Assessing the Impact of Screen Time on Children's Language, Educational Ability, and Social Functioning from Infancy to Age 8

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Executive Summary

Children today spend an unprecedented amount of time watching or interacting with screens. These widespread changes to how children and families spend their time have raised major concerns about potential impacts on children's health and development. To begin to address these concerns, the Ministry of Health released the first national screen time guidelines for children in 2017, and previous research using the *Growing Up in New Zealand* dataset has confirmed that adherence to these guidelines is associated with more favourable health and behavioural outcomes for children.

These previous findings provide preliminary evidence of the important influence screen time has in shaping children's development in contemporary New Zealand society, and suggest the need to consider a wider range of outcomes and the socio-contextual processes by which increasing screen time adversely impacts child outcomes. Two major aspects of child development critical to life-long wellbeing not yet addressed using the *Growing Up in New Zealand* dataset are language and educational abilities, and social functioning (e.g., peer relationships, social competence). Our research aimed to address this gap.

We examined screen exposure (television and electronic media) across early childhood in relation to later outcomes using data collected through the *Growing Up in New Zealand* study. Our first aim was to examine the impact of screen exposure (i.e., hours per day) on language, early educational skills, and social functioning. We examined the impact of screen exposure at different developmental periods as well as the impact of trajectories of exposure over time. Our second aim was to explicitly evaluate whether there was displacement of childhood social and sensory-rich experiences by screen exposure using a series of mediation analyses.

Our results indicate that higher levels of daily screen exposure in early childhood are associated with less optimal outcomes at ages 5 and 8. Children who spent more time on screens throughout early childhood (age 9 months through age 5 years) scored lower on measures of language and educational ability and higher on a parent-reported measure of peer problems. Further, children with high levels of screen exposure were less likely to be engaging in more socially and sensory-rich types of childhood activities. Our investigation of whether the impact of heightened screen exposure is due to reduced exposure to social and sensory-rich childhood experiences found only a very small effect of this mediated pathway. The findings of this research broadly support the continuation of existing national screen time guidelines.

Our results provide useful information for understanding the impact of screen media usage during early childhood, a developmentally sensitive period for laying the foundations of life-long trajectories of socio-emotional well-being and educational attainment. They also can inform further evidence-based policy relating to screen usage in early childhood.

Introduction

In the last decade, there has been a dramatic shift in how children and families spend their time. Children now spend an unprecedented amount of time watching or interacting with screens. Figures from the UK show that 81% of children had access to tablets at home in 2020, compared to 73% in 2015, and only 14% in 2012 (Ofcom, 2015; 2021), and 51% of infants aged 6-11 months were using a touch screen daily in 2017 (Cheung and Vota, 2016). In the US, pre-schoolers' use of mobile devices tripled between 2013 and 2017 (Rideout, 2017). Similar trends are observed in New Zealand, where the 2016/2017 New Zealand Health Survey found that 67% of 2- to 4-year-old children experience more than 2 hours of screen time per day (Ministry of Health, 2017a). Furthermore, research from the *Growing Up in New Zealand* (GUiNZ) study found that preschool children's electronic media use doubled between the ages of 2 and 4.5 years (Stewart et al., 2019).

These societal changes have raised major concerns about the effects of increasing screen exposure on children's health and development, both nationally and internationally (Canadian Paediatric Society, 2017; Madigan et al., 2019; 2020; Stewart et al., 2019). In 2017, in response to growing concerns about the adverse effects of excessive screen exposure in early childhood, the Ministry of Health released the first national screen time guidelines for children under 5. They recommended that children younger than 2 years of age have no sedentary screen time and children aged 2-5 years of age experience less than an hour per day (Ministry of Health, 2017b). Using GUiNZ data, Stewart et al. (2019) confirmed that children who adhered to these screen time guidelines had better health profiles than children who exceeded daily screen time guidelines. Children in families who did not adhere to the Ministry of Health's screen time guidelines at age 2 were more likely to be obese, had more illnesses, more doctor visits, poorer physical motor skills, and more hyperactivity problems at age 4.5 than children whose families did adhere to the guidelines (Stewart et al., 2019).

Further GUiNZ research by Corkin and colleagues (2021) showed that screen time was negatively associated with children's executive functioning, both concurrently and longitudinally. Specifically, total television exposure at age 2 was associated with poorer self-regulation assessed using a delay of gratification task at age 4.5 years. Eating meals in front of the television at age 4.5 was also associated with lower levels of inhibitory control at the same age. These findings provide preliminary evidence of the importance of screen time in shaping children's health and behavioural development in contemporary New Zealand society. They also suggest the need to consider a wider

range of outcomes and the socio-contextual processes by which increasing screen time adversely impacts child outcomes.

Major aspects of development critical to life-long wellbeing not yet addressed using the GUiNZ dataset are language and educational abilities, as well as social functioning e.g., peer relationships. Previous research has also focused on point-in-time measurements of screen time, without considering the patterns of screen usage that children are exposed to over time. Our research aimed to address these gaps.

Screen time may be detrimental to early language, educational, and social skills as a result of displacement of the social and sensory experiences necessary for their development. The more time that children spend watching TV or using electronic devices, the less time they have available for other activities beneficial to their development, such as face-to-face interactions with parents, siblings, and peers, reading books, and engaging with real-world activities such as museums, playgroups, and parks (Gentile et al., 2017; Khan et al., 2017; Lauricella et al., 2015; Vandewater et al., 2006). The Ministry of Health screen time guidelines sit within the larger context of "active play guidelines for under-fives", which emphasise the importance of play, movement, and exposure to a variety of environments, including cultural life and the arts (Ministry of Health, 2017b).

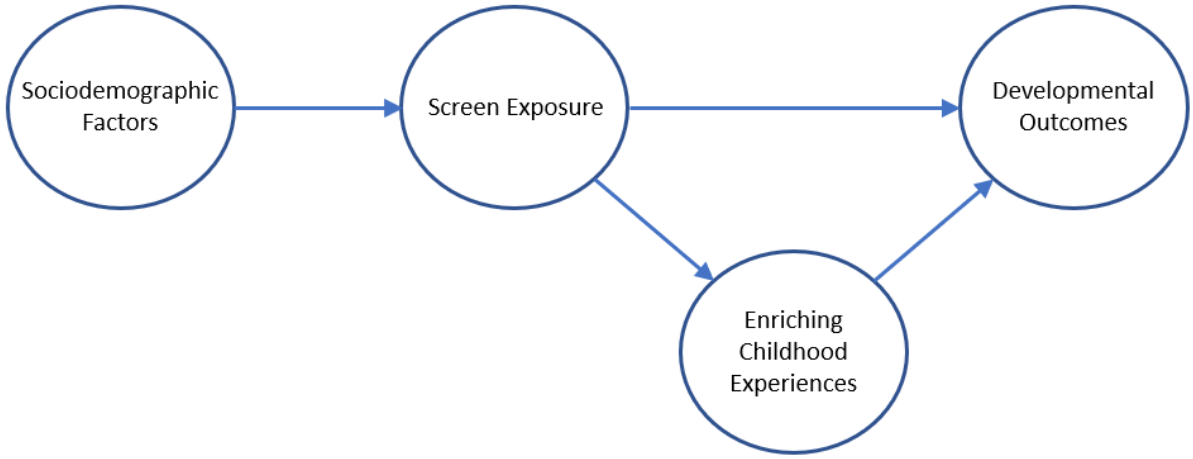
Exposing children to a diverse range of social and sensory-rich everyday experiences provides them with key contexts for developing their language, cognitive skills, and social understanding (e.g., Dewar, 2020; Kochanowski & Carr, 2014; MCC, 2020; Snow et al., 1994). For example, activities that require participation in social interactions with other adults and children (such as playgroups and extracurricular activities), in addition to immediate family members, will support the development of both language and social understanding (Carpendale & Lewis, 2004; Hoff, 2006), given the established importance of both adult-child conversations (Zimmerman et al., 2009) and peer interactions (Andresen, 2005) for language and social development in early childhood. Importantly, language development requires a communicative partner and cannot be learned through exposure via a digital device (Hoff, 2006). Similarly, face-to-face play has been shown to be critical for the social development of young children (De Klerk, 2020). For example, children learn less from on-screen models than live models (Anderson & Pempek, 2005) and are less likely to imitate the actions of an on-screen model compared to a live model (with imitation representing a crucial social learning mechanism for young children; Hayne et al., 2003).

The importance of these early experiences suggests that if quality social and sensory experiences are reduced or replaced due to time spent viewing screen media, there could be adverse consequences for children's early language, educational, and social development. Indeed, international data has linked the use of screen-based media with child language delay (Zimmerman et al., 2007; Lin et al., 2015), decreased readiness for kindergarten (Pagani et al., 2013), learning disabilities, and academic performance (Strasburger et al., 2010).

In terms of social development, Mistry et al (2007) found that sustained television viewing in 5-year-old American children was associated with aggressive behaviour and emotional reactivity and fewer social skills, including cooperation, assertion, and self-control. Similarly, Hu et al (2020) reported that passive screen time in a sample of 5-year-old Chinese children was negatively associated with social skills, including cooperation, communication, and empathy.

Thus, in the present analysis, we examined screen exposure across early childhood in relation to later outcomes using data collected as part of the *Growing Up in New Zealand* study. The first aim of this project was to examine the impact of screen exposure (i.e., hours per day) on language, educational, and social outcomes. In pursuit of this aim, we examined the impact of screen exposure at different developmental periods as well as the impact of trajectories of exposure over time. The second aim was to assess the extent to which heightened screen exposure was associated with a lower frequency of social and sensory-rich childhood experiences. We used a series of mediation analyses to determine whether screen exposure impacted child outcomes through this association with childhood experiences. Our over-arching conceptual model is shown in Figure 1.

Figure 1: Conceptual model of associations among screen exposure, enriching childhood experiences, and developmental outcomes



Our analyses include both 1) direct screen exposure (television/video viewing and electronic media use) and 2) indirect screen exposure (background television). We interpret the national guidelines as referencing direct screen exposure, given the terminology throughout the document of "sitting and watching" screens (Ministry of Health, 2017b). Thus, where appropriate our analyses focus on direct screen exposure. However, given previous research showing a negative association between background television and children's language development and social interactions (Anderson & Hanson, 2017; Madigan et al., 2020), and impacts of background television on the home linguistic environment (Anderson & Hanson, 2017; Christakis et al., 2009; Schmidt et al., 2008), we also included indirect screen exposure in our analyses.

The results of this research provide useful information for understanding the impact of screen media usage during early childhood, a developmentally sensitive period for laying the foundations of life-long developmental trajectories of socio-emotional well-being and educational attainment.

Methods

The data in this report were collected as part of the *Growing Up in New Zealand* (GUiNZ) prospective longitudinal study. A total of 6,822 pregnant women with an estimated delivery date between April 2009 and March 2010 were recruited from the Auckland, Counties Manukau, and Waikato District Health Board regions. See Morton et al. (2013; 2014) for a detailed description of the study's design, conceptual framework and recruitment procedures. In this report, we use data collected across five study waves, corresponding to the following child ages: 9 months, 2 years, 4 years (assessed at 45-months), 5 years (assessed at 54-months), and 8 years.

Measures

Daily Weekday Screen Exposure

At infant age 9 months, screen time was assessed with 3 items that asked mothers to report how often:

1. Is the TV turned on in the same room with your baby, whether or not your baby is watching?
2. Does your baby watch videos or DVDs?
3. Does your baby watch children's TV programmes?

Each item was rated on a scale of 1 (seldom), 2 (once a week), 3 (several times a week), 4 (once a day), or 5 (several times a day).

At all remaining study waves, daily screen time was measured in time per day (in hours and minutes) on a usual weekday. For example, at age 2, mothers were asked: *Thinking about the last weekday (ie yesterday/last Friday) how many hours did your child spend at home*:

1. Watching TV, DVDs, and videos?
2. Using a computer or laptop, including children's computer systems such as Leapfrog?
3. Playing with an electronic gaming system?
4. With the TV on in the same room as the child, whether or not he/she was watching it?

At ages 4 and 5, the question was worded as follows: *Thinking about a usual weekday, approximately how many hours does your child spend at home*:

1. Watching television programming including free-to-air, online, and pay TV or DVDs either on TV or other media?
2. Using electronic media eg computer or laptop, including children's computer systems such as Leapfrog, iPad, tablets, smart phones and any electronic gaming devices?
3. With the TV on in the same room as your child, whether or not he/she was watching it?

At age 8, the wording of the items was as follows:

1. Watching television programming including free-to-air, online, and pay TV or DVDs either on TV or other screen-based devices
2. Spending time with the TV on in the same room, whether they are watching it or not
3. Spending time doing activities and tasks, e.g. homework, playing games, or sending messages, on any screen-based device including computers, laptops, tablets, smartphones, or gaming devices

At each study wave, we calculated three variables of screen exposure: 1) direct screen exposure, which was the sum of television/video viewing and electronic media use; 2) indirect screen exposure, which was background television use; and 3) total screen exposure, which was the sum of both direct and indirect screen exposure. Some previous reports have excluded background television from daily screen time (e.g., Corkin et al., 2021). However, due to existing evidence showing a negative association between background television and children's language development and social interactions

(Anderson & Hanson, 2017; Christakis et al., 2009; Schmidt et al., 2008), we opted to include background television in our analyses.

A small subset of responses reported implausible levels of daily screen hours, such as 15+ hours of direct screen exposure at age 8 on a weekday, when children are (presumably) in school seven hours a day and sleeping for an additional period of time. At all ages the screen time variables were Windsorized to a maximum of 9 hours per day. The final screen exposure score were continuous measures of amount of screen exposure per weekday in hours and minutes.

Dependent Variables

Descriptive statistics (including mean, standard deviation, and range) for all dependent variables described below are provided in Appendix 1.

Language

Vocabulary – Age 2. Language ability was measured using the short form of the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 2000). Mothers were asked to report whether or not children can say each of a list of 100 words (such as dog, car, no, mum, hi, and 'uh oh'). Response options were 'yes' or 'no'. The list of words could be administered in six languages: English, Māori, Samoan, Tongan, Cantonese, or Mandarin. See Reese et al (2015; 2018) for further information about the translation of the scale and psychometric properties.

Total scores were calculated by tallying the total number of 'yes' responses out of 100. If the list of words was administered in multiple languages (e.g., English and Māori), total scores were calculated by tallying the lists across languages. In this case, total scores remained out of 100, but children received a point for each word that they could say in at least one language. Of children assessed using the CDI, 20% were assessed in more than one language.

Language – Age 4. Language ability at age 4 was assessed by asking parents 1) how often their child joined words together into short sentences, and 2) how often their child tells short stories, either repeating stories that they know or making up their own. Both items referred to ability in any language and were rated on 4-point scale of Not yet (1), Sometimes (2), Often (3), or Always (4) and a 3-point scale of Not yet (1), Sometimes (2), or Often (3), respectively. Parents also indicated which of 11 colours and 8 shapes their child could name correctly. Total scores on these 19 items were divided into quartiles to assign children a score ranging from 1 to 4 based on the extent to which they were able to name colours and shapes. A total score for language was calculated as the sum of scores on the three measures of: joining words together, telling stories, and

colour/shape naming. Cronbach's alpha for the 19 naming items was 0.88, while the alpha for the three items of joining words, telling stories and total naming score was 0.43 (inter-item correlations r = 0.21 to 0.46).

Vocabulary – Age 5. The shortened version of the Peabody Picture Vocabulary Test (PPVT; Dunn et al., 1997) was used to provide a measure of children's receptive vocabulary and verbal ability. The adapted version was based on work done in the United States for the Head Start Impact Study, which includes some word modifications for use in Australia (Rothman, 2005). Final scores on the task were the latent factor scores on the shortened PPVT.

Communication skills – Age 5. Five items were used to assess children's communication skills. Two items were rated on a 4-point scale of Never, Rarely, Sometimes or Often: *How often does your child try out new words?* and *How often is your child understandable when speaking to adults other than you or other family members?* The other three items were rated on similar 4-point scales appropriate to the question asked: Which of the following best describes your child's pattern of asking questions? ("Never or rarely asks adults questions" to "Often askes adults interesting or long questions"); Which of the following best describes your child's ability to communicate personal experiences in a clear and logical way? ("very tentative, only offers a few words" to "Tells experiences in a way that is nearly always complete, logical and understandable"); Which of the following best describes your child's ability to communicate when they are not first understood? ("Never continues trying" to "Will work hard to be understood"). The mean of these 5 items was used as a measure of children's communication skills. Cronbach's alpha for the 5 items was 0.43.

Early Educational Ability

Writing – Age 5. Two tasks from the 'Who Am I'? Developmental Assessment used by the Longitudinal Study of American Children (LSAC) were used (de Lemos & Doig, 1999). In these tasks, children were instructed to first write their name, and then write some numbers. Each of these two writing tasks was scored on a scale from 0 to 4 according to the standard scoring manual (Rothman, 2005). A total writing score was calculated by summing the two writing tasks (correlation between tasks was r = .47).

Numeracy – Age 5. To assess numeracy, interviewers asked children to first count up from 1 to 10, and then to count down from 10 to 1. These counting tasks were scored according to the number of correct numbers in the longest number sequence given by the child (ie without any interruptions or inclusion of other words/numbers). A total counting score was calculated by summing the two counting tasks (correlation between tasks was r = .38).

Letter fluency – Age 5. The Dynamic Indicators of Basic Early Literacy Skills (DIBELS) subtest of Letter Naming Fluency was used as a measure of children's letter knowledge. The letter fluency subtest assesses children's knowledge of letters, their ability to say the letters, and their naming speed. This scale has previously been validated with New Zealand children (Schaughency & Suggate, 2008). Final scores are calculated as the total number of letters corrected named in a 1-minute period.

Social Functioning

Peer problems and prosocial behaviour – Ages 5 and 8. Parental reports of child behaviour were obtained using the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) on two subscales related to peer relationships: peer problems and prosocial behaviour. The peer problems subscale includes 5 items. Example items are: "*Rather solitary, tends to play alone*" and "*Generally liked by other children*" (reverse-coded). The prosocial behaviour subscale includes 5 items, including "*Considerate of other people's feelings*" and "*Shares readily with other children*". All items were rated by parents as Not true (0), Somewhat true (1), or Certainly true (2). After reverse-coding where appropriate, items were summed across each subscale, with higher scores indicating higher levels of peer problems or prosocial behaviours, respectively. Cronbach's alpha for peer problems and prosocial behaviour was 0.55 and 0.69, respectively.

Peer victimisation – Age 8. Children self-reported on their experiences of bullying on ten items that were rated on a 5-point scale from *Never/hardly ever* to *Almost every day*. Example items include "*Do other students put you down, call you names, or tease you in a mean way?"* and "*Do other students use cell phones (like texting) or the Internet (like Facebook) to be mean to you?*" Items were summed to create an overall measure of peer victimisation. Cronbach's alpha for these 10 items was 0.83.

Peer satisfaction – Age 8. Two items assessed child-reported satisfaction with peer relationships and were also rated on a 5-point scale from *Never/hardly ever* to *Almost every day*. The two items asked children how much they agreed with the statements of "*My friends are usually nice to me*" and "*I have enough friends*". Items were summed to create an overall measure of satisfaction in peer relationships.

Childhood Experiences

Childhood experiences were assessed at ages 2 and 8 years. At age 2, parents were provided with a list of activities and places and asked to report whether or not (yes/no) their child had done those activities or been at those places at any time since

the child was born. The list included 34 items such as: library, park, zoo, music groups, museum, and outdoor walks. A total score was calculated by tallying the total number of Yes responses, reflecting the child's exposure to social and sensory-rich childhood experiences. Cronbach's alpha for the 34 items was 0.74.

At age 8, parents reported on the frequency with which their child had engaged in extracurricular activities or attended activities/events over the last 12 months. A total of 20 items were used: 7 items asked about places or events (such as a zoo, a museum, or a theme park) and 13 items asked about extracurricular activities (such as organised sport, art/music/dance lessons, reading for pleasure, and household chores). All items were rated on a 6-point scale of: *More than once per week* (5), *Once per week* (4), *Once per month* (3), *Once every 6 months* (2), *Once a year* (1), or *Never* (0). The 20 items were summed to create an overall measure of child exposure to activities and experiences over the last 12 months. Cronbach's alpha for the 20 items was 0.66.

Sociodemographic Characteristics

Six measures of child and family social background were identified from the GUINZ dataset: child ethnicity, child gender, maternal age, socioeconomic deprivation, maternal education, and childcare attendance.

Child ethnicity was reported by the mother at the 9-month assessment and was categorised as NZ European, NZ Māori, Pasifika, Asian, MELAA (Middle Eastern, Latin American, or African), or Other. Multiple ethnic affiliations were allowed. *Child gender* and *maternal age* were also collected at the 9-month study wave.

Socioeconomic deprivation was measured with the New Zealand Index of Deprivation (NZDep; Atkinson et al., 2019) at each study wave. This measure is based on nine census variables and assigns levels of deprivation to small geographic areas, displayed as a decile system. A decile of 1 represents areas with the least deprivation whereas a decile of 10 represents areas with the most deprivation.

Maternal education was assessed at the antenatal study wave by asking mothers to select their highest completed qualification from: No secondary school qualification, Secondary school/NCEA 1-4, Diploma/Trade certificate/NCEA 5-6, Bachelor's degree, or Higher degree.

Childcare attendance was measured at the 9-month, 2-year, and 5-year study waves. Mothers were asked to report whether or not their child had been looked after by anyone other than their partner over the last one month (9-month and 2-year wave) or one year (5-year wave).

Statistical Methods

Approximately 30% of children were lost to follow up at the 8-year assessment point. To deal with this missing data, we used multiple imputation to impute missing values and adjust for non-response bias, or differences in the groups of children that did and did not have data available at age 8. Data at age 8 was imputed for the subset of children with data available at the 5-year study wave. Predictors in the imputation model were gender, ethnicity, socio-economic deprivation, maternal education, and maternal age, and the final values used in analysis were the mean of 5 iterations of imputation. Imputed values were used in all results presented using data from the 8-year wave.

Given the large sample size of the GUINZ dataset, we focused on effect sizes where appropriate, and used the threshold of Hedge's $g \geq 0.2$ or η^2 (eta squared) ≥ 0.01 as an indication of a meaningful effect. We considered correlations of $r \geq 0.1$ as representing a meaningful association.

Dimension Reduction

Due to the large number of dependent variables considered in our analyses, we used exploratory and then confirmatory factor analyses (CFA) to reduce our variables to a smaller set of latent factors. CFA latent measurement models were conducted in STATA. Model fit was evaluated using the root mean squared error of the approximation (RMSEA), the Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI). RMSEA values range from 0 to 1, with smaller values indicating better fit. Values below 0.08 are considered acceptable, with values below 0.06 considered a good fit (Hu & Bentler, 1999; Xia & Yang, 2019). CFI and TLI values also range from 0 to 1, with higher values indicating better fit. Values above 0.90 are considered acceptable and above 0.95 indicate a good fit (Bentler & Bonett, 1980; Hu & Bentler, 1999; Xia & Yang, 2019).

For ease of presentation and interpretation, all final dependent variables used in the main analyses (i.e. other than initial descriptive statistics) have been standardised to a mean of 0 and standard deviation of 1.

Longitudinal Associations of Screen Exposure with Outcomes from Ages 2 to 8

Hierarchical Regression Analyses

A series of hierarchical regression models were used to determine whether total screen exposure and childhood experiences explained any additional variance in outcomes once controlling for sociodemographic confounds. For each model we entered our set of confounds in the first step (ethnicity, gender, childcare attendance, socioeconomic deprivation, maternal age, and maternal education), total screen exposure in the second

step, and childhood experiences in the final step. Improvement to model fit was evaluated at each step through significant changes to R^2.

Childhood Experiences as a Mediator

We evaluated indirect effects through childhood experiences using the Sobel test (Baron & Kenny, 1986; Sobel, 1982; MacKinnon et al., 2002). We used the following Sobel test equation to determine whether there was a significant indirect effect of total screen exposure on the dependent variable through childhood experiences: *z*-value $= a*b/\text{SQRT}(b^2*s_a^2 + a^2*s_b^2 + s_a^2*s_b^2)$, where a = the unstandardised regression coefficient for the association between screen exposure and childhood experiences; s_a =the standard error of a; b = the unstandardized regression coefficient for the association between childhood experiences and the dependent variable, when screen exposure is also a predictor; and s_b = the standard error of b (Baron & Kenny, 1986; Sobel, 1982; MacKinnon et al., 2002). All confounds were also controlled for when obtaining the above values.

Fixed Effects Regression Model

The assessment of peer problems at both 5 and 8 provided the opportunity to examine the extent to which variations in screen exposure were associated with changes in peer problems over this period. A fixed effects panel regression model fitted in a repeated measures framework was used to predict peer problems as a function of age and total screen exposure. In other words, this analysis predicted peer problems from total screen exposure (background television and direct screen time) and age (5 years and 8 years).

Evaluation of Current Screen Time Recommendations

To examine the relation of hourly increases in screen exposure with child outcomes, the dose dependent effect of screen exposure was investigated through linear predicted values on outcome variables, after adjusting for all confounding factors. Linear regressions predicted the standardised outcome measures (mean of 0, SD of 1) from all confounding variables (ethnicity, gender, childcare attendance, socioeconomic deprivation, maternal age, and maternal education) and screen exposure, and covariate adjusted means for each outcome were calculated from the fitted models at hourly intervals of screen exposure.

For this analysis, particular interest was in direct screen exposure as we have interpreted the national screen guidelines as referencing direct screen exposure (making direct screen exposure therefore the most relevant screen time variable for evaluating current guidelines). However, covariate adjusted means were obtained for both direct screen exposure and total screen exposure.

To evaluate current screen time recommendations, we used the criteria of "positive outcomes" as scoring above the mean (i.e., 0) on standardised language factor scores and standardised educational ability scores, and scoring below the mean on standardised peer problem scores (with positive outcomes in this case reflecting the absence of peer problems).

Trajectories of Screen Usage

Latent profile analysis (LPA) was used to identify subgroups of children who were characterised by similar patterns of total screen exposure over time. For this analysis, we used the subsample of children with screen usage data available at age 5 (n=6,131) with multiple imputation used to impute any missing screen exposure values across all assessment points. This model used the set of confounds and all total screen exposure variables (across study waves) to inform imputation. The LPA was run in R using the *mclust* package (Scrucca et al., 2016).

In determining the best fit to the data, we ran a series of models that varied in the number of classes (configurations of 1 to 9 classes considered) and in the variance and covariance constraints (4 model variants considered, for a total of 36 models fitted). We selected the best fitting model as that with the Bayesian Information Criterion (BIC) closest to 0 (Wardenaar, 2021).

Comparisons of sociodemographic characteristics among latent trajectory groups used chi-square analyses for categorical variables (i.e., gender, ethnicity) with post-hoc testing though tests of z-score proportions and Bonferroni adjustment. Comparisons of continuous sociodemographic characteristics (i.e., socioeconomic deprivation) used analyses of covariance (ANCOVAs) and Bonferroni post-hoc tests. Differences among latent trajectory groups on the dependent variables were assessed using ANCOVAs and η^2 effect sizes.

Results

Children's Daily Screen Use

Table 1 shows the total number of children with screen use data available at each study wave. Screen use data was imputed at age 8 using the methods described in the Statistical Methods section. This increased the total analysis sample size of data available to 6,131.

Table 1: Sample size with screen exposure data available

Study Wave	n
9 Months	6,382
2 Years	6,281
4 Years	6,197
5 Years	6,131
8 Years	3,998

We examined the amount of time children experienced different types of screen exposure at each assessment from 9 months to 8 years; these results are shown in Table 2. The mean and median daily hours of screen use are presented. Note that screen use at age 9 months was not measured in daily hours but in weekly frequency and is thus not on a comparable scale to the other study waves.

Table 2: Duration of different types of screen use (hours per day) from ages 9 months to 8 years

		Child Age				
		9 Months (n = 6,382)	2 Years (n = 6,281)	4 Years (n = 6,356)	5 Years (n = 6,131)	8 Years (n = 6,131)
Types of Direct Screen Exposure						
TV/video viewing	Mean hrs (SD)	2.15 (1.27)	1.24 (1.34)	1.59 (1.21)	1.48 (1.18)	2.65 (2.08)
	Median hrs	2.0 (1.0, 3.0)	1.0 (.25, 2.0)	1.0 (1.0, 2.0)	1.0 (.75, 2.0)	2.1 (1.0, 3.4)
Electronic media	Mean hrs (SD)	-	0.12 (.42)	0.48 (0.74)	0.60 (0.76)	1.50 (1.51)
	Median hrs	-	0 (0,0)	0.25 (0, 0.5)	0.5 (.08, 1.0)	1.0 (0.5, 2.0)
Subtotal[1]: Direct Screen Exposure	Mean hrs (SD)	2.15 (1.27)	1.35 (1.45)	2.05 (1.52)	2.06 (1.55)	3.92 (2.36)
	Median hrs	2.0 (1.0, 3.0)	1.0 (.25, 2.0)	1.67 (1, 2.5)	2.0 (1, 2.75)	3.5 (2.0, 5.3)
Indirect Screen Exposure						
Background television	Mean hrs (SD)	4.07 (1.18)	2.42 (2.31)	2.43 (1.98)	2.12 (2.03)	1.95 (1.80)
	Median hrs	4.0 (4.0, 5.0)	2.0 (.75, 3.5)	2.0 (1.0, 3.5)	2.0 (0.5, 3.0)	1.8 (0.6, 2.8)
Total Screen Exposure						
Total screen exposure	Mean hrs (SD)	2.79 (1.03)	3.51(2.79)	4.23 (2.57)	3.95 (2.63)	5.44 (2.67)
	Median hrs	2.7 (2.0, 3.7)	3.0 (1.3, 5.1)	4.0 (2.1, 6.0)	3.5 (2.0, 6.0)	5.6 (3.3, 7.9)

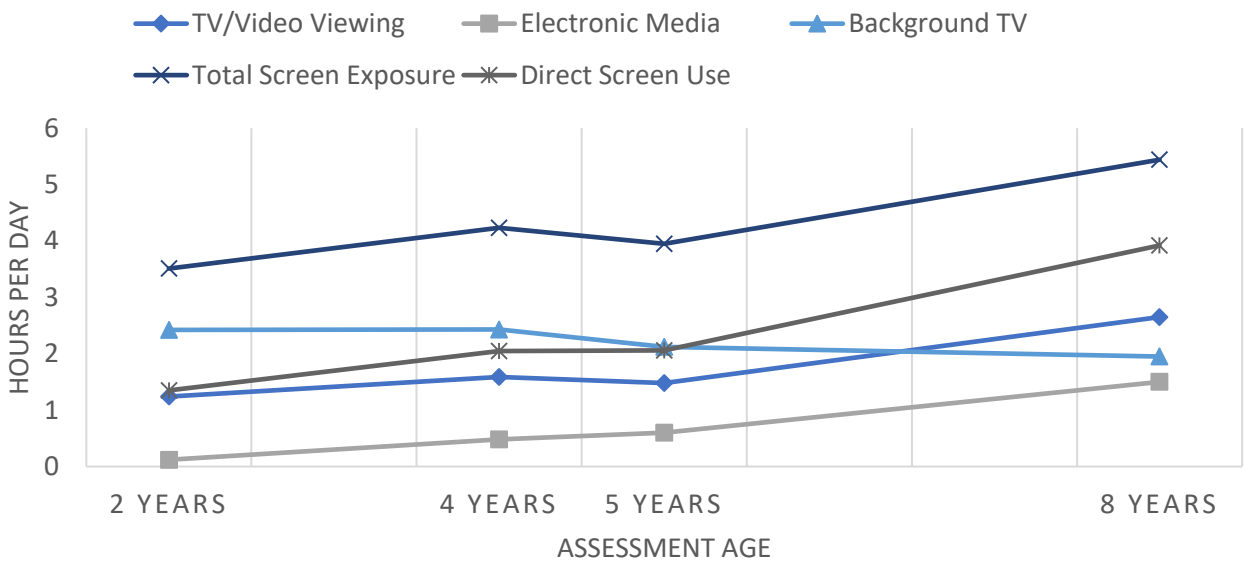
Medians are presented as Median (25th percentile, 75th percentile)

Note that 9 month data does not represent number of daily hours and is not comparable to other study waves

[1]Subtotal is less than the sum of the individual components due to truncation of values to a maximum of 9 hours per day and missing data

To further illustrate patterns of different types of screen use over time, Figure 2 shows a plot of the mean values for each type of screen time (in hours per day) between ages 2 and 8 years and illustrates the pattern of use over time.

Figure 2: Mean screen usage in hours per day between ages 2 and 8



Collectively, Table 2 and Figure 2 show a trend of increasing direct screen exposure with age. There were increases to both TV/video viewing and electronic media use with age, but a slight decrease in background television exposure.

Child and Family Factors Associated with Screen Exposure

As a preliminary step, we explored a number of potential confounding factors that might account for observed associations between screen exposure and outcomes to include in our analyses. These were selected based on previous research and theory. Controlling for these variables in our analyses rules them out as potential causal explanations for any significant associations between screen time and our dependent variables.

The confounding factors examined were ethnicity, socioeconomic deprivation, child gender, maternal age, maternal education, and childcare attendance. Appendix 2 provides means and standard deviations for screen exposure across levels of these confounding variables.

Using binary indicator variables for each ethnic group, we found that European ethnicity predicted less screen exposure at all study waves (Hedges' *g*: 9 months = 0.73; 2 years = 0.60; 4 years = 0.53; 5 years = 0.39; 8 years = 0.48). In contrast, Pasifika ethnicity

was associated with more screen exposure at all ages (Hedges' *g*: 9 months = 0.55; 2 years = 0.51; 4 years = 0.54; 5 years = 0.53; 8 years = 0.64), Māori ethnicity was associated with higher screen exposure at age 2, 4, 5 and 8 (Hedges' *g*: 9 months = 0.17; 2 years = 0.36; 4 years = 0.42; 5 years = 0.50; 8 years = 0.45), and Asian ethnicity predicted higher exposure at ages 9 months and 2 years (Hedges' *g*: 9 months = 0.43; 2 years = 0.28; 4 years = 0.13; 5 years = 0.08; 8 years = 0.02).

Child care attendance at 9 months was not associated with screen exposure (Hedges' *g* = .12). However, there was a small effect of child care attendance on screen exposure at age 2 years (Hedges' *g* = .38), with children who did not attend early childhood education/care having higher levels of screen time exposure (*M* = 4.07, *SD* = 2.99) than those who did attend care (*M* = 3.03, *SD* = 2.51). Only 3% of children were not enrolled in child care in the year prior to the 5-year assessment so comparisons were not made at this study wave.

Examination of correlations between socioeconomic deprivation and total screen exposure indicated significant positive correlations at ages 9 months (*r* = .25), 2 years (*r* = .26), 4 years (*r* = .30), 5 years (*r* = .30), and 8 years (*r* = .24). Higher deprivation was associated with more screen exposure.

Gender was not associated with screen exposure at any age (all Hedges' *g* < 0.09).

Maternal age and maternal education were both negatively correlated with screen exposure at all ages; in other words, children with older mothers and more educated mothers had less screen exposure (maternal age: 9 months, *r* = -.22; 2 years, *r* = -.24; 4 years, *r* = -.24; 5 years, *r* = -.25; 8 years, *r* = -.18; maternal education: 9 months, *r* = -.26; 2 years, *r* =-.28 ; 4 years, *r* = -.30; 5 years, *r* = -.32; 8 years, *r* = -.37).

Longitudinal Associations of Screen Exposure with Outcomes from Ages 2 to 8

Table 3 shows the bivariate associations (Pearson correlation coefficients) between total screen exposure assessed at the five study waves and both concurrent and subsequent scores on language, educational ability, social functioning, and childhood experiences. The full correlation matrix for screen exposure and outcome variables is provided in Appendix 3.

Table 3: Bivariate correlations between screen time and outcome variables

Outcome Variable	Total Screen Exposure				
	9 Months	2 Years	4 Years	5 Years	8 Years
Language and Educational Ability					
Vocabulary (age 2)	**-.21**	**-.19**	-	-	-
Language (age 4)	**-.17**	**-.16**	**-.17**	**-**	
Vocabulary (age 5)	**-.27**	**-.23**	**-.21**	**-.18**	-
Communication (age 5)	**-.17**	**-.14**	**-.14**	**-.15**	
Writing (age 5)	-.06	**-.11**	**-.15**	**-.18**	-
Counting (age 5)	**-.13**	**-.14**	**-.16**	**-.15**	-
Letter fluency (age 5)	-.05	-.09	**-.13**	**-.15**	-
Social Functioning					
Peer problems (age 5)	**.19**	**.19**	**.18**	**.21**	-
Prosocial behaviour (age 5)	.01	-.04	-.04	-.08	-
Peer problems (age 8)	**.17**	**.18**	**.16**	**.17**	**.17**
Prosocial behaviour (age 8)	-.04	-.03	-.05	-.06	-.05
Peer victimisation (age 8)	.08	.08	.09	.06	.08
Peer satisfaction (age 8)	-.06	-.05	-.06	-.05	-.05
Childhood Experiences					
Childhood experiences (age 2)	-**.20**	**-.20**	-	-	-
Childhood experiences (age 8)	-.09	**-.15**	**-.17**	-**.18**	-**.13**
Correlations above *r* = .1 are considered to be meaningful and are bolded					

Table 3 shows that duration of screen exposure assessed at earlier child ages was consistently negatively associated with children's subsequent scores on measures of language and educational ability. In other words, higher levels of total screen exposure corresponded to lower scores on language and educational ability. Regarding social outcomes, greater screen exposure predicted higher scores on later peer problems, but there was no association with prosocial behaviour. There was also no association with peer satisfaction or peer victimisation. Finally, higher screen exposure predicted lower frequency of childhood experiences as assessed at later study waves.

Dimension Reduction

Due to the large number of dependent variables considered in our analyses and the low reliability of some measures, as described in the Statistical Methods section we used exploratory and confirmatory factor analyses to reduce our variables to a smaller set of latent factors. With regards to language and educational ability outcomes at age 5, we considered both a single factor solution and a two-factor solution. Results showed that the two-factor solution (with separate latent constructs of educational ability and

language) had the best fit to the data (RMSEA = .08, CFI = .97, TLI = .91). The language factor included vocabulary and communication skills, and the educational ability factor included letter fluency, writing, and counting. The measurement model with standardised coefficients is shown in Figure 3, and Table 4 describes the correlations between these latent variables and screen exposure measured at and before age 5.

Figure 3: Latent measurement model for language and educational ability outcomes at age 5

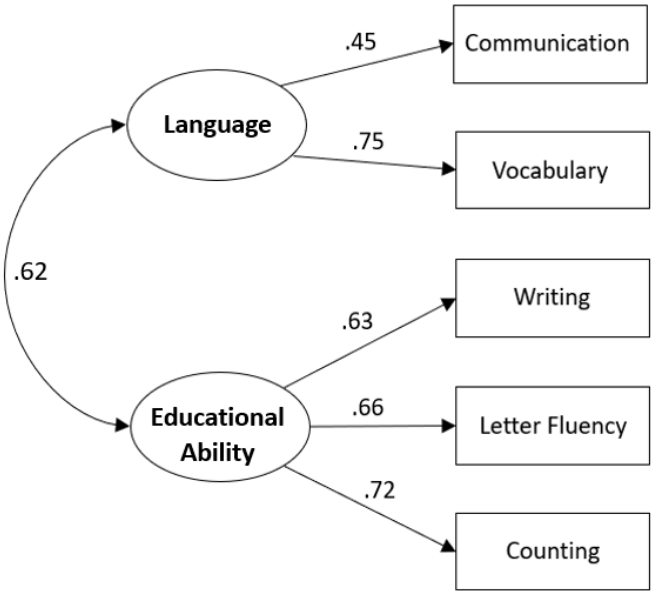


Table 4: Correlations between screen time and latent variables

Outcome Variable	Total Screen Exposure			
	9 Months	2 Years	4 Years	5 Years
Language Factor Score (age 5)	**-.25**	**-.23**	**-.23**	**-.22**
Educational Factor Score (age 5)	**-.15**	**-.17**	**-.20**	**-.21**
Correlations above *r* = .1 are considered to be significant and are bolded				

With regards to social outcomes, peer problems was the only dimension of social functioning that we found to be associated with screen exposure so we focused on peer problems as our key social functioning outcome rather than creating a latent social functioning factor.

Hierarchical Regression Analysis

The primary aim of this analysis was to examine the longitudinal associations of screen exposure with our dependent variables while controlling for potential confounding

factors, as identified through our earlier analyses. Further, we wanted to explore whether frequency of childhood experiences would mediate the association between screen exposure and outcomes. As seen in Table 3, there were negative correlations between screen exposure and childhood experiences measured both concurrently and longitudinally at older ages. In other words, higher levels of screen exposure were associated with a lower frequency of enriching childhood experiences. Mean frequencies of childhood experiences across levels of sociodemographic characteristics are provided in Appendix 4. A key pattern here is the clear relation between maternal education and the extent of children's exposure to enriching childhood experiences (with low education associated with a lower frequency of experiences).

A series of hierarchical regression models was used to determine whether screen exposure and childhood experiences explained any additional variance in outcomes once controlling for sociodemographic confounds. Our dependent variables for these analyses were the two factor scores on language and educational ability, and peer problems. For each model we entered our set of confounds in the first step, total screen exposure in the second step, and childhood experiences in the final step. As childhood experiences were only measured at ages 2 and 8, we used screen exposure at age 2 as the predictor for outcomes at age 5 and childhood experiences also measured at 2. For peer problems at age 8 we used screen exposure at age 5 as the predictor and childhood experiences at age 8.

Language

The hierarchical regression models predicting language at age 5 are shown in Table 5. The first model indicates that all sociodemographic confounding factors predicted language. After controlling for these confounds, the second model shows there was a significant effect of screen exposure at age 2 on language. Adding childhood experiences into the final step of the model (Model 3) indicated a significant amount of additional variance in language was accounted for by frequency of childhood experiences at age 2. Higher levels of screen exposure predicted lower language scores, and higher rates of childhood experiences predicted higher language scores.

Table 5: Hierarchical regression analysis predicting language at age 5

Dependent Variable: Language Factor Score at Age 5			
	Model 1	**Model 2**	**Model 3**
Model Summary	$F(9,5944)$ = 155.50***	$F(10,5943)$ = 143.42***	$F(11,5942)$ = 138.60***
R^2	R^2 = .19	R^2 = .19	R^2 = .20
R^2 change		$R^2 \Delta$ = .004***	$R^2 \Delta$ = .01***
	Std Beta	Std Beta	Std Beta
Confounding Factors			
European ethnicity	.20***	.19***	.18***
Māori ethnicity	-.07***	-.06***	-.07***
Pasifika ethnicity	-.11***	-.11***	-.11***
Asian ethnicity	-.04**	-.03*	-.02
Child gender	.09***	.09***	.09***
Maternal age	.04**	.04*	.04**
Maternal education	.15***	.14***	.12***
Socioeconomic deprivation	-.10***	-.09***	-.08***
Childcare attendance	-.04***	-.03**	-.03*
Screen Exposure			
Age 2 Years		-.07***	-.06***
Childhood Experiences			
Age 2 Years			.11***
*** $p < .001$; ** $p < .01$; * $p < .05$			
Table presents the standardised regression coefficients			

Educational Ability

The hierarchical regression models predicting educational ability at age 5 are shown in Table 6. All sociodemographic confounds aside from maternal age were predictive of educational ability. After controlling for these confounders, both screen exposure at age 2 and childhood experiences at age 2 were significant predictors of children's educational factor scores. Higher levels of screen exposure predicted lower educational ability scores, and higher rates of childhood experiences predicted higher educational ability scores.

Table 6: Hierarchical regression analysis predicting educational ability at age 5

Dependent Variable: Educational Factor Score at Age 5			
	Model 1	**Model 2**	**Model 3**
Model Summary R^2 R^2 change	$F(9,5944) = 92.26$*** $R^2 = .12$	$F(10,5943) = 85.11$*** $R^2 = .13$ $R^2 \Delta = .01$***	$F(11,5942) = 79.16$*** $R^2 = .13$ $R^2 \Delta = .003$***
	Std Beta	Std Beta	Std Beta
Confounding Factors			
European ethnicity	.07***	.07***	.06***
Māori ethnicity	-.09***	-.09***	-.10***
Pasifika ethnicity	-.08***	-.07***	-.08***
Asian ethnicity	.08***	.09***	.09***
Child gender	.10***	.10***	.10***
Maternal age	.02	.02	.02
Maternal education	.15***	.14***	.13***
Socioeconomic deprivation	-.09***	-.09***	-.08***
Childcare attendance	-.04**	-.03**	-.03*
Screen Exposure			
Age 2 Years		-.06***	-.05***
Childhood Experiences			
Age 2 Years			.05***
*** $p < .001$; ** $p < .01$; * $p < .05$ Table presents the standardised regression coefficients			

Social Functioning (Peer Problems)

Table 7 provides the results of the hierarchical regression analysis predicting peer problems at age 5. All sociodemographic confounds were predictive of peer problems. Models 2 and 3 indicate that screen exposure at age 2 and childhood experiences at age 2 were also both predictive of peer problems at age 5, even after controlling for the confounding social background factors. Higher levels of screen exposure predicted higher peer problem scores, and higher rates of childhood experiences predicted lower peer problem scores.

Table 7: Hierarchical regression analysis predicting peer problems at age 5

Dependent Variable: Peer Problems at Age 5			
	Model 1	**Model 2**	**Model 3**
Model Summary R^2 R^2 change	$F(9,5645)$ = 107.59*** R^2 = .15	$F(10,5644)$ = 98.16*** R^2 = .15 R^2 Δ = .002***	$F(11,5643)$ = 93.25*** R^2 = .15 R^2 Δ = .006***
	Std Beta	Std Beta	Std Beta
Confounding Factors			
European ethnicity	-.16***	-.15***	-.14***
Māori ethnicity	.05***	.04***	.05***
Pasifika ethnicity	.12***	.11***	.12***
Asian ethnicity	.04*	.03*	.03*
Child gender	-.05***	-.05***	-.05***
Maternal age	-.12***	-.12***	-.12***
Maternal education	-.07***	-.06***	-.05**
Socioeconomic deprivation	.09***	.08***	.08***
Childcare attendance	.04***	.04**	.04**
Screen Exposure			
Age 2 Years		.05***	.04**
Childhood Experiences			
Age 2 Years			-.08***
*** p < .001; ** p < .01; * p < .05 Table presents the standardised regression coefficients			

Table 8 provides the results of the hierarchical regression analysis predicting peer problems at age 8. In this analysis, all sociodemographic factors aside from Asian ethnicity and childcare attendance were associated with peer problems. After controlling for these confounds, we found that screen exposure at age 5 was a significant predictor of peer problems at age 8. Higher levels of screen exposure were associated with higher levels of peer problems. In the final step of the model we found that frequency of childhood experiences at age 8 also explained additional unique variance in peer problems, with fewer childhood experiences predicting higher levels of peer problems.

Table 8: Hierarchical regression analysis predicting peer problems at age 8

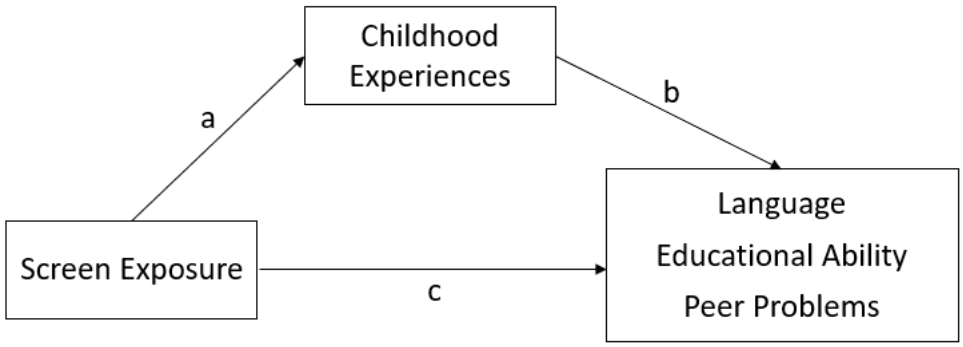
Dependent Variable: Peer Problems at Age 8			
	Model 1	**Model 2**	**Model 3**
Model Summary R^2 R^2 change	$F(9,5659) = 70.42$*** $R^2 = .11$	$F(10,5658) = 51.34$*** $R^2 = .11$ $R^2\ \Delta = .003$***	$F(11,5657) = 48.64$*** $R^2 = .12$ $R^2\ \Delta = .01$***
	Std Beta	Std Beta	Std Beta
Confounding Factors			
European ethnicity	-.13***	-.13***	-.13***
Māori ethnicity	.05**	.04**	.05***
Pasifika ethnicity	.07***	.06***	.07***
Asian ethnicity	.002	.004	.006
Child gender	-.06***	-.06***	-.05***
Maternal age	-.12***	-.11***	-.11***
Maternal education	-.09***	-.08***	-.06***
Socioeconomic deprivation	.08***	.07***	.07***
Childcare attendance	-.004	-.006	-.02
Screen Exposure			
Age 5 Years		.06*	.05
Childhood Experiences			
Age 8 Years			-.09***
*** $p < .001$; ** $p < .01$; * $p < .05$ Table presents the standardised regression coefficients			

To summarise the results of these regression analyses, sociodemographic characteristics were the largest predictor of later language, educational ability, and peer problems. After controlling for these confounding factors there remained an independent effect of both screen exposure and childhood experiences on child outcomes, although the size of these effects were relatively small.

Childhood Experiences as a Mediator

Following on from the regression models above, we next tested whether childhood experiences might mediate associations between total screen exposure and outcomes; in other words, we wanted to know whether one explanation for the impact of screen exposure on outcomes is because it reduces the frequency of social and sensory-rich childhood experiences. Figure 4 shows our hypothesised mediation model whereby total screen exposure impacts outcomes via its effect on other childhood experiences.

Figure 4: Mediation model of indirect effect of screen exposure on outcomes through childhood experiences



Screen exposure as a predictor of childhood experiences (pathway *a*) is shown in Table 3, and the direct effects of childhood experiences and screen exposure on outcomes (pathways *b* and *c*, respectively) are shown in the regression models in Tables 5 through 8. We next evaluated the indirect effect of screen exposure through childhood experiences (pathway *ab*) using the Sobel test (described in the Statistical Methods section).

For all outcomes, the Sobel test indicated a significant indirect effect of total screen exposure on outcomes through childhood experiences (language: z = -7.71, SE = .0001, $p < .001$; educational ability: z = -4.17, SE = .0004, $p < .001$; peer problems at age 5: z = 4.71, SE = .001, $p < .001$; peer problems at age 8: z = 5.29, SE = .001, $p < .001$).

To better understand the relative contributions of the predictor and mediator variables to outcomes, we decomposed the correlations between total screen exposure and outcomes into components reflecting: the correlated influence of confounders, the effect of total screen exposure, and the mediated component through childhood experiences. Results are provided in Table 9, and indicate that a large component of the correlation between screen exposure and outcomes can be explained by confounding factors. There remains an impact of screen exposure once removing the correlated influence of confounders. However, only a minimal amount of the association can be explained by the indirect effect through childhood experiences.

Table 9: Decomposition of correlations between total screen exposure and outcomes

Outcome	Total Correlation	Confounders	Total Screen Exposure	Childhood Experiences[1]
Predictor: Screen Exposure at 9 Months				
Language (age 5)	**-.25**	-.15	-.09	-.01
Educational Ability (age 5)	**-.15**	-.10	-.04	-.01
Peer Problems (age 5)	**.19**	.15	.03	.01
Peer Problems (age 8)	**.17**	.12	.04	.01
Predictor: Screen Exposure at 2 Years				
Language (age 5)	**-.23**	-.16	-.06	-.01
Educational Ability (age 5)	**-.17**	-.11	-.05	-.01
Peer Problems (age 5)	**.19**	.14	.04	.01
Peer Problems (age 8)	**.18**	.12	.05	.01
Predictor: Screen Exposure at 4 Years				
Language (age 5)	**-.23**	-.15	-.08	/
Educational Ability (age 5)	**-.20**	-.11	-.09	/
Peer Problems (age 5)	**.18**	.13	.05	/
Peer Problems (age 8)	**.16**	.12	.03	.01
Predictor: Screen Exposure at 5 Years				
Language (age 5)	**-.22**	-.15	-.07	/
Educational Ability (age 5)	**-.21**	-.13	-.08	/
Peer Problems (age 5)	**.21**	.12	.09	/
Peer Problems (age 8)	**.17**	.12	.05	.00
Predictor: Screen Exposure at 8 Years				
Peer Problems (age 8)	**.17**	.13	.04	.00

[1]Childhood experiences at age 2 used in the analyses for screen exposure at 9 months and 2 years. Childhood experiences at age 8 used for screen exposure at ages 4, 5, and 8. Mediated component not included if childhood experiences were not assessed temporally between the independent and dependent variables.

Appendix 5 provides the results in Table 9 with further decomposition of total screen exposure into the components of direct screen time (television viewing and electronic media use) and indirect screen time (background television), showing that both direct and indirect screen time contributed to outcomes.

Repeated Measures Analysis of Peer Problems

The assessment of peer problems at both 5 and 8 years provides the opportunity to explore change in outcome with change in screen exposure over this period. A fixed effects panel regression model fitted in a repeated measures framework was used to

predict peer problems as a function of age and total screen exposure at both 5 and 8. Results indicated a significant effect of time, whereby peer problems decreased from age 5 to age 8 (coeff = -0.24, $p < .001$). However, there was also a significant effect of total screen exposure (coeff = 0.08, $p < .001$) with higher levels of screen exposure predicting increases in peer problems over time.

The key advantage of this fixed effects regression model is that it takes into account all sources of confounding from fixed factors, including the effects of the confounders in the regression models above plus all other non-observed fixed factors. Thus, it provides stronger control of confounding and causality than the simple regressions above, and provides stronger evidence for screen exposure impacting later peer problems.

Evaluation of Current Screen Time Recommendations

The above analyses indicate that even after accounting for confounding factors there remained an association between screen exposure and later language, educational ability, and peer problems. Given these findings, we next examined the dose dependent impact of screen exposure on outcomes, with a particular focus on evaluating whether or not results were in alignment with the current national screen time guidelines. For this analysis we examined direct screen exposure independently from total screen exposure, as we have interpreted the national screen guidelines as referencing direct screen exposure (making direct screen exposure therefore the most relevant screen time variable for evaluating current guidelines).

The outcome variables in this analysis were standardised factor scores on the latent language and educational factors at age 5, and standardised peer problems at age 5 and 8. Adjusted means for hourly increments of screen exposure after controlling for confounds are provided in Appendix 6; values based on both direct and total screen exposure are provided. To illustrate these adjusted effects, Figures 5 through 7 below depict hourly increments of daily direct screen exposure on subsequent language, educational ability, and peer problems (respectively).

Figure 5 shows that language scores at age 5 are predicted to drop below the mean at more than one hour of direct screen time at age 2; however, effect sizes are relatively small (i.e., effect size of 0.1 for 4 hours of direct screen time compared to 0 hours).

Figure 5: Daily direct screen time at age 2 and language at age 5

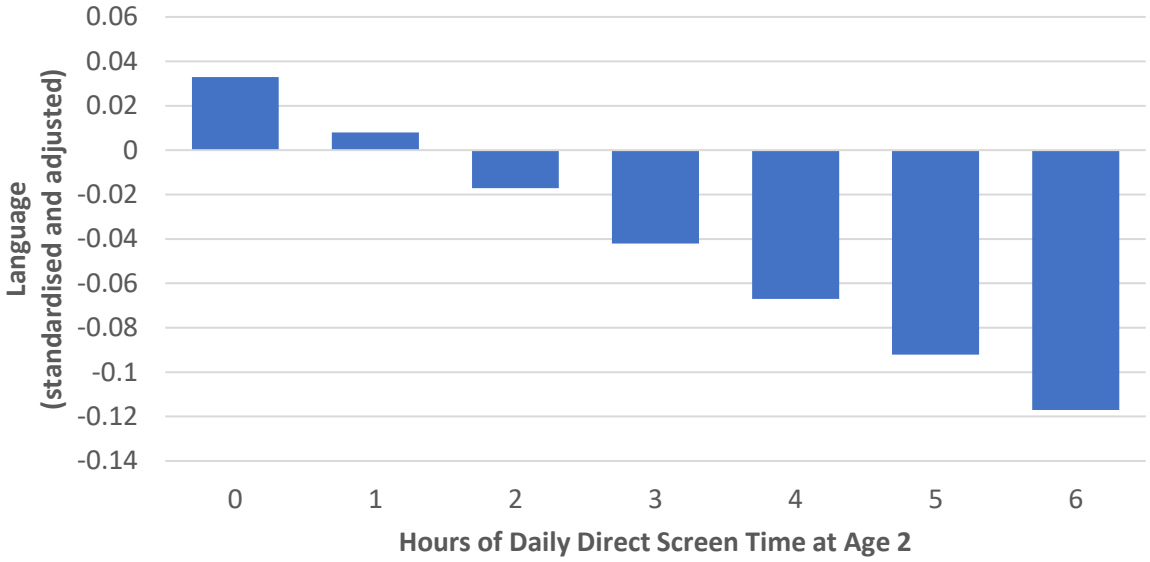


Figure 6 shows that educational ability at age 5 is predicted to drop below the mean at more than 2 hours of direct screen time at age 4. In this case, an effect size of 0.2 (our threshold for meaningful significance) is reached at 4 hours of daily direct screen exposure (compared to 0 hours).

Figure 6: Daily direct screen time at age 4 and educational ability at age 5

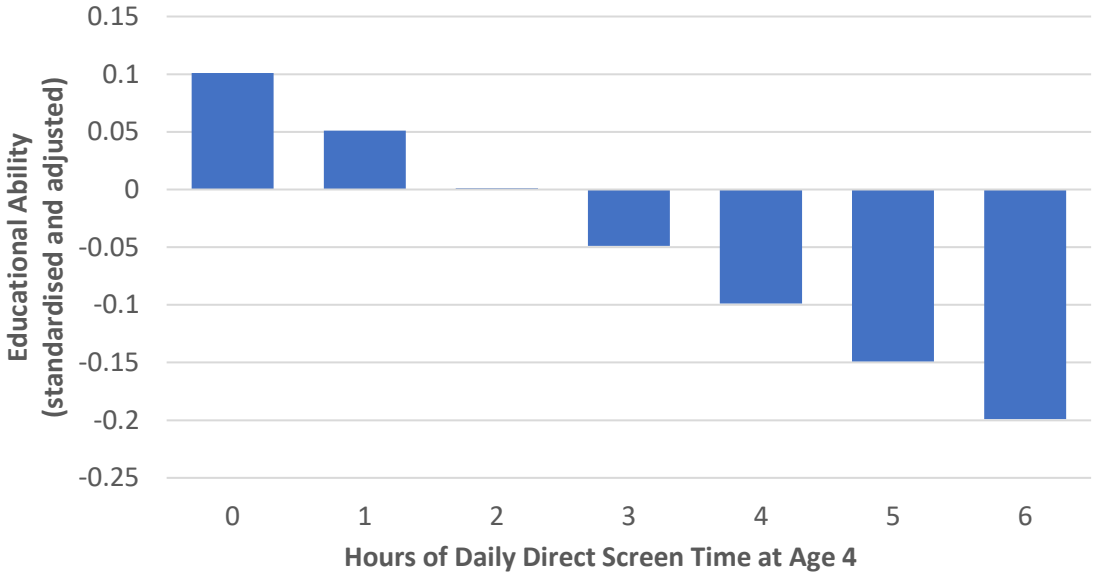
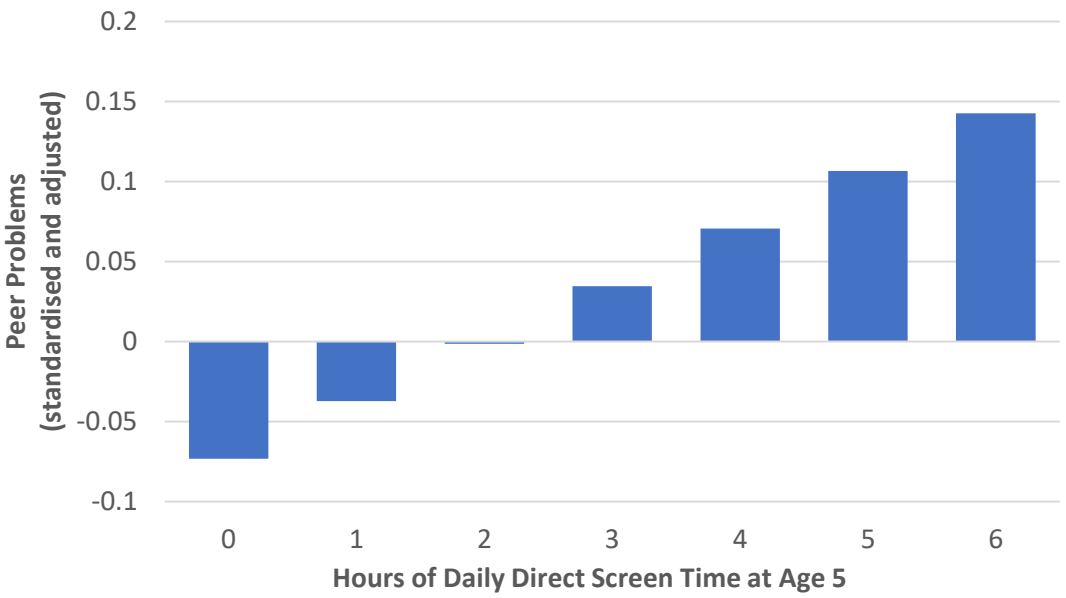


Figure 7 shows that peer problems at age 8 are predicted to increase above the mean at more than 2 hours of direct screen time at age 5; however, an effect size of 0.2 isn't exceeded until 6 hours of daily direct screen time (compared to 0 hours).

Figure 7: Daily direct screen time at age 5 and peer problems at age 8



Collectively, using the criteria for positive outcomes as scoring above the mean on language and educational ability and below the mean on peer problems, the adjusted means in Appendix 6 indicate that positive outcomes are predicted from one hour or less of direct screen hours and three or fewer hours of total screen hours at age 2. At ages 4 and 5, two or fewer hours of direct screen exposure and four or less hours of total screen exposure predicted positive later outcomes.

Trajectories of Screen Usage

For our final set of analyses, we took a different approach to examining screen exposure in relation to later outcomes. Specifically, patterns of screen usage across early childhood were examined rather than simple point-in-time measurements of exposure. We used latent profile analysis (LPA) to identify subgroups of children who showed similar trajectories of total screen exposure over the period from 9 months to 8 years of age. Based on the BIC, the optimal model was identified as a 6-class model with variances and covariances allowed to vary both within and across classes.

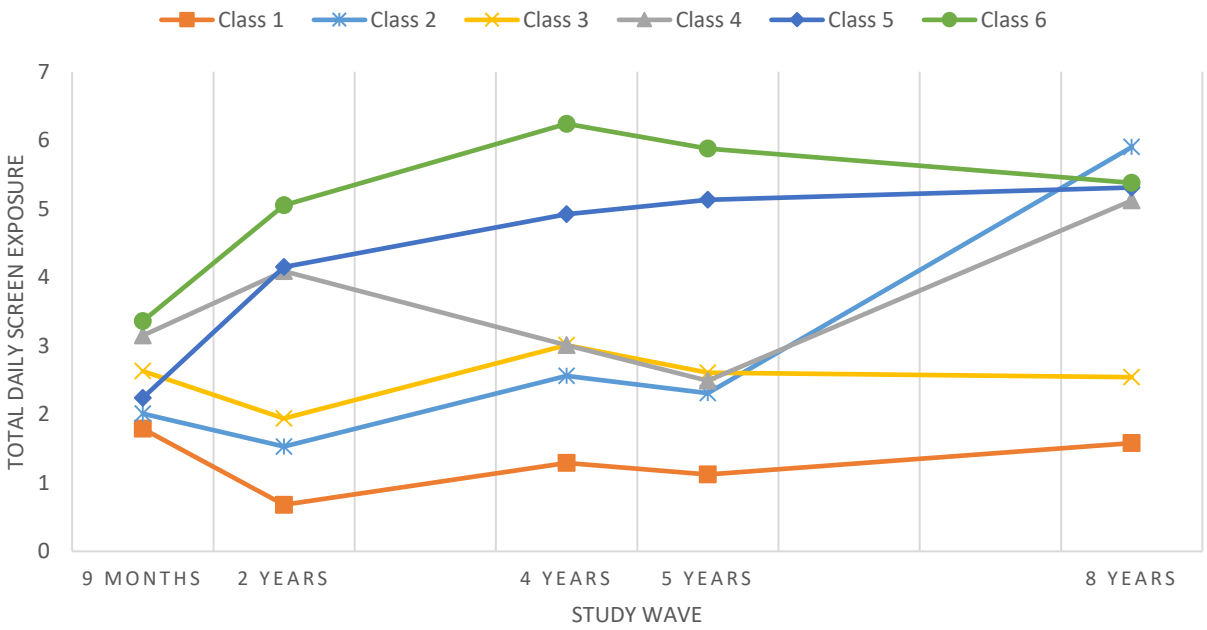
Table 10 provides the counts of children in each class.

Table 10: Counts of children within each latent trajectory class

Latent Class	n	Percent of Total
Class 1 *(Low Exposure)*	651	10.6%
Class 2 *(Late Onset Exposure)*	692	11.3%
Class 3 *(Moderate Exposure)*	1,183	19.3%
Class 4 *(Varying Exposure)*	611	10.0%
Class 5 *(Increasing Exposure)*	880	14.4%
Class 6 *(High Exposure)*	2,114	34.5%
Total	6,131	100%

Figure 8 shows the mean values of total screen exposure across study waves for each group. Note again that the measurement at 9 months differed from other study waves and does not reflect screen time measured in hours; however, it does provide information about screen usage of each group relative to one another.

Figure 8: Mean screen exposure over time by latent class



As depicted in the figure, Class 1 showed a trajectory of low screen exposure across all study waves, and was thus labelled as the *Low Exposure* group. This group had less than 2 hours of total screen exposure across all study waves. Class 2 showed a trajectory of low to moderate screen exposure during early childhood with an extreme increase in screen usage at age 8; we labelled this group as the *Late Onset Exposure* group. This group increased from just over 2 hours of total exposure a day at age 5 to over 6 hours of exposure per day at age 8. We termed Class 3 as the *Moderate Exposure* group, as

they had relatively stable and moderate levels of screen exposure across study waves (between 2 to 3 hours per day across waves). Class 4 started out with relatively high levels of screen usage that decreased at ages 4 and 5 and increased again at age 8; we labelled this group as the *Varying Exposure* Group. Class 5 had relatively low screen exposure at 9 months, and exposure increased at each subsequent wave; thus, we labelled this group the *Increasing Exposure* group. Finally, Class 6 consistently had the highest level of screen exposure across waves until age 8, and we called this group the *High Exposure* group. This group of children, which comprised one third of the sample, was exposed to more than 5 hours of screen time per day from age 2 onwards.

Comparisons of sociodemographic characteristics among latent trajectory groups indicated a significant effect of gender (χ^2 (5) = 18.54, p = .002). There was a higher proportion of girls in the *Varying Exposure* group (55.0%) and a lower proportion of girls in the *Increasing Exposure* (46.3%), *Late Onset Exposure* (45.7%), and *High Exposure* (47.2%) groups (there were no gender differences in the *Low Exposure* (51.2% female) and *Moderate Exposure* (49.9% female) groups).

The latent trajectory groups also differed in their ethnic composition (all χ^2s (5) > 105.03, p's < .001). The *Low Exposure* group and *Late Onset Exposure* group had the highest proportion of NZ European children (*Low Exposure* – 91.8% NZ European; *Late Onset Exposure* – 88.1% NZ European) while the *High Exposure* group had the lowest proportion of NZ European children (54.1%).

Children of Māori, Pacific, and Asian ethnicity were all most likely to be placed into the *High Exposure* group, with 57.0% of all Pacific children in the sample being included in this group. Compared to 46.5% of all Māori children in the sample being classed into the *High Exposure* group and 41.9% of all Asian children, only 25.6% of NZ European children were included in the *High Exposure* group.

Finally, socioeconomic deprivation differed amongst trajectory groups (F(5,5863) = 139.65, p < .001; η^2 = .11). Deprivation was highest in the *High Exposure* group (M = 6.99) and the *Varying Exposure group* (M = 5.97), and lowest in the *Low Exposure* (M = 4.50) and *Late Onset Exposure* (M = 4.68) groups. Appendix 7 provides the sociodemographic characteristics of each trajectory group.

We next examined differences among these profile groups on our dependent variables, including all social functioning variables. ANCOVAs were used to compare scores between the groups on the language factor score, educational factor score, peer problems, prosocial behaviour, peer victimisation and peer satisfaction while controlling for confounding factors. Results indicated significant differences between groups on language, educational ability, peer problems (ages 5 and 8), and prosocial behaviour at

age 5 (*F*'s > 3.86, *p*'s < .002). Effect sizes for these differences were small: educational ability $\eta^2 = 0.01$, language $\eta^2 = 0.02$, peer problems at age 5 $\eta^2 = 0.01$, peer problems at age 8 $\eta^2 = 0.01$, and prosocial behaviour at age 5 $\eta^2 = 0.003$. There were no significant differences between trajectory groups on prosocial behaviour at age 8, peer victimisation, or peer satisfaction. Table 11 provides the mean standardised scores by group on each dependent variable after adjusting for confounding factors.

Results show that the *High Exposure* group scored significantly higher on peer problems and lower on language and educational ability than most other groups, and had the poorest outcome profile of all trajectory groups. They also scored lower on prosocial behaviour at age 5 than the *Low Exposure* or *Varying Exposure* groups. The most beneficial outcomes were seen in the *Low Exposure* group, followed by the *Late Onset* and *Moderate Exposure* groups who scored quite similarly. No significant differences between trajectory groups were found in social functioning variables at age 8, aside from peer problems.

Table 11. Mean standardised scores on language, educational ability, and social functioning by latent screen exposure group

	Latent Trajectory Groups					
	Class 1 *Low Exposure*	Class 2 *Late Onset Exposure*	Class 3 *Moderate Exposure*	Class 4 *Varying Exposure*	Class 5 *Increasing Exposure*	Class 6 *High Exposure*
Language (Age 5)	0.33 (0.04)^{d}	0.15 (0.04)^{c}	0.08 (0.03)^{bc}	-0.02 (0.04)^{ab}	0.03 (0.03)^{bc}	-0.09 (0.02)^{a}
Educational Ability (age 5)	0.28 (0.04)^{c}	0.10 (0.04)^{b}	0.07 (0.03)^{b}	0.07 (0.04)^{b}	-0.03 (0.03)^{ab}	-0.08 (0.02)^{a}
Peer Problems (Age 5)	-0.07 (0.04)^{a}	-0.11 (0.04)^{a}	-0.13 (0.03)^{a}	-0.02 (0.04)^{ab}	-0.08 (0.03)^{a}	0.09 (0.02)^{b}
Peer Problems (Age 8)	-0.15 (0.04)^{a}	-0.10 (0.04)^{a}	-0.10 (0.03)^{a}	-0.05 (0.04)^{ab}	-0.03 (0.03)^{ab}	0.07 (0.02)^{b}
Prosocial behaviour (age 5)	0.09 (0.04)^{b}	0.03 (0.04)^{ab}	0.05 (0.03)^{ab}	0.09 (0.04)^{b}	-0.04 (0.03)^{ab}	-0.07 (0.02)^{a}
Prosocial behaviour (age 8)	0.04 (0.04)^{a}	0.05 (0.04)^{a}	0.03 (0.03)^{a}	0.03 (0.04)^{a}	0.05 (0.04)^{a}	-0.04 (0.03)^{a}
Peer victimisation (age 8)	-0.13 (0.04)^{a}	-0.09 (0.04)^{a}	-0.01 (0.03)^{a}	0.03 (0.04)^{a}	-0.02 (0.04)^{a}	-0.01 (0.03)^{a}
Peer satisfaction (age 8)	0.10 (0.04)^{a}	0.04 (0.04)^{a}	0.07 (0.03)^{a}	-0.03 (0.05)^{a}	-0.01 (0.04)^{a}	-0.03 (0.03)^{a}

Values are reported as: Mean (SE)

Note. *Differing superscripts indicate significant differences between groups based on Bonferroni post-hoc testing (i.e. within-row differences)*

Discussion

With the growing prevalence of digital media and the increased availability of devices such as smartphones and tablets, it is important to understand the impact of increasing screen exposure on children's development. In this study, we used data collected in the *Growing up in New Zealand* study to assess the longitudinal associations between daily screen time and children's language, educational, and social outcomes from infancy to age 8. Our results indicate that higher levels of daily screen exposure in early childhood were associated with less optimal outcomes at ages 5 and 8. Sociodemographic characteristics explained much of the variance in later outcomes. However, after controlling for these confounding factors there remained a small independent effect of screen exposure on child outcomes.

Our results show that high levels of screen exposure adversely impact children's participation in social and sensory-rich childhood activities outside the home. We hypothesised this association might be one reason that screen exposure has a detrimental impact on later outcomes. While we found statistically that lower scores on language, educational, and social outcomes were partially explained by the impact of heightened screen exposure on reducing exposure to social and sensory-rich childhood experiences, this mediation had a very small effect size. These findings provide insight to the impact of high levels of screen exposure in early childhood on later language, educational, and social outcomes, and can inform parents, practitioners, and policymakers about the impacts of screen usage in early childhood.

Trends in Screen Exposure

This research builds on previous work using GUINZ data exploring trends in screen exposure up to age 5 (Stewart et al., 2019). The present findings include data on screen usage at age 8 and show increases in both daily television/video viewing and electronic media use. There was a marked decline in background television from age 5 to age 8, resulting in a slight decline in total screen exposure despite the increase in direct screen time. These trends suggest a difference in the ways that children interact with digital media as they get older, with younger children perhaps more likely to be playing with toys or engaging in other activities whilst the television is on in the background whereas school-age children are more likely to be actively viewing or engaging with screens.

Previous research has identified a negative impact of background television on the language development of young children (Christakis et al., 2009; Kirkorian et al., 2009), and the results of the present research provide additional evidence. While previous research in this area has tended to focus exclusively on background television, we examined the contributions of both direct and indirect screen exposure to our dependent

variables. In this way we were able to show that both direct screen exposure (actively viewing/engaging with screens) and indirect screen exposure (background television) impact outcomes.

These findings are useful in highlighting particular types of screen time that families can modify for improving child outcomes. Parents may assume that background television is a more innocuous form of screen time; however, our results indicate this is not necessarily the case. Research has shown that interactions among household members are modified when background screen media is present (Anderson & Hanson, 2017; Christakis et al., 2009; Schmidt et al., 2008), suggesting that children may be exposed to a less cognitively and linguistically stimulating environment when background television is prevalent in the home.

Sociodemographic Characteristics

The result of this research confirm previous findings indicating higher levels of screen exposure among Māori, Pasifika, and Asian children in New Zealand (Stewart et al., 2019) and international research linking excessive screen exposure with higher socioeconomic deprivation (Gorely et al., 2004; Tandon et al., 2012) and lower maternal education (Cárdenas-Fuentes et al., 2021; Pons et al., 2020). Previous research is inconsistent regarding the association between maternal age and child screen time (Duch et al., 2013); however, the present findings indicate that children with older mothers have lower levels of screen exposure.

Further, our results suggest that sociodemographic characteristics were the largest predictor of later language, educational ability, and social functioning, explaining much of the association between screen exposure and outcomes. However, even after controlling for these confounding factors there remained a small effect of screen exposure and a negligible mediated effect of childhood experiences.

Language and Educational Outcomes

Our results indicate that heightened screen time in early childhood predicts lower scores on later language and educational outcomes, even after controlling for alternative explanations (i.e., potential confounding variables). The assessments of language and educational ability at the 5-year study wave were obtained prior to children starting school (at age 54-months), and thus represent an indication of children's academic school readiness, in terms of their ability to write, count, and communicate prior to participation in formal schooling. Our results indicate that, consistent with Ribner et al (2017), screen time during early childhood impacts the skills that children have on arrival to school, and the dramatic rise in screen usage over recent years may help explain anecdotal reports that school readiness has been declining over recent years

(Johnston, 2016). Understanding impacts on school readiness is important as the early skills that children have at school entry (including, for example, letter fluency and language skills) set children up for success at school and are a strong predictor of later achievement and academic success (Brinkman et al., 2013; Feinstein & Duckworth, 2006).

When examining the dose dependent relation between screen time and outcomes, positive outcomes were predicted from one or fewer hours of direct screen hours at age 2. At ages 4 and 5, two or less hours of direct screen time predicted positive later outcomes (i.e. scoring above the mean). These findings are consistent with the current Ministry of Health guidelines in recommending different thresholds for children under and over 2 years of age and in recommending two or fewer hours for under-5s. Further, we found a generally linear pattern of association, whereby the lowest levels of screen exposure were associated with the most optimal outcomes.

Social Outcomes

We examined multiple aspects of social functioning, including peer problems, prosocial behaviour, peer victimisation, and satisfaction with peers. Our results indicate a reliable association between heightened screen exposure and increased peer problems; however, we did not find significant associations with any other social outcomes. Previous research on the association between screen time and social skills is conflicting, with positive, negative, and null associations reported across studies (e.g., Connors-Burrow et al., 2011; Downey & Gibbs, 2020; Hinkley et al., 2018). Based on the present findings, screen time does not appear to impact the more positive aspects of social functioning (such as prosocial behaviour) but instead can contribute to the development of peer problems when levels of screen exposure are high. Our repeated measures analysis lends additional weight to this finding by showing that changes in peer problems between ages 5 and 8 can be partially explained by changes in screen exposure over the same period. Spending a significant amount of time using digital media or watching television may lead to difficulties in forming positive peer relationships, whether due to underdeveloped social skills or fewer opportunities to build these relationships.

Given the inconsistent results for different aspects of social functioning in this study, as well as the conflicting results of previous research in this area, it is clear that further research is needed to understand the impacts of screen media on social functioning. It may be that different types of screen media (e.g., video games vs television viewing vs social media) differentially impact on the development of social skills (Sanders et al., 2019), and these unique associations are obscured through examination of both screen usage and social functioning at a broad level.

Trajectories of Screen Exposure

Our analysis of trajectories of screen exposure across early childhood took a different approach to understanding the relation between screen exposure and outcomes by examining patterns of screen usage across early childhood rather than simple point-in-time measurements of exposure.

This analysis resulted in 6 patterns of screen usage that could be used to summarise individual trajectories. The *High Exposure* group, who had the highest screen usage at every study wave aside from age 8, scored significantly higher on peer problems and lower on language and educational ability than most other groups. Children with consistently low levels of screen usage (the *Low Exposure* group) experienced the most favourable outcomes on language, educational, and social outcomes. The *Late Onset Exposure* group (who had generally low screen usage up to age 5) also had favourable outcomes and did not differ significantly from the *Low Exposure* group at age 8 on peer problems, despite very different trajectories of screen usage from age 5 to 8 between these two groups. Further there was no change in peer problems between ages 5 and 8 within the *Late Onset Exposure* group, despite their increase in screen exposure over this time period. Thus, our results provide some preliminary evidence that there may be no detrimental impact of increasing screen exposure between ages 5 and 8. This is consistent with the current Ministry of Health guidelines that differentiate between those younger and older than 5, and allow for increased screen usage in children 5 and over (up to 2 hours per day; Ministry of Health, 2017c).

The differences among trajectory groups is striking, in terms of both daily screen exposure and overall outcome profiles. The *High Exposure* group, which constituted one third of the sample, consistently had the poorest outcome profile by far. This group of children was exposed to more than 5 hours of total screen time per day from age 2 onwards. The *Increasing Exposure* group included an additional 15% of children who averaged more than 4 hours of screen time per day and had the second poorest outcome profile. Our analysis indicates that children in these groups are more likely to be male, less likely to be of NZ European ethnicity, and came from lower socioeconomic areas. To make a difference in reducing the impact of screen exposure on language, educational, and social outcomes, these are the children and families where further supports could be targeted. Identifying culturally appropriate supports and resources that ensure all families can develop their children's foundational skills with less reliance on screen time is critical. Indeed, existing research has identified various supports for, and contexts within which, the language and literacy development of Māori and Pasifika children can thrive (Biddulph et al., 2003; Fletcher et al., 2009; Neha et al., 2020).

Displacement of Enriching Childhood Experiences

In addition to documenting the association between heightened screen exposure and poorer language, educational, and social outcomes, we also examined one explanation for why screen exposure may be detrimental to development. Our results indicate that when children spend more time on screens they are less likely to be engaging in other types of social and sensory-rich activities that are beneficial to their social and language development. Both concurrently and longitudinally, children with higher levels of screen exposure were reported to have less frequent engagement in activities such as museums, playgroups, cultural events, and extracurricular activities. We hypothesised that a reduction in these other activities may partially explain why screen exposure is detrimental to later outcomes, consistent with previous literature on the displacement of other activities by screens (Gentile et al., 2017; Khan et al., 2017; Lauricella et al., 2015; Vandewater et al., 2006). However, we found only a trivially small mediated effect through childhood experiences, suggesting the hypothesised mediation is not a particularly important explanatory factor.

Limitations

There were several limitations to the present research. First, our analysis focused on screen exposure (i.e., amount of time) exclusively, without consideration of the content of that exposure or the context within which it occurs. Research has shown that impacts differ based on screen content (such as whether children are viewing high-quality educational content) and the context within which the screen viewing occurs (such as whether parents are co-viewing and verbally engaging with their child about the content; e.g., Madigan et al., 2020). Thus, it is important whenever possible to take a more nuanced view of screen time than simply the time that children are exposed to screen media. However, the *Growing Up in New Zealand* dataset has only limited information on the qualitative aspects of children's screen time. Further, as daily screen time is correlated with the type of content children watch and the likelihood of co-viewing (Barr et al., 2010; Jago et al., 2012; 2013), it is possible that both quantity and quality of screen exposure contributed to the associations found in the present research.

A strength of our research is the inclusion of sociodemographic confounding factors in an attempt in elucidate the unique effect of screen exposure above and beyond other contributing influences. However, it is important to note that there may be other confounding factors that were not controlled for in this research (such as family structure and parent employment status) that may impact child screen exposure.

We may have found only a negligible mediated effect through childhood experiences due to the measure that we used, which did not look at daily or weekly frequency of

childhood activities but only whether each type of activity had been experienced over a set period of time. A more in-depth assessment of childhood experiences may suggest a larger impact than found in this study. Further, screen time displaces other activities beneficial for development and well-being not included in our analyses, such as sleep and quality family time (e.g., Gentile et al., 2017; Vandewater et al., 2006). We also did not consider any adverse childhood experiences as potential mediating variables.

Many of the measures used in this research were reported by parents, including the screen exposure variables. The use of parent-reports could introduce social desirability bias if parents are uncomfortable admitting the extent of their child's screen exposure. Parents are also likely to be unreliable reporters in general, which will tend to downwardly bias the observed associations.

One of the strengths of the GUINZ dataset is its longitudinal nature; however, when analysing data on a rapidly evolving aspect of society it is important to note that the data collected is necessarily reflective of the context at the time of assessment. The digital landscape worldwide and within New Zealand has changed drastically over the 12 years since the first study wave used in this report was completed. It is likely that the extent of screen exposure, particularly electronic media use, has changed over that time.

Finally, while retention rates were high across earlier study waves, there was a drop in the retention rate at the 8-year study wave. The characteristics of children and parents who remained in the study differed from those who did not participate in the 8-year follow-up, introducing attrition bias. While we have employed statistical techniques to adjust for this missing data, there may still be impacts on our results. The lack of educational data at the 8-year assessment also limits the conclusions that can be drawn, as our analyses only include measures of school readiness rather than school responsiveness.

Conclusions

This research was undertaken within the context of increasingly pervasive availability and exposure to digital media and devices such as smartphones and tablets during childhood. Our findings suggest that limiting screen exposure across early childhood is beneficial for children's development, in terms of their language, early educational ability, and preventing peer problems. While sociodemographic characteristics were the largest predictor of later outcomes, even after controlling for these confounding factors there remained an effect of screen exposure. Further, when children spend more time on screens they are less likely to be engaging in other types of social and sensory-rich childhood activities. Our results support continuation of the existing national guidelines for screen usage in childhood.

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Appendix 1: Means and standard deviations of dependent variables

	n	Mean	SD	Range
Language and Educational Ability				
Vocabulary (age 2)	6,280	48.33	25.61	0 - 100
Language (age 4)	6,179	9.17	1.57	3 - 11
Vocabulary (age 5)	5,587	0	0.90	-4 - 3
Communication (age 5)	6,116	3.49	0.41	1 - 4
Writing (age 5)	5,615	5.08	1.88	0 - 8
Counting (age 5)	5,615	12.68	5.89	0 - 20
Letter fluency (age 5)	5,464	8.39	10.53	0 - 69
Social Functioning				
Peer problems (age 5)	6,131	1.60	1.58	0 - 9
Prosocial behaviour (age 5)	6,130	7.75	1.81	0 - 10
Peer problems (age 8)	4,676	1.46	1.62	0 - 10
Prosocial behaviour (age 8)	4,676	8.14	1.83	0 - 10
Peer bullying (age 8)	4,933	16.00	6.93	10 - 50
Peer satisfaction (age 8)	4,915	8.07	1.91	1 - 10
Childhood Experiences				
Childhood experiences (age 2)	6,278	12.56	4.33	0 - 29
Childhood experiences (age 8)	4,708	48.93	10.67	0 - 93
Descriptive statistics are provided for the subset of children with screen exposure data available at each study wave				

Appendix 2: Means and standard deviations of screen exposure across levels of confounding variables

Variable	Level	n[1]	Total Screen Exposure (Hours per Weekday) Mean (SD)				
			9 Months	2 Years	4 Years	5 Years	8 Years
Ethnicity	European	4,424	2.58 (0.94)	3.01 (2.55)	3.84 (2.42)	3.66 (2.48)	5.08 (2.72)
	Māori	1,526	2.92 (0.95)	4.22 (2.88)	5.03 (2.62)	4.93 (2.70)	6.33 (2.48)
	Pasifika	1,363	3.22 (0.98)	4.59 (2.99)	5.30 (2.70)	5.03 (2.84)	6.76 (2.17)
	Asian	1,086	3.16 (1.11)	4.13 (2.90)	4.50 (2.61)	3.77 (2.60)	5.39 (2.56)
Childcare attendance (age 2)	Yes	3,383	2.65 (0.97)	3.03 (2.50)	3.91 (2.44)	3.64 (2.47)	5.26 (2.69)
	No	2,631	2.92 (1.05)	4.07 (2.99)	4.59 (2.66)	4.28 (2.75)	5.59 (2.66)
Socioeconomic deprivation[2]	High	3,588	2.99 (1.04)	4.03 (2.93)	4.72 (2.66)	4.47 (2.76)	5.92 (2.59)
	Low	2,792	2.54 (0.95)	2.79 (2.41)	3.62 (2.33)	3.32 (2.32)	4.86 (2.68)
Gender	Boy	3,302	2.79 (1.02)	3.58 (2.80)	4.30 (2.61)	4.06 (2.65)	5.47 (2.66)
	Girl	3,080	2.80 (1.03)	3.43 (2.78)	4.15 (2.53)	3.84 (2.61)	5.41 (2.68)
Maternal age (at child age 9 months)	30 and under	2,814	3.02 (1.01)	4.16 (2.93)	4.88 (2.65)	4.64 (2.75)	5.93 (2.57)
	Over 30	3,558	2.61 (1.00)	2.95 (2.54)	3.72 (2.40)	3.42 (2.40)	5.07 (2.71)
Maternal education	No secondary school qual	417	3.19 (0.94)	5.08 (3.12)	5.84 (2.71)	5.79 (2.68)	7.52 (1.91)
	Secondary school/NCEA 1-4	1,483	3.04 (1.03)	4.04 (2.84)	4.80 (2.56)	4.57 (2.67)	6.22 (2.42)
	Diploma/Trade cert/NCEA 5-6	1,956	2.92 (1.00)	3.86 (2.87)	4.67 (2.58)	4.39 (2.67)	5.91 (2.39)
	Bachelor's degree	1,474	2.56 (0.97)	2.83 (2.37)	3.54 (2.29)	3.18 (2.25)	4.71 (2.76)
	Higher degree	1,024	2.35 (0.95)	2.28 (2.19)	3.00 (2.13)	2.70 (2.10)	3.82 (2.50)

[1]sample sizes are reported for 9 month study wave

[2]high deprivation includes deciles 6 through 10 and low deprivation includes deciles 1 through 5

Cell values are presented as: Mean (Standard Deviation)

Appendix 3: Full correlation matrix for screen exposure and outcome variables

Outcome Variable	SE9	SE2	SE4	SE5	SE8	VOC2	VOC4	VOC5	COM5	WRI5	COU5	LET5	PP5	PB5	PP8	PB8	BUL8	SAT8	CE2	CE8
Screen Exposure																				
Screen exposure 9 months **SE9**	-	.39	.37	.33	.28	-.21	-.17	-.27	-.17	-.06	-.13	-.05	.19	.01	.17	-.04	.08	-.06	-.20	-.09
Screen exposure 2 years **SE2**		-	.48	.47	.31	-.19	-.16	-.23	-.14	-.11	-.14	-.09	.19	-.04	.18	-.03	.08	-.05	-.20	-.15
Screen exposure 4 years **SE4**			-	.59	.38	-.20	-.17	-.21	-.14	-.15	-.16	-.13	.18	-.04	.16	-.05	.09	-.06	-.21	-.17
Screen exposure 5 years **SE5**				-	.39	-.18	-.17	-.18	-.15	-.18	-.15	-.15	.21	-.08	.17	-.06	.06	-.05	-.19	-.18
Screen exposure 8 years **SE8**					-	-.16	-.16	-.23	-.12	-.14	-.16	-.15	.18	-.03	.17	-.05	.08	-.05	-.16	-.13
Language and Educational Ability																				
Vocabulary (age 2) **VOC2**						-	.41	.37	.33	.20	.22	.13	-.16	.12	-.15	.12	-.10	.08	.29	.14
Language (age 4) **VOC4**							-	.42	.42	.31	.35	.28	-.20	.18	-.18	.14	-.11	.09	.20	.14
Vocabulary (age 5) **VOC5**								-	.33	.26	.40	.23	-.28	.05	-.22	.08	-.17	.13	.23	.07
Communication (age 5) **COM5**									-	.18	.22	.14	-.24	.28	-.16	.19	-.11	.09	.18	.12
Writing (age 5) **WRI5**										-	.43	.46	-.15	.14	-.14	.08	-.13	.08	.06	.13
Counting (age 5) **COU5**											-	.46	-.18	.09	-.14	.05	-.12	.11	.11	.11
Letter fluency (age 5) **LET5**												-	-.07	.06	-.06	.01	-.09	.05	.00	.09
Social Functioning																				
Peer problems (age 5) **PP5**													-	-.20	.38	-.17	.10	-.08	-.18	-.11
Prosocial behaviour (age 5) **PB5**														-	-.11	.36	-.03	.04	.08	.10
Peer problems (age 8) **PP8**															-	-.28	.24	-.20	-.14	-.14
Prosocial behaviour (age 8) **PB8**																-	-.10	.09	.10	.15
Peer bullying (age 8) **BUL8**																	-	-.32	-.08	-.05
Peer satisfaction (age 8) **SAT8**																		-	.05	.07
Childhood Experiences																				
Childhood exp (age 2) **CE2**																			-	.26
Childhood exp (age 8) **CE8**																				-

Appendix 4: Mean levels of childhood experiences by sociodemographic characteristics

Variable	Level	n[1]	Frequency of Childhood Experiences Mean (SD)	
			2 Years	8 Years
Ethnicity	European	4,299	13.30 (3.95)	48.84 (8.95)
	Māori	1,452	13.24 (4.45)	47.64 (10.30)
	Pasifika	1,244	11.96 (5.02)	48.15 (10.63)
	Asian	988	11.12 (4.35)	49.80 (9.94)
Childcare attendance (age 2)	Yes	3,486	13.11 (4.00)	50.11 (9.21)
	No	2,756	11.90 (4.62)	47.09 (9.74)
Socioeconomic deprivation[2]	High	3,360	12.08 (14.53)	47.78 (10.05)
	Low	2,713	13.28 (3.87)	49.93 (8.79)
Gender	Boy	3,261	12.59 (4.32)	47.97 (9.61)
	Girl	3,054	12.54 (4.34)	49.56 (9.52)
Maternal age (at child age 9 months)	30 and under	2,622	12.11 (4.49)	47.72 (9.93)
	Over 30	3,447	13.01 (4.09)	49.52 (9.21)
Maternal education	No secondary school qual	381	10.65 (4.57)	43.05 (11.15)
	Secondary school/NCEA 1-4	1,379	11.59 (4.40)	46.51 (9.78)
	Diploma/Trade cert/NCEA 5-6	1,850	12.46 (4.31)	48.48 (9.60)
	Bachelor's degree	1,437	13.40 (3.90)	50.35 (8.40)
	Higher degree	1,004	13.98 (3.80)	51.96 (8.38)

[1]sample sizes are reported for 2 year study wave

[2]high deprivation includes deciles 6 through 10 and low deprivation includes deciles 1 through 5

Cell values are presented as: Mean (Standard Deviation)

Appendix 5: Decomposition of correlations between screen exposure and outcomes, including decomposition of direct and indirect components of screen exposure

Outcome	Total Correlation	Confounders	Direct Screen Time	Indirect Screen Time	Childhood Experiences[1]
Predictor: Screen Exposure at 9 Months					
Language (age 5)	**-.25**	-.15	-.08	-.01	-.01
Educational Ability (age 5)	**-.15**	-.10	-.03	-.01	-.01
Peer Problems (age 5)	**.19**	.15	.02	.01	.01
Peer Problems (age 8)	**.17**	.12	.03	.01	.01
Predictor: Screen Exposure at 2 Years					
Language (age 5)	**-.23**	-.16	-.01	-.05	-.01
Educational Ability (age 5)	**-.17**	-.11	-.02	-.03	-.01
Peer Problems (age 5)	**.19**	.14	.03	.01	.01
Peer Problems (age 8)	**.18**	.12	.03	.02	.01
Predictor: Screen Exposure at 4 Years					
Language (age 5)	**-.23**	-.15	-.04	-.04	/
Educational Ability (age 5)	**-.20**	-.11	-.03	-.06	/
Peer Problems (age 5)	**.18**	.13	.02	.03	/
Peer Problems (age 8)	**.16**	.12	.02	.01	.01
Predictor: Screen Exposure at 5 Years					
Language (age 5)	**-.22**	-.15	-.03	-.04	/
Educational Ability (age 5)	**-.21**	-.13	-.02	-.06	/
Peer Problems (age 5)	**.21**	.12	.02	.07	/
Peer Problems (age 8)	**.17**	.12	.01	.04	.00
Predictor: Screen Exposure at 8 Years					
Peer Problems (age 8)	**.17**	.13	.04	.00	.00

[1]Childhood experiences at age 2 used in the analyses for screen exposure at 9 months and 2 years. Childhood experiences at age 8 used for screen exposure at ages 4, 5, and 8. Mediated component not included if childhood experiences were not assessed temporally between the independent and dependent variables.

Appendix 6: Covariate adjusted means for hourly increments of screen exposure

	Hours of Daily Screen Exposure								
	0	1	2	3	4	5	6	7	8
Outcome: Educational Ability									
2 Yr Direct	0.01	0.00	-0.01	-0.02	-0.02	-0.03	-0.04	-0.05	-0.06
2 Yr Total	0.07	0.05	0.03	0.01	-0.01	-0.03	-0.05	-0.07	-0.10
4 Yr Direct	0.10	0.05	0.00	-0.05	-0.10	-0.15	-0.20	-0.25	-0.30
4 Yr Total	0.16	0.12	0.08	0.04	0.01	-0.03	-0.07	-0.10	-0.14
Outcome: Language									
2 Yr Direct	0.03	0.01	-0.02	-0.04	-0.07	-0.09	-0.12	-0.14	-0.17
2 Yr Total	0.09	0.07	0.04	0.01	-0.01	-0.04	-0.07	-0.10	-0.12
4 Yr Direct	0.10	0.05	0.00	-0.05	-0.09	-0.14	-0.19	-0.24	-0.29
4 Yr Total	0.14	0.11	0.07	0.04	0.01	-0.03	-0.06	-0.09	-0.13
Outcome: Peer Problems Age 5									
2 Yr Direct	-0.05	-0.01	0.03	0.06	0.10	0.13	0.17	0.21	0.24
2 Yr Total	-0.06	-0.04	-0.02	-0.01	0.01	0.03	0.04	0.06	0.08
4 Yr Direct	-0.08	-0.04	0.00	0.04	0.08	0.12	0.16	0.19	0.23
4 Yr Total	-0.08	-0.06	-0.04	-0.02	0.00	0.01	0.03	0.05	0.07
Outcome: Peer Problems Age 8									
2 Yr Direct	-0.04	-0.01	0.02	0.06	0.09	0.13	0.16	0.19	0.23
2 Yr Total	-0.08	-0.06	-0.03	-0.01	0.01	0.04	0.06	0.08	0.11
4 Yr Direct	-0.06	-0.03	0.00	0.03	0.06	0.09	0.12	0.15	0.19
4 Yr Total	-0.07	-0.05	-0.03	-0.02	0.00	0.01	0.03	0.05	0.06
5 Yr Direct	-0.07	-0.04	0.00	0.03	0.07	0.11	0.14	0.18	0.21
5 Yr Total	-0.09	-0.06	-0.04	-0.02	0.00	0.02	0.05	0.07	0.09

'Direct" refers to direct screen exposure (television viewing and electronic media use)

'Total' refers to total screen exposure (direct screen exposure and background television)

Outcome variables have been standardised to a mean of 0, SD of 1

Appendix 7: Sociodemographic characteristics by latent trajectory group

	Latent Trajectory Group					
	Class 1 *Low Exposure*	Class 2 *Late Onset Exposure*	Class 3 *Moderate Exposure*	Class 4 *Varying Exposure*	Class 5 *Increasing Exposure*	Class 6 *High Exposure*
% female	51.2%	45.7%	49.9%	55.0%	46.3%	47.2%
% NZ European	91.8%	88.1%	80.2%	63.7%	79.9%	54.1%
% Māori	11.0%	15.7%	17.0%	19.7%	30.5%	32.4%
% Pacific	4.7%	7.6%	12.9%	21.5%	17.6%	33.3%
% Asian	10.1%	10.5%	16.1%	25.0%	10.8%	20.0%
Socioeconomic deprivation [Mean(SD)]	4.50 (2.59)	4.68 (2.65)	5.10 (2.79)	5.97 (2.92)	5.76 (2.92)	6.99 (2.71)