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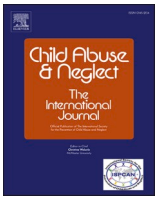

Are different types of childhood adversities correlated within and across time? A comparison of data on adversity co-occurrence from three longitudinal birth cohort studies

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ABSTRACT

Background: Existing research on adverse childhood experiences (ACEs) emphasizes that ACEs tend to co-occur, both at specific timepoints and across development. However, these conclusions are often drawn from cross-sectional data, retrospective reports, and high-risk samples. Patterns of ACE co-occurrence have yet to be investigated longitudinally using repeated, time-specific measures of ACE exposure.
Objective: Assess patterns of ACE co-occurrence across development and compare findings from three longitudinal birth cohorts.
Participants and setting: Data came from the Avon Longitudinal Study of Parents and Children (ALSPAC; U.K.), the Generation R Study (GenR; The Netherlands), and the Drakenstein Child Health Study (DCHS; South Africa).
Method: ACEs were measured repeatedly from birth to age 10 using prospective caregiver reports. Cohort-level tetrachoric correlations were estimated to characterize associations within and between ACE types and by timepoints.
Results: ACEs were only moderately correlated within and across time, with correlation estimates under $r = 0.5$ at most timepoints, even for the most prevalent exposures. In all cohorts, ACEs capturing direct victimization had the highest co-occurrence with each other. ACEs capturing

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household dysfunction tended to persist over time but were less likely to co-occur with other ACEs. ACEs were most prevalent in DCHS and had the highest co-occurrence in ALSPAC.
Conclusions: Variation exists in patterns of ACE co-occurrence by ACE type, developmental timing, and sample. Given these results, researchers and clinicians should challenge the assumption that all ACEs consistently co-occur. Instead, ACE exposure when measured via parent or participant self report - may need to be assessed repeatedly across development to better understand patterns of ACE co-occurrence and inform targeted interventions.

1. Introduction

Adverse Childhood Experiences (ACEs) refer to negative life events (e.g., physical abuse, divorce, parental substance use) occurring in a family or social environment before age 18 that cause harm or distress (Felitti et al., 1998; Kalmakis & Chandler, 2014). These life events may vary in severity and can be chronic, occurring across childhood and adolescence (Kalmakis & Chandler, 2014). ACEs are common in the general population. A recent meta-analysis of data from over 500,000 adults across 22 countries reported that 60% of adults worldwide experienced at least one ACE (Madigan et al., 2023). People who experience ACEs are at an increased risk for myriad physical and mental disorders across the life course (Anda et al., 2006; Felitti et al., 1998; Hughes et al., 2017), including somatic complaints (Flaherty et al., 2013), behavioral disorders (Bright et al., 2016), and earlier initiation of alcohol use in childhood and adolescence (Dube et al., 2006); and an increased risk for cancer, depression, and substance abuse in adulthood (Anda et al., 2006; Hughes et al., 2017; Kessler et al., 2010; Stein et al., 2019). Given the high global prevalence of ACEs and their detrimental impact on health, it is important to understand when and how ACEs occur across time.

Existing research emphasizes that ACEs tend to co-occur across development. In other words, experiencing one ACE may increase the risk of experiencing additional ACEs, whether concurrently or in the future (Dong et al., 2004; Hughes et al., 2017; McLaughlin et al., 2012). Indeed, in many widely cited papers describing the long-term consequences of ACEs (see for example Bellis et al. (2019); Edwards et al. (2003); Felitti (2002); Hughes et al. (2017)), ACE co-occurrence is stated as a core premise of what ACEs are and how they occur. Often, statements such as “ACEs tend to co-occur” or “ACEs tend to cluster together” are employed in the introductions of these and other research articles and cited as a reason to consider the cumulative impact of all ACEs, examining them all together, rather than investigating exposure timing or analyzing ACE types individually (Evans et al., 2013; Smith & Pollak, 2021). This cumulative risk approach emphasizes that the more ACEs an individual experiences, regardless of developmental timing or ACE type, the worse their physical and mental health outcomes (Evans et al., 2013; Schilling et al., 2008).

In support of the idea ACEs tend to co-occur, a handful of empirical studies have investigated how different self-reported ACEs correlate with each other. For example, Kessler et al. (2010) found that among a sample of over 50,000 adults from high, middle, and low-income countries around the world who completed the World Mental Health Survey, 59–66% of adults who reported experiencing at least one type of adversity experienced additional adversities. McLaughlin et al. (2012) had similar findings among adolescents who completed the National Comorbidity Survey Replication – Adolescent Supplement, a cross-sectional survey administered to a nationally representative sample of respondents in the U.S. In this sample, 60% of adolescents who reported experiencing at least one ACE type also reporting experiencing additional ACEs (McLaughlin et al., 2012).

Several recent studies have investigated which ACE types tend to occur together. For example, recent latent class analyses examining ACE co-occurrence have highlighted that some ACEs are more likely to co-occur with each other. In the Hispanic Community Health Study/Study of Latinos, a community-based longitudinal study following participants from four Latino/a communities in the United States, emotional and physical abuse tended to co-occur (Niño et al., 2023). In the National Survey of Child and Adolescent Wellbeing II, a national, U.S.-based study of children in contact with child welfare services, emotional abuse and caregiver divorce were highly co-occurrent in middle childhood (Brown et al., 2019). In addition, meta-analyses focusing on ACEs captured by specific measures, like the Childhood Trauma Questionnaire, have found all maltreatment types are significantly positively associated, with physical and emotional abuse being the most strongly associated ($Z = 0.72$, 95% CI [0.48, 0.96]) (Matsumoto et al., 2023).

Network analysis, a data-driven method to uncover the interrelatedness of variables in a population, has also been employed to better understand the complex relationships among different ACE types. These investigations allow researchers to better understand the direct and indirect relationships between all ACE types in a sample and can be used to assess how ACEs relate to mental health outcomes. An investigation by Carozza et al. (2022) used a network approach to assess the interrelatedness of ACE types in the Avon Longitudinal Study of Parents and Children, a longitudinal birth cohort from Avon, U.K., finding evidence for distinct networks for adversities characterized by deprivation (i.e., the absence of expected environmental input) and threat (i.e., the risk or realization of harm to a child’s survival). Other network analyses have found evidence for more general interrelatedness among ACE types, with some specific ACE types such as physical and emotional abuse emerging as strong edges in the network (de Vries et al., 2022).

However, findings from these and other investigations into ACE co-occurrence may not hold during all developmental time periods due to their reliance on cross-sectional data (Arata et al., 2007; Matsumoto et al., 2023) and retrospective reports (Bellis et al., 2015; Dong et al., 2004; Edwards et al., 2003; Niño et al., 2023) and may not generalize to all populations due to their focus on high-risk or clinical samples (Brown et al., 2019; Cecil et al., 2017). Findings from cross-sectional studies may only capture a snapshot of ACEs at a specific time point (or retrospective from that time point of assessment), which may not generalize to all stages of childhood (Danese, 2020). Retrospective reports of ACEs from adults reporting on their childhood experiences may have low levels of agreement with prospective reports, with potential misreporting due to recall bias and differences in motivation of reporters (Baldwin et al., 2019;

Hardt & Rutter, 2004; Reuben et al., 2016; Widom, 2019). Retrospective reports of childhood adversity may also provide little specificity as to exactly when in childhood ACEs occurred and if they co-occurred with other adversities at the same time or years apart (Hardt & Rutter, 2004; Widom, 2019; Widom et al., 2004). Lastly, results from studies in high-risk or clinical samples (including children who have already been identified as abused or neglected by child protective service agencies) may not generalize to the larger population, instead only highlighting the most severe cases of adversity exposure where ACE co-occurrence may be more common (Brown et al., 2019; Giano et al., 2020).

Longitudinal datasets from population-based samples with repeated measures of ACE exposure across childhood provide a stronger analytic design to characterize ACE co-occurrence across development, as these study designs overcome many of the challenges of prior research. With repeated measures of adversity exposure across childhood, researchers may be able to more accurately assess when ACEs occur and co-occur, which ACE types co-occur most frequently, and which ACEs tend to persist across childhood. Previous research into the timing of ACE exposure has highlighted that exposure to ACEs during sensitive periods in development may have worse effects on health across the life course (Dunn et al., 2020; Nelson & Garbard-Durnam, 2020; Schaefer et al., 2022) while studies analyzing the impact of different ACE types on later outcomes have highlighted that not all ACEs are equally impactful, meaning exposure to some ACE types may be more deleterious than exposure to others (Cutajar et al., 2010; Humphreys et al., 2020; McLaughlin et al., 2014). Thus, it is important to investigate the nuances of ACE co-occurrence across development to inform targeted, time-specific and ACE-specific interventions, which may be more effective than intervening based on cumulative ACE scores alone (McLaughlin et al., 2021).

Building on these points, we investigated the nuances of ACE co-occurrence across development using data from three longitudinal birth cohorts collected in three different countries: (1) the Avon Longitudinal Study of Parents and Children (ALSPAC; U.K.; $N = 14{,}308$), (2) the Generation R Study (GenR; The Netherlands; $N = 7{,}459$), and (3) the Drakenstein Child Health Study (DCHS; South Africa; $N = 1{,}037$). By selecting two European-based cohorts from upper-middle income countries (ALSPAC and GenR) and one cohort from a lower-middle income country (DCHS), we could investigate ACEs within three distinct populations and make cross-cohort comparisons about ACE co-occurrence in different cultures and contexts. In each of the three cohorts, we selected prospective measures of eight types of ACE exposure assessed consistently from birth to age 10 to characterize the prevalence, persistence, and co-occurrence of ACEs in childhood. Our investigation into patterns of ACE co-occurrence across development can elucidate when in development ACEs are most prevalent and tend to co-occur, which ACE types tend to co-occur most frequently, and which ACEs tend to persist over time. These findings can help inform future research into targeted interventions for specific developmental periods when ACE co-occurrence is most common, for ACE types that tend to co-occur, and for timepoints when ACEs are most prevalent to help improve health outcomes across the life course for individuals exposed to ACEs.

2. Method

2.1. Participants

2.1.1. Cohort Selection

We selected the ALSPAC, GenR, and DCHS cohorts for our investigation as all three are unique population-based birth cohorts with repeated, time-specific (i.e., prospective) measures of childhood adversity across development. Such measures were essential for our investigation, as they allowed us to map ACE prevalence, persistence, and co-occurrence in the cohorts across childhood, adding a level of specificity not captured with retrospective or cross-sectional reports. All cohorts also recruited participants from the general population, adding to existing research that primarily focuses on high-risk clinical samples. Finally, we chose these cohorts to allow for broader cross-cohort comparisons. While the cohorts share rigorous sampling and assessment methodology, they each have distinct socio-demographic profiles due to their differing geographical locations and cultural background, as summarized in detail below. See Table 1 for more details on each of the cohorts' socio-demographic profiles.

2.1.2. ALSPAC

The Avon Longitudinal Study of Parents and Children (ALSPAC) is a prospective, population-based longitudinal birth cohort in the United Kingdom (U.K.) designed to investigate genetic and environmental determinants of health across the lifespan (Boyd et al., 2013; Fraser et al., 2013). Pregnant women living in the county of Avon, U.K. (located in the southwest of England) with expected dates of delivery between 1st April 1991 and 31st December 1992 were invited to participate. Of the 14,541 enrolled participants, there were 14,062 live births and 13,988 children alive at 1 year of age. There was an effort to bolster the initial sample after enrolled participants were approximately 7 years old and approximately 1,000 additional children were included. Thus, the total sample of data collected after age 7 for children alive at 1 year of age is 14,901. We analyzed data from 14,308 singleton children alive at 1 year of age with at least one datapoint available. ALSPAC is a predominantly White cohort (78.1%) with high levels of maternal educational attainment at the time of pregnancy (29.2% of the sample completed O level, equivalent to a high school degree, 10.9% completed a degree or more) and middle-class socioeconomic status. On average, mothers included in the cohort had higher indicators of socioeconomic position than the comparable population of British women at the time of study enrollment (Fraser et al., 2013). Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committee. Informed consent for use of data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time. Please note the study website contains details of all the data that is available through a fully searchable data dictionary and variable search tool: http://www.bristol.ac.uk/alspac/researchers/our-data/.

Table 1
Sample Demographics of the Avon Longitudinal Study of Parents and Children (ALSPAC), the Generation R Study (GenR), and the Drakenstein Child Health Study (DCHS).
* Indicates different categories across the 3 cohorts.

	ALSPAC (N = 14,308)	GenR (N = 7459)	DCHS (N = 1037)
	N (%)	*N (%)*	*N (%)*
Gender			
Female	6,976 (48.8%)	3,700 (49.6%)	505 (48.7%)
Male	7,332 (51.2%)	3,757 (50.4%)	532 (51.3%)
Missing	0 (0.0%)	2 (0.0%)	0 (0.0%)
Race/Ethnicity*			
1	11,174 (78.1%)	4,027 (54.0%)	571 (55.1%)
2	591 (4.1%)	644 (8.6%)	465 (44.8%)
3	2,543 (17.8%)	2,563 (34.4%)	1 (0.1%)
4	N/A	225 (3.0%)	N/A
Maternal Educational Attainment*			
1	3,635 (25.4%)	658 (8.8%)	77 (7.4%)
2	4,183 (29.2%)	3,027 (40.6%)	562 (54.2%)
3	2,727 (19.1%)	3,055 (41.0%)	333 (32.1%)
4	1,553 (10.9%)	719 (9.6%)	63 (6.1%)
5	2,210 (15.4%)	N/A	2 (0.2%)
Maternal Birth Age			
Age 15–19	648 (4.5%)	226 (3.0%)	71 (6.8%)
Age 20–35	12,021 (84.0%)	6,278 (84.2%)	876 (84.5%)
Age 36+	944 (6.6%)	953 (12.8%)	90 (8.7%)
Missing	695 (4.9%)	2 (0.0%)	0 (0.0%)
Birthweight			
Very low	74 (0.5%)	47 (0.6%)	23 (2.2%)
Low	515 (3.6%)	362 (4.9%)	127 (12.2%)
Average	11,265 (78.7%)	6,083 (81.6%)	850 (82.0%)
Above average	1,588 (11.1%)	952 (12.8%)	35 (3.4%)
Missing	866 (6.1%)	15 (0.2%)	2 (0.2%)
Gestational Age			
Extremely preterm (<28 weeks)	0 (0.0%)	14 (0.2%)	0 (0.0%)
Very preterm (<32 weeks)	88 (0.6%)	37 (0.5%)	20 (1.9%)
Moderate preterm (<34 weeks)	93 (0.7%)	46 (0.6%)	27 (2.6%)
Late preterm (34–37 weeks)	505 (3.5%)	332 (4.5%)	115 (11.1%)
Full term (≥37 weeks)	12,927 (90.3%)	6,975 (93.5%)	875 (84.4%)
Missing	695 (4.9%)	55 (0.7%)	0 (0.0%)
Birth Order			
First child	5,658 (39.5%)	4,225 (56.6%)	378 (36.5%)
Second or later	6,939 (48.5%)	2,975 (39.9%)	654 (63.1%)
Missing	1,711 (12.0%)	259 (3.5%)	5 (0.5%)

Race/Ethnicity:
ALSPAC: 1 = White; 2 = Non-White; 3 = Missing.
GenR: 1 = Dutch; 2 = Non-Dutch Western; 3 = Non-Western; 4 = Missing.
DCHS: 1 = Black African; 2 = Mixed Ancestry; 3 = Missing.
Maternal Education Level:
ALSPAC: 1 = Less than O Level; 2 = O Level; 3 = A Level; 4 = Degree or above; 5 = Missing.
GenR: 1 = Low; 2 = Medium; 3 = High; 4 = Missing.
DCHS: 1 = Primary; 2 = Some Secondary; 3 = Completed Secondary; 4 = Any tertiary; 5 = Missing.

2.1.3. GenR

The Generation R Study (GenR) is a population-based, propsective, multi-ethnic cohort from fetal life onward based in Rotterdam, The Netherlands (Kooijman et al., 2016). The study aims to identify early environmental and genetic factors and causal pathways underlying growth and development during childhood. Pregnant mothers in Rotterdam, The Netherlands, were eligible to enroll if they had a delivery date between April 2002 and January 2006. In total, 9,778 mothers were enrolled in the study and 9,877 children were alive at 1 year of age. We analyzed data from 7,459 singleton children alive at 1 year with at least one datapoint available. Rotterdam was selected for the GenR study due to its multi-ethnic composition (the city of Rotterdam has inhabitants from almost 150 different ethnicities). The study sample is largely representative of the underlying population of Rotterdam, which is the second largest city in the Netherlands, although included participants are more likely to have a higher educational level and income relative to the general population of Rotterdam. Like ALSPAC, GenR is a European based study, but is relatively ethnically diverse, with 54% of participants having Dutch ancestry, 8.6% of participants having non-Dutch Western ancestry, and 34.4% having non-Western ancestry. Ethics approval was obtained from the Medical Ethical Committee of Erasmus MC (MEC-2012-165). Written informed consent was obtained from all participants' parents on behalf of their children.

2.1.4. DCHS

The Drakenstein Child Health Study (DCHS) is a longitudinal birth cohort study based out of the Drakenstein sub-district of the

Western Cape, South Africa, about 60 km outside of Cape Town, the legislative capital and second-largest city in South Africa (Stein et al., 2015; Zar et al., 2015; Zar et al., 2019). The study was initiated with the aim of comprehensively investigating the early-life determinants of child health in an impoverished area of the world. Pregnant women over age 18 who were accessing one of the two primary care clinics in the area were eligible to participate. A total of 1,143 pregnant mothers were enrolled at 20–28 weeks gestation from March 2012 to March 2015. We analyzed data from 1,037 singleton children alive at 1 year of age. The DCHS cohort is distinct from both ALSPAC and GenR, as it is based out of South Africa and comprised of Black African (55.1%) and mixed ancestry (44.8%) mother/child dyads. The DCHS cohort is representative of many peri-urban regions in South Africa and other Low- and Middle-Income Countries, with lower socioeconomic status and maternal educational attainment than ALSPAC and GenR and higher rates of psychosocial risk factors on the population level (Stein et al., 2015). Written informed consent from mothers is renewed annually. The study was approved by the Human Research Ethics Committees of the Faculties of Health Sciences of the University of Cape Town and Stellenbosch University, and by the Western Cape Provincial Research committee.

2.2. Measures

2.2.1. ACE constructs

The term ACEs classically includes a set of ten childhood exposures (Felitti et al., 1998). For our investigation, we focused on eight of the ten classic ACEs: physical, sexual, and emotional abuse; parental mental illness, intimate partner violence, parental separation, parental criminal involvement, and parental substance use (Felitti et al., 1998). We did not include physical and emotional neglect. These two constructs were difficult to reliably quantify, as the items administered for parents to report on instances of neglect varied significantly across cohorts. Additionally, neglect was not measured consistently over time in the three cohorts.

Leveraging the data available across the three cohorts, we selected established questionnaires, single items, or groups of items from specific questionnaires to operationalize each of the 8 ACE constructs as they were defined by Felitti et al. (1998) in their seminal paper on ACEs. We selected measures of *physical abuse* that capture instances of a child being physically harmed, beaten up, slapped, pinched, etc. in their home. *Sexual abuse* included measures on the child being forced do something sexual or being sexually abused in the home environment or elsewhere. *Emotional abuse* measures captured experiences of threatened harm (e.g., "Someone in your house threatened to kill this child"), emotional cruelty, and name calling in the home environment. *Parental mental illness* measures captured instances of parental psychopathology and psychological symptoms, such as depression and suicidality. *Intimate partner violence* measures referred to instances of physical harm between caregivers, such as hitting or using weapons. *Parental separation* measures captured both separation and divorce in the last year, as both quantify household disruption. *Parental criminal involvement* measures focused specifically on parents going to prison or being "in trouble with the law". *Parental substance use* measures captured problematic alcohol use and any use of illicit drugs by either parent. All ACE measures were completed by caregivers reporting on their child.

2.2.2. Time specific exposures

Time-specific measures of ACEs are important to our investigation, as patterns of ACE prevalence and co-occurrence may be time-dependent. Therefore, we focused on ACE measures that were measured prospectively, meaning items asking about adversity exposure within the last two years or with a specified age when the adversity occurred (e.g., in the past 18 months; in the past year; since the child's second birthday). By only including prospective measures of ACE exposure, we increased the likelihood each exposure captured was confined to a specific developmental period.

2.2.3. Measure selection and cross-cohort harmonization

In ALSPAC, we compiled ACE measures following the comprehensive list of childhood adversity measures administered from pregnancy to adulthood compiled by Houtepen et al. (2018), which were rigorously constructed based on established ACE definitions. We then selected items in GenR and DCHS that aligned with those available in ALSPAC as well as with the established ACE definitions. ACE measures in GenR and DCHS were aligned to definitions provided by Houtepen et al. (2018) to extend published research on childhood adversity in the ALSPAC cohort (the largest cohort we analyzed) and ensure comparability between cohorts as well as with the existing literature on ACEs. Overall, we aimed to operationalize each ACE construct as closely to the original ACE definition as possible, while also ensuring harmonization across cohorts to facilitate cross-cohort comparisons of ACE constructs. Of note, intimate partner violence and parental criminal involvement data were only examined in ALSPAC and DCHS, as items on these constructs were unavailable in GenR. For a full list of the items used to operationalize each ACE from each of the cohorts, see **Table S1.**

2.2.4. Binary exposure indicators

As the goal of our investigation was to understand the co-occurrence of ACEs across development, regardless of severity, we operationalized ACE exposure using a binary "never vs. ever" approach at each timepoint (0 = child was unexposed, 1 = child was exposed). If a child was exposed to any of the items used to operationalize a particular ACE category, they were coded as exposed for that timepoint. If they were not exposed to any of the items used to quantify that particular ACE category at a specific timepoint, they were unexposed. This binary approach ensured parsimony in our analyses and simplified cross-cohort comparisons, as no comparable ACE severity measures were available across all three cohorts. Detailed reports of the specific items used to operationalize each ACE construct can be found in **Table S1**.

2.2.5. Measurement timepoints

Each cohort administered adversity measures at different time periods. In ALSPAC, adversity measures were administered most

Table 2
Measurement Timepoints for ALSPAC, DCHS, and GenR, Grouped by Year.

ACE Category	Cohort	0-1 year	1+ to 2 years	2+ to 3 years	3+ to 4 years	4+ to 5 years	5+ to 6 years	6+ to 10 years
Physical Abuse	**ALSPAC**	8m	21m	33m	47m	61m	73m	110m
	GenR			36m				96m, 120m
	DCHS				42m	54m	72m	96m
Sexual Abuse	**ALSPAC**		18m	30m	42m	57m	69m	81m, 103m
	GenR							120m
	DCHS				42m	54m	72m	96m
Emotional Abuse	**ALSPAC**	8m	21m	33m	47m	61m	73m	110m
	GenR			36m				96m, 120m
	DCHS				42m	54m	72m	96m
Parental Mental Illness	**ALSPAC**	8m	21m	33m		61m	73m	97m, 110m
	GenR	2m, 6m		36m				120m
	DCHS	10wk, 6m, 12m	18m, 24m	36m	48m	60m	72m	96m
Intimate Partner Violence	**ALSPAC**	8m	21m	33m	47m	61m	73m	110m
	Gen R							
	DCHS	10 wk, 6m, 12m	18m, 24m	36m	48m	60m	72m	96m
Parental Separation	**ALSPAC**	8m	21m	33m	47m	61m	73m	110m
	Gen R			36m			72m	120m
	DCHS	10wk, 6m, 12m	18m, 24m	36m	48m	60m	72m	96m
Parental Criminal Involvement	**ALSPAC**	8m	21m	33m	47m	61m	73m	110m
	Gen R							
	DCHS			36m	48m	60m	72m	96m
Parental Substance Use	**ALSPAC**	8wk, 8m	21m	33m	47m	61m	73m	110m
	GenR							120m
	DCHS	10wk, 6m, 12m	18m, 24m	36m	48m	60m	72m	84m

[a] Each timepoint category is inclusive of its endpoint. For example, the 0–1 year category includes all items measured up until 12 months, including the 12 month timepoint. The subsequent timepoint category, 1+ to 2 years, captures everything after 12 months up until 24 months, including the 24-month timepoint.

consistently, roughly every year from birth to age 10. In GenR and DCHS, data were collected with varying consistency across the different ACE categories. For instance, in GenR, data on ACEs were available at ages 3, 6, and 10, with additional parental mental illness data from 0 to 1 year of age. In DCHS, only household dysfunction data were available consistently from birth to age 8, while data on abuse were not available until age 3. To facilitate cross-cohort comparisons, measurement timepoints were grouped by year from age 0–6 and by 4 years from age 6–10 (Table 2).

2.3. Data analysis

All analyses were performed on a cohort-level in each cohort separately. This approach allowed us to understand ACE patterns specific to each individual cohort, and to compare population-level results across them. We did not perform a meta-analysis of the data due to large heterogeneity in cohort background and study methodology, as described above in the **Participants** section.

Across all three cohorts, there was variability in sample size over time due to missing data, as would be expected for any longitudinal study (Figs. 1 and S1). Missingness can increase over time in longitudinal cohorts for a variety of reasons, including attrition, as those who continue to participate are often more advantaged than those lost to drop-out, which in turn can increase selection bias (Howe et al., 2013). One analytic strategy to reduce bias and minimize efficiency even in the presence of substantial missingness is multiple imputation (Madley-Dowd et al., 2019). Therefore, we followed the multiple imputation by chained equations (MICE) approach outlined by Houtepen et al. (2018). We additionally included the following sociodemographic variables as auxiliary variables to improve imputation quality: sex, self-reported ethnicity, maternal birth age, birthweight, gestational age, birth order, and maternal education level. Considering the high rate of missingness for some variables, we generated 90 imputed datasets for each cohort with 20 iterations using the *MICE* package (van Buuren & Groothuis-Oudshoorn, 2011), as recommended by prior publications (White et al., 2011). We present results pooled from all 90 datasets using Rubin's rule (Rubin, 1987).

We conducted all analyses across multiply imputed datasets in several steps. First, to understand the overall level of exposure to adversity in each cohort, prevalence estimates of each ACE were calculated across all timepoints. Second, to understand the persistence of the same ACE over time in each cohort, we examined bivariate tetrachoric correlation patterns within each ACE type at adjacent

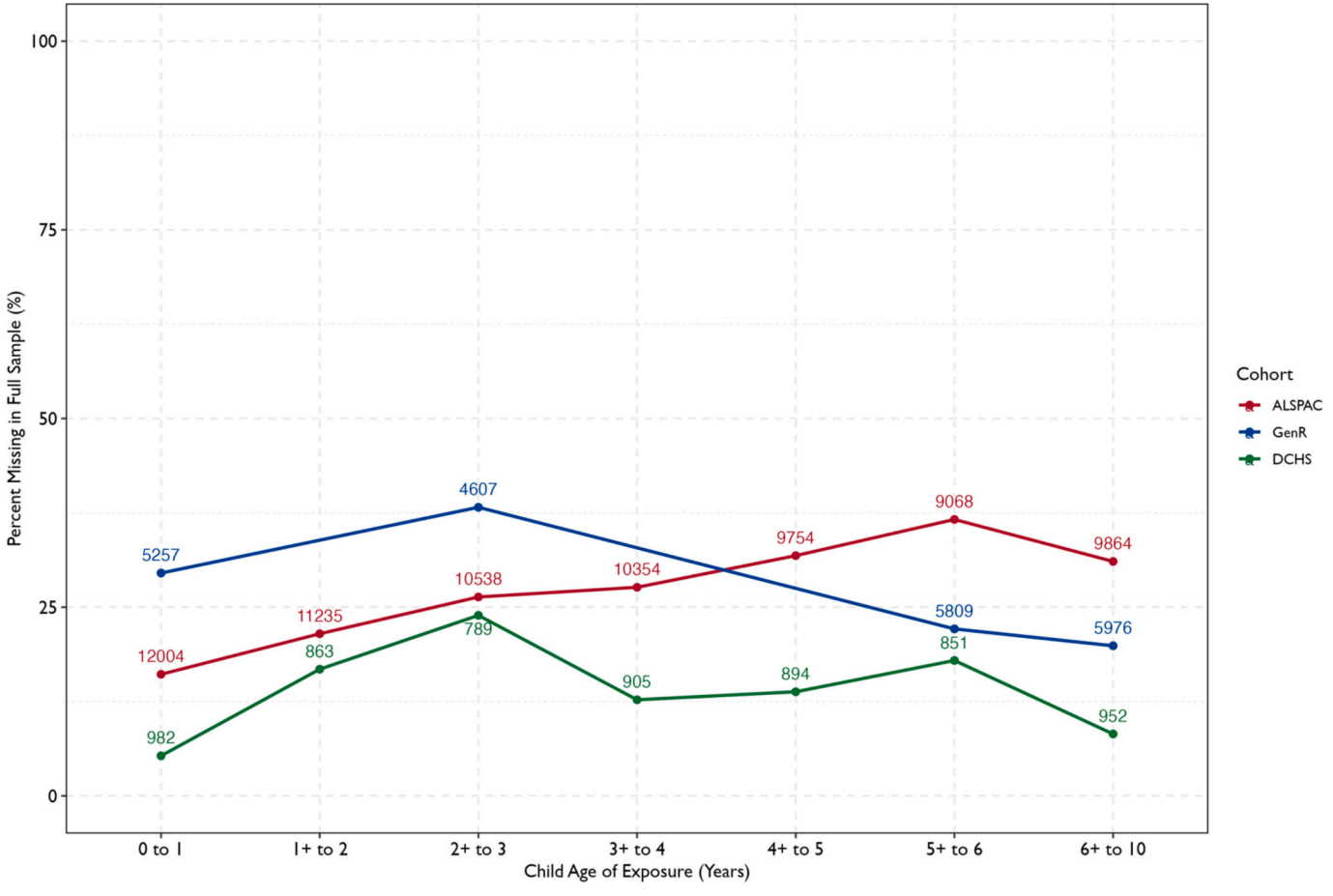

Fig. 1. Percent Missingness Over Time, By Cohort.
[a] Each timepoint category is inclusive of its endpoint (see Table 2 for more details). True sample sizes of participants with complete data at each measurement timepoint are included, rather than values derived through multiple imputation.

timepoints (e.g., the correlation between physical abuse at 0–1 year and physical abuse at 1–2 years). Of note, persistence of ACEs in GenR was not calculated due to the lack of measures of ACEs at back-to-back timepoints. Finally, to assess the co-occurrence of different ACEs across all developmental timepoints, we calculated tetrachoric correlations in each cohort. We examined the co-occurrence of different adversity types at the same timepoint in development (e.g., the correlation between physical abuse at 2–3 years and sexual abuse at 2–3 years) and across different developmental timepoints (e.g., the correlation between physical abuse at 2–3 years and sexual abuse at 6–10 years). All analyses were performed using R statistical software (R Development Core Team, 2011) and all figures were created using the *ggplot2* package (Wickham, 2016).

3. Results

3.1. How prevalent are ACEs?

ACE exposures were common in all three cohorts, with a substantial proportion of the caregivers in each cohort reporting their child experienced at least one ACE from birth to age 10 (Fig. 2). Specifically, the overall prevalence was the highest in DCHS, with at least one ACE exposure reported for 92.9% of the cohort over the study period. Overall ACE prevalence was lower in ALSPAC and GenR (63.5% and 67.3%, respectively).

Across all three cohorts, ACEs were most prevalent later in childhood. In ALSPAC, ACEs were most prevalent at ages 5+ to 6 years (31.2% exposed) while in GenR and DCHS, ACEs were most prevalent at ages 6+ to 10 years (40.6% exposed for GenR; 58.5% exposed for DCHS). ACEs were also highly prevalent early in childhood in DCHS, nearly just as prevalent at age 0–1 year (58.4% exposed) as at the 6+ to 10 year timepoint. The time-dependent prevalence estimates were higher overall and varied more substantially in DCHS (33.3–58.5%), followed by GenR (17.3–40.6%) and ALSPAC (21.4–31.2%). However, different sets of ACEs were measured across time-points in DCHS, which may drive variation in prevalence estimates across childhood. For instance, measures of physical, sexual, and emotional abuse were not introduced in the DCHS cohort until age 3+ to 4.

Patterns of prevalence over time also varied across the cohorts. In ALSPAC and GenR, prevalence estimates were more stable over time, with parental mental illness being the most commonly experienced adversity overall (9.8–16.0% in ALSPAC; 15.0–22.1% in GenR). In contrast, DCHS had more varying prevalence estimates, meaning the most prevalent ACE type depended on the timing of measurement. In early childhood, intimate partner violence was the most prevalent ACE in DCHS (35.4% at 0 to 1 year). In later childhood, parental physical and emotional abuse were the most prevalent (30.1% and 37.9%, respectively, at 6+ to 10 years). Parental substance use was consistently high across all timepoints in DCHS (11.0% to 21.2%). Of note, across all three cohorts sexual abuse was the least prevalent ACE (on average: ALSPAC = 0.2%, GenR = 2.1%, DCHS = 0.7%). However, sexual abuse is commonly underreported, especially by parents, which may partially explain its particularly low prevalence (Townsend, 2016).

3.2. Which ACE types are most persistent?

Comparing correlations between adjacent time points within each adversity in ALSPAC and DCHS, we found in general, ACEs capturing household dysfunction were more persistent over time in both cohorts (Fig. 2). Specifically, parental substance use was the most highly correlated across adjacent timepoints ($r = 0.80$–0.89 in ALSPAC; $r = 0.31$–0.56 in DCHS), reflecting that children exposed to current parental substance abuse may also be likely to be exposed to parental substance abuse in the subsequent timepoint. Exposure to intimate partner violence between caregivers was also more persistent than other ACEs at earlier time points ($r = 0.65$–0.79 before age 5 in ALSPAC, $r = 0.28$–0.56 before age 5 in DCHS). ACEs capturing direct victimization of the child appeared less persistent: sexual abuse was moderately correlated across time in ALSPAC ($r = 0.47$–0.66), and emotional abuse was the least highly correlated across time in DCHS ($r = -0.21$-0.40). Overall, when comparing across all ACE categories, the level of persistence between neighboring time-points (comparisons spanning 2 years for time points before age 5 and spanning 5 years for the last time point) was much higher in ALSPAC than DCHS (average $r = 0.68$ in ALSPAC and average $r = 0.33$ in DCHS).

Correlations between adjacent timepoints tended to be stronger at earlier timepoints and decreased in strength over time. For example, the correlation between intimate partner violence measured at the 0 to 1-year timepoint and the 1-to-2-year timepoint was 0.75 in ALSPAC and 0.56 in DCHS. However, between the 5+ to 6 year and 6+ to 10-year timepoint, the correlation for intimate partner violence dropped to 0.54 in ALSPAC and 0.19 in DCHS. This phenomenon was especially prominent in ALSPAC: for 6 out of 8 ACEs in ALSPAC, the lowest correlation across timepoints was observed at the last timepoint.

3.3. Which ACE types tend to co-occur?

The level of ACE co-occurrence was moderate in all three cohorts. Nearly all correlations between ACEs within and across time-points was below $r = 0.50$ (Fig. 3). The extent to which different ACE types co-occurred varied. Across all three cohorts, ACEs capturing direct victimization, specifically physical, sexual, and emotional abuse, were highly co-occurrent with each other *across* timepoints. Specifically, physical abuse and emotional abuse were most co-occurrent with each other across all timepoints ($r = 0.37$–0.82 in ALSPAC; $r = 0.21$–0.50 in GenR; $r = -0.06$-0.53 in DCHS), and sexual abuse and parental substance use were the least co-occurrent overall ($r = 0.03$–0.31 in ALSPAC; $r = 0.07$ in GenR; $r = -0.11$-0.37 in DCHS). (See Fig. 4.)

ACEs were particularly highly correlated with each other when measured at the same timepoints, while they were less correlated with different ACE types if those were measured a few years apart. For example, physical and emotional abuse were more highly correlated when both were measured at the 6+ to 10-year timepoint ($r = 0.75$ in ALSPAC; $r = 0.30$ in GenR; $r = 0.53$ in DCHS). This

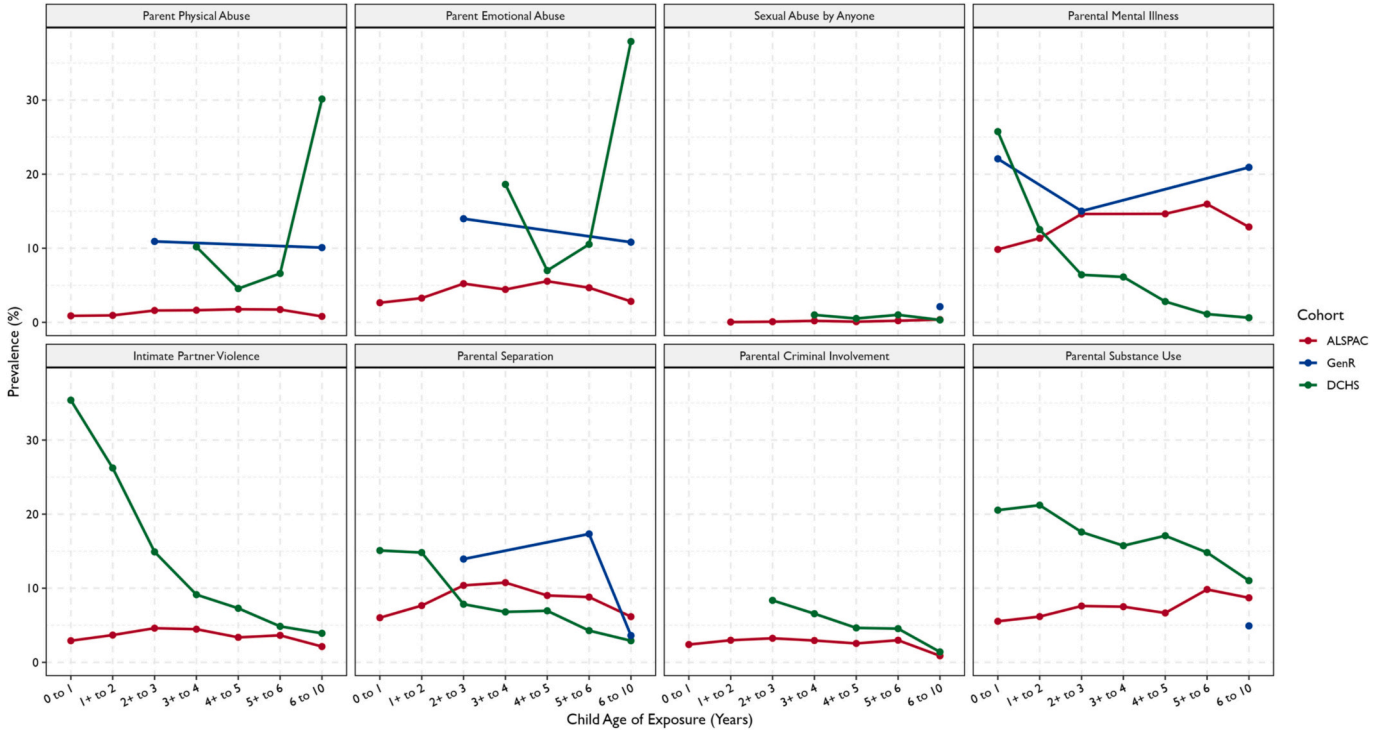

Fig. 2. Prevalence Estimates of ACEs Over Time, By Cohort.
[a] Each timepoint category is inclusive of its endpoint (see Table 2 for more details). All prevalence estimates were calculated in multiply imputed datasets. Of note, intimate partner violence and parental criminal involvement were not measured in GenR.

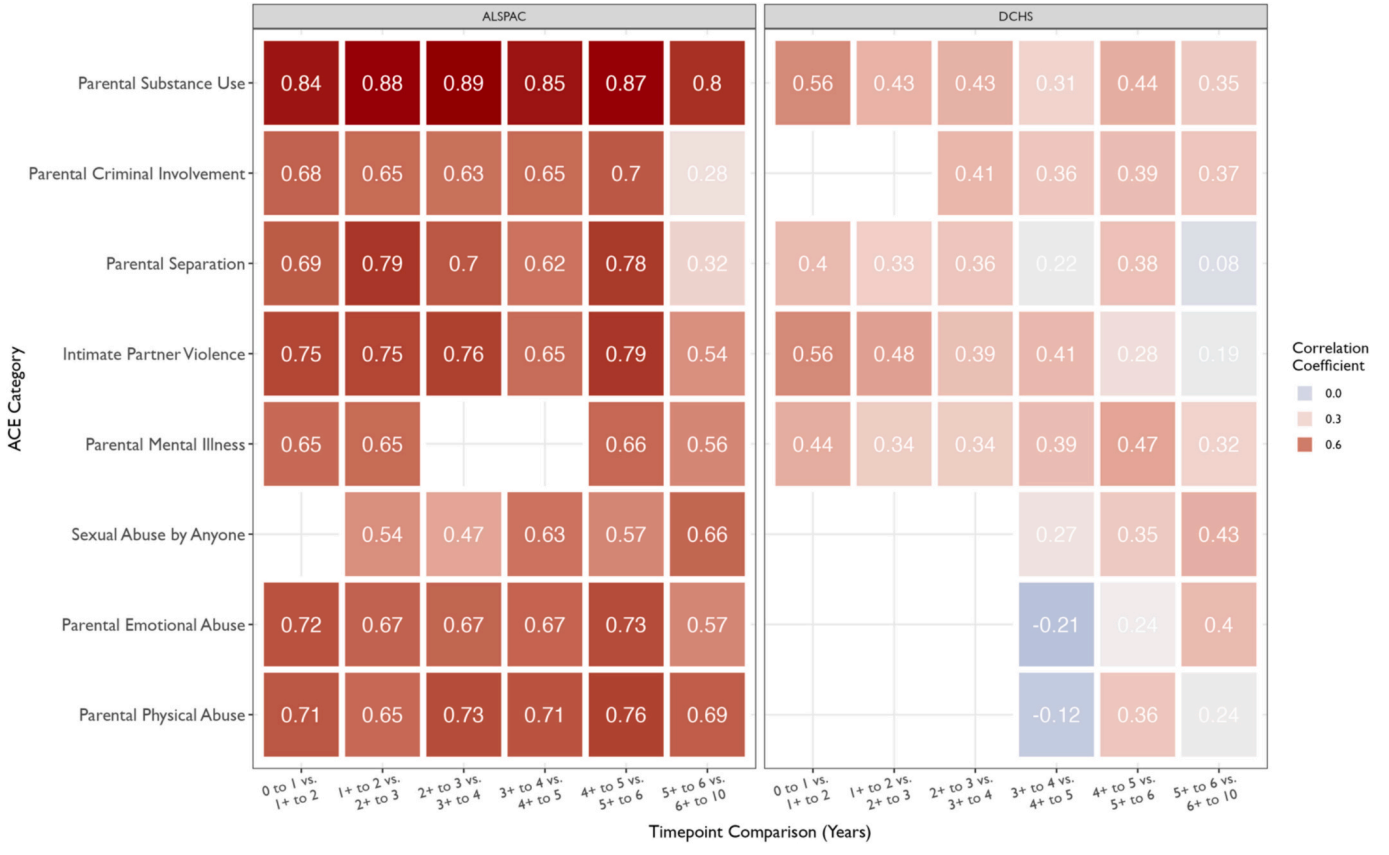

Fig. 3. Persistence of ACEs at Adjacent Timepoints in ALSPAC and DCHS.

[a] This figure shows the correlation between measures of the same ACE category at adjacent timepoints in ALSPAC and DCHS. GenR was not included in this figure due to the lack of measures of ACEs at 1-year adjacent timepoints in the cohort.

[b] While the term persistence is used, this figure demonstrates cohort-level correlations between adjacent timepoints (i.e. sample-level persistence over time). Thus, readers should note these are not necessarily the same individuals at each time point.

[c] Correlations of sexual abuse are unstable due to very small sample sizes of children exposed to sexual abuse at each timepoint.

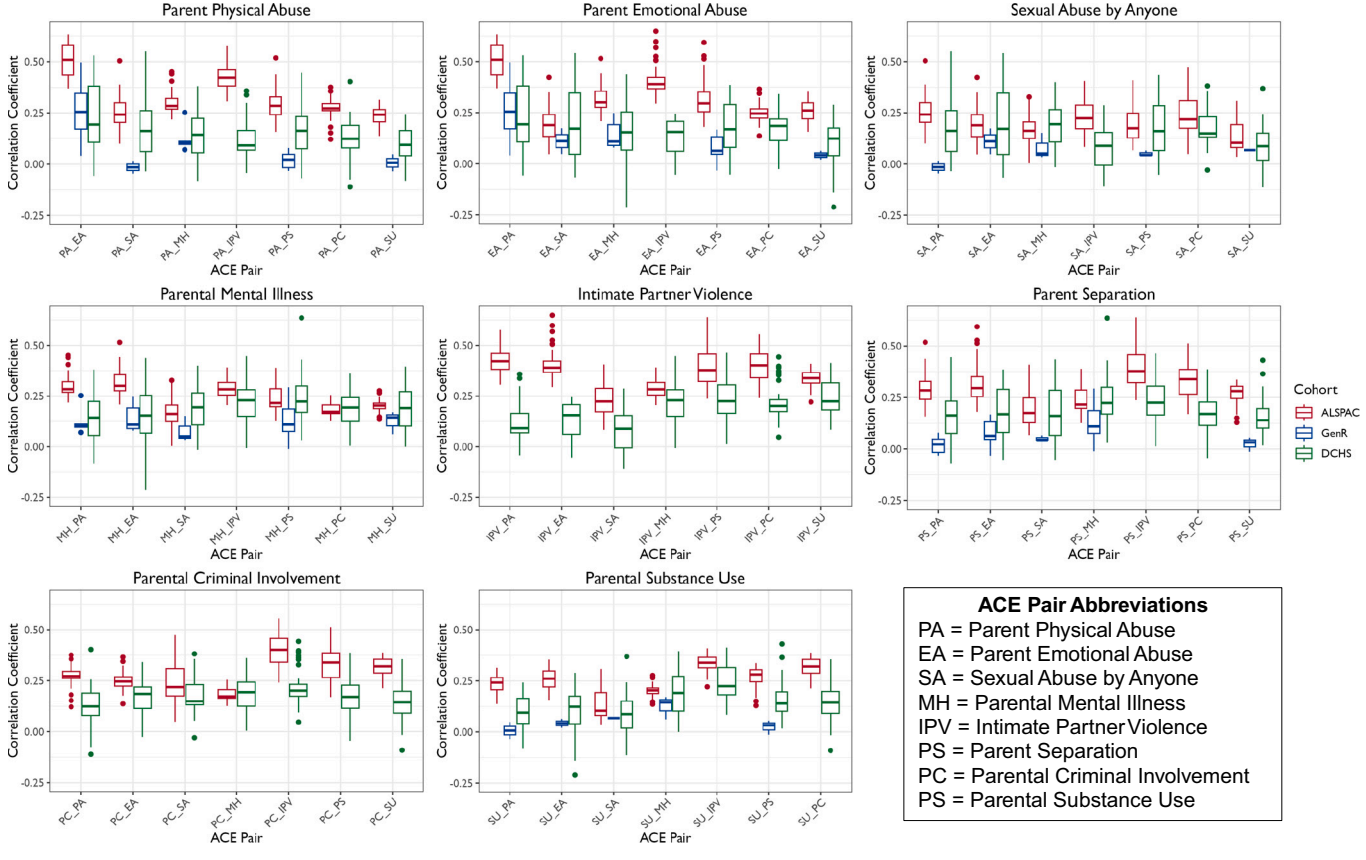

Fig. 4. Co-Occurrence of ACEs, Grouped by ACE Category.

[a]ACE Pairs listed on the X-axis refer to the tetrachoric correlations between ACE types. For example, PA_EA refers to the correlations between parent physical abuse (PA) and parent emotional abuse (EA).

[b]Correlations between ACE types are representative of all timepoints each ACE pairing was measured from 0-10 years.

correlation is considerably lower if we examine physical abuse at the earliest available timepoint and emotional abuse at the latest available timepoint ($r = 0.39$ in ALSPAC; $r = 0.04$ in GenR; $r = 0.02$ in DCHS). This pattern is well illustrated in the correlation matrices in our **Supplemental Materials (Figs. S2–S7)**.

Overall, ACEs capturing direct victimization, specifically physical, sexual, and emotional abuse, were most highly co-occurrent with each other within and across timepoints. In contrast, certain ACEs capturing household dysfunction, such as parental substance use and parental mental illness, showed lower co-occurrence with other ACE types. The highest co-occurrence between ACEs was seen in ALSPAC and the lowest levels of co-occurrence were observed in GenR.

4. Discussion

In this study, we took a detailed look at the assumption "ACEs tend to co-occur" by characterizing patterns of ACE correlations across childhood using data from three longitudinal datasets with prospective, repeated measures of ACE exposure. Our main findings indicated this statement may not be universally true. Rather, in research studies relying on parent reports of their child's exposure, ACE co-occurrence was moderate overall and varied by ACE type, developmental timing, and cohort. Thus, researchers and clinicians may need to challenge the assumption that all ACEs tend to co-occur and develop more nuanced understandings of how different ACE types occur across development and in different contexts. We draw this conclusion based on four main findings from this study.

First, we found that patterns of ACE co-occurrence varied by ACE type. ACEs capturing direct victimization, such as abuse, tended to be more highly co-occurrent than ACEs capturing household dysfunction, such as parental mental illness and parental substance use. Physical and emotional abuse tended to be the most highly correlated across all timepoints, while sexual abuse and parental substance use were the least co-occurrent overall. These findings are consistent with existing research. Results from prior latent class analyses have found that direct victimization and household dysfunction ACEs tend to emerge as separate latent classes, suggesting they may have different underlying mechanisms (Bussemakers et al., 2019; Merians et al., 2019; Shin et al., 2018). Additionally, previous investigations have found that physical and emotional abuse often form an underlying subtype of adversity due to their high levels of co-occurrence (Brown et al., 2019; Niño et al., 2023). However, the correlation estimates we found were not fully consistent with prior work. Even for our most highly co-occurrent exposures (physical and emotional abuse), correlation estimates were under 0.5 at most time points. Our correlation estimates were lower than prior studies relying on retrospective reports of adversity exposure across childhood, which have reported overall correlations above 0.6 (Dye, 2020; Gerdner & Allgulander, 2009) and concluded from those results that ACEs are highly co-occurrent. These findings suggest that investigating the patterns of ACE co-occurrence between different ACE types separately may be more accurate and may provide a more nuanced picture of ACE co-occurrence than considering the co-occurrence of all ACE types collectively.

Second, we found patterns of ACE persistence over time also differed by ACE type. Of note, high co-occurrence of different ACEs in the same timepoint was not necessarily reflective of their persistence over time. While ACEs capturing direct victimization were more co-occurrent than ACEs capturing household dysfunction, household dysfunction ACEs tended to persist more across multiple years of childhood. These differences in co-occurrence and persistence may reflect the differing nature of these ACE types. Household dysfunction ACEs, such as parental substance abuse or parental mental illness, may be more chronic in nature and persist across child development, reflecting systemic and structural psychosocial conditions that are difficult to effectively treat on the individual level (Anderson et al., 2023; Barnard & McKeganey, 2004; Smith et al., 2016). On the other hand, direct victimization ACEs, such as physical abuse, may capture more salient, episodic incidents; there are more effective prevention and intervention programs targeting these types of ACEs (van der Put et al., 2018). Thus, differences in persistence may be due to different underlying factors of direct victimization versus household dysfunction ACE types. Another possibility is that parent reports of child ACE exposure may vary over time, reflecting different comfort levels parents have in reporting ACEs, or changing conceptualizations of their child's experiences and what constitutes an ACE exposure. Future studies could apply cognitive interviewing (Beatty & Willis, 2007; DeCandia et al., 2020; Willis, 2005) to assess how ACE questions may be perceived by parents at different stages of their child's development and whether differences in perceptions may impact parent reporting of adversity exposures. Our findings that levels of persistence over time differed by ACE type further emphasizes that different ACE types may need to be considered separately, especially if trying to understand their differential impacts on health and development.

Third, we found the strength of correlations between ACEs varied based on developmental timing of assessment, with the correlations for physical and emotional abuse varying widely across development (e.g., $r = 0.37$–0.82 in ALSPAC). Overall, associations of different ACE types measured at the same timepoint tended to be more strongly correlated with each other than when measured at different timepoints years apart. Because we relied exclusively on repeated prospective measures of ACE exposure at different timepoints in development, we could detect these differences in co-occurrence levels both cross-sectionally and longitudinally. However, because many existing studies on ACE co-occurrence rely on retrospective reports of ACEs experienced throughout childhood, these developmental differences in co-occurrence may go undetected (Hardt & Rutter, 2004; Widom, 2019; Widom et al., 2004). Further, as all ACEs experienced are often considered cumulatively in these retrospective reports, our results suggest the true co-occurrence of ACEs may be overestimated. The differences we observed in ACE co-occurrence cross-sectionally versus longitudinally further solidify the importance of repeated ACE measures throughout development and the shortcomings of relying on single cross-sectional ACE scores or retrospective participant-reported assessments.

Finally, patterns of ACE prevalence, co-occurrence, and persistence differed across cohorts. ACEs were most prevalent in the DCHS cohort but were most highly co-occurrent and persistent in the ALSPAC cohort. The high prevalence of ACEs in the DCHS cohort was unsurprising, as the DCHS cohort was intentionally recruited from a higher-risk population in a lower-middle income country (LMIC) (Stein et al., 2015). Children in the DCHS cohort face multiple risk factors including high rates of poverty, substance use, and violence

in the community, as well as lower levels of maternal education, which place them at an increased risk of experiencing ACEs (Stein et al., 2015). Prior investigations into childhood adversity in South Africa have found similarly high rates of ACE exposure, both in prospective reports from children and adolescents (Meinck et al., 2015) and in retrospective reports from adults (Jewkes et al., 2010). While childhood adversity research to date has predominantly focused on high income countries, emerging evidence supports the cross-cultural relevance of ACEs and suggests ACEs may be even more common in LMICs (Hillis et al., 2016; Kidman et al., 2020; Slopen et al., 2010). Thus, the differences in prevalence, co-occurrence, and persistence of ACEs across the cohorts in our investigation may be driven in part by the broader sociodemographic contexts and economies of the counties in which these data were collected.

In addition to sociodemographic differences in the cohorts, differences in measurement timing and public understanding of childhood adversity may also account for some of the cross-cohort differences in ACE prevalence, co-occurrence, and persistence we observed. Pregnant women were recruited to participate in ALSPAC, GenR, and DCHS at different timepoints: 1991–1992, 2002–2006, and 2012–2015, respectively. Thus, the children in each of the three cohorts in our investigation were growing up at different timepoints in history. Perceptions of what constitutes childhood adversity and what caregivers were willing to report likely differed among the cohorts due to differences in public understanding of ACEs at the time when caregivers were reporting on their children's experiences. The seminal study on ACEs was first published by Felitti et al., 1998, and since then research on ACEs has proliferated, with more than half of all ACE publications from 1998 to 2018 being published between 2016 to 2018 ($N = 459$) (Struck et al., 2021). As more research on ACEs has been published, public understanding of ACEs has increased. Thus, caregivers' understanding and awareness of ACEs, as well as their willingness to report them may have differed across cohorts and over time.

Finally, the lower co-occurrence and persistence of ACEs in DCHS compared to ALSPAC despite the higher prevalence of ACEs in DCHS may have been a consequence of how ACEs unfolded in the sample. Given that 92.9% of the DCHS cohort experienced at least one ACE during childhood but did not experience high levels of persistence and ACE co-occurrence, this may mean that while more children in DCHS experienced ACEs, they may have switched in and out of exposure categories over time. This could explain the lower levels of persistence over time in the DCHS cohort but higher prevalence. On the other hand, ALSPAC is a less high-risk cohort; thus, children who were exposed to ACEs may comprise the same subset of children who were continually exposed across childhood, while more well-off individuals in the cohort remained unexposed. This could account for the higher levels of persistence and co-occurrence despite lower overall ACE prevalence. However, these differences in prevalence, persistence, and co-occurrence show low persistence does not necessarily mean low risk, and it is essential to consider the broader context in which children are growing up when determining which children may be at the highest risk for experiencing ACEs.

Collectively, our findings have several important implications for research and clinical practice. Our results suggest basic summary scores, meaning ACE counts, may not be the most appropriate method to understand ACE exposure across the life course. ACE counts are often used in research because they are easy to derive and interpret. They are also becoming increasingly used in clinical practice, due to recent policies incentivizing (or requiring) providers to use ACE counts as screening tools (Anda et al., 2020; Choi et al., 2023). A challenge of ACE counts is they prioritize the accumulation or cumulative risk model of ACEs; in other words, they presume all ACE types confer equal risk for the development of psychopathology, and due to their high levels of co-occurrence, should be considered cumulatively by calculating a sum ACE score (Evans et al., 2013). However, when cumulative ACE scores are calculated, levels of specificity in terms of ACE type, developmental timing, and sociodemographic context are lost. As we showed in this study, the patterns of ACE co-occurrence across development are more nuanced than a simple summary score. Therefore, measuring patterns of ACE frequency and duration are essential to better understanding the impact of ACEs on health and development. Researchers should adopt theoretical models in their work that consider the differential roles of different ACE types, such as the independent risk model, which examines each ACE type as an independent predictor of psychopathology (Cutajar et al., 2010), or the Dimensional Model of Adversity and Psychopathology (DMAP) approach, which groups ACEs by their underlying characteristics of either deprivation or threat to determine how they confer risk for psychopathology (McLaughlin et al., 2014; Sheridan & McLaughlin, 2014). Additionally, researchers and clinicians can consider the developmental timing of when ACEs occur and co-occur and explore potential sensitive periods for the effect of adversity (Dunn et al., 2020; Nelson & Gabard-Durnam, 2020; Schaefer et al., 2022). Finally, researchers and clinicians should consider the sociodemographic contexts that may impact the prevalence and co-occurrence of ACEs (Giano et al., 2020; Merrick et al., 2018), which are essential for developing effective intervention and prevention efforts. While there is no "one-size-fits-all" approach to measuring adversity exposure, moving away from the broad idea that "ACEs tend to co-occur" and towards efforts to capture the nuance of how ACEs unfold across the life course is essential to gain a more accurate understanding of how ACEs occur and thereby to develop precise prevention and intervention efforts.

4.1. Strengths and limitations

The present study has several strengths. We included a range of ACEs from the three cohorts and harmonized constructs across samples, providing a thorough investigation of ACE co-occurrence in childhood. Our analysis of longitudinal birth cohort data with repeated prospective measures of adversity from the same children from birth to age 10 reduced risk of recall bias and strengthened the conclusions drawn about the co-occurrence of ACEs. By studying three large birth cohorts ($N = 14{,}308$ in ALSPAC, $N = 7{,}459$ in GenR, and $N = 1{,}037$ in DCHS), our analyzes were well-powered and we could draw comparisons about ACE co-occurrence across diverse cultures and contexts. Lastly, we used multiple imputation to account for substantial missing data, which diminished possible selection bias and thus increased the possible generalizability of these results.

However, some limitations are noted. First, all analyses were conducted on a cohort-level, so findings reflect patterns of prevalence, persistence, and co-occurrence of ACEs on the population-level in ALSPAC, GenR, and DCHS. While these population level findings drawn from cohort-level tetrachoric correlations provide valuable insights to how ACEs unfold over the first 10 years of childhood in

each of three distinct cohorts, patterns of prevalence, persistence, and co-occurrence for specific individuals or sub-populations cannot be concluded. Thus, individual differences in ACE exposure, persistence, and co-occurrence are not thoroughly investigated and may have impacted our findings. Future studies utilizing methods such as meta-analysis or network analysis should continue to investigate individual differences in how ACEs unfold across development to provide additional insights into which groups within larger populations may be at greater risk for experiencing multiple ACEs or repeated ACE exposure across time. For example, Madigan et al. (2023) recently conducted a meta-analysis of moderators of ACEs using samples from 206 studies across 22 countries and found that higher ACE scores were more prevalent in minoritized populations. Second, due to inconsistencies in when and how ACEs were measured, we were unable to investigate ACE exposure at some timepoints where no exposure data were available (for example, DCHS did not collect abuse data in early childhood). We also relied on different items across time and across cohorts to measure ACE constructs. While we worked to optimize their harmonization according to established ACE definitions, the ACE constructs were not identically operationalized across cohorts given the constraints of secondary data analyses. Future studies seeking to replicate these findings should measure adversity exposure more consistently across development using widely validated childhood adversity measures based on established definitions of childhood adversity to ensure construct validity (Herrenkohl & Herrenkohl, 2009). For example, a recent meta-analysis by Matsumoto et al. (2023) analyzed the co-occurrence of childhood adversities in 11 studies measured using the Childhood Trauma Questionnaire, which ensured all adversities were operationalized in the same way, regardless of cohort. Third, we measured ACEs as binary exposures (coding participants as either exposed or unexposed) at each timepoint, rather than considering ACE severity. Our approach ensured parsimony and facilitated more straightforward comparisons across timepoints and across cohorts. Follow-up studies should investigate how the severity of exposures may impact co-occurrence patterns. Fourth, there was attrition in each cohort, which tended to increase over time and thus create smaller and varying sample sizes across timepoints analyzed. Attrition is common in longitudinal birth cohort studies and is heavily influenced by sample demographics, as participants who are more disadvantaged are less likely to continue to participate over time (Howe et al., 2013; Teague et al., 2018). A systematic review and meta-analysis of 143 longitudinal cohort studies found a mean missingness rate of 26.5% (SD = 20.1%) over 4.3 years (Teague et al., 2018). Across all three cohorts in our analysis, rates of missingness ranged from 5.3% to 36.6% with a mean missingness rate of 22.19%, thus in line with this prior meta-analysis. To mitigate the effects of missingness in each cohort, we used Multiple Imputation by Chained Equations, an established approach that alleviates missing data and helps mitigate selection bias that may be introduced through attrition (Madley-Dowd et al., 2019). Finally, our study focused entirely on caregiver reported ACE exposure. Triangulating reports from multiple respondents, such as both caregivers, teacher reports, or child self-reports could improve accuracy in reported ACE exposures, particularly in longitudinal birth cohort studies.

5. Conclusions

Overall, the findings of our study suggest ACE co-occurrence is not universal, at least for person-reported measures, but rather, depends on ACE type, developmental timing, and the sociodemographic context of the participants studied. ACE co-occurrence was also more moderate than suggested by previous investigations. Given these findings, researchers and practitioners should question the assumption "ACEs tend to co-occur" and consider adopting more nuanced approaches of measuring adversity to help clarify the links between adversity exposure and deleterious physical and mental health outcomes. We outline a variety of approaches for investigating adversity exposure researchers can use depending on the data available and the hypotheses they are investigating. By adopting any of these more nuanced approaches to assessing when and how ACEs unfold across development, researchers can better understand how ACEs confer risk for psychopathology and clinicians may gain greater insights for developing and disseminating targeted interventions.

Credit authorship contribution statement

Madison E. Bigler: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Isabel K. Schuurmans:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Yiwen Zhu:** Writing – review & editing, Visualization, Methodology, Investigation, Formal analysis. **Nitasha Siddique:** Writing – review & editing, Visualization, Investigation, Formal analysis, Conceptualization. **Nadia Hoffman:** Writing – review & editing, Investigation, Data curation. **Nastassja Koen:** Writing – review & editing, Investigation, Data curation. **Heather J. Zar:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation. **Dan J. Stein:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation. **Charlotte A.M. Cecil:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation. **Erin C. Dunn:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chiabu.2025.107315.

Data availability

Data are available from ALSPAC, GenR, and DCHS upon request and data use approval.

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