Potential of 'stacking' early childhood interventions to reduce inequities in learning outcomes

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ABSTRACT

Background Early childhood interventions are critical for reducing child health and development inequities. While most research focuses on the efficacy of single interventions, combining multiple evidence-based strategies over the early years of a child's life may yield greater impact. This study examined the association between exposure to a combination of five evidence-based services from 0 to 5 years on children's reading at 8–9 years.

Methods Data from the nationally representative birth cohort (n=5107) of the Longitudinal Study of Australian Children were utilised. Risk and exposure measures across five services from 0 to 5 years were assessed: antenatal care, nurse home-visiting, early childhood education and care, parenting programme and the early years of school. Children's reading at 8–9 years was measured using a standardised direct assessment. Linear regression analyses examined the cumulative effect of five services on reading. Interaction terms were examined to determine if the relationship differed as a function of level of disadvantage.

Results A cumulative benefit effect of participation in more services and a cumulative risk effect when exposed to more risks was found. Each additional service that the child attended was associated with an increase in reading scores (b=9.16, 95% CI=5.58 to 12.75). Conversely, each additional risk that the child was exposed to was associated with a decrease in reading skills (b=−14.03, 95% CI=−16.61 to −11.44). Effects were similar for disadvantaged and non-disadvantaged children.

Conclusion This study supports the potential value of 'stacking' early interventions across the early years of a child's life to maximise impacts on child outcomes.

INTRODUCTION

Inequities in early childhood health and development are differential outcomes that are unjust and preventable and systematically effect vulnerable populations.[1] Early childhood development lays the foundation for health and well-being over the life course.[2 3] Inequities emerging in early childhood often continue into adulthood, contributing to unequal rates of low educational attainment, poor physical and mental health, and low income in adulthood.[4] This generates substantial social costs across health, education and welfare budgets.[4]

Inequities in children's outcomes are particularly apparent in the academic domain.[5] Research has shown that the academic performance of socioeconomically disadvantaged 15-year-olds is on average more than 2 years behind that of their most advantaged peers.[6] Australian data from standardised national testing (reading and maths) have found an approximate 1-year difference in skill levels between disadvantaged and advantaged children in year 3, which increased to a 3-year gap by year 9.[7] Developmental trajectories are difficult to shift as children get older,[2 3] and the link between educational underachievement and poorer health, social and life-course outcomes is well documented.[8 9] Certainly, our ability to function in complex social and economic environments is significantly influenced by reading ability and literacy. Data also show that increasing reading ability has the potential to accumulate other educational advantages that can act to reduce equity gaps and ultimately better health and quality of life (eg, see refs. [10 11]). These data highlight the importance of the early years for reducing risk and optimising health and educational achievement.

Further evidence has shown that intervening early can produce positive, sustained effects on child outcomes, in particular for children from disadvantaged families.[12 13] This includes from interventions such as antenatal care (ANC),[14] nurse home visiting (NHV),[15] early childhood education and care (ECEC),[16] parenting programme (PP)[17] and the early years of school (EYS).[18] There is strong evidence demonstrating a positive effect when each of these interventions has been evaluated as a single-strategy intervention on specific aspects of child development/behaviour at a specific point in time.[19]

In addition, interest in the potential of 'stacking' such early childhood interventions simultaneously and sequentially over time is emerging.[20 21] Heckman and Mosso emphasises the importance of 'continuity' of services (the timing, duration and quality content of child health and development services) as well as the 'complementarity' of services (different types of services with diverse focus and target groups) as being necessary to promote human capital.[22] Targeting multiple health and educational interventions in the early life of a child therefore may exceed that of a single intervention strategy. This potential 'added benefit' to children who have access to more evidence-based services throughout early childhood offers important new directions for research and policy.

While limited, research seems to support the cumulative benefit of simultaneously applying multiple evidence-based interventions. For example, the Research-based Developmentally Informed

(REDI) project in the USA conducted a randomised control trial to examine the individual and combined effect of an enhanced classroom preschool programme and home visiting programme (designed to increase parent support for home learning) for disadvantaged children aged 4–5 years.[20] Both programmes were effective at improving child outcomes 3 years later, and the combination of preschool and the home visiting programme produced better learning outcomes compared with the preschool programme alone.[20]

In contrast to the paucity of research on the added benefit of stacking multiple interventions, there is large evidence base demonstrating that exposure to multiple risk factors can combine to magnify the negative effect seen from any singular risk.[23] Research has consistently demonstrated a dose-response relationship between the number of adversities a child is exposed to (cumulative risk) and poorer health outcomes in adolescence and adulthood across a range of outcome domains.[23 24]

Given the potential mutual benefit of continuity and complementarity of services to address inequity, we hypothesised that parent report of accessing multiple early years services would yield greater effect on child developmental outcomes compared with access to fewer services. It was also expected that cumulative service use would benefit children from disadvantaged families to a greater extent than for non-disadvantaged children because they potentially have more to gain from these interventions. In secondary analyses, we also examine the cumulative risk effect (ie, the effect of exposure to more risk associated with the five interventions) on child reading, with the expectation that there would also be a similar relationship in the opposite direction. We draw on data from the Longitudinal Study of Australian Children (LSAC) to estimate the effect of 'stacking' five health and education platforms/interventions—(ANC, NHV, ECEC, PP and EYS)—on reading at age 8 to 9 years.

METHODS

Data source

The LSAC is a nationally representative sample of two cohorts of Australian children—the birth cohort of 5107 infants, and the kindergarten cohort of 4983 children aged 4 years—each of which commenced in 2004.[25] The LSAC design and sampling methodology are described elsewhere.[25 26] In brief, a complex survey design was used to select a sample that was broadly representative of all Australian children except those living in remote areas. Data were collected on multiple aspects of child development as well as family and community characteristics, and multiple information sources were utilised including parent interviews, direct child assessments and observational measures, parent and teacher self-report questionnaires and linkage to administrative data sets.

The current study drew on data from the birth cohort (51.2% male), focusing primarily on parent-reported data regarding family characteristics and environment, collected when children were aged 0–1 (Wave 1; n=5107), 2–3 (Wave 2; n=4606) and 4–5 years (Wave 3; n=4386). We also drew on children's results from a direct assessment of academic skills at 8–9 years: the National Assessment Programme—Literacy and Numeracy (NAPLAN) conducted on all Australian students. NAPLAN was successfully linked for n=3790 (86.4%) of Wave 3 participants.[27] This retention rate (85.9%) between Waves 1 and 3 compares favourably with those achieved by other comparable overseas studies.[28]

Measures

Exposure measures

We explored the effect of stacking five health and education platforms/interventions, primarily delivered as services (hereafter referred to as services for brevity), shown to be effective at improving child outcomes: ANC,[14] NHV,[15] ECEC,[16] PP[17] and the EYS.[18] The services are evidence-based and satisfy the criteria of continuity across the early years (ANC, ECEC, EYS) as well as complementarity (NV, PP). Specifically they are ecologically focused (targeting the child and parent dyad), together capturing a relatively comprehensive view of the ecological context in which children live and grow and are able to be targeted or intensified to benefit the bottom 25%.[19]

Children's exposure to each of these services was measured in LSAC by parent reports of direct service use and/or proxies (eg, poor parenting practices that would reflect the target of a PP) related to each of the five interventions (table 1). Notably, the indicators used in this study are more modifiable (eg, maternal smoking during pregnancy, parenting styles) than other commonly used indicators (eg, marital status, disability status)[23 29] (see online supplementary file 1 for more details). Each service variable was coded in two different ways: service use measures (ie, was the service accessed) and risk measures (ie, inadequate number of ANC visits). Cumulative scores were derived using a count approach. Of note, the cumulative analysis conducted here does not take into account any sequential or weighted approaches to each service strategy.

Service use measures

Service use indicators for the other four interventions were binary (yes=accessed the service or no=no access) and did not include measures of dose (how often) or duration (how long). An exception was ANC, which was measured by the number of medical visits before birth. Following previous research,[30] the ANC indicator was dichotomised using the top 20th percentile for interpretability and represented women who accessed a relatively higher level of ANC than the rest of the cohort. In relation to EYS, all Australian children attend the compulsory school years (from age 6 years) and hence all children were coded as 'yes' for access to this service. A total service use score was created by summing the number of services accessed (ie, maximum score of 5) to represent the cumulative exposure to five services.

Risk measures

The number of risk indicators ranged from 1 to 4 for each of the five services. Some indicators were binary (yes or no) and other indicators were continuous (eg, hostile parenting scores) and were dichotomised at the top 20th percentile. A summed score was then created for each service. These overall risk scores for each service were then dichotomised (0=not at risk, 1=at risk). A cumulative risk score was created to reflect how many risks children and/or their parents were exposed to across all services. The cumulative risk metric ranged from 0 to 5, with 5 representing risks associated with all five areas.

Outcome measures

Reading skill

Based on the fact that educational attainment is an important social determinant of a child's lifelong health, we have selected an academic measure as our main outcome variable. Reading skill at 8–9 years was assessed using the reading subscale of the NAPLAN assessment. Students were provided with a selection of texts in different writing styles and answered questions reflecting

Table 1 Five services and their indicators related to service use and exposure to risk

	Service use			Risk		
Service	**Indicator**	**Age**	**Values**	**Indicator**	**Age**	**Values**
Antenatal Care (ANC)	Appropriate number of medical visits before birth	0–1 years	0=inadequate service use (<10 times of visits) 1=service use (≥10 times of visits)	Inadequate number of medical visits before birth*	0–1 year	0=not at risk (≥10 times of visits) 1=at risk (<10 times of visits)
				Maternal smoking during pregnancy†	0–1 year	0=not at risk (no smoking) 1=at risk (smoking)
				Overall risk‡	**0–1 year**	**0=not at risk (0 ANC risk) 1=at risk (one or two ANC risks)**
Nurse Home Visiting (NHV)	Received a maternal and child health nurse visit in the last 12 months	0–1 year	0=no service use 1=yes service use	Did not have maternal and child health nurse visit in the last 12 months*	0–1 year	0=not at risk 1=at risk
Early Childhood Education and Care (ECEC)	Attended a preschool programme	3–5 years	0=no service use 1=yes service use	Inadequate weekly hours at day care§	2–3 years	0=not at risk (>7 hours) 1=at risk (≤7 hours)
				Did not attend a preschool programme*	3–5 years	0=not at risk (attended a preschool programme) 1=at risk (did not attend a preschool programme)
				Inadequate material resources at centre§	4–5 years	0=not at risk (>4 scores) 1=at risk (≤4 scores)
				Inadequate space resources at centre§	4–5 years	0=not at risk (>3 scores) 1=at risk (≤3 scores)
				Overall risk‡	**2–5 years**	**0=not at risk (0 or 1 ECEC risk) 1=at risk (two or three or four ECEC risks)**
Parenting Programme (PP)	Attended a parenting programme in the last 12 months	4–5 years	0=no service use 1=yes service use	Did not attend a parenting programme in the last 12 months*	4–5 years	0=not at risk (attended a parenting programme) 1=at risk (did not attend a parenting programme)
				Parenting behaviours—high hostility†	4–5 years	0=not at risk (<4.33 scores) 1=at risk (≥4.33 scores)
				Parenting behaviours—low spontaneous praise†	4–5 years	0=not at risk 1=at risk
				Parenting behaviours—low consistency†	4–5 years	0=not at risk (>3.6 scores) 1=at risk (≤3.6 scores)
				Overall risk‡	**4–5 years**	**0=not at risk (0 or 1 PP risk) 1=at risk (two or three or 4 PP risks)**
Early Years of School (EYS)	Attended early years of school	4–5 years	0=no service use 1=yes service use	Low quality of work environment§	4–5 years	0=not at risk (>4 scores) 1=at risk (≤4 scores)
				Low communication between teacher and parent§	4–5 years	0=not at risk (<2.83) 1=at risk (≥2.83 scores)
				Overall risk‡	**4–5 years**	**0=not at risk (0 EYS risk) 1=at risk (one or 2 EYS risks)**
	Total Service Use	**0–5 years**	**0=no service 1=accessed one service 2=accessed two services 3=accessed three services 4=accessed four services 5=accessed five services**	**Cumulative risk¶**	**0–5 years**	**0=no risk 1=one service overall risk 2=two service overall risks 3=three service overall risks 4=four service overall risks 5=five service overall risks**

*Indicators of direct service use.
†Proxy indicators related to service quality.
‡Overall risk within each service was created by dichotomising the summed scores of indicators in that service with the top 20th percentile.
§Indicators of service quality.
¶Cumulative risk was created by summing the overall risk score of each service. Full details of each indicator are presented in online supplementary file 1.

their comprehension of the content, key messages and meaning of particular words or phrases. Rasch modelling was used to convert the raw reading scores into scaled scores ranging from 0 to 1000.[27] Scores on the NAPLAN reading domain at year 3 were used as an indicator of academic performance at 8–9 years in this study because reading is a fundamental literacy skill[31] and has a strong correlation with students' overall academic achievement.[27]

Family characteristics measures

Socioeconomic position

Socioeconomic position (SEP) at 0–1 year was measured as a composite of each parent's self-reported annual income, highest education and occupation level. Family SEP at 0–1 year was used given the salience of this period for children's development.[32] A continuous score was created: values for each parent's income, education and occupation variable were standardised to have a mean of zero and an SD of one.[33] An unweighted mean score was created by averaging the standardised scores, which was then re-standardised to have a mean of zero and an SD of one. The bottom 25% were categorised as 'disadvantaged' and the top 75% as 'not disadvantaged'

Potential confounders and additional covariates

Covariates were identified that were not mediators and were either a cause of the exposure, or of the outcome, or of both, but not an instrumental variable.[34] Child's sex was used as a potential confounder of the relationship between intervention exposure and reading outcomes, as previous studies have shown that females perform on average better than males in reading and gender can impact on child's likelihood of service attendance.[35] To ensure NAPLAN scores were directly comparable across children, additional covariates included whether the child had repeated a grade at school by the time of NAPLAN testing and age in months when NAPLAN testing occurred.[34]

Analytic approach

Multivariable linear regression analyses with ordinary least square method were conducted to examine the five services as predictors of children's reading skills at 8–9 years. First, models were run to examine the effect of each service on reading separately, considering each service from both a use and risk perspective, within each service (eg, for all ANC variables, not taking into account the other four service variables). All models, including those subsequently described, were adjusted for child sex, whether the child had repeated a grade and child's age.

Second, analysis was conducted to examine the effect of each service use and overall risk within each service, respectively, adjusting for the other four service use variables and overall risk. Finally, analysis was undertaken to examine the added benefit of five total service use variables and the cumulative risk effect across the five services (eg, using five total service use as a predictor). Specifically, the cumulative risk score and, separately, cumulative service scores were examined as predictors of reading outcomes in linear regression models. We were also interested in whether the relationship between cumulative exposure to five services and reading outcomes was different for disadvantaged and non-disadvantaged children; therefore, we included an interaction term (ie, the number of services used × disadvantage status) in the models.

All models were adjusted for SEP, potential confounders and additional covariates described above. The percentages of missing values for all variables ranged from 0% to 36.48%. All models were analysed using multiple imputation by chained equations under the missing at random assumption to produce 20 imputed data sets, with results combined using Rubin's rules.[36] The imputation model included all variables in the analysis model and four auxiliary variables (parent's age at birth, parent English proficiency, child's Aboriginal and/or Torres Strait Islander status and two parent household status) to help predict missing data. Analyses with multiple imputation showed similar results with analyses using the sampling weights as an alternative to accounting for sample attrition; the results from imputed data are reported throughout. Analyses were conducted with Stata V.15.1.

RESULTS

Participant characteristics

The LSAC B cohort is a representative sample of 5107 children, 51% male. The average age of children was 8.5 years and 5.2% of children had repeated a grade by the time of NAPLAN testing at year 3. The mean NAPLAN reading score was 429.32±1.97, with disadvantaged children having a significantly lower mean score than non-disadvantaged children (382.78±3.10 vs 444.92±1.92, p<0.01).

Participation in service use and exposure to risk

The proportion of children accessing services across the five services were ANC (70.2%), NHV (66.5%), ECEC (81.4%) and PP (7.7%). Disadvantaged children were less likely to access each of the services than non-disadvantaged peers: ANC (66.0% vs 71.6%, p<0.01), NHV (59.1% vs 69.0%, p<0.01), ECEC (75.7% vs 83.3%, p<0.01) and PP (5.5% vs 8.4%, p=0.01).

The proportion of children exposed to risk associated with each service ranged from 22.7% to 46.1% (ANC: 41.7%, NHV: 33.5%, ECEC: 22.7%, PP: 46.1%, EYS: 40.0%). A higher proportion of disadvantaged children had been exposed to risk related to each service than non-disadvantaged children: ANC (56.5% vs 36.8%, p<0.01), NHV (40.9% vs 31.0%, p<0.01), ECEC (26.7% vs 21.4%, p<0.01), PP (59.6% vs 41.5%, p<0.01) and EYS (43.5% vs 38.8%, p=0.03).

Likewise the distribution of total service use showed that a lower proportion of disadvantaged children utilised four services than their advantaged peers (31.9% vs 42.2%, p<0.05) (figure 1A) and the distribution of cumulative risk showed disadvantaged children had higher proportion of exposure to three risks (23.7% vs 16.8%, p<0.05), four risks (13.4% vs 5.6%, p<0.05) and five risks (3.7% vs 0.9%, p<0.05) (figure 1B).

Effect of participation in service use and exposure to risk on reading

Disadvantaged children had lower reading scores than non-disadvantaged children (mean=382.78±3.10, 95% CI=376.65 to 388.92 vs mean=444.92±1.92, 95% CI=441.13 to 448.70). When the cumulative service use indicator was examined as a predictor of reading outcomes, higher total service use scores were associated with higher reading scores. After adjusting for covariates, each additional service use was associated with an increase of 9.16 points on the literacy measure. From the risk perspective, we found that the overall risk of ANC, NHV and PP was associated with an average drop of 12.53, 14.38 and 29.23 points, respectively. However, when combining the overall risk across the five services, there was a similar pattern whereby higher total cumulative risk was associated with poorer reading scores (table 2).

We found no evidence that the effect of total service use/cumulative risk on reading outcomes differed depending on whether the child was disadvantaged or not.

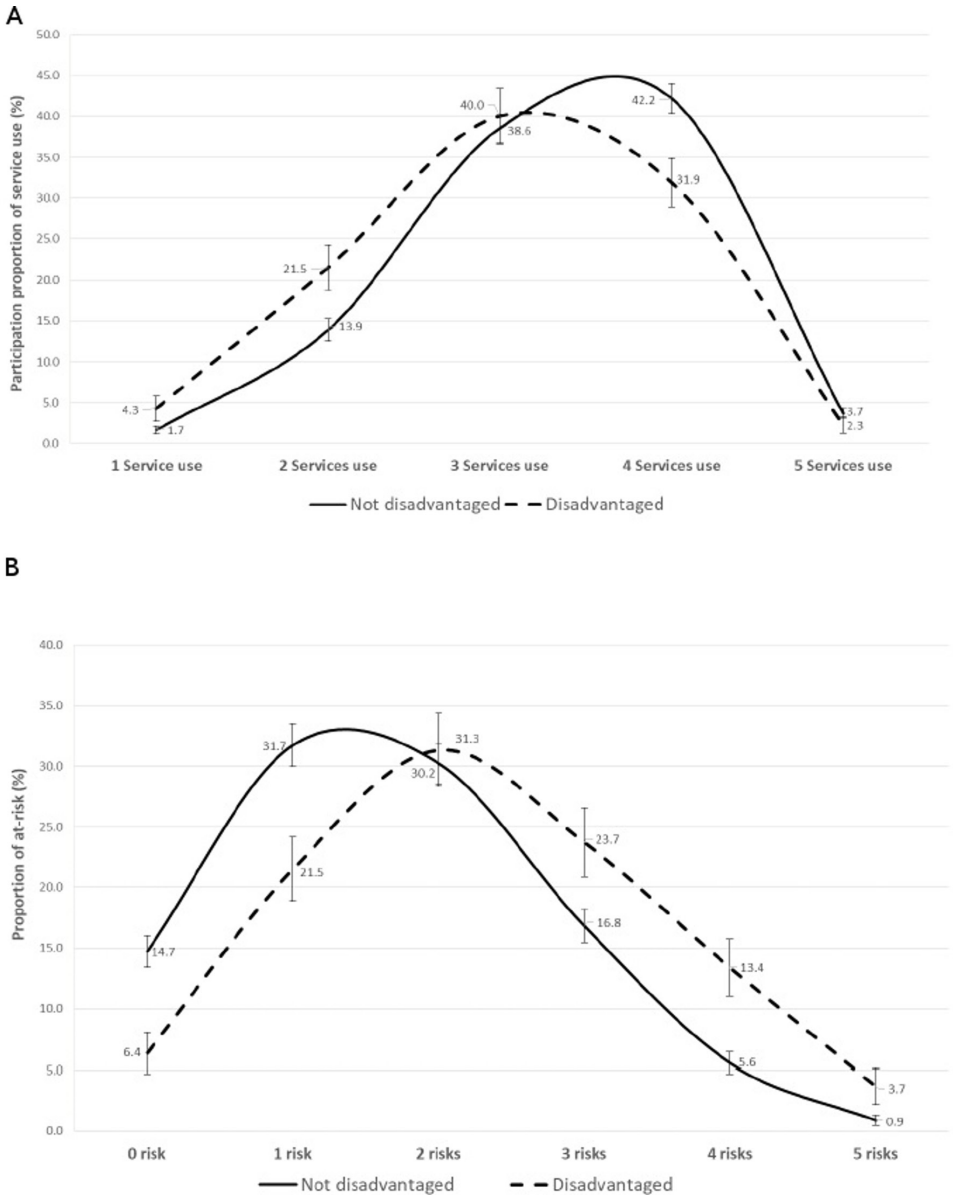

Figure 1 (A) Participation proportion of total service use. (B) Proportion of exposure to cumulative risk.

The interaction terms reflecting 'total service use × disadvantaged status' and 'cumulative risk × disadvantaged status' in each model had wide CIs overlapping zero (table 3).

DISCUSSION

This study utilised data from the LSAC to estimate the effect of 'stacking' five health and education services (ANC, NHV, ECEC, PP and the EYS) on reading at age 8–9 years. Two different approaches were utilised: direct service use (as a potential benefit) and exposure to risk (as a proxy for lack of service access). The indicators across the five services were selected from an ecological and a life course perspective, thus the total service use and cumulative risk variable captured a relatively comprehensive view of the ecological service context in which children live and grow. As hypothesised, the results suggest that children's reading scores at year 3 were higher after accessing more services and when exposed to fewer risks compared with those with lower service use and higher risks. This pattern of 'added benefit' from access to more services and 'cumulative risk' from exposure to more risks associated with five key early services was similar for disadvantaged and non-disadvantaged children, with no evidence of differential benefit.

Despite increasing policy and research interest in early childhood, this has mostly focused on single interventions or cumulative risk. However, our novel approach evaluates the 'stacking' effect of continuity (ANC, ECEC, EYS) and complementarity (NHV, PP) of service use. This aligns with findings from two recent studies, suggesting that combining early intervention strategies that target child and parent can result in better child academic outcomes beyond that of using a single intervention approach alone.[20 21] Combined with current findings, this reinforces the importance of both measuring and testing the cumulative benefit of early childhood interventions. Importantly, research has consistently demonstrated a strong link between early educational achievement and health throughout the life course.[37 38]

We also examined the effect of cumulative risk related to the five services. This cumulative risk approach has been widely used in child research to examine the adverse effect of intrapersonal, interpersonal and environmental risk factors on health and

Table 2 Linear regression models predicting reading scores at 8–9 years from service use and risk perspectives

	Service use		Risk	
Services	**Indicator**	**β (95% CI)**	**Indicator**	**β (95% CI)**
Antenatal Care	Appropriate number of medical visits before birth*	−0.84 (−7.41 to 5.72)	Inadequate number of medical visits before birth†	1.01 (−5.35 to 7.38)
			Maternal smoking during pregnancy†	−39.16 (−47.81 to −30.50)
			Overall antenatal care risk‡	−12.53 (−18.43 to −6.63)
Nurse Home Visiting	Had maternal and child health nurse visit in the last 12 months*	16.33 (9.05 to 23.61)	Did not have maternal and child health nurse visit in the last 12 months†	−17.33 (−24.49 to −10.17)
			Overall nurse home visiting risk‡	−14.38 (−21.63 to −7.14)
Early Childhood Education and Care	Attended a preschool programme*	14.16 (4.29 to 24.02)	Few weekly hours at day care†	0.09 (−10.51 to 10.69)
			Did not attend a preschool programme†	−14.58 (−24.98 to −4.18)
			Inadequate material resources at centre†	−9.01 (−18.31 to 0.28)
			Inadequate space resources at centre†	1.29 (−7.90 to 10.48)
			Overall early childhood education and care risk‡	−7.01 (−15.90 to 1.89)
Parenting Programme	Attended a parenting programme in the last 12 months*	3.27 (−9.06 to 15.59)	Did not attend a parenting programme in the last 12 months†	−4.18 (−16.28 to 7.91)
			Parenting behaviours—high hostility†	−16.90 (−24.76 to −9.05)
			Parenting behaviours—low spontaneous praise†	−23.58 (−31.27 to −15.89)
			Parenting behaviours—low consistency†	−27.48 (−35.97 to −18.98)
			Overall parenting programme risk‡	−29.23 (−36.03 to −22.44)
Early Years of School	Attended a programme of early years of school*	0 (omitted)	Low quality of work environment†	−4.11 (−12.58 to 4.36)
			Low communication between teacher with parent†	−11.84 (−19.66 to −4.01)
			Overall early years of school risk‡	−6.25 (−13.24 to 0.74)
	Total service use	9.16 (5.58 to 12.75)	Cumulative risk	−14.03 (−16.61 to −11.44)

All models were run separately, adjusting for child sex, whether child had repeated a grade, child's age in months at National Assessment Program—Literacy and Numeracy (NAPLAN) testing.
*Adjusted for all other four interventions' service use.
†Adjusted for all other intervention variables within each intervention.
‡Adjusted for all other four interventions' overall risk.

development outcomes.[23] However, few studies have specifically examined the cumulative effect of lack of access to early years services, that is, cumulative 'missing out'. It is clear from single intervention studies and population-based studies that children who miss out on early education opportunities lag behind their peers.[39] Our data suggest that this effect may be exacerbated if multiple early opportunities are missed. The results from this study are consistent with previous findings across early childhood research that suggests that higher cumulative risk relates to poorer developmental and health outcomes.[8 29]

Table 3 Linear regression models predicting reading scores at 8–9 years from service use and risk perspectives (including interaction terms)

	Reading scores at 8–9 years
Predictor	**β (95% CI)**
Model 1: Service use	
Child sex (0=male, 1=female)	12.89 (7.11 to 18.66)
Repeated grade (0=no, 1=yes)	−54.01 (−71.80 to −36.23)
Child age (continuous, months)	3.18 (2.50 to 3.87)
Disadvantaged status (0=no, 1=yes)	−67.27 (−96.77 to −37.77)
Total service use (ordinal, 1–5, 1=1 service, 5=5 services)	4.62 (0.64 to 8.61)
Disadvantaged status × total service use	3.36 (−5.88 to 12.60)
Model 2: Risk	
Child sex (0=male, 1=female)	12.48 (6.80 to 18.15)
Repeated grade (0=no, 1=yes)	−49.60 (−67.42 to −31.78)
Child age (continuous, months)	2.91 (2.23 to 3.59)
Disadvantaged status (0=no, 1=yes)	−48.14 (−63.39 to −32.90)
Cumulative risk (ordinal, 0–5, 0=0 risk, 5=5 risks)	−9.59 (−12.57 to −6.61)
Disadvantaged status × cumulative risk	−2.12 (−8.69 to 4.44)

We found that disadvantaged children were exposed to more risks with subsequent lower reading scores. Although disadvantaged children have a lot to potentially gain from services, we did not find evidence of an interaction effect of disadvantage and total service use/cumulative risk on reading. This suggests that while accessing more services seems to benefit all children, it does not translate to reducing the academic gap observed between disadvantaged and advantaged children by differentially benefiting them. Similarly, exposure to more risk factors does not appear to be more detrimental on reading outcomes for disadvantaged children.

There are at least two possible explanations for these findings. First, service quality was not examined in respect to the variable 'service use', it was simply a measure of access (yes or no). Evidence related to single interventions/early years services and their ability to close the inequity gap is variable. For example, several studies have reported that access to high-quality ECEC has stronger developmental benefits for children from disadvantaged backgrounds,[39] whereas others have found no support for this 'compensatory hypothesis'.[40] A possibility

is that what children are exposed to within a service across socioeconomic contexts are not the same. Second, only crude measures of participation were examined in the present study. All services except ANC were measured by parent report as a binary response (yes or no). Important factors such as dose and duration,[15 41] not measured here, may differ between the service experiences of disadvantaged and non-disadvantaged children. Thus, we were unable to test whether there was a differential benefit for disadvantaged children when exposed to the same services as advantaged peers, an important avenue for further research. Data related to ANC, ECEC and NHV in particular show that participation at a certain dose is important to see the benefits[15] and/or reduce risks.[42] However, studies have shown that the availability and quality of early childhood services vary as a function of socioeconomic status often to the detriment of communities with higher levels of disadvantaged.[43] Indeed, our analyses show that families from disadvantaged backgrounds access fewer services than children from more advantaged backgrounds, consistent with other national data sets (eg, ANC[44]). Understanding the reasons for poor or non-participation, particularly for disadvantaged families, is critical if communities and governments are to provide targeted, locally driven solutions, even to universal services. Important, since research shows that inequities in health and education often affect the same individuals and communities.[45]

The richness of data available across multiple early years services (ie, both access and risk variables) as well as the size and representativeness of the study sample enabled us to delve deeply into population variables that very few studies are able to accomplish. Nevertheless, there are a number of limitations that should be considered in the interpretation of these findings. First, as with any longitudinal study of this duration, there has been gradual attrition of the LSAC sample and this was greatest for the most disadvantaged children. We used multiple imputation to reduce (but cannot eliminate) the potential for selection bias arising from missing data.[25 46] Second, this is not a purpose-designed study and has not assessed the efficacy of 'stacking' interventions by randomised controlled trial, which nonetheless would likely be infeasible. Measurement of indicators across the five services is only approximate and the indicators do not allow analysis of other important factors such as quality and participation. The index of total service use/cumulative risk is additive based on an equal weight for each indicator; it is possible that services/risk factors differentially contribute to benefit/risk to reading.[47] Fourth, our research question focuses on cumulative benefit and risk, for which the relatively blunt service indicators are sufficient, but precludes in depth analysis of the relative merits of each intervention. It was beyond the scope of the current study to differentiate the relative impact of individual services, which may not be contributing equally to the overall picture, an interesting avenue for future research. Finally, it is not possible to determine causality from this data alone. For example, service attenders and non-attenders may be systematically different on other factors (eg, attitudes and beliefs) that in turn explains the association with children's reading.[48]

While previously intuitive, the finding that exposure to five early childhood services (mainly already existing) is related to better reading at age 8 years compared with access to fewer services could have an important policy and practice contribution. If future research also supports our premise that risks and benefits accumulate and disproportionately impact children/families living in disadvantage, there are opportunities to make a difference to the ongoing health and educational inequities for Australia's children. In particular, our data draw attention to the low participation rates for disadvantaged children even in universal services, suggesting governments and local communities need to better understand the barriers and implement effective solutions. Importantly, the five early years services examined here are typically already available in almost all Australian communities (and a version of these services is also available in many international contexts, particularly high-income countries), suggesting a ready-made opportunity for policy makers to consolidate on how these services/interventions are delivered and accessed. These data hold promise for approaches capitalising on system-wide and place-based initiatives that are potentially fertile ground for 'stacking' and testing evidence-based early health and education services/interventions. Similarly, place-based initiatives could also provide opportunities to explore the value of stacking with customised variables, including quality and participation dose and duration factors. We have used existing observational data to gain preliminary insights into potential impacts of stacking interventions on child development, strengthened by the temporal separation of exposures and outcomes. While a causal impact is plausible, further evidence will help to strengthen this interpretation. For example, methods based on a counterfactual framework such as propensity score matching[49] and causal mediation analysis[50] could be used to further explore the associations observed here. Triangulation with strands of different types of evidence, such as from RCT, will even further help to unpick causality.

CONCLUSION

Our study suggests that 'stacking' early years services that are continuous across the early years, evidence-based and include programme that are targeted to the most disadvantaged (complementarity of service) hold promise for maximising the impact on child educational attainment, important for health outcomes over the life course. Although 'stacking' these services failed to reduce the inequity gap between the least and most disadvantaged, this may be due to inadequate data on quality and participation dose and duration. Of concern is the finding that

What is already known on this subject

- Educational attainment is a social determinant of health and accumulates advantageously across the life course. Indeed, intervening early in children's lives lays the foundation for healthy development over the life course and is often the most cost-effective approach. Considered in isolation, a number of early childhood interventions have been found to be effective, but not sufficient to substantially close the gap in academic outcomes for disadvantaged children.

What this study adds

- This study demonstrates the potential that five early childhood interventions have a cumulative effect on reading skills by school entry. This suggests that researchers and policy makers should consider the potential value of purposefully 'stacking' through evidence-based health and education service delivery platforms for cumulative positive exposure over the early childhood years. Reducing educational and developmental inequities will likely influence health across the life course.

Policy implications

- Exposure to five evidence-based (and mainly already existing) early childhood services is related to better reading at age 8 years compared with access to fewer services.
- The five evidence-based services examined here are typically already available in almost all Australian communities (and a version of these services is also available in many international contexts, particularly high-income countries), suggesting a ready-made opportunity for policy makers to consolidate on how these services/interventions are delivered and accessed.
- These data hold promise for approaches capitalising on system-wide and place-based initiatives that are potentially fertile ground for 'stacking' and testing evidence-based early health and education services/interventions.

disadvantaged children attend fewer services than their advantaged peers. 'Place-based approaches' to community health and education are increasingly popular and signal a potential avenue for considering how systems might better stack interventions and test the impact of quality and participation dose across the early years of childhood.

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