Higher Education (2023) 85:1–26
https://doi.org/10.1007/s10734-021-00809-1

Study progression and degree completion of autistic students in higher education: a longitudinal study

Theo Bakker[1] · **Lydia Krabbendam**[1] · **Sandjai Bhulai**[2] · **Martijn Meeter**[1] · **Sander Begeer**[1]

Accepted: 14 December 2021 / Published online: 12 March 2022

Abstract
Individuals with autism increasingly enroll in universities, but researchers know little about how their study progresses over time towards degree completion. This exploratory population study uses structural equation modeling to examine patterns in study progression and degree completion of bachelor's students with autism spectrum disorder ($n = 101$) in comparison to students with other recorded conditions ($n = 2{,}465$) and students with no recorded conditions ($n = 25{,}077$) at a major Dutch university. Propensity score weighting is applied to balance outcomes. The research shows that most outcomes (grade point average, dropout rates, resits, credits, and degree completion) were similar across the three groups. Students with autism had more no-shows in the second year than their peers, which affected degree completion after 3 years. The overall performance of autistic students appeared to be adequate and comparable to their peers. However, addressing participation and inclusivity is vital to improve academic support for students with autism. These insights can enable universities to develop appropriate and timely support for all talented students to progress in their studies and complete their degrees.

Keywords Autism · Student retention · Degree completion · Higher education · Propensity score weighting · Structural equation modeling

Introduction

Autism (autism spectrum disorder; ASD; American Psychiatric Association ([2013]) is a neurodevelopmental condition characterized by qualitative differences in social interaction, communication, and sensory perception and repetitive, stereotyped behavior. Although a growing number of autistic students are enrolling in higher education

✉ Theo Bakker
t.c.bakker@vu.nl

[1] Department of Clinical, Neuro- & Developmental Psychology, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

[2] Department of Mathematics, Faculty of Science, Vrije Universiteit Amsterdam, De Boelelaan 1105, Amsterdam 1081 HV, The Netherlands

(Bakker et al., 2019a; Van Hees et al., 2015; Zeedyk et al., 2016), they generally show lower degree completion rates compared with their fellow students (Chown et al., 2016; Newman et al., 2011; Shattuck et al., 2012). However, researchers know little about autistic students' academic progress during their time at university (Madaus et al., 2020).

Autistic students face both social and academic challenges (A. H. Anderson et al., 2017; Gelbar et al., 2014). Many have difficulty with social activities in college, such as group work and oral presentations, or social interaction such as forming and maintaining relationships (VanBergeijk et al., 2008). Academic barriers for autistic students include difficulty with abstract or ambiguous concepts and diverse points of view, and the expression of their thoughts in writing (Gelbar et al., 2015; Knott & Taylor, 2014; Van Hees et al., 2015). Poor executive skills cause many to mismanage time or procrastinate (J. M. Anderson, 2014) and to become overly focused on detail (Shmulsky et al., 2015), resulting in exam stress, anxiety, and problems with test taking (Bakker et al., 2020a; Beardon & Edmonds, 2007; Shmulsky et al., 2017). As the curriculum progresses and social and academic skills become crucial for complex assessments such as internships or academic writing, effective studying becomes increasingly difficult for autistic students (Shmulsky & Gobbo, 2013).

Autistic students have problems with social clues, resilience, over-stimulation, making choices, and identifying critical points (Jansen et al., 2016; Vincent et al., 2016). Therefore, they report more difficulties with social skills (e.g., social interactions, group work, presentations; Jansen et al., 2016; Van Hees et al., 2015) and academic skills (e.g., executive functioning, goal setting, planning, complete tasks; Bolourian et al., 2018; Hillier et al., 2018). These challenges often coincide with mental health issues (e.g., loneliness, comorbidity, anxiety, and depression; A. H. Anderson, 2018; Griffin & Pollak, 2009; Van Hees et al., 2018), leading to avoidance of participation, procrastination and delays, and lower graduation rates (Robertson & Ne'eman, 2021; Vincent, 2019).

The few longitudinal studies on autistic students' degree completion show the long-term effects of these problems. The National Longitudinal Transition Study-2 (NLTS2; United States, 2011) shows that within 8 years after leaving high school, 39% of autistic students graduated with a postsecondary degree, compared with 41% of students with any condition and 52% of the general population (Newman et al., 2011). In a national survey in the UK, 21 universities reported graduation rates covering at least 5 years. In 72% of universities, the graduation rate of autistic students was below average (Chown et al., 2016). Autistic students who graduate have considerably better income and employment opportunities than autistic non-graduates (Hendrickson et al., 2013). To safeguard equal opportunities for students with conditions, research is needed to examine degree completion and academic progress (Barber, 2012). To determine when academic support could be most appropriate, we should ascertain when issues arise and compare outcomes (A. H. Anderson et al., 2019).

Although the body of research on autistic students' experiences and degree completion in higher education is growing, records on longitudinal student progression on an institutional level are largely nonexistent (Chown et al., 2016). The only population study we found on progression showed similar grade point averages (GPAs) in 22 first-year autistic students compared to 8,861 neurotypical students at two four-year colleges in the USA from 2008 to 2017 (Morgan, 2018). A recent review of empirical research found 14 studies with some data regarding the progression of autistic students (A. H. Anderson et al., 2019). However, only four were not self-reported (28.6%). These studies showed improved

academic success of autistic students or similar results compared with their peers thanks to transition programs or academic support.

In addition to the scarcity of existing research on progression, sample sizes are typically small, and formally confirmed ASD diagnoses are limited (Bakker et al., 2020a; A. H. Anderson et al., 2017; Chown et al., 2016). Additionally, comparisons of autistic students to students with other conditions or neurotypical students are rare (Cage et al., 2020), and studies often do not control for differences in sample sizes and background characteristics (Morgan, 2018). These limitations make it difficult to justify the attribution of potential differences in outcomes to autism, instead of confounding factors (McLeod, 2019).

In this preregistered study (Bakker et al., 2020b), we compare progression and completion of bachelor's degrees within 3 years between autistic students and non-autistic students. We studied longitudinal data from a population sample that included three groups at a major Dutch university: autistic students, students with other conditions such as ADD/ADHD and dyslexia, and students with no conditions. We explored the relationship over time between GPAs, resits, no-shows, credit accumulation, and bachelor's degree program completion rate. We expected (RQ1) similar GPAs and dropout rates across groups (Bakker et al., 2020a; Morgan, 2018) but (RQ2) lower participation and credit accumulation (Bakker et al., 2020a; Vincent, 2019) and (RQ3) more issues with graduation assignments (Nuske et al., 2019; Vincent et al., 2016), (RQ4) resulting in a lower rate of degree completion in three years (Chown et al., 2016; Newman et al., 2011). To justify the attribution of potential differences in outcomes, we used propensity score weighting (PSW) and structural equation modeling (SEM): with PSW, we balanced the measures' distribution and control for group size differences and selection biases (Rosenbaum & Rubin, 1983, 1984), and with SEM, we determined path dependencies.

Methods

Study population

Our sample included 27,643 first-year, full-time students from 54 bachelor's programs at a major university in the Netherlands from 2010 to 2016 ($M = 19$ years of age, 55.0% female) with study measures from the student information system of the university (Bakker et al., 2020a). The Scientific and Ethical Review Board of the institution granted ethical clearance (reference number VCWE-2017–123).

The study population consisted of three mutually exclusive participant groups: (1) 101 students with at least a clinical diagnosis of ASD (AS; 0.37%); (2) 2,465 students with other conditions such as ADD/ADHD and dyslexia (OC; 8.92%); and (3) 25,077 students with no recorded conditions (NC; 90.72%). Comorbidity was 28.7% in AS and 11.6% in OC. AS and OC were restricted to those who disclosed their formally registered diagnosis (Bakker et al., 2020a) provided by qualified clinicians independently from this study. In the Netherlands, psychiatrist diagnoses ASD according to established DSM-IV-TR or DSM-5 criteria based on an elaborate examination, including observations and parent interviews by multiple experienced clinicians (psychologists, psychiatrists, and educators). We excluded students with an international pre-education.

Measures

See Appendix A1 for a list of all variables and their measurement scales.

(1) Demographic and enrollment characteristics

Sex is male or female. *Age (in years)* in Dutch higher education is recorded on October 1 in the year students enroll. *Cohort* is the academic year a student enrolled for the first time in the academic program of their choice (Bakker et al., 2019a).

(2) Educational background

Highest pre-education. In the Netherlands, there are five learning paths to higher education: (a) pre-university secondary education (Dutch abbreviation: VWO); (b) higher general secondary education followed by 1 year of applied university education (Dutch abbreviations: HAVO, 1-year HBO); (c) a qualification in Dutch higher education (academic or applied sciences); (d) other Dutch qualifications, such as a university entrance exam (colloquium doctum); and (e) a foreign qualification equivalent to pre-university secondary education (Bakker et al., 2020a). *Average grade math algebra secondary education* is the average grade in math algebra at secondary school; grades range from 1 to 10.

(3) Progression, dropout, and degree completion

Exam participation, credits, and GPA. All bachelor's degree programs consist of 180 European credits (ECs) with 60 ECs in each of 3 academic years. *Dropout* means was no longer enrolled in the same bachelor program in the following academic year. *Degree completion nominal* means the student completed the bachelor's degree program in 3 years. Academic years consist of six periods with courses, examinations, and resits and one additional period with resits only (i.e., 7 periods a year, 21 periods over a bachelor's degree program). For each period and year, information was available on exam participation (resits and no-shows), the number of ECs, and GPA. The university enrolled students for a course and a corresponding examination at the end of the same period. Students could take one resit for each course in the following period or at the end of the academic year.

(4) Graduation assignment

All bachelor's programs have a mandatory graduation assignment to complete the program. *Graduation assignment completed* means a student completed a course registered as a graduation assignment.

Analytical strategy

We used R version 4.0.2 for statistical computing, data wrangling, and data analysis (R Core Team, 2017). We analyzed the outcomes using PSW to address biases associated

with the differences in group sizes. The propensity score is a number between zero and one and represents the conditional probability that a person is assigned to a particular group given a set of confounders (Austin, 2011). We assessed covariate balance using the cobalt package, version 4.2.3 (Greifer, 2019). We analyzed progression, dropout, and degree completion, examining the GPA, the number of examinations, resits, no-shows, the credit accumulation in each period and year, and the dropout rate after the first, second, and third year. Additionally, we analyzed completion of the graduation assignments.

Data selection, imputation, propensity score weighting, and variable balance evaluation

For data selection and imputation, we repeated the previously applied procedure (Bakker et al., 2020a). The measures sex, highest pre-education, cohort, and average grade math secondary education with median imputation and stop method maximum absolute standardized mean difference (es.max) gave the best balance. This method had an overlap in the interquartile range of 10.9% for AS-OC and 14.3% for AS-NC. We kept the sample size of the AS group constant at 101 and reduced the sample size of the OC group from 2,465 to a weighted size of 89.38 and that of the NC group from 25,077 to a weighted size of 92.28. Table 1 presents the balance of AS, OC, and NC. The weighted samples represent the best-matched comparison between the three groups. However, their limited size reduces statistical power, and weighting might have introduced new biases. We therefore also performed the analyses on unweighted data (i.e., including all students).

To estimate effects, we applied weighted multiple regression analysis using the survey package (Lumley, 2004). We applied the Benjamini–Hochberg correction to adjust for multiple testing (Benjamini & Hochberg, 1995).

Transformation and outlier removal

As none of the continuous measures was normally distributed, we transformed the data, assessing each measure's best method using the bestNormalize package, version 1.6.1 (Peterson & Cavanaugh, 2019; log transformation for no-shows, inverse hyperbolic sine transformation for resits (Abramowitz & Stegun, 1972)). For optimal model convergence, we scaled GPA, resits, no-shows, and ECs. We removed outliers that were more than 3 standard deviations (z-scores) away from the mean (AS, 4, 3.96%; OC, 87, 3.53%; NC, 743, 2.96%; weighted totals, AS, 97.0; OC, 89.4; NC, 92.3; unweighted totals, AS, 97; OC, 2,378; NC, 24,334). Table 2 presents the descriptive statistics of AS, OC, and NC without outliers.

Structural equation modeling

We performed SEM on both the weighted and unweighted data to answer our degree completion research questions. SEM is a statistical method of testing multivariate, theory-derived models for cause-effect links between variables, quantifying these links, and decomposing these causal effects (Bollen, 1989). We also performed a SEM on the

Table 1 Balance of AS versus OC and NC

Measures	Unweighted means/%			Weighted means/%			Population
	AS	OC	NC	AS	OC	NC	Mean/%
Sex							
Male	0.71	0.41	0.45	0.71	0.62	0.61	0.45
Female	0.29	0.59	0.55	0.29	0.38	0.39	0.55
Highest pre-education							
High school VWO	0.75	0.80	0.83	0.75	0.81	0.81	0.83
High school HAVO, one year HBO	0.13	0.14	0.10	0.13	0.12	0.09	0.10
Degree in higher education	0.02	0.04	0.05	0.02	0.03	0.04	0.05
Other Dutch pre-education	0.10	0.03	0.02	0.10	0.04	0.05	0.02
Cohort							
2010	0.11	0.10	0.19	0.11	0.09	0.15	0.18
2011	0.21	0.12	0.16	0.21	0.16	0.18	0.16
2012	0.11	0.13	0.14	0.11	0.12	0.12	0.14
2013	0.07	0.15	0.14	0.07	0.13	0.11	0.14
2014	0.20	0.18	0.13	0.20	0.18	0.17	0.13
2015	0.17	0.17	0.11	0.17	0.17	0.13	0.12
2016	0.14	0.16	0.13	0.14	0.15	0.14	0.13
Avg. grade							
Avg. grade math	6.54	6.59	6.57	6.54	6.52	6.52	6.58
Not missing	0.85	0.92	0.93	0.85	0.94	0.93	0.93
Missing	0.15	0.08	0.07	0.15	0.06	0.07	0.07

AS students with ASD, OC students with other conditions, NC students with no recorded conditions

unweighted data to compare direction of the results because of the weighted data's limited power.

Our hypothesized model is described graphically in Fig. 1. All variables were observed. We selected GPA, resits, exam participation, no-shows, credit accumulation, and drop-out for each bachelor's degree year. For the third year, we selected graduation assignment completion and degree completion. A higher number of resits increase exam participation, while more no-shows decrease exam participation. Higher exam participation and higher GPA both increase credit accumulation in each year. Higher credit accumulation increases credit accumulation in the following year. Graduation assignment completion contributes to credit accumulation in the third year. Retention and credit accumulation contribute to degree completion.

We performed the SEM with the lavaan package, version 0.6–6 (Rosseel, 2012), for unweighted data and the lavaan.survey package, version 1.1.3.1 (Oberski, 2014), for weighted data. Data from the second year and third year were missing not at random for students who dropped out in the first or second year, respectively (AS, year 2, 25; year 3, 38; OC, year 2, 557; year 3, 705; NC, year 2, 7,384; year 3, 8,641). We estimated models using the maximum likelihood estimator (ML for weighted data; MLR for unweighted data due to non-normality), without removing missing data (missing patterns: AS, 6; OC, 18; NC, 18), and we added a mean structure to the model. We determined covariance,

Table 2 Descriptives and educational history for the three participant groups without outliers ($N = 26{,}809$)

	AS $N = 97$	OC $N = 2{,}378$	NC $N = 24{,}334$	p	Group differences
Age (in years)	20.0 [18.0–21.0]	19.0 [18.0–21.0]	19.0 [18.0–20.0]	0.022	AS > NC; OC > NC
Grade Dutch secondary education	7.0 [6.0–7.0]	6.0 [6.0–7.0]	6.5 [6.0–7.0]	1.000	n.s
Grade English secondary education	7.0 [6.0–8.0]	7.0 [6.0–7.0]	7.0 [6.0–7.0]	< 0.001	AS > OC and NC
Grade math algebra secondary education	6.0 [6.0–7.0]	7.0 [6.0–7.0]	7.0 [6.0–7.0]	1.000	n.s
Average grade secondary education	6.7 [6.4–7.1]	6.6 [6.3–6.9]	6.6 [6.3–7.0]	1.000	n.s
Sex: female	29 (29.9%)	1,411 (59.3%)	13,424 (55.2%)	< 0.001	AS < NC < OC
Highest pre-education:				< 0.001	
High school VWO	72 (74.2%)	1,905 (80.1%)	20,286 (83.4%)		AS < OC < NC
High school HAVO, one year HBO	13 (13.4%)	317 (13.3%)	2,398 (9.9%)		AS > OC > NC
Degree in higher education	2 (2.1%)	86 (3.6%)	1,132 (4.7%)		AS < OC < NC
Other Dutch pre-education	10 (10.3%)	70 (2.9%)	518 (2.1%)		AS > OC > NC

AS students with ASD, OC students with other conditions, NC students with no recorded conditions

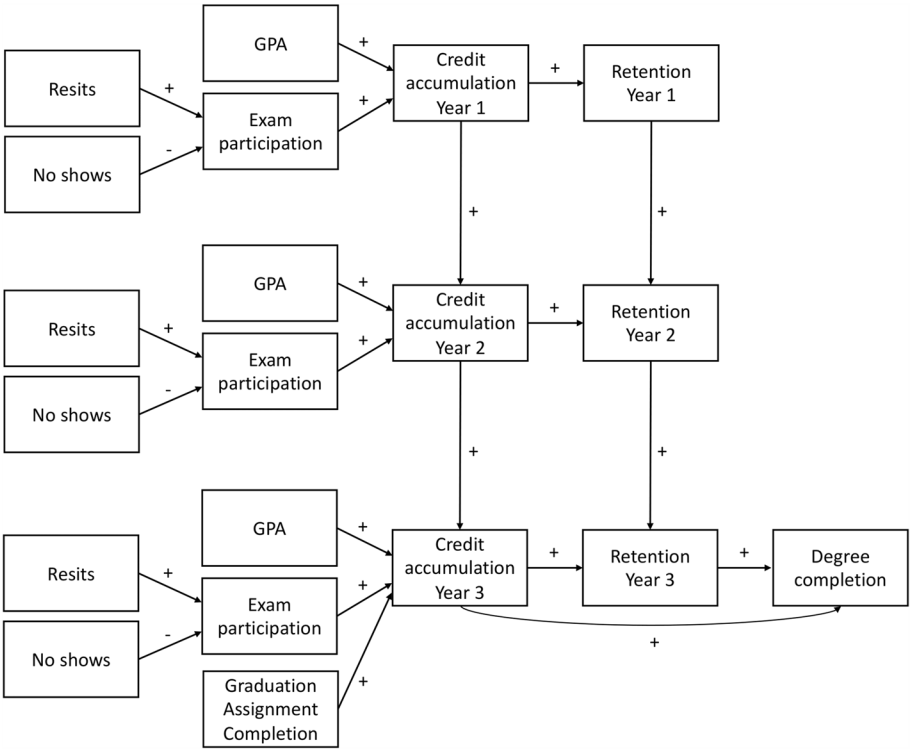

Fig. 1 Hypothesized structural equation model. Created with Microsoft PowerPoint

collinearity, and multicollinearity and removed collinear measures from the model (drop-out after 1, 2, and 3 years; exam participation; and graduation assignment completion).

To determine model fit, we examined the comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square errors of approximation (RMSEA), and standardized root mean square residuals (SRMR) to achieve an adequate fit with CFI ≥ 0.95, TLI ≥ 0.95, RMSEA ≤ 0.06, and SRMR ≤ 0.08 (Hooper et al., 2008; Marsh et al., 2004; Schermelleh-Engel et al., 2003). We optimized the model fit based on modification indices while considering the sequence of events and bachelor degree years, adding degree year 3 ~ EC year 1 + GPA year 2 + no-shows year 2 + EC year 2 + resits year 3, EC year 3 ~ GPA year 2 + resits year 2, and EC year 2 ~ GPA year 1.

Subsequently, we assessed a group-independent constrained model by equalizing path loadings to assess whether the factor structure differed between groups for GPA, resits, no-shows, a combination of resits and no-shows, and ECs. We optimized each constrained model by inspecting a Lagrange multiplier test's significance for releasing one or more constrained parameters (Bentler & Chou, 1992). We compared all models using an analysis of variance (ANOVA) and selected the optimal models based on the Bayesian information criterion (BIC). To determine significant differences between groups, we performed a scaled chi-square difference test using a simple approximation (Satorra & Bentler, 2001) and compared the overlap of the confidence intervals of the parameter estimates between groups.

We analyzed group differences in the path analysis using a multiple weighted linear regression to predict ECs in year 3 based on ECs in year 2 and research group.

Preregistration

Following this study's preregistration (Bakker et al., 2020b), we report additional data exclusions, inclusions, and changes. Due to the paucity of research on student progression and degree completion of AS, we changed the study from confirmatory to exploratory research. Based on the variable balance evaluation, we decided not to remove OC because of the comparable balance between AS and OC and AS and NC. We removed outliers that were more than 3 standard deviations (z-scores) from the mean. Based on covariance, collinearity, and multicollinearity, we excluded collinear measures from the model (dropout rate after 1, 2, and 3 years; exam participation; and graduation assignment completion). We did not apply a weighted Bayesian inference, as we removed dropout rates, and issues with degree completion concerned no-shows and credit accumulation instead of GPA.

Results

We analyzed complete longitudinal data on four sets of outcomes during 21 periods of students' bachelor's degree studies: (1) GPA, (2) resits, (3) no-shows, and (4) accumulated credits. Furthermore, we analyzed (5) degree completion after three years.

Group differences

Table 3 lists the success measures, effect sizes, and Kolmogorov–Smirnov test results of AS versus OC and NC per year, while Figs. 2, 3, and 4 show average GPA, resits, no-shows, and credit accumulation for each period and dropout rates for weighted AS, OC, and NC. We found no group differences in GPA, resits, no-shows, dropout rates, or degree completion rates in 3 years between AS and their peers. We found AS to have a lower credit accumulation in years 2 and 3 compared to NC (ECs Y2, AS, 41.84; NC, 49.82, $p = 0.032$, $V = 0.33$; ECs Y3, AS, 45.10; NC, 51.98, $p = 0.032$, $V = 0.31$). See Supplement S1 for the selected measures, effect sizes, and Kolmogorov–Smirnov test results per period.

Structural equation modeling

We assessed the hierarchical model for weighted groups (model W1) and compared it to a model in which there were no differences between groups (i.e., all parameters were equal for the three groups, model W2). In model W2, we kept path loadings consistent across both models for resits and no-shows. After optimization model fit indices indicated a good fit (W1: CFI = 0.973, TLI = 0.948, RMSEA = 0.059, SRMR = 0.019) and met the pre-determined cutoff criteria (see Table 4). Compared to model W1, model W2 yielded a significant deterioration in fit, indicating that groups do indeed differ on resits and no-shows ($p < 0.001$). We applied the same procedure to an unweighted version of the model

Table 3 Mean, 95% confidence interval for success measures of AS versus OC and NC per year; *p* refers to AS

Measures	Year	AS[a]		OC (weighted)			NC (weighted)			KS[b]	*V*
		Values (95% CI)	SE	Values (95% CI)	SE	*p*	Values (95% CI)	SE	*p*		
Resits	1	6.01 (4.77, 7.25)	0.63	7.71 (5.07, 10.35)	0.67	0.176	7.09 (4.85, 9.32)	0.64	0.217	9.03	0.20
	2	5.88 (4.13, 7.63)	0.89	7.81 (4.86, 10.76)	0.93	0.304	7.98 (5.31, 10.65)	0.90	0.101	15.84	0.25
	3	4.98 (3.35, 6.62)	0.83	5.25 (3.03, 7.48)	0.86	0.861	4.69 (2.66, 6.73)	0.84	0.895	5.44	0.21
No-shows	1	1.15 (0.77, 1.54)	0.20	0.99 (0.49, 1.49)	0.20	0.595	0.83 (0.31, 1.34)	0.20	0.217	6.60	0.13
	2	1.48 (1.03, 1.93)	0.23	1.81 (1.11, 2.52)	0.25	0.461	1.35 (0.74, 1.96)	0.23	0.848	14.23	0.17
	3	1.19 (0.78, 1.60)	0.21	1.58 (0.93, 2.23)	0.22	0.320	1.15 (0.62, 1.68)	0.21	0.920	6.45	0.15
GPA	1	6.56 (6.33, 6.79)	0.12	6.34 (6.02, 6.67)	0.12	0.320	6.38 (6.06, 6.71)	0.12	0.262	8.95	0.64
	2	6.53 (6.27, 6.79)	0.13	6.47 (6.20, 6.73)	0.13	0.823	6.67 (6.38, 6.95)	0.13	0.546	9.13	0.71
	3	6.79 (6.55, 7.03)	0.12	6.67 (6.41, 6.94)	0.13	0.595	6.88 (6.61, 7.14)	0.12	0.776	8.57	0.68
EC	1	39.88 (35.64, 44.11)	2.16	40.26 (33.84, 46.69)	2.22	0.862	39.66 (33.30, 46.01)	2.17	0.920	7.78	0.22
	2	41.84 (36.61, 47.07)	2.67	45.07 (39.68, 50.45)	2.72	0.508	49.82 (43.89, 55.76)	2.67	0.032*	17.80	0.33
	3	45.10 (40.41, 49.78)	2.39	47.19 (41.24, 53.14)	2.47	0.595	51.98 (46.44, 57.51)	2.40	0.032*	16.06	0.31
Dropout	1	0.22 (0.13, 0.30)	0.04	0.23 (0.10, 0.35)	0.04	0.862	0.29 (0.16, 0.41)	0.04	0.217		
	2	0.35 (0.26, 0.45)	0.05	0.27 (0.14, 0.41)	0.05	0.400	0.33 (0.19, 0.47)	0.05	0.895		
	3	0.35 (0.26, 0.45)	0.05	0.29 (0.16, 0.43)	0.05	0.508	0.34 (0.21, 0.48)	0.05	0.920		
Degree	3	0.22 (0.13, 0.30)	0.04	0.23 (0.10, 0.36)	0.04	0.861	0.29 (0.16, 0.41)	0.04	0.217		

AS students with ASD, OC students with other conditions, NC students with no recorded conditions, KS Kolmogorov–Smirnov test

[a]All *p* values for AS are < 0.001

[b]All *p* values for KS are < 0.001;. $= p < 0.1$, * $= p < 0.05$, *** $= p < 0.001$

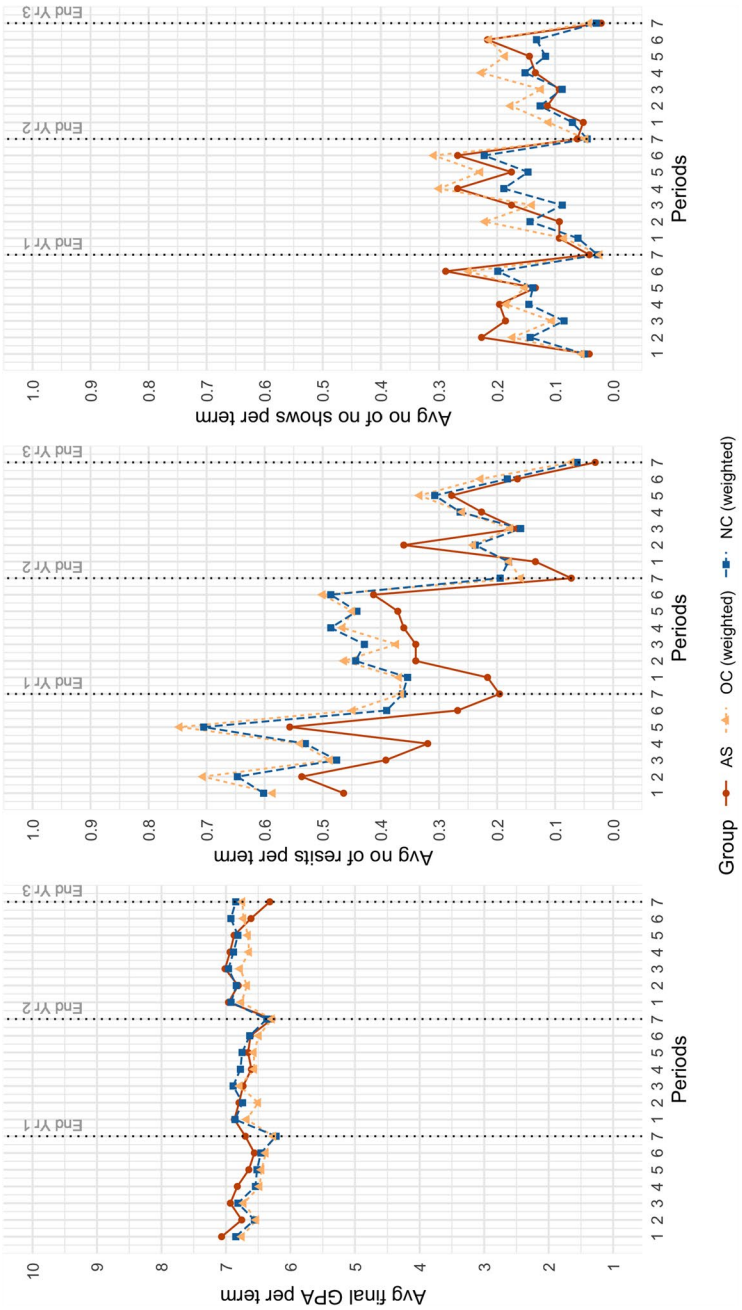

Fig. 2 Average GPA, resits, and no-shows for each period for weighted AS/OC/NC; full data including confidence intervals is reported in Table S1. Created with R version 4.0.2 for statistical computing, data wrangling and data analysis (R Core Team, 2017), and ggplot package

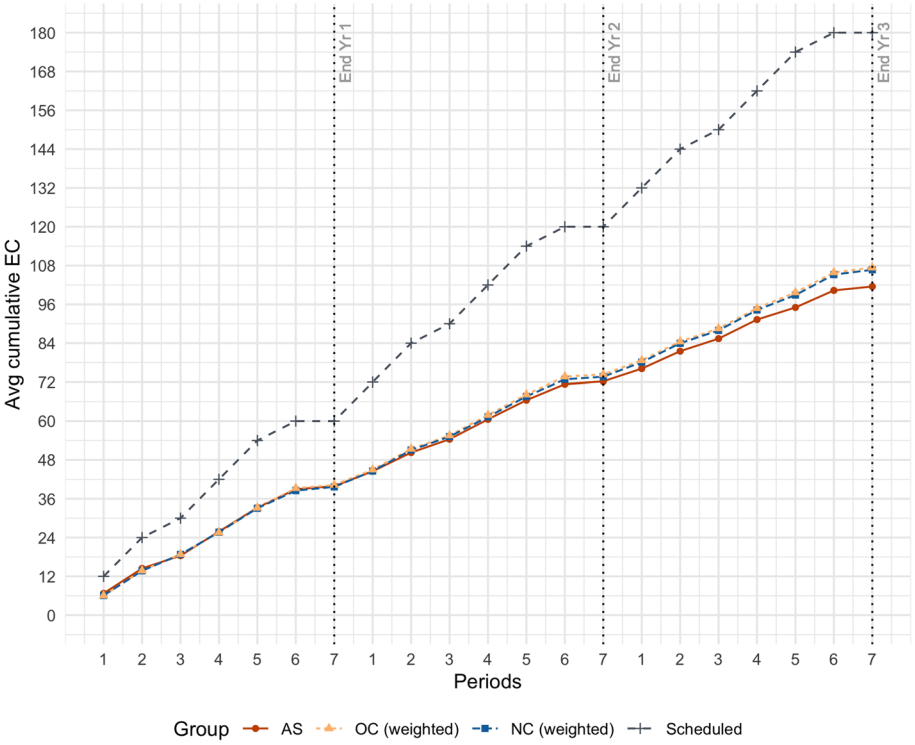

Fig. 3 Cumulative ECs for each period for weighted AS/OC/NC; full data including confidence intervals is reported in Table S1. Created with R version 4.0.2 for statistical computing, data wrangling and data analysis (R Core Team, 2017), and ggplot package

(UW1: CFI = 0.973, TLI = 0.954, RMSEA = 0.053, SRMR = 0.036) with similar results ($p < 0.001$).

Path analysis

Inspection of the *weighted hierarchical model* (W1) showed that path loadings are largely equal in AS compared to OC and NC (see Fig. 5), but three standardized coefficients were significantly different: (i) The number of ECs that AS earned in year 2 had a more negative correlation with degree in year 3 than that of OC and NC (AS, − 0.20; OC, 0.07; NC, 0.08; SE: AS, 0.046; OC, 0.012; NC, 0.004); (ii) no-shows of AS in year 2 had a more negative correlation with degree in year 3 than OC and NC (AS, − 0.38; OC, − 0.13; NC, − 0.10; SE: AS, 0.034; OC, 0.009; NC, 0.003); and (iii) the number of ECs that AS earned in year 3 had a more positive correlation with degree in year 3 than that of OC and NC (AS, 0.60; OC, 0.37; NC, 0.39; SE: AS, 0.035; OC, 0.008; NC, 0.003).

The multiple weighted linear regression to predict ECs in year 3 based on the research group and ECs in year 2 resulted in a significant equation ($F(5, 26{,}803) = 9.278 * 10^4$, $p < 0.001$), with an R^2 of 0.9478. Students' predicted ECs in

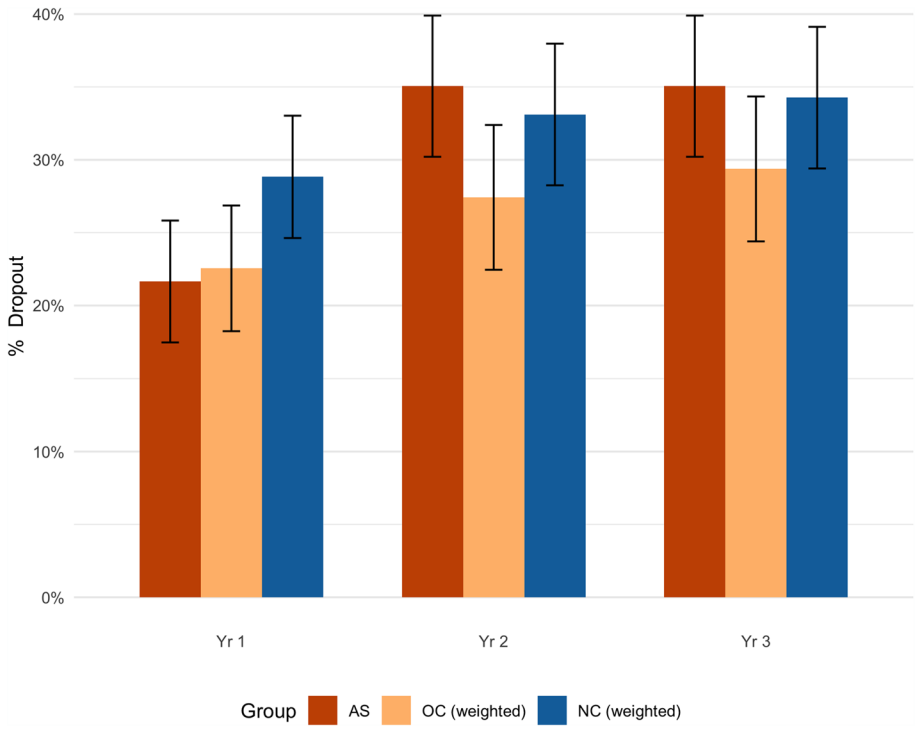

Fig. 4 Average dropout rates per year for weighted AS/OC/NC. Created with R version 4.0.2 for statistical computing, data wrangling and data analysis (R Core Team, 2017), and ggplot package

year 3 was equal to − 6.388 + 1.494 (ECs in year 2). AS's ECs in year 3 increased 1.494 for each EC in year 2, while OC accumulated 1.261 ECs more than AS, and NC accumulated 1.421 ECs more than AS. Both ECs in year 2 and the research group were significant predictors of ECs in year 3.

Several path loadings differed significantly between OC and NC, but not with AS: (i) GPA of OC in year 1 had a more positive correlation with ECs in year 1 (AS, 0.68; OC, 0.65; NC, 0.56; SE: AS, 0.046; OC, 0.013; NC, 0.004) and (ii) a less positive correlation with ECs in year 2 (AS, − 0.20; OC, − 0.24; NC, − 0.17; SE: AS, 0.178; OC, 0.030; NC, 0.009); (iii) resits of OC in year 1 had a more positive correlation with ECs in year 1 (AS, − 0.12; OC, 0.04; NC, − 0.01; SE: AS, 0.039; OC, 0.010; NC, 0.003); (iv) the number of ECs that OC earned in year 1 had a more positive correlation with ECs in year 2 (AS, 0.24; OC, 0.20; NC, 0.14; SE: AS, 0.206; OC, 0.030; NC, 0.009); (v) ECs of OC in year 2 had a more positive correlation with ECs in year 3 (AS, 0.32; OC, 0.32; NC, 0.24; SE: AS, 0.095; OC, 0.023; NC, 0.008); and (vi) the number of ECs that OC earned in year 3 had a less positive correlation with degree in year 3 (AS, 0.60; OC, 0.37; NC, 0.39; SE: AS, 0.035; OC, 0.008; NC, 0.003). The weighted covariance and correlation tables with means and standard deviations are shown in Table 5.

Inspection of the *unweighted hierarchical model* (UW1) showed that path loadings are largely equal in AS compared to OC and NC (see Fig. 6), but one

Table 4 Goodness-of-fit indicators of hierarchical models

Model[a]	Weighted/unweighted	Number of parameters	χ^2	df	p	CFI	TLI	RMSEA	RMSEA CI-lower	RMSEA CI-upper	SRMR
Model W1	Weighted	246	2123.25	66	< 0.001	0.973	0.948	0.059	0.057	0.061	0.019
Model W2	Weighted	230	2158.26	82	< 0.001	0.973	0.958	0.053	0.051	0.055	0.019
Model UW1	Unweighted	237	1974.08	75	< 0.001	0.973	0.954	0.053	0.051	0.055	0.036
Model UW2	Unweighted	229	1985.44	83	< 0.001	0.973	0.958	0.051	0.049	0.053	0.036

[a]In model W2 and UW2, path loadings were kept consistent across both groups for resits and no-shows. *CFI* comparative fit index, *TLI* Tucker-Lewis index, *RMSEA* root mean square errors of approximation, *CI* 95% confidence interval, *SRMR* standardized root mean square residuals

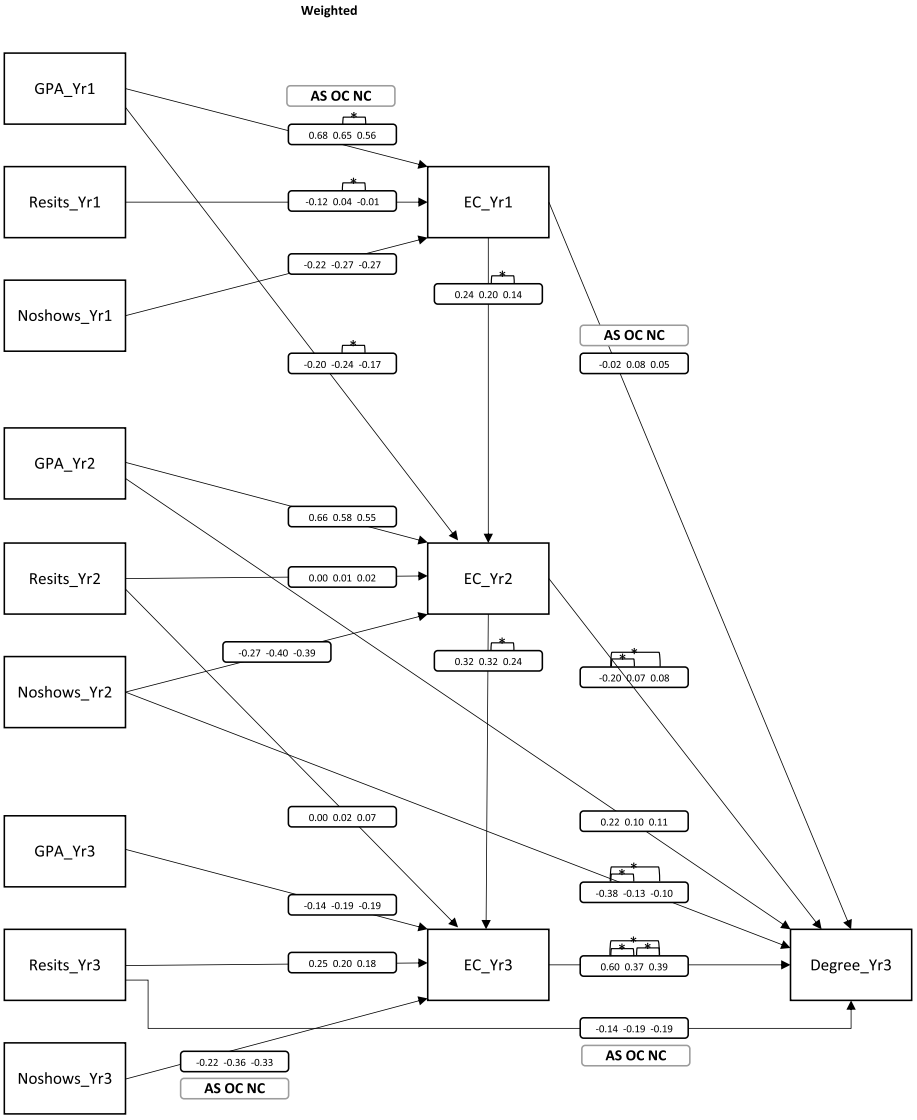

Fig. 5 Weighted structural equation model (W1) with parameter values for AS/OC/NC; full data including confidence intervals is reported in Table S1. Created with Microsoft PowerPoint

standardized coefficient was significantly different: (i) no-shows of AS in year 2 had a more negative correlation with degree in year 3 than OC and NC (AS, – 0.35; OC, – 0.17; NC, – 0.13; SE: AS, 0.034; OC, 0.009; NC, 0.003), as in the weighted model. Several path loadings differed significantly between OC and NC: (i) Resits of OC in year 1 had a less positive correlation with ECs in year 1 (AS, 0.17; OC, 0.18; NC, 0.22; SE: AS, 0.063; OC, 0.014; NC, 0.005); and (ii) the number of ECs that OC earned in year 3 had a less positive correlation with degree in year 3 (AS, 0.63; OC, 0.52; NC, 0.62; SE: AS, 0.044; OC, 0.013; NC, 0.006). The unweighted

Table 5 Weighted correlations (above diagonal) and variances/covariances (on/below diagonal)

AS	Dgr_Y3	EC_Y3	EC_Y2	EC_Y1	GPA_Y3	Rs_Y3	Ns_Y3	GPA_Y2	Rs_Y2	Ns_Y2	GPA_Y1	Rs_Y1	Ns_Y1
Degree_Y3	0.219	0.698	0.483	0.403	0.555	-0.400	-0.375	0.533	-0.362	-0.501	0.477	-0.385	-0.192
EC_Y3	0.312	0.915	0.503	0.442	0.695	-0.219	-0.333	0.503	-0.226	-0.186	0.519	-0.324	-0.123
EC_Y2	0.227	0.477	0.930	0.533	0.444	-0.355	-0.213	0.728	-0.413	-0.487	0.537	-0.417	-0.196
EC_Y1	0.096	0.228	0.228	0.247	0.553	-0.356	-0.236	0.588	-0.377	-0.236	0.785	-0.584	-0.369
GPA_Y3	0.271	0.707	0.483	0.295	1.116	-0.426	-0.283	0.644	-0.377	-0.108	0.701	-0.494	-0.089
Resits_Y3	-0.187	-0.223	-0.395	-0.189	-0.450	1.001	0.499	-0.404	0.540	0.315	-0.392	0.597	0.095
Noshows_Y3	-0.152	-0.314	-0.250	-0.198	-0.280	0.468	0.877	-0.197	0.096	0.290	-0.256	0.273	0.139
GPA_Y2	0.258	0.489	0.716	0.257	0.703	-0.418	-0.191	1.068	-0.465	-0.307	0.757	-0.500	-0.067
Resits_Y2	-0.169	-0.194	-0.359	-0.147	-0.364	0.494	0.082	-0.439	0.836	0.369	-0.388	0.699	0.150
Noshows_Y2	-0.220	-0.163	-0.443	-0.098	-0.108	0.296	0.255	-0.299	0.317	0.883	-0.189	0.251	0.362
GPA_Y1	0.170	0.352	0.400	0.296	0.562	-0.298	-0.182	0.595	-0.270	-0.135	0.577	-0.586	-0.170
Resits_Y1	-0.170	-0.269	-0.399	-0.269	-0.484	0.554	0.237	-0.479	0.593	0.219	-0.413	0.860	0.324
Noshows_Y1	-0.089	-0.127	-0.195	-0.165	-0.084	0.086	0.117	-0.063	0.123	0.305	-0.116	0.270	0.807
M	0.216	-0.332	-0.414	-0.048	-0.078	0.033	0.083	-0.118	-0.26	0.254	0.145	-0.072	0.291
SD	0.414	0.961	1.251	0.943	1.057	1.038	0.942	1.135	0.982	0.965	0.916	0.919	1.123

OC	Dgr_Y3	EC_Y3	EC_Y2	EC_Y1	GPA_Y3	Rs_Y3	Ns_Y3	GPA_Y2	Rs_Y2	Ns_Y2	GPA_Y1	Rs_Y1	Ns_Y1
Degree_Y3	0.218	0.575	0.514	0.368	0.519	-0.463	-0.439	0.477	-0.366	-0.487	0.400	-0.286	-0.253
EC_Y3	0.280	1.052	0.496	0.301	0.602	-0.294	-0.541	0.390	-0.239	-0.428	0.326	-0.200	-0.252
EC_Y2	0.224	0.483	0.813	0.432	0.515	-0.432	-0.374	0.676	-0.422	-0.622	0.422	-0.287	-0.298
EC_Y1	0.103	0.198	0.212	0.304	0.443	-0.323	-0.256	0.479	-0.283	-0.326	0.699	-0.285	-0.418
GPA_Y3	0.237	0.629	0.494	0.241	1.029	-0.544	-0.422	0.712	-0.435	-0.423	0.611	-0.355	-0.219
Resits_Y3	-0.201	-0.288	-0.403	-0.191	-0.500	0.822	0.497	-0.514	0.635	0.465	-0.448	0.488	0.187
Noshows_Y3	-0.220	-0.604	-0.428	-0.182	-0.451	0.474	1.107	-0.312	0.347	0.530	-0.269	0.265	0.332
GPA_Y2	0.205	0.367	0.563	0.223	0.675	-0.435	-0.307	0.875	-0.514	-0.429	0.672	-0.338	-0.201
Resits_Y2	-0.157	-0.211	-0.333	-0.139	-0.385	0.502	0.318	-0.419	0.759	0.435	-0.399	0.609	0.172
Noshows_Y2	-0.239	-0.474	-0.587	-0.214	-0.442	0.434	0.575	-0.414	0.390	1.061	-0.354	0.341	0.397
GPA_Y1	0.128	0.209	0.248	0.251	0.403	-0.264	-0.184	0.408	-0.226	-0.237	0.422	-0.396	-0.237
Resits_Y1	-0.107	-0.181	-0.224	-0.136	-0.311	0.381	0.241	-0.272	0.457	0.303	-0.222	0.743	0.242
Noshows_Y1	-0.115	-0.273	-0.274	-0.205	-0.198	0.150	0.310	-0.167	0.133	0.364	-0.137	0.185	0.789
M	0.230	-0.226	-0.24	-0.031	-0.203	0.138	0.216	-0.187	0.038	0.234	-0.029	0.096	0.191
SD	0.421	1.062	1.024	0.929	1.018	0.951	1.068	0.991	0.927	1.037	0.886	0.939	1.077

NC	Dgr_Y3	EC_Y3	EC_Y2	EC_Y1	GPA_Y3	Rs_Y3	Ns_Y3	GPA_Y2	Rs_Y2	Ns_Y2	GPA_Y1	Rs_Y1	Ns_Y1
Degree_Y3	0.244	0.562	0.480	0.326	0.518	-0.450	-0.429	0.468	-0.346	-0.451	0.386	-0.259	-0.243
EC_Y3	0.266	0.890	0.415	0.246	0.557	-0.270	-0.506	0.338	-0.177	-0.374	0.301	-0.138	-0.218
EC_Y2	0.202	0.345	0.661	0.395	0.502	-0.420	-0.377	0.654	-0.403	-0.600	0.431	-0.263	-0.289
EC_Y1	0.085	0.134	0.152	0.236	0.410	-0.317	-0.263	0.442	-0.307	-0.328	0.630	-0.298	-0.409
GPA_Y3	0.240	0.489	0.411	0.184	0.851	-0.600	-0.479	0.700	-0.475	-0.448	0.604	-0.368	-0.253
Resits_Y3	-0.210	-0.244	-0.359	-0.171	-0.509	0.844	0.493	-0.529	0.657	0.450	-0.441	0.523	0.239
Noshows_Y3	-0.219	-0.476	-0.357	-0.156	-0.429	0.439	0.943	-0.353	0.324	0.533	-0.310	0.228	0.325
GPA_Y2	0.194	0.267	0.448	0.162	0.549	-0.413	-0.292	0.722	-0.538	-0.441	0.679	-0.347	-0.218
Resits_Y2	-0.164	-0.153	-0.304	-0.147	-0.403	0.555	0.289	-0.420	0.846	0.412	-0.440	0.641	0.197
Noshows_Y2	-0.220	-0.348	-0.484	-0.176	-0.406	0.406	0.508	-0.367	0.372	0.962	-0.384	0.290	0.411
GPA_Y1	0.123	0.181	0.218	0.190	0.346	-0.252	-0.187	0.359	-0.251	-0.234	0.386	-0.404	-0.249
Resits_Y1	-0.101	-0.117	-0.182	-0.128	-0.301	0.427	0.196	-0.262	0.524	0.252	-0.223	0.789	0.218
Noshows_Y1	-0.095	-0.179	-0.193	-0.150	-0.176	0.166	0.238	-0.140	0.137	0.304	-0.117	0.146	0.570
M	0.288	0.014	0.016	-0.058	0.014	-0.019	-0.001	0.022	-0.014	0.015	0.002	-0.03	0.059
SD	0.453	0.975	0.951	1.002	0.917	0.984	0.974	0.900	0.989	1.003	0.922	0.989	1.032

AS students with ASD, OC students with other conditions, NC students with no recorded conditions

covariance and correlation tables with means and standard deviations are shown in Supplement Table S2.

Discussion

This longitudinal study examined progression during 3 years of bachelor's degree studies and degree completion within three years of autistic students. Since we had to remove related SEM measures on graduation assignments because of multicollinearity, answering our research question on graduation assignments (RQ3) was not possible (Table 6).

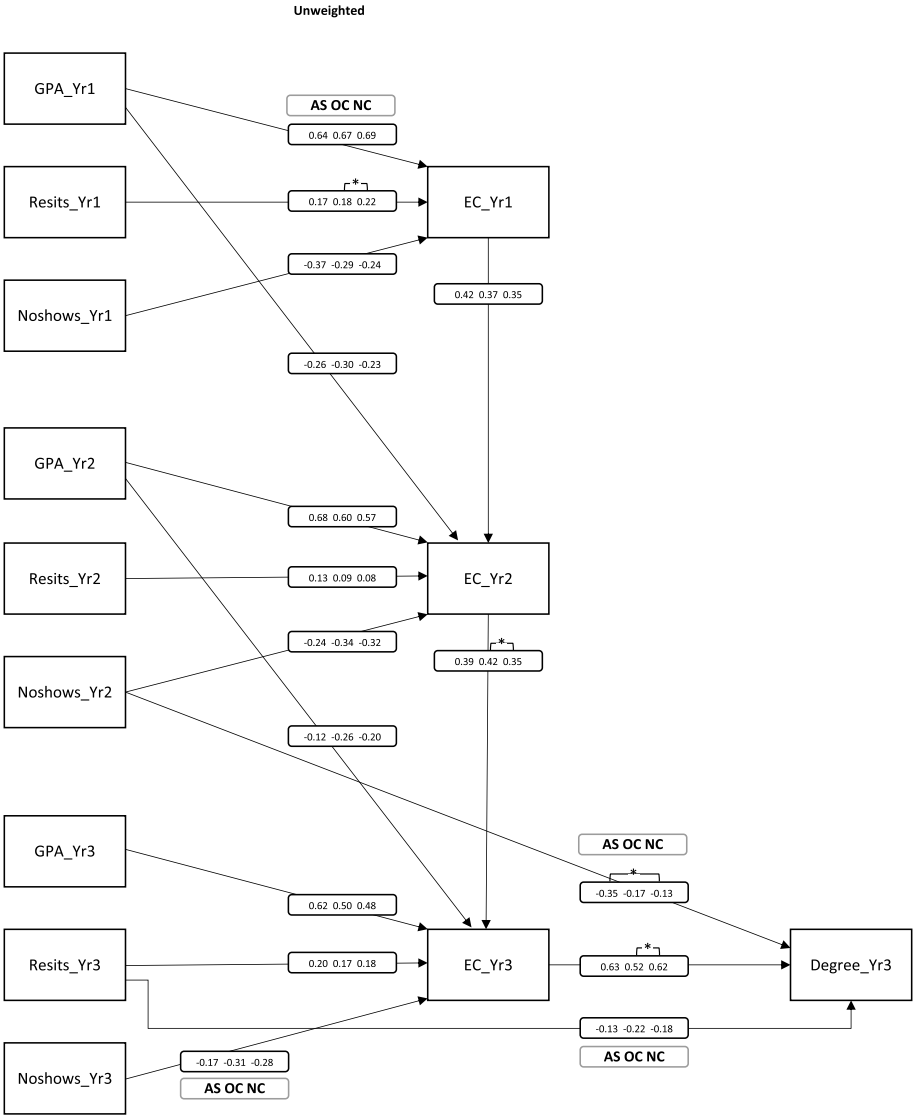

Fig. 6 Unweighted structural equation model (UW1) with parameter values for AS/OC/NC; full data including confidence intervals is reported in Table S1. Created with Microsoft PowerPoint

RQ1: GPA and dropout rates

A promising finding is that, following our expectations, we found no differences in dropout rates in 3 years between autistic students and their peers nor did we find differences in GPA.

We assume that we eliminated unweighted differences in dropout and GPA by employing PSW (Bakker et al., 2020a). Earlier studies may have focused too heavily on autistic students with educational problems. The current study solves this possible bias, as we rely on a large

Table 6 Research questions, expectations, and findings

Research questions	Expectations	Findings
RQ1: GPA and dropout rates	Similar GPAs and dropout rates	No differences
RQ2: Participation and credit accumulation	Lower participation (resits and no-shows) and lower credit accumulation	No differences in resits and no-shows Significant differences in credit accumulation in years 2 and 3 compared to students with no recorded conditions
RQ4: Degree completion	Lower rate of degree completion in three years	No differences

population sample with seven cohorts of formal data and weighted outcomes based on background features and earlier performances of autistic students (e.g., the average grade in math in secondary education). An additional explanation for the lack of differences might be that we studied autistic students who applied for academic accommodations. Therefore, they are likely to have benefited from these services (Adreon & Durocher, 2007; Madaus et al., 2020; Roberts, 2010). However, these benefits apply to both autistic students and students with other conditions, and we do see significant differences between these groups in no-shows in year 2 and credit accumulation in year 3 (see below). A more elementary explanation could be that autistic students enjoy their studies and study just as adequately as their peers.

RQ2: Participation and credit accumulation

Even though most participation outcomes are similar across groups, as expected, we did find significant differences in credit accumulation in years 2 and 3 compared to students with no recorded conditions. After the first year, progression problems seem to emerge. The accumulation of credits for some autistic students declines compared to their peers, leading to problems with degree completion within 3 years. Not showing up at exams differentiates autistic students with problems in progression from other autistic students whose progression remains normal.

These findings support findings from qualitative research on autistic students' growing procrastination, feelings of disengagement, and thoughts of withdrawal (J. M. Anderson, 2014; Cage & Howes, 2020; Gurbuz et al., 2019). The paths between no-shows in year 2, credit accumulation in years 2 and 3, and degree completion support the evidence that effective studying becomes increasingly challenging for autistic students (Shmulsky & Gobbo, 2013). After the first year of a bachelor's program, assignments become more complex. Group assignments or internships, for example, put higher demands on social skills; writing a thesis or conducting research requires more academic and self-management skills (Van Hees et al., 2015). The academic responsibilities of autistic students, such as planning, processing information, and critical thinking, increasingly become deciding factors in study progression and degree completion. While most students without autism can rely on social and academic skills to cope with these transitions, autistic students often do not have similar skills nor a social network to rely on when in doubt (Gurbuz et al., 2019; Tobin et al., 2014). As the severity of these challenges differs within the group of autistic students, so does their need for help, their progression, and their degree completion (Cage et al., 2020). Our research found that second-year no-shows appear to be an early proxy for progression difficulties, and universities should use these early signs of failure to involve students proactively (Cage & Howes, 2020; Dijkhuis et al., 2020).

RQ4: Degree completion

Contrary to our expectations, we did not find differences in degree completion within 3 years. The differences in degree completion rates as found in earlier longitudinal studies (Chown et al., 2016; Newman et al., 2011) was absent. We expect the elimination of differences for GPA and dropout rates, as mentioned earlier, eliminated differences in degree completion as well.

Although the overall outcomes are comparable to their peers, we see room for improvement to support autistic students. Because participation is critical, support

should focus on inclusivity and embracing neurodiversity to avoid reaching a crisis (Clouder et al., 2020; Robertson & Ne'eman, 2021). Educational inclusivity can be reached by Universal Learning Design strategies (A. H. Anderson, 2018; Berry et al., 2006), promoting understanding and acceptance of autistic students by peers and staff (Sarrett, 2017), alternative teaching and assessment (Griffin & Pollak, 2009; Jansen et al., 2016), and examination assistance (Sarrett, 2017). To prevent loneliness and stress, autistic students can benefit from resilience and anxiety management (A. H. Anderson, 2018; Bolourian et al., 2018) and social support groups (Barnhill, 2016; Hillier et al., 2018; Van Hees et al., 2015).

Limitations and future directions

Potential limitations of the present study must be recognized. We studied autistic students who applied for academic accommodations. However, the possible benefits of accommodations apply to both autistic students and students with other conditions, and we do see significant differences between these groups. In addition, no data was available on whether students' requests for academic accommodations were granted, if they used accommodations, and benefitted from them. Likewise, a possible negative influence of comorbidity on progression and degree completion was unknown. Possible benefits or disadvantages of educational history, such as highest pre-education or earlier results, are uncertain. More research into possible confounding factors is required.

Additionally, it is unclear whether autistic students autonomously decide to skip examinations (e.g., as a coping strategy) or others advise them to do so, such as student counselors, teachers, or family members. More research into these topics is required. Finally, we expect the handling and completion of graduation assignments to be essential for degree completion, but, as noted, we had to remove related SEM measures because of multicollinearity. More research into graduation assignments is needed.

Significance

To our knowledge, this is the first population study to use PSW and SEM to analyze progression and degree completion of autistic students in comparison to a major control group of students with other conditions and students with no recorded conditions. This innovative methodological approach demonstrates that autistic students, with the possible benefits of academic accommodations, can have similar success rates to other students. Room for improvement can be found by giving special attention to early signals of diminishing participation as expressed in second-year test taking. These quantitative insights are a valuable addition to the more qualitative evidence so far.

Appendix

Table A1 *Description of variablesand measurement scales*

Category	Variables	Measurement scales
Enrollment	Cohort	2010, 2011, 2012, 2013, 2014, 2015, 2016
Demographics	Gender	Female, Male
	Age (in years)	Age
Conditions	ASD	FALSE = No, TRUE = Yes
Secondary Education	Highest Pre-education	High school VWO, Vocational foundation year, Degree in higher education, Other pre-education, Foreign degree
Secondary Education Examination Grades	Grade Math Algebra Secondary Education	1-10
Student Success	GPA Endresults	1.0-10.0
	EC Year 1	0-109
	EC Year 2	0-105
	EC Year 3	0-108
	No-shows Year 1	0-17
	No-shows Year 2	0-21
	No-shows Year 3	0-13
	Resits Year 1	0-81
	Resits Year 2	0-91
	Resits Year 3	0-89
	Retention Year 1	FALSE = No, TRUE = Yes
	Retention Year 2	FALSE = No, TRUE = Yes
	Retention Year 3	FALSE = No, TRUE = Yes
	Degree completion Year 3	FALSE = No, TRUE = Yes

Table A2 *Mean, 95% confidence interval for success measures of AS versus OC and NC per year; p refers to AS*

Measures	Year	AS[a]		OC (weighted)			NC (weighted)			KS[b]	*V*
		Values (95% CI)	SE	Values (95% CI)	SE	*p*	Values (95% CI)	SE	*p*		
Resits (year)	1	6.01 (4.77, 7.25)	0.63	7.71 (5.07, 10.35)	0.67	0.176	7.09 (4.85, 9.32)	0.64	0.217	9.03	0.20
	2	5.88 (4.13, 7.63)	0.89	7.81 (4.86, 10.76)	0.93	0.304	7.98 (5.31, 10.65)	0.90	0.101	15.84	0.25
	3	4.98 (3.35, 6.62)	0.83	5.25 (3.03, 7.48)	0.86	0.861	4.69 (2.66, 6.73)	0.84	0.895	5.44	0.21
No-shows (year)	1	1.15 (0.77, 1.54)	0.20	0.99 (0.49, 1.49)	0.20	0.595	0.83 (0.31, 1.34)	0.20	0.217	6.60	0.13
	2	1.48 (1.03, 1.93)	0.23	1.81 (1.11, 2.52)	0.25	0.461	1.35 (0.74, 1.96)	0.23	0.848	14.23	0.17
	3	1.19 (0.78, 1.60)	0.21	1.58 (0.93, 2.23)	0.22	0.320	1.15 (0.62, 1.68)	0.21	0.920	6.45	0.15
GPA (year)	1	6.56 (6.33, 6.79)	0.12	6.34 (6.02, 6.67)	0.12	0.320	6.38 (6.06, 6.71)	0.12	0.262	8.95	0.64
	2	6.53 (6.27, 6.79)	0.13	6.47 (6.20, 6.73)	0.13	0.823	6.67 (6.38, 6.95)	0.13	0.546	9.13	0.71
	3	6.79 (6.55, 7.03)	0.12	6.67 (6.41, 6.94)	0.13	0.595	6.88 (6.61, 7.14)	0.12	0.776	8.57	0.68
EC (year)	1	39.88 (35.64, 44.11)	2.16	40.26 (33.84, 46.69)	2.22	0.862	39.66 (33.30, 46.01)	2.17	0.920	7.78	0.22
	2	41.84 (36.61, 47.07)	2.67	45.07 (39.68, 50.45)	2.72	0.508	49.82 (43.89, 55.76)	2.67	0.032 *	17.80	0.33
	3	45.10 (40.41, 49.78)	2.39	47.19 (41.24, 53.14)	2.47	0.595	51.98 (46.44, 57.51)	2.40	0.032 *	16.06	0.31
Dropout	1	0.22 (0.13, 0.30)	0.04	0.23 (0.10, 0.35)	0.04	0.862	0.29 (0.16, 0.41)	0.04	0.217		
	2	0.35 (0.26, 0.45)	0.05	0.27 (0.14, 0.41)	0.05	0.400	0.33 (0.19, 0.47)	0.05	0.895		
	3	0.35 (0.26, 0.45)	0.05	0.29 (0.16, 0.43)	0.05	0.508	0.34 (0.21, 0.48)	0.05	0.920		
Degree	3	0.22 (0.13, 0.30)	0.04	0.23 (0.10, 0.36)	0.04	0.861	0.29 (0.16, 0.41)	0.04	0.217		

AS, students with ASD; OC: students with other conditions; NC: students with no recorded conditions; KS: Kolmogorov-Smirnov test; [a] all p.values for AS are < 0.001; [b] all p.values for KS are < 0.001; . = $p < 0.1$, * = $p < 0.05$, *** = $p < 0.001$

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10734-021-00809-1.

Acknowledgements We thank Erna Klein Ikkink, Director of the Department of Student and Educational Affairs of the Vrije Universiteit, for supporting this research.

Author contribution Theo Bakker conceived of the study, participated in its design and coordination, performed the measurement and the statistical analysis, and drafted the manuscript; Lydia Krabbendam conceived of the study, participated in its design and coordination, and helped to draft the manuscript; Martijn Meeter conceived of the study, participated in its design and coordination, and helped to draft the manuscript; Sandjai Bhulai conceived of the study, participated in its design and coordination, and helped to draft the manuscript; Sander Begeer conceived of the study, participated in its design and coordination, and helped to draft the manuscript. All authors read and approved the final manuscript.

Funding The corresponding author was financially supported by the Vrije Universiteit Amsterdam, Department of Student and Educational Affairs, The Netherlands. This study was not funded through any grant.

Availability of data and material The data for this research is not available.

Code availability The software code for this research is not available.

Declarations

Ethics approval The Scientific and Ethical Review Board of the Department of Clinical, Neuro- & Developmental Psychology, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, granted ethical clearance (reference number VCWE-2017–123).

Consent to participate/consent for publication 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. For this type of study, formal consent is not required.

Conflict of interest The authors declare no competing interests.

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