

Is there a direct relation between the development of vocabulary and grammar?

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Research highlights

- Children's vocabulary and grammatical development between the ages of 4 and 6 were characterized by enduring trait-like stability.
- We found no evidence of direct influences of vocabulary on grammatical development, but there was a small yet significant contribution from grammar to vocabulary growth.
- There was a close relation between the trait-like stability components of vocabulary and grammar, indicating the presence of a common source of influence.
- A set of home literacy predictors was able to explain 16% and 11% of the variances in the trait-like stability components of vocabulary and grammar, respectively.

Abstract

Previous studies of individual differences have revealed strong correlations between children's vocabulary and grammatical abilities, and these data have been used to support theoretical accounts positing direct developmental relations between these two areas of language. However, between-person differences do not necessarily reflect intra-individual dynamics. Thus, in the present study, we analysed longitudinal data from three annual assessments of vocabulary and grammar in 217 children ($M_{\text{age}} = 4$ years and 3 months at first assessment) using a modelling strategy with some utility in distinguishing relations at the between- and within-person levels. The results revealed strong correlations between grammar and vocabulary at the between-person level, but the evidence of direct dependencies between the variables at the within-person level was rather limited. Specifically, we found a small direct contribution from grammar to vocabulary for children between the ages of four and five, but there was no evidence of any direct contributions from vocabulary to grammar. Further analyses suggested that the home literacy environment may represent a common source of individual differences in children's vocabulary and grammatical skills. In light of these results, we argue that the evidence of direct relations between vocabulary and grammatical development in preschool-aged children may not be as strong as previously assumed.

Key words: vocabulary and grammar; developmental relations; home literacy environment; individual differences; longitudinal data; within-person analysis.

In recent decades, a series of studies have repeatedly revealed strong correlations between the size of children's early vocabularies and their level of grammatical proficiency (Bates, Bretherton, & Snyder, 1988; Dale, Dionne, Eley, & Plomin, 2000; Fenson et al., 1994; Moyle, Weismer, Evans, & Lindstrom, 2007). Such findings have often been used in support of theoretical accounts in which children's vocabulary development is considered the foundation for grammatical acquisition (Bates & Goodman, 2001). For example, one could argue that learning words involves learning both their lexical-semantic and morphosyntactic properties, making words the fodder for grammatical analysis (Marchman, Martínez-Sussmann, & Dale, 2004). Put another way, the correlation between children's vocabulary and grammar is explained in terms of a direct and causal dependence of grammar on lexical growth. In addition to the correlational evidence linking children's grammatical and lexical acquisition, support for so-called lexicalist theories has been provided by observations of a developmental asynchrony between grammar and vocabulary, in which children seem to acquire lexical knowledge more rapidly than grammar in the initial stages of development (Caselli, Casadio, & Bates, 1999; Marchman & Bates, 1994; Marchman et al., 2004). This developmental ordering has been used to argue that a "critical mass" of lexical items is needed to abstract and generalize grammatical representations.

Although the critical mass hypothesis has been influential in theories of child language, several studies have challenged the idea that vocabulary development precedes that of grammar. First, recent work has shown that formal correlates of word order are mastered at infancy (Benavides-Varela & Gervain, 2017; Gervain & Werker, 2013), indicating that the appearance of developmental ordering may be a function of the type of grammatical knowledge measured rather than a lack of grammatical knowledge per se. In line with this hypothesis, Dixon and Marchman (2007) found no evidence of developmental ordering in a

study of children between the ages of 16 and 30 months; lexicon and grammar seemed to develop in a synchronous manner.

Another possible limitation of the critical mass hypothesis is that the hypothesis pertains to the initial stages of development. Accordingly, the majority of previous studies of vocabulary-grammar relations have focused on children in their first two or three years of life. However, the dynamics of a relation may change over time, and even if the acquisition of grammar is intimately related to vocabulary growth at the onset of language development, such a relation may not exist at subsequent stages of development. It has been suggested that grammatical development may, at some point, take off on its own course (Bates & Goodman, 2001; Tomasello, 2000), but if and when this decoupling takes place is unclear. Based on analyses of the dimensionality of language in a longitudinal study of school-aged children, Tomblin and Zhang (2006) argued in favour of a unidimensional model of vocabulary and grammar among children in their early school years but recognized a trend toward differentiation of the two language factors among older children. In contrast, Pérez-Leroux, Castilla-Earls, and Brunner (2012) presented evidence in support of a bidimensional model of vocabulary and grammar in a sample of young children between the ages of 3 and 5. However, the two factors were positively related, and based on a path analysis Pérez-Leroux et al. (2012) argued that vocabulary growth still determines at least parts of children's morphosyntactic acquisition during this developmental stage.

Last, one may argue that strong lexicalist interpretations of the correlation between children's vocabulary and grammatical skills are challenged by observations from laboratory experiments and corpus-based studies on the process of syntactic bootstrapping (Gleitman, 1990; Landau & Gleitman, 1985; Naigles, 1990). Specifically, these studies have demonstrated that children are able to solve the uncertainties of word-referent mapping by constraining the hypothesized meaning of a newly encountered word using the morphological

and syntactic context of the word (Fisher, Klingler, & Song, 2006; Gertner, Fisher, & Eisengart, 2006; Hall, Lee, & Bélanger, 2001; Hirsh-Pasek, Golinkoff, & Naigles, 1996; Yuan & Fisher, 2009). Thus, although few would argue that the size of children's vocabularies is fully determined by their level of grammatical competence, the correlation between vocabulary and grammar may at least in part be explained by a developmental link from grammar to the lexicon. Dixon and Marchman (2007) took this possibility into account by suggesting that the developmental synchrony they observed may be explained by reciprocal contributions between vocabulary and grammar. In their study, 68% of the variance in children's grammatical complexity was explained by their vocabulary skills, and 78% of the variance in children's productive vocabulary was accounted for by their grammatical abilities – results suggestive of a strong and mutual relationship between these two areas of language.

However, although tight connections between grammar and vocabulary skills have been demonstrated in children across a wide variety of language populations, including samples of bilingual children and children with language delay, relatively few observational studies have come close to discerning the nature of the developmental influences underlying the correlation between vocabulary and grammar. For example, a substantial number of studies in the field, including the studies by Dixon and Marchman (2007) and Pérez-Leroux et al. (2012), have used cross-sectional or simple concurrent designs (see also Caselli et al., 1999; Dale et al., 2000; Dethorne, Johnson, & Loeb, 2005; Devescovi et al., 2005; Fenson et al., 1994; Marchman & Bates, 1994; Marchman et al., 2004; Stolt, Haataja, Lapinleimu, & Lehtonen, 2009; Thordardottir, Weismer, & Evans, 2002). These studies have thereby failed to meet the requirements for establishing temporal precedence, which is a necessary condition for making inferences regarding the dynamics of a developmental relation (Biesanz, 2012). Granted, several studies have included longitudinal data, such as Bates et al. (1988), Conboy and Thal (2006), Labrell et al. (2014), and Tomblin and Zhang (2006). However, none of these studies

tested the alternative paths of influence that may underlie the correlation between vocabulary and grammar. For example, although the study by Tomblin and Zhang (2006) included several measurement occasions, their results were based on four concurrent factor analyses that were run separately. Thus, even if the authors make inferences regarding developmental trends, the dynamics underlying the longitudinal relation between grammatical and vocabulary skills were not investigated.

When reviewing the handful of studies that have actually tested different paths of influence that may underlie the correlation between vocabulary and grammar, the evidence of a strong relation between these two variables seems less convincing. For example, Dionne, Dale, Boivin, and Plomin (2003) used an autoregressive cross-lagged panel model to investigate longitudinal relations between grammatical and lexical abilities in a large sample of twins 2-3 years of age at the times of assessment. The pattern of results reported in this study is not easy to interpret. Although the analyses revealed concurrent bidirectional effects between measures of vocabulary and grammar at year 2, only the concurrent path from grammar to vocabulary was statistically significant at year 3. When looking at the longitudinal cross-lagged effects, the results were somewhat different. A positive and statistically significant cross-effect was identified from vocabulary at year 2 to grammar at year 3, whereas the longitudinal path from grammar to vocabulary was negative (though small in size). Although the authors conclude that there are bidirectional influences between grammar and vocabulary, the evidence is not clear.

Moyle, Weismer, Evans, and Lindstrom (2007) used cross-lagged correlational analyses to investigate the developmental relation between grammar and vocabulary. An array of instruments was used to assess lexical and grammatical skills in two groups of typically and atypically developing children at five different time points (from age 2 to 5 years; 6 months). Similar to the study by Dionne et al. (2003), the results did not consistently reveal mutual

relations between lexical and grammatical development. Positive and statistically significant bidirectional cross-effects between composite measures of lexical and grammatical skills were only detected between the ages of 2;0 (years; months) and 2;6 in the typically developing group. In the group of children with language delay, unidirectional cross-effects from lexicon to grammar were detected from age 2;6 to 4;6, followed by a unidirectional cross-effect from grammar to lexical abilities between the ages of 4;6 and 5;6. In other words, the study demonstrated mutual relations between lexical and grammatical abilities in typically developing toddlers, but it did not provide conclusive evidence of such relations beyond the initial stages of development. Evidence from the typically developing group indicated a decoupling of vocabulary and grammatical development at an early age, whereas evidence from the group of children with language delay reflected a shift in the developmental dynamics between the ages of 4 and 5 – from lexically driven growth to grammatical influences on vocabulary development. However, there is uncertainty surrounding the directionality of the effects reported by Moyle et al. (2007), considering that the results of this study were based on cross-lagged correlations. In a seminal paper, Rogosa (1980) demonstrated that cross-lagged correlations may show contradictory patterns across time points depending on the stability of the constructs under investigation (i.e., the longitudinal consistency in the rank order of individuals). Consequently, the use of cross-lagged correlations has largely been abandoned and replaced by models in which the stability of constructs from one measurement occasion to the next is controlled for through the inclusion of autoregressive parameters (as in Dionne et al., 2003).

However, Hamaker, Kuiper, and Grasman (2015) argued that not only should developmental studies account for stability but also the *right kind* of stability must be taken into consideration. Using both simulated and empirical datasets, Hamaker et al. (2015) showed that if the stability of constructs is partly characterized by trait-like, time-invariant individual

differences, estimates of cross-lagged regression parameters may reflect relations at the between-person level rather than the underlying dynamics at the within-person level. Moreover, Hamaker et al. (2015) argued that inadequate control for the time-invariant stability of constructs is equivalent to the “omitted variable problem” and may lead to erroneous conclusions regarding the presence of causal relations, the causal dominance of two variables, and even the positive or negative nature of a causal influence.

To the best of our knowledge, only one longitudinal study has tested alternative hypotheses regarding the correlation between vocabulary and grammar using a modelling strategy that attempts to distinguish between time-invariant stability in individual differences and temporal relations at the within-person level. In a recent study, Hoff, Quinn, and Giguere (2017) used latent change score modelling to examine dynamic relations between vocabulary and grammar among Spanish-English bilingual children assessed at six-month intervals between 30 and 48 months of age. The results of a set of analyses – both within and across languages – showed that growth in vocabulary and grammar was correlated but uncoupled. In other words, although measures of vocabulary and grammar were robustly correlated at the between-person level, vocabulary performance could not predict changes in grammar at a within-person level from one occasion to the next. Nor was there any evidence that the children’s grammatical development was predictive of their vocabulary growth from one occasion to the next. Thus, the authors hypothesize that the correlation between vocabulary and grammar can be explained by a third factor: the common influence of properties of input. Although the authors do not pinpoint the aspects of children’s language input responsible for the correlation between vocabulary and grammar, several candidates are discussed. For example, the total amount of input that children are exposed to is suggested as one relevant variable. Additionally, the richness and variety of linguistic input is suggested to support both vocabulary and grammatical development. However, none of these potential third variables

were tested by Hoff et al. (2017); the only input-related variable included in their study was an estimate provided by primary caregivers of the children's relative exposure to English and Spanish at home, and this covariate was not used in the analyses of within-language associations between vocabulary and grammar. Thus, the authors' question "What explains the correlation between growth in vocabulary and grammar?" remains open.

In sum, when taken at face value, the evidence from many previous studies in the field indicates a strong relation between children's vocabulary and grammatical development. However, the developmental dynamics underlying this relation are not well understood. We therefore present data from a study that may add to our understanding of the relation between grammar and vocabulary. Four main hypotheses derived from the extant body of literature formed the basis of this study: (1) children's vocabulary predict subsequent levels of grammatical proficiency, and vice versa, (2) there are unidirectional relations between the size of children's vocabularies and subsequent grammatical abilities, (3) there are unidirectional relations between children's grammatical competence and subsequent vocabulary skills, and (4) there are no direct relations between vocabulary and grammatical development.

Additionally, we sought to further explore a hypothesis proposed by Hoff et al. (2017) that the parallel development of vocabulary and grammar can be explained by the common influence of properties of input (hypothesis 5). We note that the first four hypotheses are mutually exclusive hypotheses, whereas the fifth hypothesis can technically coincide with all of the previous hypotheses.

To investigate the five hypotheses in our study, we conducted three annual assessments of vocabulary and grammar in a cohort of children when they were between the ages of 4 and 6. During this period, children's grammatical growth is believed to reach its height before it levels off sometime during middle childhood (Tomblin and Zhang, 2006). Thus, the present study addresses a previously understudied period of development in terms of vocabulary-

grammar relations: the age at which children have learned to master most of the basic grammatical structures and enter a period characterized by more advanced grammatical growth.

In addition to measures of grammar and vocabulary, we used parental reports to gather information about the children's home language environment, with a particular focus on literacy-related variables. We chose to include home literacy variables in the present study for two reasons. First, it has been suggested that variables such as the frequency of shared book reading and the number of picture books in the home reflect an emphasis on language-promoting activities in the family, thereby representing rough indicators of a child's language environment (Fletcher & Reese, 2005; Mol, Bus, de Jong, & Smeets, 2008). Second, because the lexical and syntactic structure of written language is more varied and complex than that of spoken language, literacy activities are often considered rich sources of linguistic stimulation. For example, participation in shared book reading interactions has previously been linked to individual differences among children in measures of oral language (Bus, van Ijzendoorn, & Pellegrini, 1995; Mol & Bus, 2011). In addition to their relation to other important characteristics of children's language environment, home literacy variables may therefore be directly responsible for some of the correlated growth between grammar and vocabulary.

Method

Participants

The participants included two hundred and seventeen children (107 girls; 110 boys) recruited from Norwegian preschools. The average age was 4 years and 3 months ($SD = 2.2$ months) at Time 1 and 6 years and 3 months ($SD = 2.3$ months) at Time 3. Children with Norwegian as a second language, children diagnosed with general learning disabilities, and children with auditory impairments were excluded from the study.

Design and procedure

The children were tested, with parental permission, annually over a period of two years. The children were observed individually in their respective preschools at Times 1 and 2 and in their schools at Time 3. The measures of vocabulary and grammar that we used in the present study were components of a comprehensive test battery administered in a fixed order across three (at Time 1) or two sessions (at Times 2 and 3). All tests were administered by trained research assistants. We also gathered data about the children's home literacy environments through parental questionnaires at Time 1.

Measures

Vocabulary. A Norwegian standardized version of the British Picture Vocabulary Scale-II (BPVS; Dunn, Dunn, Whetton, & Burley, 1997) was used as a measure of vocabulary. In this test, the child was presented with a set of four line drawings and prompted to choose the drawing that corresponded to a word spoken by the administrator. The test comprised 144 items arranged in 12 blocks of increasing difficulty. Testing was discontinued when the child made 8 or more errors within the same block. The participant's raw scores on the BPVS were used in the analyses.

Grammatical skills. A Norwegian standardized version of the Test for Reception of Grammar-2 (TROG; Bishop, 2003) was administered as a measure of comprehension of grammatical structure. For each test item, the child was shown four line drawings while the administrator read a sentence. The child was then prompted to choose the drawing that best illustrated the sentence. The 80 test items were arranged in 20 blocks representing different grammatical structures of increasing complexity (e.g., comparative, reversible passive, and use of relative clauses). Testing was halted if the child made one or more errors in five consecutive blocks. The participant's raw scores on the TROG were used in the analyses.

Home literacy environment. At the first measurement occasion, the children's primary caregivers answered three questions regarding their home literacy environment: 1) How often do you read to your child? 2) How many picture books for children do you have at home? 3) How much does your child enjoy book reading? In addition, we gathered information about the parents' level of education, which has shown to be an indicator of children's home literacy environment (Davis-Kean, 2005; Hemmerechts, Agirdag, & Kavadias, 2017). The distribution of the parents' answers to the home literacy environment questions, coded on a categorical five point scale, is presented in Table 1. As seen from the table, the distribution of answers was relatively skewed in the sample, and the parents were, on average, highly educated.

Data analysis

Our data analyses were conducted according to a longitudinal study design and within a structural equation modelling (SEM) framework. To analyse our data, we used the Lavaan package (Rosseel, 2012) in the statistical software environment R. Missing data were limited for the measures of vocabulary and grammar. Out of 217 participants, 200 (92%) had complete data for BPVS and TROG for all three measurement occasions. Furthermore, complete data for both of these measures were acquired for at least 208 participants (96%) at each session. However, the amount of missing data for questions on participants' home environment was non-negligible, with up to 20% and 13% missing for questions regarding home literacy and parental education, respectively. Full information maximum likelihood was used for model estimation to utilize all available information for each individual under the missing-at-random assumption. Robust Huber-White standard errors were used for inferences on specific estimated model parameters. Model fit was comprehensively evaluated using (a) common goodness-of-fit indices (Hu & Bentler, 1999), including the χ^2 test of exact model fit, the root mean square error of approximation (RMSEA: $\leq .08$ = acceptable, $\leq .05$ = good) for assessing closeness of fit, the comparative fit index (CFI: $\geq .95$ = good) with respect to the

independence null model, and the standardized root mean square residual (SRMR: $\leq .05$ = good) and (b) comparisons of competing models.

Autoregressive models. We used two types of autoregressive models to assess the longitudinal relations between vocabulary and grammar: a traditional cross-lagged panel model (CLPM) and a random intercepts cross-lagged panel model (RI-CLPM; see Hamaker et al., 2015 for a comparison of the two models). The CLPM represents an improvement from simple cross-lagged correlations by assessing whether two constructs predict variance in one another while controlling for the autoregressive prediction of each construct on itself. In the CLPM, an autoregressive parameter represents the consistency of the rank order of individuals from one time point to the next, which is often referred to as *temporal stability*. However, as previously discussed, controlling for temporal stability is not sufficient if the stability of constructs is characterized by enduring individual differences. In addition to the CLPM, we therefore estimated a RI-CLPM to investigate whether this type of trait-like time-invariant stability characterized the participants' development of vocabulary and grammatical skills. The RI-CLPM resembles the traditional CLPM in that it estimates the longitudinal influence of two variables on each other while accounting for temporal stability. Unlike the traditional panel model, however, the RI-CLPM includes a random intercept that partials out the between-person variance that is stable across all measurement occasions. With the inclusion of this time-invariant stability component, the point of reference shifts, such that bivariate cross-effects from one occasion to the next no longer relate to between-person differences but rather to within-person dynamics (Hamaker et al., 2015). We note that the interpretation of the model's autoregressive parameters also changes with the addition of the random intercept. Instead of representing the stability of the rank order of individuals, the autoregressive parameters in the RI-CLPM relate to the degree of within-person carry-over effects. For example, a positive autoregressive parameter implies that an individual grows more from one

occasion to the next than expected based on the time-invariant stability component (Hamaker et al., 2015). A graphical representation of the CLPM and RI-CLPM for three waves of data is shown in the left and right panels of Figure 1, respectively. Note that we used latent variable versions of the CLPM and the RI-CLPM, which allowed us to test for measurement invariance and account for measurement error (Little, Preacher, Selig, & Card, 2007). Effect coding was used to identify the scale of the latent variables.

Research hypotheses and model comparisons. A series of *a priori* model comparisons were used to systematically test the five hypotheses described previously in this article. For both the CLPM and the RI-CLPM, a fully unrestricted model representing bidirectional relations between the participants' development of vocabulary and grammatical skills (hypothesis 1) served as a starting point. These unrestricted models were subsequently compared to three nested models depicting either unidirectional cross-lagged effects from vocabulary to grammar (hypothesis 2), unidirectional cross-lagged effects from grammar to vocabulary (hypothesis 3), or a model not including cross-effects between vocabulary and grammar (hypothesis 4). As previously noted, these four models represent competing hypotheses. Thus, only the best fitting of these models was used to test the fifth non-competing hypothesis that individual differences in vocabulary and grammar can be explained by the common influence of properties of input.

Results

Descriptive statistics

The mean scores and standard deviations of the observed measures of grammar and vocabulary at all three time points are shown in Table 2. Correlations between the measures are shown in Table 3. The data reveal a clear trend of increasing performance for both measures over time. The measure of vocabulary shows relatively stable variance across the

three time points, whereas the variance in grammar decreases over time. The correlations between the two measures are predominantly in the moderate range, but the concurrent correlations between the constructs seem to diminish over time.

Measurement model

Before examining the relation between children's results on TROG and BPVS, we specified a measurement model mapping these two observed variables onto the theoretical constructs of interest: grammar and vocabulary. This process involved two important steps. First, because we used only one measure of each construct, we used four parcels from TROG and BPVS as indicators for grammar and vocabulary, respectively, thus avoiding effect size attenuation due to measurement error. All loadings between the parcel indicators and the latent factors were significantly different from zero ($p < .001$) and ranged from .81 to .96. Next, we tested whether the factorial structure of the two latent variables remained constant over time. An absence of measurement invariance would indicate that the constructs were not the same across the three measurement occasions, which would prohibit comparisons within constructs across time and render potential connections between constructs difficult to interpret (McArdle, 2009). Through systematic testing of measurement invariance, we established scalar invariance for the two constructs in our model (BPVS: $\chi^2 [51] = 63, p = .129, CFI = .99, RMSEA = .03, SRMR = .05$; TROG: $\chi^2 [51] = 42, p = .82, CFI = 1.00, RMSEA = .00, SRMR = .02$), thus fulfilling requirements for measurement invariance.

The longitudinal relation between grammar and vocabulary

Having successfully established measurement invariance for grammar and vocabulary across the three time points in our study, we began exploring the hypotheses proposed earlier in this article. As a first step, we used SEM to estimate an unrestricted cross-lagged panel model (CLPM), which provided a good fit to the data ($\chi^2 [241] = 288, p = .021, CFI = .99, RMSEA$

= .03, SRMR = .05). As noted, the unrestricted CLPM represented the hypothesis of bidirectional relations between the participants' development of vocabulary and grammatical skills (hypothesis 1). All subsequent comparisons with nested models representing competing hypotheses of the relation between vocabulary and grammar (i.e., hypotheses 2-4) resulted in significant reductions in model fit (p -values ranging from .003 to $< .001$), and the full unrestricted model was thus retained. This model is shown in Figure 2. As seen from the figure, we found a strong positive correlation between the initial levels of grammar and vocabulary ($r = .58$). This finding was expected given that strong correlations between the two constructs have been consistently demonstrated in previous studies. Of most interest to our hypotheses, however, are the cross-effects in the model. The results revealed that all four bivariate cross-lagged effects were positive and statistically significant, indicating that the participants' level of grammatical performance could account for variance in vocabulary at successive time points, and vice versa. In other words, the traditional CLPM supported the hypothesis of bidirectional relations between grammar and vocabulary across time.

Next, we estimated an unrestricted random intercepts cross-lagged panel model (RI-CLPM), which provided a very good fit to the data ($\chi^2 [238] = 274, p = .056, CFI = .99, RMSEA = .03, SRMR = .04$). Moreover, a comparison of the RI-CLPM and the traditional panel model revealed that the unrestricted CLPM had a significantly poorer fit to the data than the RI-CLPM ($\Delta\chi^2 [3] = 15, p = .002$). This finding indicates that children's development of grammar and vocabulary are in fact characterized by enduring trait-like individual differences, which are not accounted for by the standard CLPM. We therefore repeated the *a priori* sequence of nested model comparisons using the RI-CLPM. According to this set of analyses, two of the more parsimonious models showed equally good fits to the data compared to the unrestricted model. This was true for the model with unidirectional cross-effects from grammar to vocabulary (hypothesis 3; $\Delta\chi^2 [2] = .9, p = .630$) and the model representing the hypothesis of

no developmental relations between the constructs (hypothesis 4; $\Delta\chi^2[4] = 7, p = .131$).

These two nested models were then compared, revealing a significantly poorer fit for the model in which all cross-effects had been eliminated ($\Delta\chi^2[2] = 6, p = .049$). Thus, the RI-CLPM with unidirectional cross-effects from grammar to vocabulary represented the best fitting model of the bivariate relation between grammar and vocabulary. This model is shown in Figure 3.

Several of the model parameters presented in Figure 3 are worthy of note. First, there was a strong correlation between the time-invariant stability components of grammar and vocabulary ($r = .72$), indicating that the trait-like characteristics of each construct are intimately related. Second, we noted the presence of a residual correlation between grammar and vocabulary at the first measurement ($r = .52$). At this particular time point, a residual correlation indicates that the two constructs have more in common than can be explained by the time-invariant stability components. Finally, there was a relatively small but positive and statistically significant cross-lagged effect from grammar measured at age four to vocabulary at age five ($\beta = .23, p = .019$). This cross-effect did not carry over to the next measurement occasion. In other words, the data in the present study partially support the hypothesis that children's grammatical competence influences vocabulary development. We found no evidence of the opposite pattern, as there were no cross-lagged effects from vocabulary to grammar.

Predicting grammar and vocabulary from home literacy environment

In the final stage of our analyses, we explored the hypothesis that the relation between vocabulary and grammar can be explained by the common influence of properties of input, here represented by variables related to home literacy and parental education. Because all of the predictors served as very rough indicators of children's language environment, our main

interest was in the predictors' joint contribution. The predictors were therefore treated as a block in the analyses. This block was added to the best fitting model from the previous series of model comparisons (i.e., the model presented in Figure 3) and evaluated according to the following two steps. First, a comparison of two alternative predictor models revealed that a model in which paths from the block of predictors were restricted to the time-invariant stability components of vocabulary and grammar fitted the data equally well as a model including direct paths to all measurement occasions ($\Delta\chi^2[20] = 16, p = .705$). The more parsimonious model that only included paths towards the trait-like components was thus retained. A final model comparison revealed that dropping the predictor block altogether led to a significant reduction in model fit ($\Delta\chi^2[10] = 26, p = .005$).

In sum, the introduction of predictor variables to our best fitting model resulted in a significant improvement in the model's fit. However, the overall contribution from the set of predictors was somewhat limited. Together, the predictors explained a total of 16% and 11% of the variance in the time-invariant stability components of vocabulary and grammar, respectively (Vocabulary: $R^2 = .16, F(5,211) = 8.07, p < .001$; Grammar: $R^2 = .11, F(5,211) = 5.33, p < .001$). As noted, we viewed the predictors as rough indicators of the same underlying concept, and our primary interest was therefore in the predictors' joint contribution. However, for the sake of completeness, individual regression coefficients and simple correlations between each predictor and the time-invariant stability components of vocabulary and grammar are presented in Table 4. As seen in the table, none of the predictors were able to explain variance over and above the other predictors, with the exception of frequency of book reading, which could explain 3.3% of the unique variance in trait-like individual vocabulary differences.

Discussion

In the present study, we sought to explore the dynamics underlying the relation between the development of vocabulary and grammar among children between the ages of four and six. In the following discussion, we would like to highlight four main findings that emerged from the study.

First, we found that the children's development of vocabulary and grammar were characterized by enduring trait-like individual differences. This finding implies that traditional analyses that do not account for the time-invariant stability of constructs (e.g., cross-lagged correlational analyses or standard autoregressive panel models), may generate erroneous conclusions regarding the presence of causal relations between vocabulary and grammar (Hamaker et al., 2015). In our study, we compared a standard panel model with a model in which time-invariant between-person variance was partialled out through the inclusion of a random intercept. The outcomes of this comparison had marked consequences for the results of our study. The traditional panel model showed significant bidirectional cross-lagged effects between vocabulary and grammar, whereas the better fitting random intercept model, which more closely assesses dynamics at the intra-individual level, yielded no evidence of a reciprocal relation between the variables. To be precise, we found no evidence of a direct influence of vocabulary on grammar – a result which stands in stark contrast to the widespread claim that the development of vocabulary is a driving force in grammatical acquisition (Bates & Goodman, 2001; Marchman et al., 2004). This particular finding must be interpreted within the limits of the present study. As many have previously noted, the absence of evidence is not evidence of absence (Alderson, 2004; Altman & Bland, 1995); several characteristics related to the design of the present study may have impeded our ability to identify vocabulary-grammar associations. For example, similar to the majority of previous observational studies in the field, we relied on relatively global measurement instruments designed to assess children's overall level of vocabulary and grammatical skills. However,

Dixon and Marchman (2007) argued that it would be naïve to assume that the influence of lexicon on grammar operates in a monolithic fashion across all of vocabulary and grammatical development. In fact, one of the most widely known studies of the critical mass effect, conducted by Marchman and Bates (1994), was specifically focused on relations between the size of children's regular verb lexicon and their production of past tense over-regularization errors. Moreover, as discussed in the introduction, many theories of how lexicon operates on grammar, such as accounts of the critical mass effect, pertain to the onset of language development. There is a chance that children's grammatical development takes its own course once a minimum number of words are acquired, and by sampling children at the age of four we may have missed a developmental window for studying lexical effects on grammar. Nonetheless, several authors have argued that the association between vocabulary and grammar persists beyond the initial stages of development (Pérez-Leroux et al., 2012; Tomblin & Zhang, 2006), and some have even suggested that the lexicalist approach is supported by evidence in adults (Bates & Goodman, 2001). Furthermore, the literature provides numerous accounts of how children's lexical development may facilitate the acquisition of a range of different syntactical and morphological structures (e.g., Bassano, Laaha, Maillochon, & Dressler, 2004; Caselli et al., 1999; Marchman et al., 2004; Pérez-Leroux et al., 2012; Stolt et al., 2009; Tomasello, 2000). It is therefore not unreasonable to presume that some of these hypothesized relations would be assessed with more general measures of vocabulary and grammatical skills. Thus, although we cannot readily falsify hypotheses of lexical effects on grammar based on the data in the present study, we argue that the evidence supporting lexicalist theories may not be as strong as previously assumed – at least not for children who have passed the initial stages of language development.

The absence of evidence of a direct contribution from vocabulary to grammar in the present study is consistent with observations made by Hoff et al. (2017), who did not detect any

longitudinal cross-effects between vocabulary and grammar. In this regard, our second main finding differs from the results reported by Hoff et al. (2017). Although we could not identify any direct contributions from vocabulary to grammar, we did find some evidence of a developmental link in the opposite direction – from grammar to vocabulary. In some respects, this finding was not surprising. As previously mentioned, a series of experimental studies have demonstrated that children’s sophisticated knowledge of grammar is of particular use in guiding verb learning (Gertner et al., 2006; Hirsh-Pasek et al., 1996) but also for learning words in other categories (e.g., Fisher et al., 2006; Hall et al., 2001; Subrahmanyam, Landau, & Gelman, 1999). However, even if well-designed laboratory experiments are ideal for testing precise hypotheses concerning grammar-vocabulary relations, these experiments by necessity tend to be restricted in both time and the type of stimuli used. Consequently, the impact of any influences revealed by single experiments may prove negligible in children’s real-life development. Although we cannot say anything about the specific mechanisms underlying the observed cross-effect from grammar to vocabulary, this finding serves an important role by corroborating evidence from the experimental regime. Granted, the size of the direct contribution from grammar to vocabulary was somewhat limited and restricted to the first two measurement occasions in the study. However, when considering that we used a relatively strict autoregressive modelling strategy, even this small contribution must be regarded as nontrivial.

Even if evidence of direct associations between the development of vocabulary and grammar was limited in the present study, the results of the study do not necessarily imply that vocabulary and grammar are dissociated areas of language. On the contrary, our third main finding relates precisely to the intimate relation we observed between the time-invariant trait-like components of vocabulary and grammar. This finding indicates, as Hoff et al. (2017) suggested, that individual differences within these two areas of language can be explained by

a common source of influence or alternatively by correlated sources of influence. As to what these common influences comprise, different perspectives can be found in the literature. For example, the idea of domain-general learning capacities has long been present in the field of language research. According to several authors (e.g., Dawson & Gerken, 2009; Saffran, Johnson, Aslin, & Newport, 1999; Saffran & Thiessen, 2007), learners are equipped with a set of cognitive and perceptual mechanisms that are applied to the task of learning within different domains, including language. In the last decade, researchers have particularly focused on the role of statistical learning (i.e., the ability to extract statistical regularities in the environment, such as the co-occurrence of events), and a series of studies have demonstrated that learners' attention to regularities in input is associated with both lexical and grammatical acquisition (e.g., Gomez & Gerken, 1999; Saffran, 2001; Yu & Smith, 2007). For example, Saffran and Wilson (2003) found that children as young as 12 months old were able to track multiple levels of regularities in an artificial language. From continuous speech, the children were able to identify word-level representations and subsequently discover the simple grammar governing the ordering of these representations. In other words, the acquisitions of the different language levels were intrinsically related, as the output of word-level learning served as internally generated input for grammar acquisition (Saffran & Wilson, 2003). The ability to track the statistical regularities of language may thus represent one example of a common underlying learning mechanism responsible for development within both vocabulary and grammar.

Another potential common source of influence was proposed by Hoff et al. (2017).

Specifically, they argued that the richness of children's language input represents a third variable that explains the correlation between vocabulary and grammar. Although this particular source of influence is not incompatible with the presence of domain-general learning mechanisms, Hoff et al. (2017) suggested that language input provided an even better

explanation for the parallel growth of vocabulary and grammar they observed in their sample of bilingual children. Their reasoning rests on evidence of language specificity; that is, the slopes of vocabulary and grammatical growth were strongly and positively related within languages, whereas correlations across languages were weak to non-existent (see also Marchman et al., 2004, for a discussion of language specificity based on cross-sectional data). Consequently, children's lexical and grammatical development must share a common reliance on factors that are specific to each language in question as opposed to a general language learning ability. Although this argument is sound, it must be noted that Hoff et al. (2017) included only an estimate of children's relative exposure to English and Spanish at home to account for the fact that the amount of experience with one language may occur at the expense of the other – which would negatively affect across-language correlations. However, there are other factors that could potentially attenuate across-language correlations. For example, bilingual caregivers often have disparate levels of competencies in each of their home languages, or the quality of input may differ between languages for other reasons (Marchman, Martínez, Hurtado, Grüter, & Fernald, 2017). Furthermore, a measure of relative language exposure at home cannot account for differences in the amount of time children are exposed to each language in other arenas.

Although we were not able to investigate the issue of language specificity in our monolingual sample of children, the hypothesized role of input as a common source of vocabulary and grammatical growth leads us to the last of the study's main findings. We found that a set of home literacy predictors could explain 16% and 11% of the variance in the trait-like components of vocabulary and grammar, respectively. This finding indicates that children's home literacy environment may represent a common source of stable individual differences in vocabulary and grammatical development. This observation was not completely unexpected, as several longitudinal studies have demonstrated long-lasting socioeconomic disparities in

children's language skills (Hart & Risley, 1995; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Rowe, 2012; Uccelli, Demir-Lira, Rowe, Levine, & Goldin-Meadow, 2018). However, we were still somewhat surprised by the magnitude of the home literacy effects, considering that all of the predictors were very rough measures with a restricted range of scores in the sample and a nontrivial degree of missing data. Despite these limitations, one of the predictors, the frequency of joint book reading, even showed a unique contribution to children's vocabulary skills beyond the other predictor variables. This finding is consistent with previous research showing that the frequency of reading is more strongly related to children's vocabulary development than to other language skills (Hood, Conlon, & Andrews, 2008; Sénéchal & LeFevre, 2002).

The relation between home literacy and children's vocabulary and grammatical skills identified in the present study must be interpreted with some caution. As noted, we used very coarse measures of children's literacy environment, and we did not have any direct observations of their home language input. Moreover, biological and environmental factors are often intertwined (Hart et al., 2009; van Bergen, van Zuijen, Bishop, & de Jong, 2017), and we had no means of disentangling potential genetic and input-related sources of influence. In this respect, however, it is worth noting that Dale et al. (2000) found that most of the phenotypic correlation between vocabulary and grammar measures in a sample of two-year-old twins could be explained by shared environmental effects.

Limitations and final remarks

On several occasions in this article, we have suggested that the evidence supporting theories of direct relations between children's vocabulary and grammatical development may not be as strong as previously argued in the literature. In light of the results of the present study, we maintain this point of view – particularly for the hypothesized presence of lexical effects on

grammar. At the same time, we recognize that these two areas of language are intimately related through common sources of influence, such as children's home language environment and possibly domain-general learning capacities.

We have already addressed several limitations of the present study. However, before we conclude this article we would like to highlight a few additional limitations inherent to the design of the study. First and foremost, although we were able to establish important conditions for causal interpretation such as temporal precedence and control for autoregressive effects, the present study is observational by nature, and great caution should be exercised when making causal inferences based on the results. Second, even though the sample size in our study was more than twice that of Hoff et al. (2017), questions of statistical power are always important to consider when reporting null-effects. We remind the readership to bear in mind the limits imposed by the size of our sample when interpreting the lack of direct effects from vocabulary to grammar. Furthermore, the data in the present study were based on three measurement occasions spanning two years. More measurement occasions with shorter time-intervals would offer both a broader and more detailed image of children's acquisition of vocabulary and grammar. We hope that future studies will overcome these shortcomings and continue to explore the dynamics underlying the relation between the development of vocabulary and grammar. In particular, we welcome long-lasting longitudinal studies following children from the onset of language development to when they reach the height of their grammatical acquisition. As a final remark, we would like to stress that recent advances in the field of statistics have equipped researchers with powerful methods for modelling developmental relations (e.g., Curran & Bollen, 2001; Ferrer & McArdle, 2010; Hamaker et al., 2015). We therefore encourage researchers to challenge prior conclusions by using these advancements in analysing data from new longitudinal studies or, alternatively, to reanalyse previously reported data.

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Table 1

Distribution of primary caregivers' answers to questions regarding home literacy and educational level

| Home Literacy | | | | | | Caregivers' educational level | | |
|------------------|------|-------------------------|------|-------------------|------|-------------------------------|--------|--------|
| Number of books | % | Frequency of reading | % | Reading enjoyment | % | | Father | Mother |
| 1. 0-2 | 0 | 1. Almost never | 3.5 | 1. Not at all | 1.7 | 1. Compulsory school | 6.2% | 9.6% |
| 2. 3-10 | 5.8 | 2. Once/twice a month | 4.6 | 2. Some | 2.9 | 2. High-school - vocational | 9.8% | 19.7% |
| 3. 10-50 | 50.9 | 3. Once a week | 9.2 | 3. Fairly well | 2.3 | 3. High-school - academic | 17.6% | 13.3% |
| 4. 50-100 | 36.4 | 4. Several times a week | 28.9 | 4. Much | 12.7 | 4. University level < 4 years | 31.1% | 26.6% |
| 5. More than 100 | 6.9 | 5. Almost every day | 53.8 | 5. Very much | 80.3 | 5. University level ≥ 4 years | 35.2% | 30.9% |
| <i>(N = 173)</i> | | | | | | <i>(N = 188) (N = 193)</i> | | |

Note. Number of books = “How many picture books for children do you have at home?”; Frequency of reading = “How often do you read to your child?”; Reading enjoyment = “How much does your child enjoy book reading?”; Caregivers' educational level = The highest level of completed education. In Norway, the standard study duration of a bachelor's programme is three years.

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Table 2

Means, standard deviations (SDs) and ranges for observed measures of vocabulary and grammar at all three time points

| Measure | Time 1 (age 4) | | Time 2 (age 5) | | Time 3 (age 6) | |
|---------|----------------|---------|----------------|---------|----------------|---------|
| | Mean (SD) | Min-Max | Mean (SD) | Min-Max | Mean (SD) | Min-Max |
| TROG | 37.42 (17.00) | 5-76 | 49.90 (14.31) | 10-74 | 61.14 (12.89) | 10-79 |
| BPVS | 42.11 (11.04) | 16-75 | 56.88 (11.41) | 28-90 | 73.01 (11.83) | 43-104 |

Note. All test scores = raw scores; TROG = Test for Reception of Grammar-2; BPVS = British Picture Vocabulary Scale-II; Min-Max = Range of scores in the sample.

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Table 3

Correlations between observed measures of vocabulary and grammar at all three time points

| Measure | 1. | 2. | 3. | 4. | 5. |
|------------|------|------|------|------|------|
| 1. TROG T1 | - | | | | |
| 2. BPVS T1 | .54* | - | | | |
| 3. TROG T2 | .45* | .37* | - | | |
| 4. BPVS T2 | .45* | .52* | .48* | - | |
| 5. TROG T3 | .38* | .26* | .47* | .39* | - |
| 6. BPVS T3 | .31* | .45* | .39* | .58* | .33* |

Note. TROG = Test for Reception of Grammar-2; BPVS = British Picture Vocabulary Scale-II; T =

Time. *All correlations are significant at the .01 level (2-tailed).

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Table 4

Regression coefficients and correlations between predictors and time-invariant stability components

| Predictors | Time-invariant vocabulary | | Time-invariant grammar | |
|------------------------------|---------------------------|----------|------------------------|----------|
| | <i>b</i> (<i>SE</i>) | <i>r</i> | <i>b</i> (<i>SE</i>) | <i>r</i> |
| Mother's education | .05 (.15) | .11 | .08 (.21) | .12 |
| Father's education | .07 (.14) | .18* | .14 (.20) | .19* |
| Number of picture books | .17 (.23) | .19* | .40 (.31) | .21* |
| Frequency of reading | .39* (.16) | .36** | .25 (.23) | .26** |
| Child's enjoyment of reading | .37 (.21) | .32** | .54 (.33) | .27** |
| | $R^2 = .16^{**}$ | | $R^2 = .11^{**}$ | |

Note. *b* = unstandardized regression coefficients; *SE* = standard errors; *r* = Pearson's *r*. * significant

at $p \leq .05$, ** significant at $p \leq .005$.

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Figure 1. Graphical representation of the CLPM (on the left) and the RI-CLPM (on the right) for three waves of data. Circles represent latent variables. For clarity, the measurement models and mean structures are omitted from the diagram. The double-headed arrows represent (residual) correlations, the short single-headed arrows represent (residual) variances, and the long unidirectional arrows represent regression effects.

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Figure 2. CLPM of the longitudinal relation between vocabulary and grammar. For clarity, the measurement model and mean structure are omitted from the diagram. The double-headed arrows represent (residual) correlations, and the long unidirectional arrows represent regression effects. All coefficients are standardized.

Note. Paths with solid lines = significant at $p < .05$. Dashed lines = non-significant paths ($p > .05$).

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Figure 3. RI-CLPM of the longitudinal relation between vocabulary and grammar. For clarity, the measurement model and mean structure are omitted from the diagram. The double-headed arrows represent (residual) correlations, and the long unidirectional arrows represent regression effects. All coefficients are standardized.

Note. Paths with solid lines = significant at $p < .05$. Dashed lines = non-significant paths ($p > .05$).

