Attainment and loss of early social-communication skills across neurodevelopmental conditions in the Norwegian Mother, Father and Child Cohort Study

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Abstract

Background: Delays and loss of early-emerging social-communication skills are often discussed as unique to autism. However, most studies of regression have relied on retrospective recall and clinical samples. Here we examine attainment and loss of social-communication skills in the population-based Norwegian Mother, Father and Child Cohort Study (MoBa).

Methods: Mothers rated their child's attainment of 10 early-emerging social-communication skills at ages 18 and 36 months (N=40,613, 50.9% male). Prospectively reported loss was defined as skill presence at 18 months but absence at 36 months. At 36 months, mothers also recalled whether the child had lost social-communication skills. The Norwegian Patient Registry was used to capture diagnoses of Autism Spectrum Disorder (autism) and other neurodevelopmental disabilities (NDDs).

Results: Delay in at least one skill was observed in 14% of the sample and loss in 5.4%. Recalled loss of social-communication skills was rare (0.86%) and showed low convergence with prospectively reported loss. Delay and especially loss were associated with elevated odds of an autism diagnosis (n=383) versus no autism diagnosis (n=40,230) (≥3 skills delayed: OR=7.09[4.15,12.11]; ≥3 skills lost: OR=30.66[17.30,54.33]). They were also associated with increased likelihood of autism compared to some other NDDs. Delay (relative risk [RR]=4.16[2.08, 8.33]) and loss (RR=10.00[3.70, 25.00]) associated with increased likelihood of autism versus ADHD, and loss (RR=4.35[1.28,14.29]), but not delay (RR=2.00[0.78,5.26]), associated with increased likelihood of autism compared to language disability. Conversely, delay conferred decreased likelihood of autism versus intellectual disability (RR=0.11[0.06,0.21]), and loss was not reliably associated with likelihood of autism versus intellectual disability (RR=1.89[0.44,8.33]).

Conclusions: This population-based study suggests that loss of early social communication skills is more common than studies using retrospective report have indicated and is observed across several

NDD diagnoses (not just autism). Nevertheless, across diagnoses, the majority of children showed no reported delay or loss in these prospectively measured skills.

Keywords: autism, regression, milestones, skill attainment, MoBa, MBRN

Abbreviations: The Norwegian Mother, Father and Child Cohort Study (MoBa); Medical Birth Registry of Norway (MBRN); Attention Deficit Hyperactivity Disorder (ADHD); Modified Checklist for Autism in Toddlers (M-CHAT); Early Screening for Autistic Traits (ESAT)

Introduction

Regression, the loss of previously acquired skills, was recognized as a feature of autism in the earliest descriptions (Kanner, 1943; Kanner & Eisenberg, 1953). While language regression was an early focus, more recent studies found that decreases in general social engagement may comprise most of the regression reported in autism (Barger, Campbell, & McDonough, 2013). Recent conceptualizations also emphasize that regression is not simply dichotomous, but varies in degree, and is best captured in the context of the individual's developmental trajectory (Ozonoff & Iosif, 2019; Thurm, Powell, Neul, Wagner, & Zwaigenbaum, 2018).

Estimates of regression prevalence in autism are derived from a variety of sources (Barger et al., 2013), including neurology clinics (McVicar, Ballaban-Gil, Rapin, Moshe, & Shinnar, 2005; Shinnar et al., 2001), autism diagnostic clinics (Hansen et al., 2008; Lord, Shulman, & DiLavore, 2004; Luyster et al., 2005), internet-based registries (Kalb, Law, Landa, & Law, 2010), and some population-based samples (Baird et al., 2008; Brignell et al., 2017; Taylor et al., 2002; Wiggins, Rice, & Baio, 2009). Most studies have used retrospective interviews or questionnaires at the time of diagnosis. However, retrospective recall of regression does not reliably agree with prospective clinical observation, particularly for subtle aspects of social-communication (Ozonoff & Iosif, 2019). Further, studies that prospectively track attainment and loss of skills (e.g., infant sibling studies) are limited by their relatively small, non-representative samples, and diagnostic follow-up windows that do not extend past the early developmental period (Pearson, Charman, Happé, Bolton, & McEwen, 2018). This makes it difficult to understand associations between early skill loss and later diagnoses of autism or other neurodevelopmental disabilities (NDDs) (Szatmari et al., 2016).

Outside of autism, much of the work on regression has been in the context of neurodegenerative disorders or rare genetic conditions, including those wherein regression is a diagnostic feature (Goin-Kochel, Trinh, Barber, & Bernier, 2017; Spagnoli, Fusco, & Pisani, 2021; Thurm et al., 2018). Exceptions include data from convenience samples suggesting that language loss occurs (rarely) among children with language disability without autism and average-range

nonverbal cognition (Pickles et al., 2009), and that loss is retrospectively reported in a range of NDDs (Brignell et al., 2017; Luyster et al., 2005; Thurm, Manwaring, Luckenbaugh, Lord, & Swedo, 2014). However, because retrospective reports are collected *after* the point of clinical referral, or as part of research targeting children identified as high risk for developmental problems, there is a gap in knowledge about skill loss at the population level. While at least one population-based study indicated that retrospectively reported early loss of language skills is not unique to autism (Baird et al., 2008), other types of loss were not evaluated.

Historically, when regression status has been used to stratify autism samples into more phenotypically or genetically homogeneous subgroups, it is defined based on loss of specific skills (e.g., language loss), and without regard to whether the skill had been acquired on-time. This method of categorization may have contributed to the apparent unique association with autism, as the delayed acquisition of skills among children with other NDDs (e.g., intellectual disability; ID) may preclude the ability to show regression in early development.

Information about the *acquisition* of specific social-communication skills is lacking for both the general population and those with NDDs. There are some general population convenience sample data (e.g., Sheldrick & Perrin, 2013; Visser-Bochane, Reijneveld, Krijnen, van der Schans, & Luinge, 2020) and reports from government and regulatory agencies (Zubler et al., 2022), about the age by which various skills are likely to be established. In the context of NDDs, the few reports which have jointly considered both the timing of acquisition and the presence of loss (Luyster et al., 2005; Prescott & Ellis Weismer, 2021; Thurm et al., 2014) are subject to the same ascertainment and retrospective reporting limitations described above. To better understand the regression phenomenon across clinical and non-clinical populations, it is necessary to examine the initial attainment of skills as a pre-requisite to any loss of those skills, and to do so *before* the point of clinical referral. This information is also critical to forming a more complete picture of the early developmental course associated with various behaviorally defined conditions, which is ultimately needed to identify mechanisms underlying their associated impairments.

For insights into attainment and loss of early social-communication skills in the general population, we used the Norwegian Mother, Father and Child Cohort Study (MoBa), a population-based prospective pregnancy cohort study. Population-based samples help reduce recall or other types of bias that affect retrospective (Hus, Taylor, & Lord, 2011) or even prospective (Ozonoff et al., 2011) parent reports in at-risk samples. By linking MoBa to the nationwide patient registry, we were able to examine how patterns of attainment and loss of social-communication skills are associated with a later diagnosis of autism, compared with ID, language disability and other NDDs.

Methods

Sample

MoBa is a population-based pregnancy cohort study conducted by the Norwegian Institute of Public Health (Magnus et al., 2016). Participants were recruited country-wide from 1999 to 2008. The participation rate among pregnancies approached for recruitment was 41%. The cohort includes approximately 114,500 children, 95,200 mothers and 75,200 fathers. This study is based on version 10 of the quality-assured data files released for research in June 2017.

Ethical considerations

The establishment of MoBa and initial data collection was based on a license from the Norwegian Data Protection Agency and approval from The Regional Committees for Medical and Health Research Ethics (REC). MoBa is currently regulated by the Norwegian Health Registry Act. All participating mothers and fathers in MoBa provided informed written consent. This study was approved by REC (2013/201).

Measures

Prospectively reported skills

From instruments designed to screen for developmental delays in social-communication (Modified Checklist for Autism in Toddlers (Robins, Fein, Barton, & Green, 2001); Early

Screening for Autistic Traits (Swinkels et al., 2006), and the Social-communication Questionnaire (Rutter, Bailey, & Lord, 2003)), we selected 10 items with yes/no response format: showing objects, imitating, pointing to indicate interest, showing interest in peers, following pointing gesture, responsive smiling, responding to name, easy to make eye contact with, responding to speech, communicative facial expressions (**Table S1 and S2**).

Each skill was coded using a three-level scheme: "delayed" if the parent endorsed "no" on the 18-month questionnaire, "attained and maintained" if the parent endorsed "yes" on both the 18-month and 36-month questionnaire, and "lost" if the parent endorsed "yes" at 18 months and "no" at 36 months. Missingness across the 10 skills is shown in Table S3. Based on their values across all 10 skills, each participant was assigned to one of four profiles: 1) Neither delay nor loss, 2) delay in ≥1 skill with no loss, 3) loss of ≥1 skill with no delay, and 4) combined delay and loss (≥1 delayed and ≥1 lost). We note that the degree of delay is not reflected in these categories; the typical age of attainment for the selected items had a wide range, but lack of attainment of any skill by 18 months was coded in the same way ("delayed"). The duration of loss could not be captured through this coding scheme.

Retrospective recall loss of skills

While the 36-month questionnaire did not ask specifically about whether each of the 10 skills were lost individually, two items were drawn from the 36-month questionnaire on recalled loss of social-communication skills since the age of 18 months: "Has your child lost any social skills (e.g., could wave or say "Hi" to greet someone, then lost this skill)?", and "Has your child turned out to be less sociable (e.g., he/she is more difficult to have eye contact with, is less interested in other people now)?". Responses were binary (yes/no; "not sure" treated as missing). The binary summary variable "Any recalled social-communication loss" was coded as present if at least one of the two items was endorsed "yes," and absent otherwise (treated as missing if either item was missing).

Recalled loss of language and motor skills was included for descriptive purposes: “Has your child lost any language skills (for example, used single words or sentences for a time and then stopped using the words)?” and “Has your child lost any motor skills (e.g., could run and jump while remaining steady, but falls over much more now)?”. The duration of loss was not captured.

Clinical diagnoses

Information about NDD diagnoses was obtained from the Norwegian Patient Registry (Bakken, Ariansen, Knudsen, Johansen & Vollset, 2020), which capture all diagnoses from government-financed hospitals and outpatient clinics, coded using the International Classification of Diseases, Tenth Revision (World Health Organization, 2008). We included all diagnoses of autism (F84: Childhood autism/Atypical autism/Asperger syndrome/Childhood disintegrative disorder/Pervasive Developmental Disorder-Not Otherwise Specified), ID (F70-F79), language disability (LD) (F80), and ADHD (F90) registered from 2008 through 2018 (age range at end of follow-up: 9–19).

Other characteristics

MBRN provided information on the child’s sex and birth year, and the MoBa maternal-report questionnaires on age at questionnaire completion, maternal education, age at first walking (36-month questionnaire), age at first words and phrases (5-year questionnaire), and whether the child had been referred to educational/psychiatric/habilitation services by age 36 months.

Statistical Analysis

First, we aimed to describe patterns of early social-communication skill attainment in a population-based sample. We used descriptive statistics to examine the sample proportion with prospectively reported neither delay nor loss, delay only, loss only, and combined delay and loss, and to summarize the demographic (sex, maternal education), early developmental (major milestones), and clinical characteristics (NDD diagnoses) of these profiles. We also summarized the milestone responses at the skill level (**Table S4**), though to increase reliability of measurement, analysis was based on the summary of all items rather than single items (see Methods). To anchor

the prospective results to existing literature on retrospectively recalled loss, we calculated descriptive agreement statistics, including sensitivity, specificity, and positive predictive value of retrospective recall corresponding to prospective report.

Second, we aimed to evaluate the relationship between delayed acquisition of skills, loss of skills, and autism diagnosis. Accordingly, we used binomial logistic regression to model autism diagnosis (versus no autism diagnosis, to include children with other diagnoses) as a function of the number of skills which were delayed (0/reference, 1, 2, or 3+) and the number of skills which were lost (0/reference, 1, 2, or 3+). While we did not hypothesize an interaction between loss and delay, we planned to include this term in the model and retain only if it contributed robustly (i.e., p-value < 0.10). The parameters in this model are expressed as odds ratios, where an autism diagnosis is the event. When an event is rare, odds ratios and relative risk ratios are generally interchangeable (Sedgwick, 2014).

We expanded upon this model to examine whether the skill delay and/or loss were specifically associated with an autism diagnosis or more broadly with a range of NDD diagnoses. We used multinomial logistic regression to model NDD diagnostic outcome (autism, ID, LD, ADHD, and none).For the purpose of this analysis, diagnosis was assigned hierarchically to compare autism with ID, LD and ADHD (autism > ID > LD > ADHD). The parameters in this model are expressed as relative risk ratios.

For all main analyses, complete-case analysis was used, restricting to children with data on all 10 social-communication skills at 18 and 36 months of age (participant disposition in **Figure S1**). We compared the subsample with complete data to the rest of the cohort on background characteristics and proportions with autism, ID, LD, ADHD (**Table S5**). Given that complete case analysis can be biased by selective attrition, we performed sensitivity analyses assessing the impact of missing data on the results by using inverse probability weighting. We weighted the included participants by the inverse of the probability of being included in the complete-case analysis, deriving the weights from a logistic regression model using key background variables and

diagnostic group outcomes as predictors (see **Table S5**). All regression models included the covariates child's sex, birth year, and age at completion of the 18- and 36-month questionnaires, and standard errors were robustly estimated with clustering by maternal reporter to account for sibships (n=4,804). All covariates (child's sex, birth year, and age at completion of the 18- and 36-month questionnaires) were specified *a priori* and retained in the models no matter their effect size.

Results

A total of 40,613 children (n=20,665[50.88%] male) were included (**Figure S1**). The prevalence of any NDD diagnosis was 4.53% (n = 1,840); n = 1,546 (3.81% of total) had only one diagnosis, n = 254 (0.63%) had two diagnoses, and n = 40 (0.10%) had three or four diagnoses. The prevalence of NDD diagnosis (not mutually exclusive) was highest for ADHD (n=1,340, 3.30%), followed by autism (n=383, 0.94%), LD (n=319, 0.79%), and ID (n=135, 0.33%). The pattern of attaining all skills by 18 months and maintaining them at 36 months was most common (82.11% of all children) (**Table 1 and Table S6**). Of the remaining attainment patterns, Delay with no loss was the largest (12.51%), followed by Loss with no delay (3.91%) and Combined delay and loss (1.47%).

Among children with available data (n=40,023), 0.86% had retrospectively recalled social-communication skill loss by 36 months. Of 345 with retrospective loss and 2,077 with prospective loss, only 70 reported loss both prospectively and retrospectively. Correlation between the two sources was poor (φ=.06). Comparing retrospective to prospective loss, the sensitivity (proportion with prospective loss who had retrospective loss; 3.37%) and positive predictive value (proportion with retrospective loss who had prospective loss; 20.29%) were very low. As loss in general was relatively rare, specificity (proportion without retrospective loss who also did not have prospective loss; 99.28%) and negative predictive value (proportion without prospective loss who also did not have retrospective loss; 94.94%) were high.

Table 2 and Table S7 shows the sample demographic and developmental characteristics, summarized by NDD diagnostic group. While the rate of loss (with or without delay) was highest

for ID, the rate of loss *in the absence of delay* was highest for the autism group. As shown in **Figure 1**, social-communication skill acquisition patterns characterized by any loss or delay were most common for the ID group, followed by autism, LD, ADHD, and no diagnosis. We quantified the relationship of skill delay and loss to later autism diagnosis using binomial logistic regression, showing that increasing numbers of both delayed and lost skills were associated with increased odds of an autism diagnosis (relative to no autism diagnosis, with or without other NDD diagnosis) (**Table 3; IPW results in Table S8**. However, loss was more strongly associated with an autism diagnosis (with or without other NDD diagnosis) than was delay. Although children with ≥3 delayed skills had much greater odds of an autism diagnosis than those with no delayed skills (OR=7.09[4.15,12.11]), this value was even higher for children with ≥3 lost skills (OR=30.66[17.30,54.33]).

We next used multinomial logistic regression to probe whether the associations between skill delay and loss were specific to autism diagnosis (**Figure 2; Table S9A**). The interaction term between delay and loss was omitted because of large p-value. Increasing number of delayed skills were related to *increasing risk of an ID diagnosis* compared to an autism diagnosis. Whereas increasing numbers of lost skills were related to increased risk of an autism diagnosis compared to ID, the 95% confidence intervals for the relative risk ratios included 1. Increasing numbers of delayed and lost skills were both related to increased risk of an autism diagnosis compared to a LD diagnosis, though the effects were more robust for loss than delay. Finally, both delay and loss were associated with increased relative risk of autism in comparison to ADHD. The results of the inverse probability weighted analyses were consistent with the results from the primary complete-case analyses (Table S9 B). Further, we found similar results when stratifying the sample based on ID diagnosis (Table S9 C). Excluding children diagnosed with Rett Syndrome (n=3) did not affect the results.

Discussion

This study addresses a major gap in understanding of early social-communication development by exploring prospectively recorded acquisition and loss of several specific social-communication skills, and subsequent NDD diagnoses, in a population-based sample. While we found that both delay and loss in social-communication skills was associated with later autism diagnosis, *all* NDD diagnostic groups experienced higher rates of delay and loss in social-communication skills than those without any NDD diagnosis.

Our findings may help define typical attainment patterns of social-communication skills, which is needed to inform the development of guidelines for identifying social-communication delays (Gadomski, Riley, Scribani, & Tallman, 2018; Zubler et al., 2022). In this general population sample, 82% were reported to have attained all 10 early emerging social-communication skills by 18 months, supporting the idea that these skills are typically attained by 18 months and may be useful when screening for developmental delays in very young children. Prospectively collected population-based data may also be helpful in generating a more detailed understanding of the specific timing of individual social-communication milestone attainment, as has recently been done with language milestones (Visser-Bochane et al., 2020).

Both delay and loss of social-communication skills were more common among children who later received NDD diagnoses than those who did not; delays and/or loss were reported in two-thirds of the ID group, 43% of the autism group, 34% of the LD group and 22% of the ADHD group. That loss of social-communication skills was observed to some extent in all NDD diagnostic groups suggests that it is best conceptualized as a sign of risk for NDDs generally, rather than autism specifically. These findings add to a growing body of literature highlighting the need to describe early developmental phenotypes among populations at risk for NDDs that may not manifest fully in the first 3 years of life (Ozonoff, Young, et al., 2018; Stenberg et al., 2021).

Despite the association between loss and NDD diagnoses, an important finding is that a substantial proportion of each diagnostic group showed neither delay nor loss across a range of

social-communication skills. Thus, clinicians should not view the apparent absence of delay or loss in the first years of life as clear evidence of typical development.

The prevalence of skill loss estimated by this study is much lower than that of recent prospective behavioral coding studies (Ozonoff et al., 2010), which is likely attributable to differences in methodology. As shown in recent work that compares methods and reporters (Ozonoff, Gangi, et al., 2018) behavioral coding that captures frequency and uses a dimensional approach is likely to be more sensitive to subtler changes, allowing for more opportunities for a child to evidence skill loss than with the high-level and very specific parent report questions used in the current study. Further, the strikingly low sensitivity (3.36%) and low positive predictive value (20.29%) of retrospective recall of social-communication loss for detecting prospectively reported loss corroborates others' findings that existing estimates of regression—based largely on retrospective report—may be underestimates (Ozonoff, Gangi, et al., 2018; Ozonoff, Li, et al., 2018). Taken together, these findings add to a growing body of research on skill loss, which underscores the importance of carefully considering how "loss" is operationalized and calling into question the validity of retrospectively reported regression as a stratification factor in autism research (Goin-Kochel et al., 2017; Pearson et al., 2018).

Limitations

The population-based cohort ascertainment and the large sample size of prospectively collected data are primary strengths. However, as for all cohort studies, MoBa has certain participation biases, such as underrepresentation of younger parents and those with lower education (Biele et al., 2019; Magnus et al., 2016; Nilsen et al., 2009). There were also missing data on the repeated rating of the 10 social skills. However, we carried out inverse probability weighting on variables associated with missing data and found consistent results, suggesting that our findings were not substantially impacted by missing data bias. Further, we were unable to capture any NDD diagnoses occurring after age 9 for the youngest children in MoBa. The resulting misclassification

may have weakened the predictive power of the delay and loss variables. We selected only behaviors with consistent response scales, but the use of multiple forms may have contributed to measurement error. Because of the way prospective loss was categorized (a skill present at 18 months which was not present at 36 months), lack of test-retest reliability in parent report was indistinguishable from true loss. This may have inflated the rate of prospective loss. Conversely, the rate of loss may have been deflated by excluding loss which occurred prior to 18 months, after 36 months, or in skills not assessed. We also point out differences in how data was collected such that retrospective loss was ascertained via broad questions with only a few examples, and parents may or may not have been thinking of the exact same 10 skills that were described in the other questionnaires that were obtained prospectively when responding to the retrospective items. The focus of this study on prospectively reported loss of discrete social-communication skills, rather than broad categories, may limit comparability between the rates of delay and loss observed here and in other studies. Future studies could examine if diagnostic groups are differentiated further based on profiles of delays and losses in specific skills.

Conclusion

There is growing consensus that early skill acquisition and onset patterns among children with autism and other NDDs may provide important insights relevant to clinical management and scientific understanding of these conditions. Further, numerous studies indicate that information about the timing of delays in and losses of skills during NDD onset is best captured through prospective means (Pearson et al., 2018; Zhang et al., 2019). Our study provides evidence that while both delay and loss of early social-communication skills are associated with NDD diagnoses, they are neither specific to nor uniformly observed within autism. This highlights the need for a more nuanced conceptualization of the relationship between skill loss and autism, considering both degree and domain of skill loss, as well as recognition that it is not specific to autism. Clinically, these results support the current American Academy of Pediatrics recommendation to ask about developmental milestone acquisition multiple times during early development (Hyman, Levy, &

Myers, 2020). This will likely yield more cases of possible loss, which should be considered an early indicator of risk for NDDs.

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Key Points:

- Prospective population-based data are crucial for understanding the timing of skill attainment and frequency of loss of social-communication skills.
- A large population-based sample with diagnostic outcomes was used to show that most social-communication skills are attained by 18 months in typically developing children.
- Both delay and loss of social-communication skills occur between 18 and 36 months among children diagnosed with varied neurodevelopmental conditions (autism spectrum disorder, intellectual disability, language disability, and attention deficit hyperactivity disorder).

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Figure 1. Overall pattern of social skill development by neurodevelopmental diagnostic group.

Note: Diagnosis was categorized hierarchically for mutually exclusive categories.

Figure 2. Relative risk ratios associated with the number of skills delayed or lost for other diagnostic category compared to autism.

Note: Number of skills lost is listed on the Y-axis. Relative risk ratio (RR) indicates the magnitude of risk associated with autism compared to the other diagnosis for a given number of skills lost/delayed compared to no skills lost/delayed. The risk ratios have been parameterized so that values >1.0 indicate a higher risk of autism than for the other diagnosis, and values <1.0 indicate a higher risk of the other diagnosis than for autism. Both delay and loss of >=3 skills were associated with increased relative risk of autism versus no NDD (inverse RR=9.09[5.56,16.67] and RR=33[25,100], respectively). Loss (RR=4.35[1.28,14.29]), but not delay (RR=2.00[0.78,5.26]), was associated with increased relative risk of autism compared to language disability. Delay conferred decreased relative risk of autism versus intellectual disability (RR=0.11[0.06,0.21]), and while loss was associated with increased relative risk, the confidence interval included 1 (RR=1.89[0.44,8.33]).

Table 1: Sample characteristics by pattern of early social skills development

Profile	Neither delay nor loss		Delay with No Loss		Loss with No Delay		Combined Delay and Loss		Total	
Total n	n=33,348 (82.10%)		n=5,080 (12.51%)		n=1,587 (3.91%)		n=598 (1.47%)		N=40,613 (100%)	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Background characteristics										
Male	16,451	49.33 %	2,930	57.68 %	905	57.03 %	379	63.38 %	20,665	50.88 %
Maternal education ≥13 years	24,012	72.00 %	3,401	66.95 %	1,086	68.43 %	379	63.38 %	28,878	71.11 %
Low birth weight (<2500 gram)	1,119	3.36 %	295	5.81 %	66	4.16 %	34	5.69 %	1,514	3.73 %
Preterm (<37 weeks) (n=40,456) [1]	1,748	5.26 %	423	8.35 %	95	6.03 %	45	7.55 %	2,311	5.71 %
Congenital malformation	1,581	4.74 %	328	6.46 %	80	5.04 %	42	7.02 %	2,031	5.00 %
Clinical diagnosis										
Autism (all)	217	0.65 %	93	1.83 %	37	2.33 %	36	6.02 %	383	0.94 %
Autism with ID	7	0.02 %	9	0.18 %	<5	-	13	2.17 %	31	0.08 %
Autism without ID	210	0.63 %	84	1.65 %	35	2.21 %	23	3.85 %	352	0.87 %
ID (w/o autism)	38	0.11 %	36	0.71 %	6	0.38 %	24	4.01 %	104	0.26 %
LD (w/o autism or ID)	167	0.50%	60	1.18%	12	0.76%	14	2.34%	253	0.62%
ADHD (w/o autism, ID or LD)	855	2.56%	150	2.95%	68	4.28%	27	4.52%	1,100	2.71%
Any NDD	1,277	3.83 %	339	6.67 %	123	7.75 %	101	16.89 %	1,840	4.53 %
1 NDD dx	1,112	3.33 %	268	5.28 %	100	6.30 %	66	11.04 %	1,546	3.81 %
2 NDD dx	148	0.44 %	59	1.16 %	17	1.07 %	30	5.02 %	254	0.63 %
3-4 NDD dx	17	0.05 %	12	0.24 %	6	0.38 %	5	0.84 %	40	0.10 %
Recalled loss in 36-month questionnaire[2]										
Lost any language skills? (n= 40,549)[1]	413	1.24 %	101	1.99 %	54	3.41 %	33	5.53 %	601	1.48 %
Lost any motor skills? (n=40 538) [1]	102	0.31 %	25	0.49 %	<5	-	6	1.01 %	137	0.34 %
Social skill 1: Lost any social skills? (n=40 554) [1]	137	0.41 %	32	0.63 %	17	1.07 %	14	2.35 %	200	0.49 %
Social skill 2: Become less sociable? (n=40 545) [1]	138	0.41 %	41	0.81 %	26	1.64 %	20	3.36 %	225	0.55 %
Any recalled social-communication loss (n=40 023) [1]	213	0.65 %	62	1.25 %	41	2.69 %	29	5.23 %	345	0.86 %

[1]Has missing, total n provided in the parenthesis. [2]Responses of "not sure" were treated as missing (resulting n for each question listed). Percentages are out of the total of non-missing responses within each group. Cells with <5 individuals are shown as <5 to for anonymity. W/o=without. NDD=neurodevelopmental diagnosis. ID=intellectual disability. LD=language disability. ADHD=attention deficit hyperactivity disorder.

Table 2: Overall skill development pattern and descriptives by neurodevelopmental diagnostic group.

	No NDD diagnosis		**Autism (all)**		Autism w/o ID		Autism w/ID		**ID (w/o autism)**		**LD (w/o autism or ID)**		**ADHD (w/o autism, ID or LD)**	
Total n	n=38733		n=383		n=352		n=31		n=104		n=253		n=1100	
Overall pattern of skill attainment	n		n		n		n		n		n		n	
Neither delay nor loss	32,071	82.71	217	56.66	210	59.66	7	22.58	38	36.54	167	66.01	855	77.73
Delay with No Loss	4,741	12.23	93	24.28	84	23.86	9	29.03	36	34.62	60	23.72	150	13.64
Loss with No Delay	1,464	3.78	37	9.66	35	9.94	<5	-	6	5.77	12	4.74	68	6.18
Combined Delay and Loss	497	1.28	36	9.40	23	6.53	13	41.94	24	23.08	14	5.53	27	2.45
Any skill lost	1,961	5.06	73	19.06	58	16.48	15	48.39	30	28.85	26	10.28	95	8.64
Any skill delayed	5,238	13.51	129	33.68	107	30.40	22	70.97	60	57.69	74	29.25	177	16.09
Recalled loss (36-month Q)[1,2]														
Lost any language skills? (n= 40,549)	499	1.32	33	9.22	26	7.88	7	25.00	15	15.96	22	9.28	32	3.05
Lost any motor skills? (n=40 538)	119	0.31	<5	-	<5	-	0	0.00	8	7.84	<5	-	7	0.64
Social skill 1: Lost any social skills? (n=40 554)	177	0.46	9	2.42	7	2.04	<5	-	6	5.94	<5	-	7	0.64

Social skill 2: Become less sociable? (n=40 545)	194	0.51	10	2.72	9	2.67	<5	-	5	5.10	<5	-	13	1.21
Any recalled social-communication loss (n=40 023)	304	0.79	16	4.42	13	3.90	<5	-	6	6.25	<5	-	15	1.40

[1]Has missing, total n provided in the parenthesis. [2] "Not sure" responses treated as missing (resulting n listed). Percentages are of the total of non-missing responses within group. Cells with <5 individuals are shown as <5 for anonymity. Diagnosis was categorized hierarchically for mutually exclusive categories to compare with autism. W/o=without. NDD=neurodevelopmental diagnosis. ID=intellectual disability. LD=language disability. ADHD=attention deficit hyperactivity disorder.

Table 3. Results of logistic regression predicting autism (n=386) versus no autism diagnosis (n=40,230) from skill delay and loss.

	Odds Ratio	[95% Conf.	Interval]	p-value
Delayed skills (reference:0)				
1	1.99	1.52	2.60	<0.0001
2	3.62	2.41	5.44	<0.0001
>=3	7.09	4.15	12.11	<0.0001
Lost skills (reference:0)				
1	1.85	1.29	2.66	0.001
2	5.59	3.23	9.66	<0.0001
>=3	30.66	17.30	54.33	<0.0001

Covariates: child's sex, birthyear, age at questionnaire completion.