with possible risk factors, who could then receive early intervention. Motor behaviour, based on motor skills, is an easily observable, core element in young children's everyday lives. Serious problems in achieving age-adequate motor tasks in daily life in ECECs may be trustworthy, initial indicators that we should also pay attention to other domains of development that are not as distinct as motor skills (Son & Meisels, 2006).

Limitations

The ceiling effect in both TRAS and the EYMSC, and the fact that the instruments produced ordinal data, limit the opportunity to apply more powerful statistical analyses. Future research should use instruments that offer enough variance for average and high-performing children.

One can assume that standardised instruments and individual testing routines conducted by advanced students of psychology or special needs education would lead to more reliable assessment scores than those carried out by staff. However, our initial assumption that ECEC teachers tend to evaluate children's skills in a positively biased way due to positive attitudes towards children in general, and their desire for the children in their units to do well, does not appear to be the case. Even though the staff were trained in applying the instrument, the large number of data collectors still might be a problem. It may also be a limitation that it was different staff collecting the data at T1 and T2. The rating scale provides room for interpretation in assessing children's motor-life and language skills. Notwithstanding, these measurement errors would not have a systematic effect. This is supported by the fact that the data revealed a normal distribution of the results at T1, and that the variance in language and motor-life skills was sufficient. In addition, because two staff members conducted all observations independently, the findings' reliability is strengthened.

Since many of the effect sizes found in our study are of small to medium size, this leaves plenty room for alternative interpretations, and we must be careful not to draw too strong conclusions.

Our design and data do not allow statements about causality or determine whether the associations between motor-life and language skills are an expression of general development across domains or an expression of domain-specific trajectories. There might be a common developmental factor that influences all domains of development. Studies based on multivariate growth-curve models (Rhemtulla & Tucker-Drob, 2011) have shown that a global dimension of development accounts for as much as 42% of the variance across domains (linguistic, mathematics, reading, gross motor and fine motor skills).

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