Six Developmental Trajectories Characterize Children With Autism

WHAT'S KNOWN ON THIS SUBJECT: Autism is widely considered a heterogeneous disorder in terms of etiology and phenotype. Although autism is usually a lifelong disorder, little is known about the rate or timing of how children develop regarding their communication and social functioning.

WHAT THIS STUDY ADDS: Utilizing annual evaluations for a large population of children with autism, we describe the 6 most common trajectories from diagnosis through age 14 years. Trajectories revealed considerable variation, and high socioeconomic status children were more likely to experience rapid improvement.

abstract

OBJECTIVE: The goal of this study was to describe the typical longitudinal developmental trajectories of social and communication functioning in children with autism and to determine the correlates of these trajectories.

METHODS: Children with autism who were born in California from 1992 through 2001 and enrolled with the California Department of Developmental Services were identified. Subjects with <4 evaluations present in the database were excluded, resulting in a sample of 6975 children aged 2 to 14 years. Score sequences were constructed based on 9 evaluative items for social, communication, and repetitive behavior functioning. Typical trajectories were identified by using group-based latent trajectory modeling, and multinomial logistic regression models were used to determine the odds of classification within each trajectory varied by individual and family-level factors.

RESULTS: Six typical patterns of social, communication, and repetitive behavior functioning were identified. These trajectories displayed significant heterogeneity in developmental pathways, and children whose symptoms were least severe at first diagnosis tended to improve more rapidly than those severely affected. One group of ~10% of children experienced rapid gains, moving from severely affected to high functioning. Socioeconomic factors were correlated with trajectory outcomes; children with non-Hispanic, white, well-educated mothers were more likely to be high functioning, and minority children with less-educated mothers or intellectual disabilities were very unlikely to experience rapid gains.

CONCLUSIONS: Children with autism have heterogeneous developmental pathways. One group of children evidenced remarkable developmental change over time. Understanding what drives these outcomes is thus critical. *Pediatrics* 2012;129:e1112–e1120

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KEY WORDS
autistic disorder, longitudinal outcomes, trajectory models

ABBREVIATIONS
BIC—Bayesian Information Criterion
CDER—Client Development Evaluation Report
DDS—Department of Developmental Services
HF—high-functioning
LF—low-functioning
OR—odds ratio
RR—relative risk

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Autism is a neurodevelopmental disorder with varying phenotypic expressions typically diagnosed in early childhood and characterized by deficits of communication and social interaction as well as repetitive and stereotyped behaviors. In recent years, autism has become more visible, as both incidence and prevalence have increased. Recent prevalence estimates have reached 1 per 110 children aged 8 years.[1]

Autism's phenotypic heterogeneity is likely associated with different etiologies. Recent studies found inherited and de novo deletions and duplications in a wide range of locations on the genome in autism cases compared with controls, suggesting heterogeneous genetic predispositions.[2–4] Family aggregation studies similarly suggest that core characteristics of autism have different levels of heritability.[5–7] Autism has also been associated with various factors relating to prenatal and perinatal environments, labor and delivery complications, parental characteristics, and socioeconomic status, each possibly pointing to mechanisms that lead to heterogeneous symptom presentation.[8–15]

A paucity of data on developmental trajectories for children with autism compounds the difficulty in understanding whether different etiologies are associated with differing phenotypic expression. Examining autism's varied presentations only at first diagnosis neglects the developmental course of the disorder.[16] Although most children diagnosed with autism retain the diagnosis as adolescents[17,18] and adults,[19] what we know about the unfolding dynamics of the disorder is limited. Recent longitudinal studies reveal substantial diversity in trajectories through childhood and adolescence.[20,21] However, most extant studies have largely spanned relatively short time frames,[22–26] included infrequent follow-ups,[18,19,27] used small sample populations,[18,22–25,27,28] are often inconsistent in findings of stability or change,[26,28] and pay little attention to how characteristics of children and their families might affect these trajectory patterns.

Filling in this knowledge gap with regard to autism symptom trajectories may point to how etiology and/or resources or treatment shape dynamics of the disorder. Researchers have noted the need for more knowledge about developmental trajectories in autism,[29] arguing that it would improve intervention and care.[16,18] Furthermore, conceptualizing developmental delay in terms of trajectories can highlight different causal mechanisms[30] and improve diagnostic systems.[31]

We observed autism symptom trajectories of children in California from diagnosis until they were up to 14 years old. We used group-based trajectory modeling to identify heterogeneous subsets of symptom trajectories. We describe here the typical patterns of longitudinal development along autism's 3 main symptom domains, consider their relationships to one another, and then examine the correlates of trajectories: what kinds of children follow each pattern, and what makes them different? Finally, we explored the implications of our findings for autism research and treatment.

METHODS

Population

Our data set links birth records from the California birth master files with autism caseload records from the California Department of Developmental Services (DDS). In California, the DDS, through its 21 regional centers, is responsible for coordinating diagnoses, services, and support for persons with developmental disabilities (including autism). The DDS provides services to patients with autistic disorder (*Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*, code 299.0[32]) but not to those with other disorders on the autism spectrum unless they have another qualifying condition. Although enrollment is voluntary, the vast majority of individuals with autism in California are enrolled, making the DDS the largest administrative source of data on autism diagnoses.[33] All autism diagnoses are confirmed by DDS staff, either by on-site diagnostic teams or by professionals with expertise in diagnosing autism.[34] Diagnoses were informed by using 1 or more of several diagnostic instruments, including the Autism Diagnostic Interview or the Autism Diagnostic Observation Schedule. We used the records of children who were born between 1992 and 2001 and who received an autism diagnosis by 2006. Of these 16 681 children, we excluded those born outside of California and those with <4 annual records. This left us with a sample population of 6975 individuals from whose records the trajectories are derived. From the autism caseload records, we also extracted information on the presence of an intellectual disability. This diagnosis was made or confirmed by regional center clinicians on the basis of IQ test results.

Demographic information was obtained from the linked birth records. Eighty-five percent of DDS records for children ever diagnosed with autism were successfully linked to birth records. Those not linked were typically born outside of California. Variables extracted from the birth records include: maternal age at birth, education, and race and ethnicity; place of birth; child's gender and birth weight (<2500 g was considered low birth weight); and whether the birth was paid for by Medi-Cal (California's Medicaid program). Missing data on covariates reduced the sample to 6968 for some analyses.

Symptom scores were obtained from the Client Development Evaluation Report (CDER) database of the DDS. During the CDER interview, DDS clients' symptom severity and functioning across several dimensions are recorded. The CDER is intended to determine appropriate services based on level of functioning, not serve as a diagnostic instrument. Nonetheless, the CDER is completed by trained DDS staff and covers the 3 core domains of autism symptoms. It is conducted with someone who interacts closely with the child on a regular basis, typically a parent or caregiver. Although CDERs are missing for some children in some years, most children were evaluated approximately annually.

To create scores for communication and social functioning, we summed the CDER's 3 items that measure communication and 5 items that measure social interaction, weighting each item equally, and then rescaled the sums such that the minimum, or low-functioning (LF), score was 0 and the maximum possible score was 100. (Details on items, score construction, and the distributions of these scores are described in the Supplemental Information.) Scores between these extremes can be achieved through multiple combinations of behaviors along the facets of communication and social interaction measured by CDER items. In addition, we used the evaluation item describing the presence of repetitive behavior. This item has 5 possible levels, ranging from 1 (repetitive body movements occur without cessation during waking hours) to 5 (no apparent repetitive body movements) (Supplemental Table 4; Distributions of scores on the three symptom dimensions at selected ages can be found in Supplemental Figure 2). Evaluations for children too young or too disabled for repetitive behavior to be observed were coded as missing, reducing the sample for that dimension to 6938 children. Finally, we assembled each individual's sequence of scores over time for each of the 3 dimensions. Sequence lengths vary, depending on birth cohort, age at diagnosis, time in the DDS caseload, and frequency of evaluation.

This study was approved by the Columbia University institutional review board and the California Committee for the Protection of Human Subjects. A waiver of informed consent was obtained because the risk to confidentiality arising from contacting subjects to obtain consent would far exceed any risk from the study itself.

Modeling

The goal of this analysis was to identify and describe subgroups within the data that have similar developmental trajectories. To achieve this goal, we used group-based latent trajectory modeling implemented with the PROC TRAJ module for SAS (SAS Institute, Inc, Cary, NC).[35–37] This modeling strategy uses a polynomial equation to capture the relationship between age and behavior, where the outcome is a latent variable characterizing individual i's autism symptom level at time t. Symptom outcomes then depend on a cubic function of i's age at time t and membership in 1 of j groups. The β parameters describe the shape of the trajectories and are permitted to vary across the j groups, allowing each group's trajectory to be shaped differently. This method reveals the heterogeneity across a population both in age-specific presentation of symptoms and in the way symptoms change over time.

The model parameters describe the functional form of each trajectory as well as the population-level probabilities of the size of each trajectory group, which are estimated by using maximum likelihood methods. After testing the model with different numbers of trajectory groups, 6 group models were selected. Goodness of fit criteria included the Bayesian Information Criterion (BIC), which selects the model with the highest likelihood while penalizing complex models, and conceptual clarity. Posterior probabilities for each individual's membership to each group were used to assign each child to his or her most likely trajectory.

To describe the composition of each trajectory's population, we calculated proportions for selected demographic variables and autism risk factors for the population and for each trajectory subgroup and conducted χ^2 tests of independence. For each communication and social group, we then calculated the relative risks (RRs) of being in each of the other's trajectory categories and each repetitive behavior category for children in that group compared with all other children in the sample and conducted 2-tailed significance tests with $\alpha = 0.05$. To clarify which factors distinguish the trajectories, we recoded the 6 trajectory groups of the communication and social dimensions into 3 groups representing high, low, and rapid improvement, and estimated multinomial logistic regression models predicting the log odds of group membership on the basis of demographic and autism risk factors. Odds ratios (ORs) and their 95% confidence intervals are presented.

RESULTS

Symptom Trajectories

The fitted trajectories for the 6 group models are displayed graphically in Fig 1. (Coefficients can be found in Supplemental Table 5.) Figure 1 A, B, and C displays the communication, social, and repetitive behavior trajectories, respectively. The communication and social graphs have 4 features of note. First, many children experienced substantial development. Particularly on the communication dimension, most of the trajectories increased steadily over

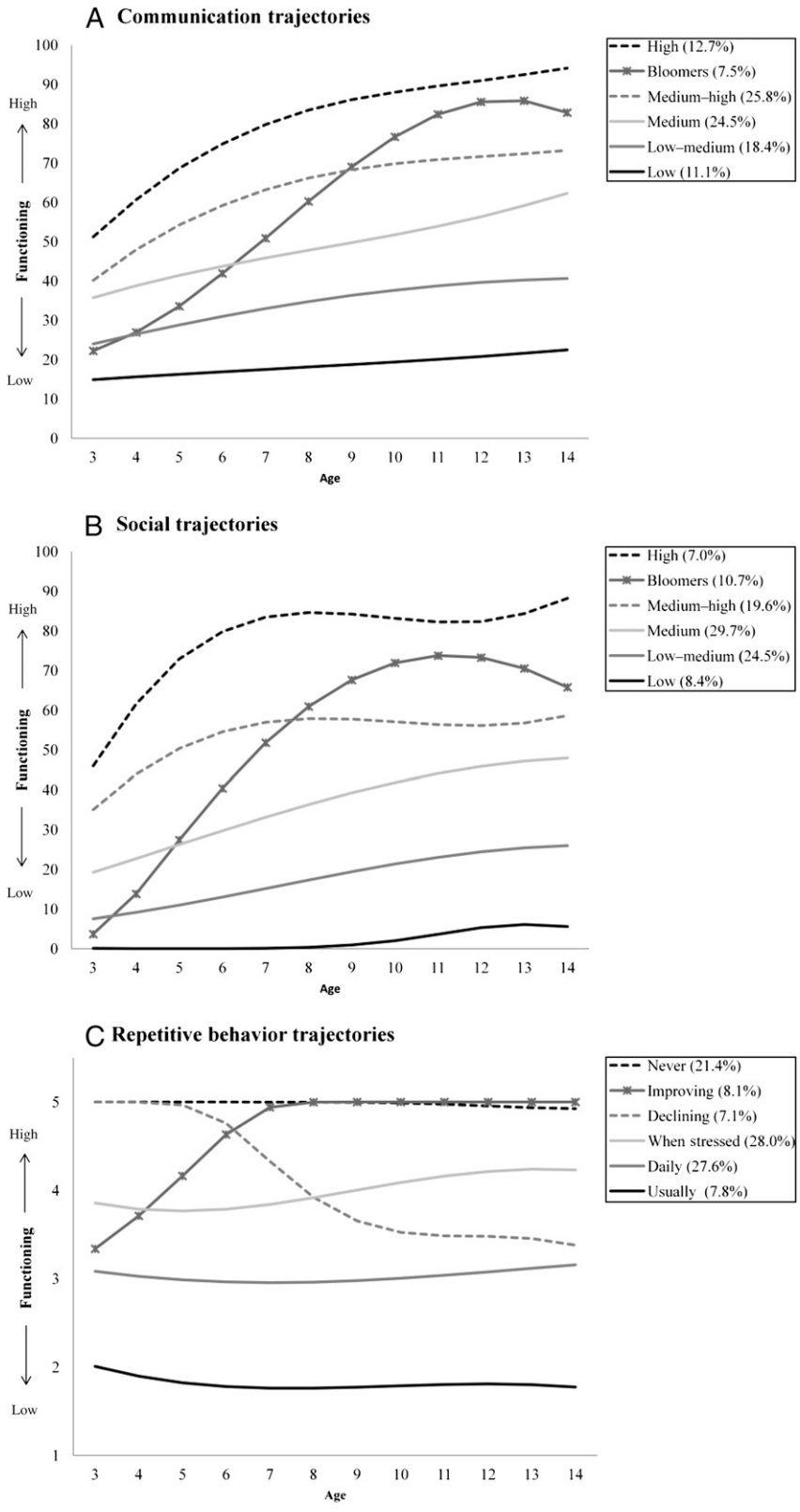

FIGURE 1

(A) Modeled communication, (B) social, and (C) repetitive behavior symptom trajectories based on CDER scores by age.

time. Second, there was substantial heterogeneity in the extent of this development; some children improved much more than others. This heterogeneity is especially visible in the social dimension; some groups improved whereas others, particularly the "low" group, were relatively flat. With 1 important exception, groups that were high-functioning (HF) at the start improved more rapidly. Third, the most rapid development occurred before age 6 years, and several of the trajectories tended to flatten out after that. Finally, both the communication and social dimensions have a group, here identified as "bloomers," that improved especially quickly. These children started with low scores, comparable to those on the LF trajectories, and improved at a rapid pace, ending with scores comparable to those on the HF trajectories.

In contrast, the repetitive behavior trajectories remained relatively stable, except for 1 that decreased in severity and 1 that increased. Although there was diversity in the amount of repetitive behavior observed, only ~15% of children seemed to change significantly over time, one-half of these improving and one-half getting worse. In the analyses that follow, we describe the differences in the composition of the trajectory groups and distinguish bloomers from other children with autism.

Composition of Trajectory Groups

Table 1 contains descriptive statistics on the population, as well as according to subgroup membership. In general, children on the highest trajectories tended to have been born in the most recent cohorts. Trajectory groups did not differ according to gender. The LF trajectory groups were less likely to be white, more likely to be born as a Medi-Cal recipient, and to have younger, foreign-born mothers with fewer years

TABLE 1 Descriptive Statistics for Sample of Persons With Autism With at Least 4 Valid Evaluations

	Total Population	Communication Trajectories						Social Trajectories						Repetitive Behavior Trajectories					
		Low	Low–Medium	Medium	Bloomers	Medium–High	High	Low	Low–Medium	Medium	Bloomers	Medium–High	High	Usually	Daily	When Stressed	Improving	Declining	Never
Trajectory Group																			
n	6975	769	1293	1758	451	1827	877	582	1719	2107	701	1378	488	554	1894	2015	476	439	1597
%	100.0	11.0	18.5	25.2	6.5	26.2	12.6	8.3	24.6	30.2	10.1	19.8	7.0	7.9	27.2	28.9	6.8	6.3	22.9
Birth cohort[a,b,c]																			
1992–1994	36.7	35.5	39.4	34.1	42.8	36.7	35.8	31.6	40.2	38.8	35.8	32.1	35.9	36.5	40.7	33.7	28.4	46.7	35.5
1995–1997	40.4	41.0	37.8	40.7	41.2	43.2	37.1	43.1	38.4	41.2	41.2	41.6	36.5	40.3	38.6	40.7	41.0	39.2	42.4
1998+	22.9	23.5	22.7	25.1	16.0	20.1	27.1	25.3	21.4	20.0	23.0	26.3	27.7	23.3	20.6	25.5	30.7	14.1	22.1
Male	82.0	78.9	80.7	83.1	83.8	81.9	83.2	84.0	82.7	81.7	82.7	80.8	80.3	82.1	82.3	82.1	81.7	83.1	81.2
Low birth weight	7.8	9.1	8.0	8.0	7.3	6.6	8.7	6.5	8.0	7.4	6.4	8.6	10.0	7.6	7.3	7.8	8.0	8.4	8.1
Medi-Cal[a,b,c]	28.5	41.9	35.7	28.0	31.0	24.3	14.6	40.5	31.2	26.9	27.4	23.7	27.0	29.2	29.6	26.1	30.3	33.0	28.2
Age of autism diagnosis, y[a,b,c]																			
≤3	58.3	69.6	65.4	60.5	57.4	49.6	52.2	59.1	60.8	56.7	51.6	60.4	59.0	65.0	59.7	56.6	65.1	61.5	53.6
4	20.0	18.9	20.2	19.7	18.0	20.7	20.8	23.4	19.8	18.1	24.4	20.0	18.0	16.4	19.1	20.3	22.7	22.1	20.5
5	10.6	7.3	8.6	10.4	11.1	13.7	10.1	10.7	10.5	11.7	12.3	8.2	10.5	10.6	10.2	9.7	10.1	10.9	12.2
≥6	11.1	4.3	5.9	9.4	13.5	15.9	16.9	6.9	8.8	13.5	11.7	11.3	12.5	7.9	11.0	13.4	2.1	5.5	13.7
Intellectual disability[a,b,c]	37.3	58.8	52.0	41.0	33.9	26.0	14.4	50.5	43.4	37.9	31.2	29.2	28.7	44.0	40.8	33.2	31.9	46.0	35.1
Mother foreign-born[a,b,c]	39.4	53.2	49.3	40.5	46.3	32.1	21.9	58.8	45.8	39.4	35.9	29.7	25.8	40.6	35.5	37.3	37.4	43.1	45.7
Mother Non-Hispanic, white (n = 6968)[a,b,c]	41.8	26.9	31.0	36.1	36.8	50.7	66.1	26.3	36.4	43.3	45.2	48.3	49.2	39.4	44.9	43.8	39.9	42.6	36.8
Maternal education[a,b,c]																			
<High school	17.1	29.8	24.2	16.7	16.6	12.8	5.9	30.8	19.6	15.3	16.5	12.7	13.5	22.0	17.1	14.9	17.6	17.5	18.1
High school graduate/ some college	53.2	54.2	53.8	53.1	61.0	53.4	47.3	47.4	53.9	53.8	52.1	52.8	58.2	50.2	54.4	53.8	57.4	51.9	51.3
College+	29.6	16.0	22.0	30.2	22.4	33.8	46.8	21.8	26.5	30.9	31.4	34.5	28.3	27.8	28.6	31.3	25.0	30.5	30.6
Maternal age, y (n = 6974)[a]																			
<20	4.5	5.9	5.4	5.2	5.5	3.5	2.1	5.3	4.5	4.3	4.4	4.0	5.7	6.9	5.0	3.9	5.3	3.2	3.9
20–34	72.9	74.9	75.3	72.2	72.1	72.9	69.8	74.7	72.2	75.0	71.5	70.8	72.3	72.0	72.2	72.7	74.6	74.7	73.4
≥35	22.6	19.2	19.3	22.5	22.4	23.6	28.2	19.9	23.3	20.6	24.1	25.2	21.7	21.1	22.8	23.3	20.2	22.1	22.7

Data are presented as %, unless otherwise indicated.

[a] χ^2 test of independence for communication trajectories significant at $P \leq .05$.

[b] χ^2 test of independence for social trajectories significant at $P \leq .05$.

[c] χ^2 test of independence for repetitive behavior trajectories significant at $P \leq .05$.

of education. The HF children tended to be born to older, more educated, white mothers, and were less likely to be a Medi-Cal recipient. Children with intellectual disabilities were more likely to be on LF trajectories.

Relationship Between Trajectories

Table 2 describes the relationships between trajectory group memberships. Those on the lowest communication trajectory had ~6 times the risk of being on the lowest social trajectory and were extremely unlikely to be on HF social trajectories. Communication bloomers were heavily concentrated among the social bloomers (RR: 2.58) as well as among the medium–high and high groups, which, like the bloomers, show significant improvement over time, and social bloomers are heavily concentrated among the communication bloomers (RR: 2.75). Meanwhile, communication and social bloomers were unlikely to be in the other's LF group. Similarly, those on LF social and communication trajectories were more likely to exhibit frequent repetitive behaviors, whereas those on HF trajectories were more likely to exhibit fewer or none.

In general, we found that the 3 dimensions were associated with one another, such that children who were HF on 1 dimension were unlikely to be LF on the others. Yet, there is some independence, so that children may develop at a different pace along these 3 dimensions.

Correlates of "Blooming"

We next investigated the factors that distinguish bloomers, who improve rapidly, from the LF children they initially resemble and the HF children they resemble at the end of the observed trajectory. In Table 3, we present the adjusted ORs for being in 1 of the 2 lowest or 2 highest social and communication trajectories, relative to being a bloomer. The middle trajectory was excluded from this analysis to provide a cleaner comparison.

Beginning with the communication trajectories, we found that children diagnosed later were more likely to be on HF trajectories, and were less likely to be LF, than bloomers. Children with intellectual disabilities were more than twice as likely to be LF than bloomers (OR: 2.15) and very unlikely to be HF. Children with foreign-born mothers were less likely to be HF than bloomers, but there was no significant difference for the LF group. LF children were less likely to be white (OR: 0.69), whereas HF children were more likely to be white (OR: 1.86). However, among nonwhites, Hispanic children had greater odds of being HF and lower odds of being LF. The LF children were likely to have less-educated mothers, and the highest-educated mothers were more likely to have HF children. Finally, there was no significant difference according to gender or being a recipient of Medi-Cal.

The pattern for social bloomers was similar. There was no difference according to gender or being a Medi-Cal recipient, and maternal education did not affect social trajectories. Both HF and LF groups were less likely than bloomers to be diagnosed after age 3 years. Having an intellectual disability was strongly associated with LF trajectories, as was having a foreign-born mother. Finally, children of white mothers were less likely to be LF than bloomers, as were children of Hispanic mothers (relative to nonwhites).

TABLE 2 RRs for Trajectory Group Membership

A: RRs for Communication Group Members of Assignment to Each Social and Repetitive Behavior Group, Relative to All Others

Communication trajectory group	Social Trajectory Group						Repetitive Behavior Trajectory Group					
	Low	Low–Medium	Medium	Bloomers	Medium–High	High	Usually	Daily	When Stressed	Improving	Declining	Never
Low	6.08[a]	1.87[a]	0.58[a]	0.22[a]	0.17[a]	0.10[a]	3.22[a]	1.32[a]	0.72[a]	0.35[a]	0.79	0.66[a]
Low–medium	2.21[a]	2.00[a]	0.93	0.41[a]	0.40[a]	0.17[a]	1.66[a]	1.39[a]	0.81[a]	0.48[a]	1.12	0.76[a]
Medium	0.59[a]	1.22[a]	1.36[a]	0.50[a]	0.92	0.50[a]	0.76[a]	1.16[a]	0.97	0.80[a]	0.85	1.06
Bloomers	0.28[a]	0.88[a]	1.10[a]	2.58[a]	0.79[a]	0.46[a]	0.86	0.81[a]	1.08	1.08	1.37[a]	1.05
Medium–high	0.12[a]	0.42[a]	1.15[a]	1.72[a]	1.79[a]	1.49[a]	0.43[a]	0.78[a]	1.12[a]	1.67[a]	1.10	1.18[a]
High	0.06[a]	0.14[a]	0.63[a]	1.88[a]	1.97[a]	5.25[a]	0.36[a]	0.52[a]	1.34[a]	1.80[a]	0.93	1.24[a]

B: RRs for Social Group Members of Assignment to Each Communication and Repetitive Behavior Group, Relative to All Others

Social trajectory group	Communication Trajectory Group						Repetitive Behavior Trajectory Group					
	Low	Low–Medium	Medium	Bloomers	Medium–High	High	Usually	Daily	When Stressed	Improving	Declining	Never
Low	5.29[a]	1.95[a]	0.64[a]	0.27[a]	0.15[a]	0.06[a]	3.07[a]	1.26[a]	0.65[a]	0.28[a]	0.75	0.84[a]
Low–medium	2.23[a]	2.17[a]	1.22[a]	0.86	0.43[a]	0.12[a]	1.98[a]	1.43[a]	0.82[a]	0.66[a]	0.95	0.66[a]
Medium	0.52[a]	0.92	1.40[a]	1.14	1.16[a]	0.58[a]	0.71[a]	1.05	1.14[a]	0.72[a]	1.09	0.96
Bloomers	0.23[a]	0.44[a]	0.55[a]	2.75[a]	1.53[a]	1.83[a]	0.46[a]	0.92	1.12	1.78[a]	0.97	0.94
Medium–high	0.16[a]	0.39[a]	0.92	0.76[a]	1.68[a]	2.15[a]	0.38[a]	0.64[a]	1.16[a]	1.35[a]	1.03	1.44[a]
High	0.10[a]	0.19[a]	0.55[a]	0.46[a]	1.36[a]	4.19[a]	0.27[a]	0.51[a]	0.99	2.25[a]	1.12	1.52[a]

[a] RR statistics significant at 2-tailed $P < .05$.

TABLE 3 ORs and 95% Confidence Intervals From Multinomial Logistic Regression Results Showing Correlates of LF and HF Trajectories Versus Blooming

Variable	Communication Trajectories (n = 4828)		Social Trajectories (n = 4497)	
	LF	HF	LF	HF
Male	0.86 (0.65–1.14)	0.98 (0.75–1.30)	1.04 (0.82–1.32)	0.85 (0.67–1.08)
Medi-Cal recipient	1.19 (0.92–1.56)	0.90 (0.69–1.17)	1.07 (0.85–1.34)	0.92 (0.72–1.16)
Age of diagnosis, y				
≤3	1.00	1.00	1.00	1.00
4	1.00 (0.75–1.32)	1.49 (1.13–1.97)[a]	0.73 (0.59–0.91)[a]	0.75 (0.60–0.93)[a]
5	0.62 (0.43–0.88)[a]	1.49 (1.07–2.09)[a]	0.73 (0.55–0.96)[a]	0.67 (0.50–0.90)[a]
≥6	0.34 (0.24–0.48)[a]	1.45 (1.06–1.98)[a]	0.62 (0.46–0.83)[a]	0.89 (0.67–1.18)
Intellectual disability	2.15 (1.71–2.7)[a]	0.60 (0.48–0.76)[a]	1.55 (1.28–1.88)[a]	0.75 (0.61–0.92)[a]
Mother foreign-born	0.99 (0.77–1.28)	0.61 (0.48–0.79)[a]	1.51 (1.23–1.87)[a]	0.74 (0.59–0.92)[a]
Mother race/ethnicity				
Non-Hispanic, white	0.69 (0.50–0.93)[a]	1.86 (1.38–2.51)[a]	0.70 (0.55–0.90)[a]	1.03 (0.80–1.34)
Hispanic	0.73 (0.55–0.98)[a]	1.38 (1.03–1.85)[a]	0.68 (0.53–0.87)[a]	1.11 (0.85–1.45)
All other races	1.00	1.00	1.00	1.00
Maternal education				
<High school	1.82 (1.30–2.54)[a]	1.01 (0.72–1.42)	1.26 (0.95–1.66)	0.86 (0.64–1.17)
High school or some college	1.00	1.00	1.00	1.00
College graduate	1.06 (0.80–1.40)	1.93 (1.48–2.51)[a]	0.81 (0.66–1.01)	0.97 (0.78–1.20)

[a] ORs significant at $P \leq .05$ (2-tailed).

DISCUSSION

There is significant heterogeneity in the developmental trajectories of these study children with autism. Some children improved rapidly, whereas the trajectories of others were both slower and less likely to reveal significant improvement. This is especially true of the social and communication dimensions; most children showed little change in repetitive behaviors over the observed period. Furthermore, these dimensions show some association with one another yet are also independent; 1 child may show different patterns of change on these 3 dimensions, further contributing to the heterogeneity of autism. The pattern of overrepresentation of HF trajectories among more recent cohorts may be evidence of a broadening of diagnostic criteria over time, as more mild cases are identified relative to previous years.[38] Improved awareness and screening in recent years may also have contributed to this result.

Our findings are consistent with some previous research showing heterogeneous outcomes, as well as change in autism symptoms over time.[16,18,27,28] Some researchers have found a subgroup of children with autism who improve substantially and may even lose their diagnosis over time.[16,21,39] However, this research differs from previous work by providing a more detailed and nuanced understanding of the pace and timing of symptom change across a broad swath of childhood and early adolescence for a large population in a diverse state.

Children who begin with HF scores tend to improve more rapidly over time. One significant exception is the group we call bloomers; these children start out with scores placing them among the most severely affected but improve so substantially that they enter adolescence with scores comparable to the HF children.

Bloomers differ from other children with respect to intellectual disability and socioeconomic characteristics. Among young children with severe autism, those most likely to "bloom" are those without intellectual disability and those with more educated, nonminority mothers. Although we are unable to identify the specific mechanisms through which socioeconomic status affects trajectory outcomes, the intervening variables likely include home and neighborhood environments, quality and intensity of treatment, quality of education, the efficacy with which parents are able to advocate for their children with institutions providing services, and many other factors in various permutations. If this heterogeneity in outcomes is associated with parental and community resources, then equal access to early intervention and treatment resources for less-advantaged children is vital. Although some trajectories may be associated with different etiologic drivers, if etiology alone were driving outcomes, we would be less likely to observe the strong socioeconomic effects unless socioeconomic status was associated with exposure to some biological risk factor for a particular autism subtype.

Linking the DDS data to California's birth master files required that our data sets contain information only on those children who were both born in California and enrolled with the DDS, possibly biasing the results. There are several limitations associated with use of the DDS data. First, the symptom severity items were collected by the DDS for the purpose of resource allocation, not diagnostic evaluation. Second, the fact that the DDS only provides services to those with autistic disorder but not to those with other disorders on the autism spectrum may result in overdiagnosis of autism. Third, we used the first entry into the DDS as a proxy for age of diagnosis, which may lag first diagnosis in the community by several months or more. In addition, longer follow-up through adolescence and into adulthood would have been preferable, but data were available on outcomes only into 2006. Moreover, regional centers operate

independently and may be applying evaluative items according to different criteria. However, results were robust to fixed-effects models adjusting for regional center catchment areas (results not shown). Finally, given the socioeconomic differences we find, it is unfortunate that we do not have any information on types and quantities of services used by individual children. This subject topic is a critical avenue for future research.

CONCLUSIONS

Six trajectories characterized the typical social, communication, and repetitive behavior development of children with autism in this population. This research differs from other longitudinal work on autism outcomes by using data for a large sample with far more frequent follow-ups over a wide swath of childhood and early adolescence. It is important to observe the developmental pathways children with autism follow over time to understand the pace and timing of changes. More work is needed to discover whether these longitudinal patterns will help us not only to understand the diversity of autism but also to better target interventions and improve treatment.

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