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# Language Delay and Externalizing Problems in Preschool Age: A Prospective Cohort Study

Mari Vaage Wang [1] · Leif Edvard Aarø [1] · Eivind Ystrom [1,2]



## Abstract

This study sought to examine the direction of causation between language delay and two externalizing problems; inattention and aggression. Autoregressive fixed effects models were fitted to data from 25,474 children (age 1.5 to 5 years; 50.8% boys) in the population-based longitudinal Norwegian Mother and Child Cohort Study (MoBa), to model the direction of causality for language delay and inattention and aggression, respectively. The most parsimonious model for the relationship between language delay and inattention was one where both common factors and reciprocal causation were estimated. Adjusted for common factors, language delay was estimated to have a non-significant effect on inattention by $b = 0.12$ ($p = 0.06$), and inattention to have a significant effect on language delay by $b = 0.19$ ($p = 0.03$). The most parsimonious model for the direction of causality for language delay and aggression was one where the entire association could be explained by language delay having effect on aggression $b = 0.12$ ($p < 0.02$). It appears that while language delay can best be conceptualized as an epiphenomenon of inattention partly related to both common factors and causal processes, aggression can best be conceptualized as caused by language delay. This illumination of the hypothetical causal links between two common problem domains in preschool-aged children has clear implications on where to implement interventions to prevent co-occurrence of language delay and externalizing problems.

**Keywords** Direction of causality · Population based · Language delay · Externalizing problems · MoBa

Language delay is one of the most common childhood problems with between 5 and 10% of preschoolers being affected. Among children with language delay 50–70% have co-occurring mental disorders (Toppelberg and Shapiro 2000). The most prevalent co-occurring symptoms reside within externalizing behavior problems. In recent years, a growing body of population- based research has focused on co-occurrence of language delay and externalizing problems.

While some researchers find weak or no associations (Campbell et al. 2010; Horowitz et al. 2003), others find that these symptoms co-occur in various ways (Girard et al. 2016; Petersen et al. 2013). Several studies have investigated how the association develops over age, but to date we know little of the potential causal relationship between these problems. Arguing for a reduction in anger with increased language skills one study followed a population sample of young children over three occasions to investigate whether language status predicted change in anger expression between 18 and 24 months. One-hundred and twenty children were investigated and results from structural equations with linear growth models showed that children with better language skills also had better anger regulation (Roben et al. 2013). In this study, associations between early anger and later language skills were not as strong as prospective relations between early language ability and a decline in anger reactivity, arguing in favor of an association going from language skills to anger rather than the opposite. The researchers underline that the findings underscore the need to more closely examine reciprocal relations between language and externalizing problems in early childhood, and include better control for confounding variables. In two recent studies, Girard and colleagues investigated the developmental association between aggressive symptoms and language ability (Girard et al. 2015; Girard et al. 2014). In the first study

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✉ Mari Vaage Wang
mari.vaage.wang@fhi.no

[1] Division of Mental and Physical Health, Norwegian Institute of Public Health, PO box 4404, Nydalen, N-0403 Oslo, Norway

[2] Department of Psychology, University of Oslo, PO box 1094, Blindern, 0317 Oslo, Norway

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2057 children enrolled in the Quebec Longitudinal Study of Child Development (QLSCD) were assessed longitudinally via parent report and standardized assessments to investigate whether poor language skills in early development increase the likelihood of physical aggression at 72 months or vice versa. Result from cross lagged models suggests strong autoregressive, but minimal cross lagged associations. One suggested explanation was that these abilities are parallel rather than predictive processes (Girard et al. 2016; Girard et al. 2014). In the second study the cross lagged association between conduct problems and expressive language from 3 to 5 years of age were investigated in a birth cohort of 14,000 participants (Girard et al. 2015). The results supported statistically significant but modest cross-lagged associations suggesting that conduct problems at 3 years were associated with poor language skills at 5 years and that poor expressive language skills were associated with increased conduct problems at age 5. Thus, change in one domain had a modest effect on change in the other over and above what was explained by stability within each domain and concurrent correlation between the domains, supporting a hypothetical causal relationship. Using a similar design, Morgan et al. (2008), estimated the predictive strength of poor reading on later externalizing problems while controlling for concurrent externalizing problems and vice versa, and including a large number of covariates using multivariate logistic regression models. They concluded that their results supported a bidirectional causal association between reading and behavior problems (Morgan et al. 2008). Using two independent prospective longitudinal samples, Bornstein and colleagues fail to find a cross-time cross-domain prediction when investigating potential paths between language and externalizing problems in children from 5 to 14 years of age (Bornstein et al. 2013).

One of several reasons why the literature presents contrasting findings can be that different studies use different operationalization of externalizing problems. Whereas some look at aggression/symptoms of conduct disorders alone others look at aggression and inattention/symptoms of attention deficit hyperactivity disorder (ADHD) together. While aggression is a behavioral problem, described by disruptive behavior with directional or relational actions, inattention is a cognitive problem and actions are often introverted rather than relational. Few have compared different externalizing outcomes when investigating co-occurring difficulties with language delay in the general population. However, Séguin and colleagues found that while aggression was related to language delay, hyperactivity was associated with non-verbal deficits (Séguin et al. 2009). Another study found that when subdividing ADHD symptoms, inattention frequently overlapped with language delay compared with combined type, which includes both hyperactivity and inattention (Mueller and Tomblin 2012). These varied findings could indicate different etiologies for the association between language impairment and different externalizing problems, such as aggression and inattention.

The co-occurrence of language delay and externalizing problems may be explained in two ways. First, language delay and externalizing problems could be caused by common genetic and environmental factors. A community sample of twins, the Twin Early Development Study, reported modest associations between behavior problems and verbal cognition, and found no differences in associations with verbal cognition between subdomains of behavioral problems (Plomin et al. 2002). Despite genetic overlap, genetic differences best described the relationship between behavior problems and verbal cognition. Another community sample of twins found that the co-occurrence of reading disability and inattention could be attributed to common genetic influences (Willcutt et al. 2007). There may be residual associations between language delay and externalizing problems after controlling for common factors. Such residual associations suggest that there are mechanisms contributing to co-occurrence between the two problems that cannot simply be attributed to common confounding factors. Second, language delay and externalizing problems could be related in a causal way. For example, language delay might increase the risk of aggressive behavior resulting from frustration due to poor communication skills. Findings from a twin study of 19-month-old children showed the association between expressive vocabulary and aggression was better explained by a model where expressive vocabulary causes aggression, rather than purely genetic and environmental factors (Dionne et al. 2003). Less is known about the association between inattention and language delay.

For approaching causality in developmental studies, the rationale of the cotwin control design can be applied to longitudinal data using fixed-effects regression models (Boden et al. 2010; Hamaker and Wichers 2017). The utilization of such models is becoming more and more common in developmental psychology (Ystrom et al. 2017; Zachrisson and Dearing 2015). However, there are to our knowledge, no corresponding population-based studies estimating the hypothetical direction of causation for co-occurrence of language delay and either aggression or inattention. In the current study, we utilize structural equations with fixed effects models to explore the hypothesized direction of causality between language delay and externalizing problems (aggression and inattention). These statistical models allow modelling reciprocal effects and statistically fixing all unobserved time-invariant variables, basing all estimates on within time-variation only. This method has several strengths when testing research hypotheses of direction of causality compared to the more common cross-lagged panel analyses. The suggested use of cross-lagged models is for better understanding the longitudinal associations between variables that can further our understanding of developmental processes, rather than investigating causality. In a recent paper discussing the use of cross-lagged

panel models it is argued that these models fail to align with the theoretical processes that is intended to test (Berry and Willoughby 2016). The cross-lagged panel analyses did not disaggregate between- and within-subjects effects, which further limits the ability to determine (or disprove) bidirectional causality (see Berry and Willoughby 2016).

This study utilized data on 25,474 children in a population-based study sampled at three occasions during the preschool years. Our primary aim was to describe the hypothetical causal relationship between language and externalizing problems (aggression and inattention). We used autoregressive fixed effects models to investigate if the etiological relationship is best conceptualized as driven by common factors, language delay having effect on externalizing problems, or externalizing problems having effect on language delay.

## Method

### Participants

The Norwegian Mother and Child Cohort Study (MoBa) is a prospective, population-based, pregnancy cohort study conducted by the Norwegian Institute of Public Health (Magnus et al. 2006). Participants were recruited from all over Norway from 1999 to 2008. Thirty eight percent of the women invited consented to participate. Potential self-selection bias in MoBa has previously been examined on demographic, health-, pregnancy- and birth-related variables. Despite risk prevalence differences between the sample and the population, estimates of exposure-outcome associations were not biased due to self-selection in the MoBa (Nilsen et al. 2009). The cohort now includes maternal reports of 109,018 children. Informed written consent was obtained from all participants. Follow-up is conducted by questionnaires administered at regular intervals (during pregnancy and when children were 6 months, 1.5, 3 and 5 years of age) and by linkage to national health registries. The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate.

By June 2011 (data release version 5), 25,474 children had turned 5 years of age and were therefore eligible for the present study. Data from 3 waves of data collection were used; 1.5 years (Q5), 3 years (Q6), and 5 years (Q7). A total of 12,930 boys and 12,500 girls with assessments on all occasions were included (gender for 44 children was unknown).

### Sample Size

The present analyses are based on the sample of 25,474 participants for whom data on externalizing and language delay were available on at least one occasion at ages 1.5, 3, and 5 years of age. However, because not all of the participants were assessed at all follow up points, the observed sample population varied between 1.5 years ($N = 18,685$), 3 years ($N = 15,215$), and 5 years ($N = 12,634$). These samples represent 73.3%, 59.7%, and 49.6% of the total sample of 25,474 participants, respectively.

### Measures of Language Delay

Language delay were assessed through maternal ratings on selected items from the Ages and Stages Questionnaire (ASQ; Squires et al. 1999) at all three time points. The ASQ has been validated in a Norwegian sample and found to be a successful diagnostic tool for developmental difficulties, including communication difficulties (Richter and Janson 2007). At all 3 age time points, the items included three response categories (yes, sometimes, and not yet). Most items had a skewed distribution across response categories. To create groups of children with language delay, a cut-off point was introduced at 1.5 SD above the mean (high score indicating risk) in accordance with previous analyses of the MoBa data, and in line with ASQ recommendations (Squires et al. 1997; Zambrana et al. 2014). At 1.5 years of age, this group included 4.8% of the children, and the language measure consisted of three items from the ASQ communication scale suited for these age groups. At 3 years, language was measured by six ASQ items. Four of these items were from the age appropriate scale, as well as one item from the 18 month scale and one item from the 48 month scale. The group of children with language delay at 3 years of age consisted of 5.7% of the participating children. At 5 years, all six items included in the original age-appropriate communication scale were used as a measure of language. At 5 years of age, the cut-off for language delay was 6.4%.

### Measures of Externalizing Problems

Externalizing problems were measured using mother reports on selected items from the Child Behaviour Checklist (CBCL; Achenbach and Rescorla 2000). This CBCL has been validated in a Norwegian general population sample (Novik 1999) with results supporting good external validity, satisfactory sensitivity and high specificity. In the current study externalizing problems were divided into subdomains of aggression and inattention, with three items to measure each domain (see online supplementary material for a presentation of all included items). These items were available in the MoBa data on all three occasions for each domain. Cut points were introduced at the 85th percentile. The same cut off score was used on the following occasions. This gave dichotomous groups of 11.7% and 12.4% with higher rates of inattention and aggression, respectively, at 1.5 years of age, 7.1% and 26%, respectively, at 3 years, and 3.8% and 8.8%, respectively, at 5 years. Cut points at the 95th percentile were then introduced to give a robustness test including

a more severely affected sample of children. Dichotomous groups then included 3.0 and 2.9% of children with higher rates of inattention and aggression respectively at 1.5 years of age, 2.1 and 8.5% at 3 years, and 1.3 and 2.4% at 5 years.

## Covariate Adjustment

To account for the age differences at each measurement point, we included age-correcting variables as covariates at each time point for all analyses. Because of gender differences (Table 1) in both language and externalizing problems, gender was included as a control variable in the structural equation models.

## Associations between Language and Externalizing Problems

In the first stage of the analyses, logistic regression models were used to capture the associations between language and aggression and language and inattention, respectively, at each time point.

## Structural Equation Modeling

To explore the direction of causality between language and externalizing problems, three structural equation models were fitted to the measures observed for the three age intervals of 1.5, 3, and 5 years of language together with inattention and aggression separately. Models included fixed effects influencing the measures of language and externalizing problems over time, and the potential to examine both unidirectional and reciprocal effects between language and externalizing problems within time intervals. A model with reciprocal causal effects between language and externalizing problems is presented in Fig. 1. The model assumes that a) the observed symptom measures of language delay and externalizing problems at all ages are influenced by fixed sources of variation that are constant over time, and by time-dynamic sources of variation; b) the fixed sources of variation for language delay are permitted to correlate with the fixed sources of variation for externalizing problems; c) the time-dynamic components of language delay and externalizing problems are linked by autoregressive processes in which past language symptoms predicted future language symptoms, and past externalizing symptoms predict future externalizing symptoms, respectively; and d) the time-dynamic components of language and externalizing symptoms are reciprocally related at 3 and 5 years so that current time-dynamic sources of variation in language delay influence current time-dynamic sources of variation in externalizing problems and vice versa. These reciprocal effects were assumed to be constant over time, and e) the time-dynamic components at 1.5 years were assumed to be correlated rather than reciprocally related in order to obtain model identifiability. The fixed effects are latent variables that summarize the effect of all non-observed fixed factors that exercise a constant effect on the measures of language and externalizing problems, respectively, over time. These factors include all childhood, family, and personal characteristics that have a fixed effect on outcomes over time and thus include both genetic and environmental influences. The time-dynamic components of the model represent the effect of all other sources of variance in language and externalizing symptoms not solely attributable to fixed factors.

**Table 1** Descriptive table of included variables at all measurement points overall (boys/girls)

| | N | Min/ Max | M | SD | 95th pct | 85th pct |
|---|---|---|---|---|---|---|
| Language delay | | | | | | |
| 1.5 years | 18,198 | 3/9 | 4.3 (4.6/4.0) | 1.6 (1.6/1.4) | 4.8 (6.5/3.1) | |
| 3 years | 14,551 | 6/17 | 7.1 (7.1/7.0) | 1.3 (1.4/1.1) | 4.2 (7.5/3.9) | |
| 5 years | 10,952 | 6/18 | 6.7 (6.8/6.6) | 1.2 (1.3/1.1) | 6.4 (7.4/5.3) | |
| Inattention | | | | | | |
| 1.5 years | 18,378 | 3/9 | 4.8 (4.9/4.7) | 1.3 (1.3/1.2) | 3.0 (3.6/2.5) | 11.7 (12.5/9.8) |
| 3 years | 15,000 | 3/9 | 4.5 (4.5/4.4) | 1.3 (1.3/1.2) | 2.1 (2.4/1.8) | 7.1 (7.6/6.5) |
| 5 years | 12,485 | 3/9 | 4.0 (4.1/3.9) | 1.2 (1.3/1.1) | 1.3 (1.8/0.8) | 3.8 (4.8/2.7) |
| Aggression | | | | | | |
| 1.5 years | 18,425 | 3/9 | 4.2 (4.3/4.2) | 1.1 (1.1/1.1) | 2.9 (2.9/2.8) | 12.4 (13.5/11.4) |
| 3 years | 15,009 | 3/9 | 4.8 (4.8/4.7) | 1.2 (1.2/1.2) | 8.5 (9.2/7.8) | 26 (28.4/23.5) |
| 5 years | 12,507 | 3/9 | 3.9 (4.0/3.9) | 1.1 (1.1/1.0) | 2.4 (2.7/2.0) | 8.8 (10.7/6.9) |

*Min/max* Minimum/maximum value

*M* Mean

*SD* Standard deviation

*Pct* Percentile

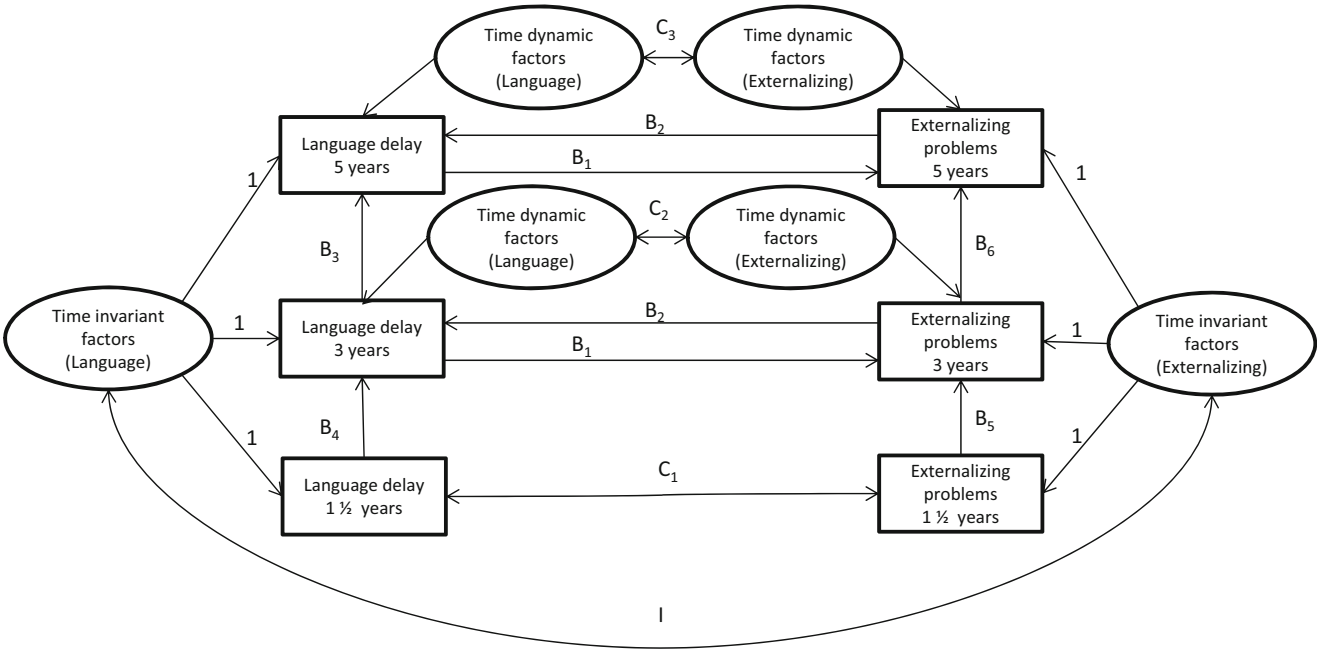



**Fig. 1** Autoregressive model of language and externalizing problems, incorporating fixed effects and reciprocal paths between time-dynamic components of language and externalizing problems

## Data Analyses with Fixed Effects Model for Covariate Adjustment

To adjust for unobserved fixed and observed time dynamic-factors confounding the association between language delay and externalizing problems, a conditional fixed effects regression model was fitted to the joint data over the three measurement periods (see Fig. 1). The time invariant factors are latent variables summarizing the fixed effects of all non- observed influences that employ a constant effect on the measures of language delay and externalizing problems, irrespective of measurement time. The variance of the time invariant fixed factors is an estimate of the percentage of variance in the observations that are stable. The time-dynamic factors of the model represent the effect of all other sources of variance in language delay and externalizing problems, respectively, that are not solely due to fixed factors. These variables are allowed to covariate within time to represent common factors for language delay and externalizing problems. The autoregressive paths (*B3-B6*) compose observed language delay and externalizing problems that is stable over measurement points. The reciprocal effect of language delay on externalizing problems, and vice versa is represented by *B1-B2*, respectively. The reciprocal cause model was fitted to the observed measures of language delay and externalizing problems. The fit was then compared to the fit of two models assuming unidirectional relationship with direction of causality suggesting that language delay cause externalizing problems, or unidirectional relationship with direction of causality suggesting that externalizing problems cause language delay. Comparable models were described in more detail by those who developed them (Boden et al. 2010; Fergusson et al. 2009; Fergusson et al. 2011). The structural equation models were fitted to the data using Mplus version 6.12 (Muthén and Muthén 2007). We fitted the data using the robust WLS (WLSMV) estimator in Mplus. By including all participants that had reached 5 years of age and fitting the models on data with missing entries. To select models, we used difference in Akaike's information criterion (AIC; Akaike 1987).

# Results

## Associations between Language Delay and Externalizing Problems

Odds-ratios (OR) and 95% confidence intervals (95% CI) for the association between language and externalizing problems at 1.5, 3, and 5 years of age showed that language delay was a significant risk factor for inattention at age 1.5 OR: 1.85, 95% CI [1.43, 2.40], 3 OR: 2.27, 95% CI [1.73, 2.97], and 5 OR: 2.63, 95% CI [1.88, 3.68], and for aggression at age 3 OR: 1.37, 95% CI [1.13, 1.67] and 5 OR: 2.30, 95% CI [1.80, 2.95], but not at 1.5 years OR: 1.02, 95% CI [0.76, 1.37].

When reversing the association, making predictions from inattention and aggression to language delay, we found similar results. Inattention was a significant risk factor for language delay at age 1.5 OR: 1.65, 95% CI [1.38, 1.98], 3 OR: 2.59, 95% CI [2.12, 3.16], and 5 OR: 4.29, 95% CI [3.33, 5.54] years. Aggression was a significant risk factor for language delay at age 3 OR: 1.41, 95% CI [1.21, 1.64] and 5 OR: 2.83,

**Table 2** Summary of fitted model coefficients for the causal associations between symptoms of language delay and inattention, AIC values, and model goodness of fit indices (85th percentile cut off)

| | B (s.e.) | p | Δχ2 | Δdf | sig | ΔAIC | RMSEA | CFI |
|---|---|---|---|---|---|---|---|---|
| Step 1 | | | | | | | | |
| $B_1$ | 0.116 (0.061) | 0.061 | | | | | 0.007 | 0.995 |
| $B_2$ | 0.185 (0.087) | 0.034 | | | | | | |
| Step 2 | | | | | | | | |
| $B_1$ | 0.020 (0.053) | 0.715 | 3.899 | 1 | 0.048 | 1.899 | 0.008 | 0.994 |
| Step 3 | | | | | | | | |
| $B_2$ | 0.058 (0.074) | 0.434 | 3.245 | 1 | 0.072 | 1.245 | 0.008 | 0.994 |

$B_1$ = Effect of language delay on inattention adjusted for age and gender; $B_2$ = Effect of inattention on language delay adjusted for age and gender

Other estimates from the best fitting model: Variance for the time invariant factor for language = 0.482, $p = 0.000$; variance for the time invariant factor for inattention = 0.294, $p = 0.000$; covariance between language delay and inattention at 1.5 years of age ($C_1$) = 0.084, $p = 0.097$; covariance between time dynamic factors of language delay and inattention at 3 years of age ($C_2$) = −0.125, $p = 143$; covariance between time dynamic factors of language delay and inattention at 5 years of age ($C_3$) = −0.052, $p = 0.591$, covariance between time invariant factors of language delay and inattention (I) = 0.046, $p = 0.306$, regression coefficient for language delay at 1 ½ on language delay at 3 years of age ($B_4$) = 0.110, $p = 0.056$, regression coefficient for language delay at 3 on language delay at 5 years of age ($B_3$) = 0.172, $p = 0.011$, regression coefficient for inattention at 1 ½ on inattention at 3 years of age ($B_5$) = 0.188, $p = 0.002$, regression coefficient for inattention at 3 on inattention at 5 years of age ($B_6$) = 0.207, $p = 0.010$

95% CI [2.31, 3.46] years, but not at age 1.5 years OR: 1.03, 95% CI [0.84, 1.27].

## Structural Equation Modeling of the Causal Relationship between Language Delay and Externalizing Problems

The findings from the logistic regression models are consistent with a causal relationship between externalizing problems and language delay, but do not establish the direction of causality. To estimate the direction of causation between language delay and externalizing problems, three structural equation models were fitted to the data. Table 2 shows estimates of the effects of language and inattention on each other, difference in AIC values, and associated goodness of fit indices for the estimated models. In step 1 for analyses of language delay and inattention, we estimated a model that, in addition to both time-invariant and time-dependent effects,

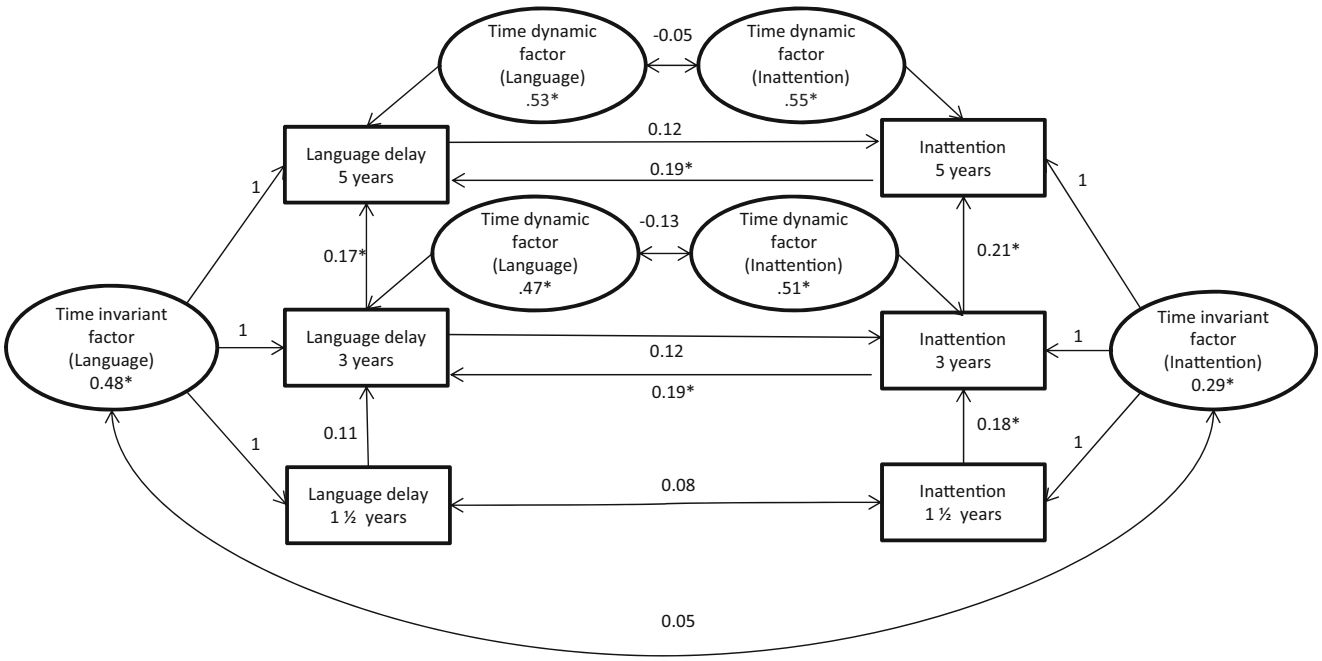



**Fig. 2** Structural equation modeling of the direction of causality between language delay and inattention

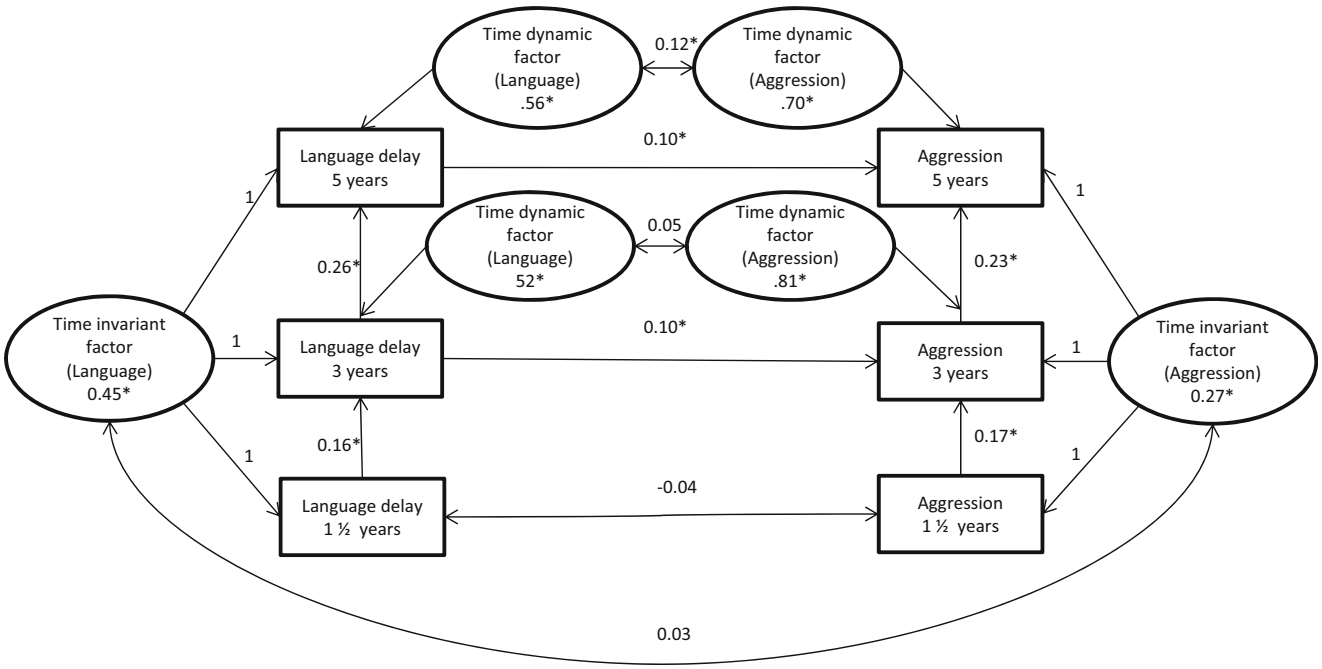
**Table 3** Summary of fitted model coefficients for the causal associations between symptoms of language delay and aggression, AIC values, and model goodness of fit indices (85th percentile cut off)

| | B (s.e.) | p | $\Delta\chi 2$ | $\Delta$df | sig | $\Delta$AIC | RMSEA | CFI |
|---|---|---|---|---|---|---|---|---|
| Step 1 | | | | | | | | |
| $B_1$ | 0.119 (0.051) | 0.021 | | | | | 0.003 | 0.999 |
| $B_2$ | 0.039 (0.075) | 0.600 | | | | | | |
| Step 2 | | | | | | | | |
| $B_1$ | 0.100 (0.046) | 0.028 | 0.446 | 1 | 0.504 | −1.554 | 0.003 | 0.999 |
| Step 3 | | | | | | | | |
| $B_2$ | −0.076 (0.068) | 0.241 | 5.649 | 1 | 0.018 | 3.649 | 0.004 | 0.998 |

$B_1$ = Effect of language delay on aggression adjusted for age and gender; $B_2$ = Effect of aggression on language delay adjusted for age and gender

Other estimates from the best fitting model: Variance for the time invariant factor for language = 0.446, $p = 0.000$; variance for the time invariant factor for aggression = 0.270, $p = 0.000$; covariance between language delay and aggression at 1.5 years of age ($C_1$) = −0.040, $p = 0.271$; covariance between time dynamic factors of language delay and aggression at 3 years of age ($C_2$) = − 0.052, $p$ =0.212; covariance between time dynamic factors of language delay and aggression at 5 years of age ($C_3$) = 0.116, $p = 0.025$, covariance between time invariant factors of language delay and aggression (I) = 0.033, $p = 0.149$, regression coefficient for language delay at 1 ½ on language delay at 3 years of age ($B_4$) = 0.159, $p = 0.007$, regression coefficient for language delay at 3 on language delay at 5 years of age ($B_3$) = 0.255, $p = 0.000$, regression coefficient for aggression at 1 ½ on aggression at 3 years of age ($B_5$) = 0.172, $p = 0.000$, regression coefficient for aggression at 3 on aggression at 5 years of age ($B_6$) = 0.228, $p = 0.000$

assumes a reciprocal association between inattention and language delay. This served as the base model for the following analyses. In step 2, we estimated a model that assumes a unidirectional causal effect from language to inattention, and in step 3 we estimated a model that assumes a unidirectional causal effect from inattention to language delay. Both model 2 and 3 had an inferior fit to the data (difference in AIC = 1.899 for language delay causing inattention, difference in AIC = 1.245 for inattention causing language delay), indicating reciprocal causal links between language delay and inattention (Fig. 2). When applying the 95th percentile cut point for creating groups including children within the more severe spectrum of inattention problems, both models had superior fit to the baseline model, with the model for language delay causing inattention presenting being slightly more parsimonious than the model for inattention causing language delay (difference in AIC = −1.987 for language delay causing inattention, difference in AIC = −1.868 for inattention causing




* Significant at the p<0.05 level

**Fig. 3** Structural equation modeling of the direction of causality between language delay and aggression

language delay). Thus, these results favor a direct causal effect from language delay to inattention.

Table 3 shows estimates for the effects of language and aggression problems. In step 1, we fitted the baseline model containing time-invariant factors, time-dependent factors, and reciprocal causation. This model served as the baseline model. In step 2, we estimated a model that assumes a unidirectional causal effect from language delay to aggression. In step 3, we estimated a model that assumes a unidirectional causal effect from aggression to language delay. The best fitted and most parsimonious model was the unidirectional model in step 2 (difference in AIC = −1.554), conversely, the model in step 3, where aggression causes language delay had an inferior fit to the data (difference in AIC = 3.649). These results indicate a direct causal effect from language delay to aggression (Fig. 3). When applying a cut off for aggression at the 95th percentile the unidirectional model in step 2 still proved to be the most parsimonious model with language delay causing aggression, but not vice versa (difference in AIC -1.747 for language delay causing aggression compared to difference in AIC of 2.672 for aggression causing language delay).

## Discussion

This study presents a novel way of addressing the relationship between language and two subdomains of externalizing behavioral problems during the preschool years; inattention and aggression. Our findings are consistent with a model that has different etiologies for co-occurrence of language delay and inattention and language delay and aggression.

Several studies have confirmed the co-occurrence of externalizing problems and language delay in preschool-aged children, but few have studied the underlying mechanisms or the hypothetical causal relationship of this co-occurrence. Using advanced statistical modeling methods to control for non-observed confounding factors and to explore pathways, we investigated the hypothetical direction of causation for language delay and aggression and inattention, respectively. The analyses led to the following conclusions: First, there was evidence for a significant co-occurrence of language and externalizing problems. This was true for both inattention and aggression. The association became stronger with increasing age, and the odds were higher for inattention than for aggression. However, all relationships were significant, except for the odds of being aggressive if language was delayed at 1.5 years of age. Second, for exploring the possible pathways between language delay and externalizing problems, structural equation modeling was used to fit a reciprocal causation model. This analysis suggested that the best fitting and most parsimonious model for the relationship between language and inattention was one in which there were a reciprocal relationship where both language and inattention significantly predicted each other. For the relationship between language delay and aggression, the best fitting and most parsimonious model was one in which language delay significantly predicted aggression, but not the other way around.

Contrary to the findings of Mueller and Tomblin (Mueller and Tomblin 2012) showing that children with symptoms of inattention are less at risk for language delay than children with language delay are for symptoms of inattention, we found that the odds of having symptoms of inattention in children with language delay were 2.63 at 5 years, whereas the odds of having language delay for children with symptoms of inattention were 4.29.

When investigating the relationship further, we found that a reciprocal causation model was best suited for the relationship between language and inattention. Neither time-dependent nor time-invariant common factors significantly contributed in explaining the relationship between language and inattention in the original model. When applying a more stringent cut off (95th percentile) a more complex pattern appeared where both common time-invariant and time-dependent factors significantly contributed to the model. Thus, for more severely affected cases there is several factors contributing to the reciprocal association between these constructs. This is consistent with previous literature arguing for common unobserved variables influencing both inattention and language delay (Tannock and Schachar 1996). Others have also found a symmetrical relationship between language and inattention, with a relative risk of 2.34 for language delay conditioned on inattention, whereas for inattention conditioned on language delay the relative risk was 2.36 (Mueller and Tomblin 2012). A recent study on co-occurrence of language delay and ADHD showed that the rate for ADHD in children with language delay was higher than language delay in children with ADHD (Mueller and Tomblin 2012). However, when comparing the relative risk for ADHD given language delay and vice versa, the symmetry indicated no directional relationship between the two. These researchers also found that the risk for ADHD was positively associated with a family history of communication disorders, as was the comorbidity between ADHD and language impairment. Our findings are in line with the assumption that inattention and language are caused by common genetic and environmental factors, which equally influence both areas of development. Thus, difficulties in these domains represent shared etiologies.

We found that the best fitting and most parsimonious model for co-occurrence of language delay and aggression was

one where language delay has an effect on aggression. These findings are consistent with the literature arguing that poor language skills lead to aggression in young children (Brownlie et al. 2004; Moffitt 1993). The result was robust also when applying a more stringent cut off (95th percentile). While other studies have findings supporting a reciprocal association between language and aggression (Girard et al. 2015; Girard et al. 2014), none of these studies have utilized designs suited for modeling direction of causation. Cross-lagged models are advantageous to investigate development over time but also exhibit several limitations. The suggested use of cross-lagged models is for identifying the relationship between variables over time, and to shed light on longitudinal associations between variables that can further our understanding of developmental processes. Other models are available for analyses that get us closer to investigating causality without experimental designs. Such models include fixed effects models.

Language skills have been found to mediate the relationship between externalizing problems and social cognition (Yaghoub Zadeh et al. 2007). It has also been argued that neuropsychological problems — including verbal performance — underlie manifestations of externalizing behavior, such as delinquency (Moffitt 1990) and conduct disorder (Moffitt 1993). In resemblance, our results suggest that the association between language delay and aggression cannot be explained by shared etiologies. This is in line with previous studies (Dionne et al. 2003). The only significant regression coefficient in the three models was the regression coefficient where change in language delay predicts change in aggression. The regression coefficients where changes in aggression predicted changes in language delay were not. The model estimating the causal effect of aggression on language delay did not fit as well to the data as the model where language delay causes aggression. Thus, we cannot reject the hypothesis that language delay leads to aggression, but we can reject the hypothesis that aggression leads to language delay.

The main strengths of this study are the utilization of a large population and the collection of longitudinal data designed to simultaneously estimate the causal effects of delayed language development on inattention and aggression, respectively, and vice versa. It is, however, important to recognize that the results from the current study should be interpreted in light of five limitations. First, using short scales to measure complex phenomena might result in narrow operationalization of otherwise wide concepts. Second, we rely solely on maternal reporting. Direct observation or performance tests would not be feasible in a population-based sample of this size. Even though we investigated the measurement models carefully with confirmatory factor analyses, we cannot exclude the possibility that a mother's judgments of her child's skills are influenced by factors that are not measured. However, since reporting bias that is stable in the mother would come out as time- invariant variance in the model, and reporting bias that is time-dependent (e.g., due to a major depressive episode) would come out as time-dependent variance, it is not immediately apparent how maternal reporting might bias these results. Third, we have little knowledge of the participants lost to follow up in MoBa. A major strength of the current study is that all children that have reached 5 years with valid data at one or more time-points were included. Hence, according to the missing at random assumption, bias introduced by attrition due to factors included into the model is accounted for. Fourth, it is also important to recognize the assumptions underlying the causal models. These are necessary to identify such models, but also introduce some uncertainties. Potential confounding factors that might contribute to the association between language delay and externalizing problems are accounted for in the time- invariant effects. For the purpose of the present study the main aim was to disentangle the direction of causality, but for future research mechanisms explaining a larger proportion of the correlation between these domains should be investigated. In our results we cannot know if the common factors accounted for in the estimated models are common genetic risk factors or common environmental factors. The assumption that these etiological mechanisms are equal across age could be an oversimplification, and as suggested by the logistic regression analyses there is in fact reason to believe that that the relationship increase in strength over time. Further, restricting intra-individual variability to be constant over time is a main limitation of applying this model to our data. However, these restrictions are also the methodological strength of fixed-effects estimation allowing for estimations of direction of causality. Results should be interpreted with these limitations in mind.

## Conclusion

Our results support the hypothesis that language delay has effect on problems in both inattention and aggression. However, whereas the relationship between language delay and aggression is best described as unidirectional, the relationship between language and inattention is explained by common factors as well as a reciprocal relationship.

Different etiologies for these two subdomains of externalizing behavior problems can help explain the diverse findings in earlier studies. Inattention and aggression have different etiological relationships with language delay. Whereas delayed language development seems to lead to aggression in preschool-aged children, language delay and inattention seem to result from common factors and reciprocally influence each other. Causation is the sine qua non for effective prevention. Therefore, it is of the highest importance to illuminate the putative etiological links between problem spectra. According to the current study, one might expect a reduction in aggressive behavior after improvement in language skills.

Conversely, one would expect that inattention problems would improve after language skills improve and vice versa.

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## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent** Informed written consent was obtained from all individual participants included in the study. The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate.

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