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The 3D-Transition Study: Objectives, Methods, and Implementation of an Innovative Planned Missing Data Design

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Abstract

The prevalence of mental health problems represents a significant burden on school and community health resources as early as preschool. Reducing this burden requires a better understanding of the developmental mechanisms linking children's early vulnerabilities with mental health after the transition to formal schooling. The 3D-Transition study (2017-2021; ClinicalTrials.org ID: NCT04873518) follows 939 participants from a pregnancy cohort in Québec (Canada) as they transition to kindergarten and first grade to examine these mechanisms. Biannual assessments include questionnaires from two parents as well as teachers, parent-child observations, anthropometric measurements, and age-sensitive cognitive assessments. Salivary cortisol is also collected on 11 days over a 16-month period in a subsample of 384 participants to examine possible changes in child salivary cortisol levels across the school transition, and their role in difficulties observed during the transition. A combination of planned missing data designs is implemented to reduce participant burden, where incomplete data is collected without introducing bias after the use of multiple imputation. The 3D-Transition study will contribute to an evidence-based developmental framework of child mental health from pregnancy to school age. In turn, this framework can help inform prevention programs delivered in health care settings during pregnancy, childcare centers, preschools, and schools.

Keywords: Childhood, Cortisol, Externalizing, Family, Internalizing, Longitudinal, School, Stress

Abbreviations: CAD, Canadian Dollars; COVID-19, Coronavirus disease 2019; df, Degrees of freedom; G1, Grade 1; G2, Grade 2; K − 1, 1 year before kindergarten; K, Kindergarten; RA: research assistant; SES, socio-economic status

Mental health disorders in youth increased in prevalence in the last decades in Canada and the United States (1, 2) and represent a significant burden on school and community health resources evident as early as preschool (3). Research shows that most adult mental health disorders have an onset or trajectory that began in childhood or adolescence (4-8), with some having perinatal origins (9). Evidence shows that 28% of children are ill prepared for the academic and social challenges of school entry (10). Among children with risk factors for mental health problems at 2-3 years whose problems persisted across the school entry transition, 22% met criteria for a DSM-IV diagnosis of externalizing or internalizing disorder with impairment (11).

Reducing this burden requires a clear understanding of the developmental mechanisms linking early vulnerabilities (i.e., externalizing/internalizing symptoms, low academic skills) and later mental health problems after the transition to formal schooling. There are several complementary, developmental hypotheses that could explain these associations. First, some research suggests that processes that are specific to the transition to kindergarten and grade school (e.g., establishment of teacher-child relationships) cumulate with child preschool vulnerabilities to increase the frequency and severity of impairments (12, 13). Second, vulnerabilities originating as early as the perinatal period (e.g., perinatal adversity, early home chaos) may be responsible for emerging mental health problems during the transition to school (9). Third, high-quality family and/or school environments may moderate the association between preschool vulnerabilities and later impairments (14, 15), which may also vary according to child sex (16). Fourth, the child stress response may be one of the mechanisms linking early vulnerabilities to later impairments. Indeed, a recent systematic review found that the transition to formal schooling is associated with increases in cortisol concentration and that it could take 3–

6 months before kindergartener's cortisol concentration returns to baseline levels (i.e., recovery), but the evidence was scant (17).

Research integrating and contrasting these four hypotheses is lacking and is important as they have different implications for when, where, and with whom to intervene in prevention programs. Accordingly, building on an existing pregnancy cohort, the 3D-Transition study was designed to examine four questions:

1. Are there (1) cascading effects, in which preschool vulnerabilities (externalizing *or* internalizing symptoms, *or* low academic skills) spill over to impact more of these domains through the transition to formal schooling, and (2) transactional effects, in which impairments that emerge during the transition to formal schooling as a consequence of preschool vulnerabilities feedforward to increase post-transition symptoms or low academic skills (see Figure 1A)?
2. Do early risk factors (perinatal adversity, early home chaos) contribute to these cascading/transactional effects (see Figure 1B)?
3. Are cascading/transactional effects moderated by the quality of concurrent family and school environments or by sex (see Figure 1C)?
4. Could the child stress response, as assessed by changes in salivary cortisol level across the school transition, play a role in the increasing impairments observed during the transition by mediating the cascading/transactional effects (see Figure 2)?

METHODS

Sample

The 3D (Design, Develop, Discover) cohort study was established to examine the associations between adverse exposures during gestation, birth outcomes and later health

outcomes in children (see Fraser et al. (18) and ClinicalTrials.gov Identifier NCT03113331). Women were recruited in the 1st trimester of pregnancy over a three-year period and 2366 women planning to deliver in collaborating University Hospital Centers in Québec (Canada) participated in the study. Women were able to communicate in French or English and participated with their partner and infant. Participants were assessed during the 1st, 2nd and 3rd trimesters as well as at delivery. Postnatal follow-ups occurred at 3 months, 1 year and 2 years of age.

The 3D-Transition study (ClinicalTrials.gov Identifier NCT04873518) is a follow-up of the 3D study during the transition to kindergarten and grade school. From the initial 3D study, 1551 families agreed to be contacted for follow-up and were invited to participate. Of these, 939 agreed to participate for at least one wave of the study. Sociodemographic characteristics at first wave are provided in Table 1. Compared to the remainder of the initial 3D sample, 3D-Transition mothers had more years of schooling, were older at delivery, had a higher household income, and were more likely to be married, born in Canada, or White (see Tables 2 and 3).

Following a cohort-sequential design, the sample included three cohorts based on child age on September 30, which serves as a cutoff in Québec, Canada for determining early academic levels (pre-kindergarten, kindergarten, grade 1, etc.). Among the 939 children, 208, 508, and 223 were respectively 5, 4, and 3 years old in September 2016. They entered kindergarten in the fall of 2016, 2017, and 2018, respectively. Six waves of testing were planned from the spring before kindergarten (K − 1) until the fall of Grade 2 (G2), although the first two assessments could not be done for the first cohort because they were already in kindergarten when the 3D-Transition follow-up began in 2017 (see Table 4). Data collection is ongoing and will be completed in the summer of 2021. We aimed to recruit 400 of the 731 participants from

the second and third cohorts (that could be assessed in K − 1), to participate in cortisol sampling. To ensure families of all socio-economic status (SES) backgrounds were included in this subsample and adequate variance on two key early temperament risk factors, we oversampled from low SES participants, and participants high on temperamental risk factors (on high surgency and/or fear (19) measured at age 2). Sampling was first done randomly within these three pools of participants with the aim of obtaining 200 participants, then the remaining 200 participants were randomly selected from the rest of the sample. In the end, 384 participants agreed to participate in cortisol sampling (42 low SES, 73 high fear, 65 high surgency, 204 rest of the sample). Following these recruitment strategies, the proportion of mothers who were White or born in Canada was smaller in the cortisol sample compared to the remainder of the 3D-Transition sample (see Tables 2 and 3).

Data collection

Home assessments. Home assessments were conducted in the spring and summer of each year, with a minority occurring in the early fall. Home assessments were initially planned for all data collection waves, but the G2 assessment was canceled due to a funding agency-wide budget cut. Home visits included age-sensitive cognitive assessments of memory, visuo-spatial integration, executive function, theory of mind, emotion understanding, school readiness, language development, and motor development (complete list of tasks in Web Table 1, order was counterbalanced). Cardiovascular and anthropometric measurements were taken (twice - three times when there were discrepancies) and included child heart rate, blood pressure, skinfold thickness, height, waist and weight, as well as child, mother, and father head circumference. Preschool children (K − 1 and K) completed a number-to-image matching activity called *Mystero* (20) with a parent, which was filmed in order to code dyadic interactions. The activity was used

in previous research and presents a good challenge for preschoolers, providing an effective context for evaluating parent-child interactions (21, 22).

Salivary cortisol sampling. A recent review on the cortisol response to the transition to formal schooling found that previous research was limited by a lack of repeated measures over the school year, i.e., lack of sufficiently frequent time intervals to capture rapid recoveries, and sufficiently long follow-up period for recovery to be observed in most children (17). Our design aimed to address these limitations. A measurement burst design was used to assess salivary cortisol twice daily (before breakfast and before bedtime) on Wednesdays (to control for time and week effects, and avoid confounding stress associated with school with other sources of stress that might occur on weekends (17)). The two daily measurements will allow examining a) morning cortisol, which should reflect the anticipation of daily challenges, and b) a cortisol change score from morning to evening, which indicates how well the HPA system regulated itself across the day and reflects how the child copes with daily challenges. The salivary samples were collected in June and August preceding entry into kindergarten (two baselines), then twice one week apart at kindergarten entry in early September, then on the first Wednesday of November, February, and April. The June, August, and two September assessments were also repeated in first grade, for a total of 22 samples on 11 days over a 16-month period. The last cortisol samples were collected in the fall of 2019, before the onset of the Coronavirus disease 2019 (COVID-19) pandemic. Parents were trained in sample collection procedures and completed a diary log on each sampling day, assessing functional indicators (e.g., child behavior problems, somatic complaints) and confounding variables (e.g., medication).

Questionnaires. Three respondents were contacted to answer self-reported questionnaires for each child participant, i.e., two parents (respondents 1 and 2 - mother and/or father and/or

stepparent and/or other person who provides the second parent role - may change between assessments) and the child's main teacher (respondent 3 - new teachers solicited each year). A longer parent questionnaire was answered by one parent if both parents lived together or by both parents if they lived apart, but a shorter parent questionnaire was answered by the second parent if both parents lived together. The questionnaires assessed a wide array of constructs related to child, parent, family, and school characteristics (see Web Table 2). All questionnaires were shortened with a three-form planned missing data design (see below). Perinatal assessments are fully described in Fraser et al. (18).

COVID-19 survey. All respondents were asked to complete additional questionnaires following the onset of the COVID-19 pandemic. The items were complementary to the core questionnaires and were adapted from The Coronavirus Health Impact Survey (23) and the work of our team experts on stress, school environments and media use. Items (121 for parents, 17 for teachers) covered: parent and child stress, physical and mental health; social interactions and support; changes and challenges faced in the family including job situation, working from home, single parenthood, and shared custody; and challenges faced in the schooling context including communications between schooling authorities and parents, challenges faced by the teachers, and support for home schooling. These questionnaires will provide data that will allow addressing the four main research questions while taking into account the impact of the pandemic (e.g., as confounding variables or moderators).

Planned missing data design

The high number of questionnaire items combined with recurring home assessments represented a high participant burden. To reduce this burden while maintaining efficiency, a combination of planned missing data designs was implemented. These designs allow for the

collection of incomplete data while ensuring that the missing data introduced is missing completely at random and, thereby, does not introduce bias after the use of missing data treatments (24). In the 3D-Transition study, full information maximum likelihood (FIML) will be used when examining the main research questions, but multiple imputation may be used for secondary data analyses not using structural equation modeling.

Multiform design for questionnaires. A three-form design was implemented to randomly assign participants to have missing questionnaire items. Each item was assigned to one of four sets (X, A, B, C) which were then combined to create three forms (i.e., questionnaire versions). The X set was common to all three forms, while one different set among sets A, B and C was left out (i.e., missing) from each form (24), see Table 5. Assignment of items to each set followed a within-block design, where scale items are spread across forms. This design (compared to keeping scale items together within each form) is associated with smaller standard errors, narrower confidence intervals and greater power (25-27) and leads to a more manageable assessment for participants, who view questionnaires from a within-block design as shorter, less boring and less repetitive (27). As recommended by methodological research, the X set included dependent variables not measured with multiple indicators (28), potential predictors of unplanned missingness, and the most reliable items from each scale (24). Demographic variables were included in this set as they have often been shown to predict missingness and attrition (i.e., dropout) in longitudinal studies (29, 30). We used one of four rules to select the most reliable items, going to the next option in the order of priority only when the previous one was not available: items with the highest factor loadings or item-total correlations (1) in published analyses or (2) in analyses conducted on the scale when used in previous data collections of the

3D study or in a previous study from our laboratory (31); (3) most general items; (4) randomly selected items.

Little methodological research examined how the three forms should be assigned across assessments in longitudinal research and across multiple respondents. Only one study examined assignment across assessments, finding that assigning the same or different forms did not influence efficiency for longitudinal mediation models using a within-block designs (28). This has not been examined for other models or with multiple respondents. Theoretically, attributing different forms across assessments and respondents could provide more information on highly correlated items, which can facilitate missing data handling (32). Accordingly, each respondent was assigned a different form per assessment within three consecutive assessments (but were assigned each form twice across the six planned assessments). Since the two parents (respondents 1 and 2) had questionnaires including the same scales, they had different form numbers within each assessment. However, since the teacher (respondent 3) had different questions than those answered by the parents even when scales were measuring the same domains, they were attributed the same form number as respondent 1. The attribution of forms across assessments and respondents can be found in Table 6.

Wave-missing design for home assessments. A wave-missing design was implemented by randomly assigning participants to have missing home assessments. Seven profiles were established, with different profiles for the first cohort that could not be assessed in K − 1, and profiles with and without cortisol sampling for the second and third cohorts (see Table 7). Methodological research on the patterns of missed assessments in wave-missing designs has been limited to growth modeling (24, 33-36). While there is little guidance on optimal assignments for panel models and large-scale longitudinal studies, a key component is to ensure

covariance coverage (24). Accordingly, the assignment of home assessments to profiles included all possible pairs of assessments. For participants *without* cortisol sampling: 15% had one home assessment, 60% had two home assessments, and 25% had three home assessments. For participants *with* cortisol sampling: 15% had two home assessments, 60% had three home assessments, and 25% had four home assessments, with *all* participants having the wave 1 home assessment to allow for parent training in sample collection procedures. These profiles were determined and assigned to families *before* the cancellation of G2 home assessments. Despite this change in protocol, all possible pairs of assessments from K − 1 to G1 were assessed through the planned profiles.

Assignment to waves and forms. When participants consented to participate in 3D-Transition, they were randomized to a questionnaire form profile (6 profiles; see Table 6) and a wave-missing profile (7 profiles; see Table 7).

Randomization for cognitive tasks. The first home visits of 2017 for K − 1 and K, initially planned to last 2h, were found to be too long (see Quality assurance and control section). We implemented a randomization selection procedure for certain cognitive tasks as of spring 2018, which brought down duration to a maximum of 2h15 while still assessing all planned cognitive domains. To do so, participants were randomly assigned to one of two tasks measuring similar underlying cognitive dimensions. K − 1 and K children were randomized to one of two tasks measuring working memory (see Web Table 3). Participants who had home visits before the implementation of this procedure completed all tasks, which will allow for the estimation of their covariances in missing data treatments. Visits for the cortisol subsample took longer due to the additional parent training. Thus, children in this subsample were also randomized to complete

one of two tasks measuring school readiness (see Web Table 4). No randomization was added for G1 as these visits were within planned time limits.

Quality assurance and control

Each year, research assistants (RAs) received a two-day manualized training session. RAs, psychology students (or related fields) with experience working with children and families, often returned yearly. Training involved best practices in interacting with children and their families, conducting anthropometric and cardiovascular assessments, and focused mainly on cognitive testing (37): 1) RAs recorded practice sessions with non-cohort children in the same age range, and 2) all cognitive testing with study participants was recorded. A thorough 3-page checklist, typical for these types of assessments, and covering general and specific steps of test administration for each task, was used to score both practice and quality control videos. RAs were assigned study participants once they were able to conduct practice sessions with minimal errors, which did not threaten task validity and could be corrected with simple feedback. Afterwards, videos were examined systematically for the first three home visits and later examined randomly to ensure compliance with the testing protocol. The child's state, in general and during each test, as well as the extent to which protocol deviations may affect test validity, were carefully recorded by RAs and will allow adjustments for experimental and measurement error.

To foster lasting and meaningful participant engagement in this longitudinal study, we developed a mixed methods design where we work with families in several ways to understand their expectations and concerns about participating in the study and better tailor our approaches to them. This design was four-pronged: 1) visits were followed up with a scripted satisfaction call (by a different RA than the one doing the visit) asking parents open questions about their

experience with our staff and the protocol, 2) at the end of each wave a self-report survey was sent to all parents, 3) we interviewed a small number of families representing various patterns of participation to address targeted issues, and 4) we embedded open questions in the questionnaires themselves. This allowed improvements to the study. For example, the first approach led us to adjust the length of home visits by randomizing tasks (see Planned missing data design section), and the third approach helped us correct barriers to navigating our online research platform. Applying the fourth approach to the 2020 COVID-19 questionnaire allowed taking into consideration participant concerns about the content and format of the questionnaire for the design of our 2021 COVID-19 follow-up questionnaire. Newsletters were also developed following the interests and suggestions expressed by both parents and teachers. For the quantitative aspect, we monitored week-by-week participation rates and the frequency of participant comments on key issues following implemented changes. While some outcomes of these approaches are readily observable and show improvement, others will allow studying the mechanisms of engagement which will guide future follow-ups of the study.

Ethical approval

The multicenter protocol of the 3D-Transition study was coordinated by the research ethics committee of the Ste-Justine University Hospital Centre. Informed consent was obtained once from all respondents before their first participation in 3D-Transition. All participants, received a financial compensation, and children could choose among a variety of toys.

DISCUSSION

The study design of the 3D-Transition study is well-suited to address developmental questions (see Figure 3). Although the method was designed to address four key research questions, our extensive experience in longitudinal designs and population studies served us to

integrate a broader set of measures that will allow secondary data analyses addressing related developmental questions. The follow-up of a pregnancy cohort through the transition to formal schooling capitalizes on previously collected data and will allow the examination of perinatal predictors of school-aged children's mental health. Furthermore, the longitudinal design of the study will allow for the examination of bidirectional links when testing hypotheses. Since questionnaires are completed by two parents and children's teachers, in addition to observational measures and cognitive assessments, the study will have extensive measures of environmental and child factors, which will also help mitigate common limitations of questionnaire-based studies such as shared method variance. Finally, the cohort-sequential design helps to control for cohort effects and the addition of COVID-19 surveys will allow taking into account the impact of the pandemic on the variables of interest, thus avoiding potential historical event confounds.

The cortisol sampling plan is a particularly important strength of the study. Studies of cortisol reactivity to the school transition have been especially limited by 1) small sample sizes of 28 to 112 participants, 2) only one baseline measure; and 3) few recovery measures (17). With a sample of 384 participants for salivary cortisol sampling, the 3D-Transition study can reliably explore patterns of cortisol responses, their predictors and functional correlates, and small to moderate intra- and inter-individual differences. Two baseline measures will allow to better isolate sources of stress specifically related to the school transition in kindergarten and grade 1. Finally, two measures early in the school year will allow capturing quick, early recoveries, and three additional measures throughout the kindergarten year, with the last one in April, will allow to capture recovery in most children, even those with long recovery periods.

The study also included innovative planned missing data designs. Much research has shown that planned missing data designs are associated with valid results (27, 28, 34, 35, 38-40)

and their use provides many advantages. In particular for the 3D-Transition study, planned missing data designs reduced participant burden, which was an important advantage considering that the design had long questionnaires and repeated home visits. The reduction in participant fatigue obtained through these designs has been shown to lead to improved validity, stronger associations, and less unplanned missingness due to skipped items and attrition (41). However, the implementation of these methods in 3D-Transition required some decisions to be based on theory and careful reasoning rather than empirical evidence. Accordingly, undergoing this process highlighted knowledge gaps that could be answered by future methodological research. As mentioned above, the assignment of questionnaire forms across time for longitudinal studies has only been examined in one study (28), and the assignment of forms across several respondents has not been examined. Furthermore, research on missing data patterns in wave-missing designs have been examined exclusively in the context of growth modeling (24, 33-36) and was thus of limited utility for this cohort study. To better guide researchers, wave-missing designs should also be examined in the context of other prevalent longitudinal models, such as panel models (e.g., cross-lagged panel models, longitudinal mediation models). Complex designs also need to be examined. For example, the 3D-Transition study includes nested data (participants are nested within cohorts). The planned missing data designs were applied as they would have been for non-nested data, but methodological research examining how planned missingness performs in those instances would be particularly useful for applied research.

While the 3D-Transition study has many strengths, it also has some limitations. The sample is >80% White (see Table 1) and less diverse than the initial 3D sample (see Table 2). While this is representative of the ethnic and racial distribution of the population in Québec (42), it will limit the possibility of examining race and ethnic origin as a moderating factor due to

limited power. The sample also has average SES and parent education levels that are slightly higher than for the general population, which may limit generalizability. Finally, although the longitudinal design allows for more reliable examination of developmental associations, the design remains correlational, and will not allow any causal conclusions.

Despite these limitations, the 3D-Transition study will be well-positioned to make significant contributions to the understanding of child mental health. A better understanding of the developmental mechanisms that may explain how children's early vulnerabilities develop into mental health problems between pregnancy and grade school has key implication with regards to when, where, and on whom to intervene in future prevention programs. The 3D-Transition study will contribute to an evidence-based developmental framework of mental health from pregnancy to school age. In turn, this can help improve programs delivered in community and health care settings during pregnancy, as well as in daycare centers, preschools and schools, which represent important settings of influence for public policy, screening and prevention.

DATA AVAILABILITY

Data are under the jurisdiction of the CHU Ste-Justine Research Ethics committee and subject to current provincial and national privacy laws guiding their ethical use in Québec, Canada. To submit a request, please visit the following website: http://www.irnpqeo.ca/en/researchers/ or contact the corresponding author.

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References

1. Perou R, Bitsko RH, Blumberg SJ, et al. Mental Health Surveillance Among Children - United States, 2005-2011. *MMWR-Morb Mortal Wkly Rep.* 2013;62(2):1-35.
2. Comeau J, Georgiades K, Duncan L, et al. Changes in the Prevalence of Child and Youth Mental Disorders and Perceived Need for Professional Help between 1983 and 2014: Evidence from the Ontario Child Health Study. *Can J Psychiat-Rev Can Psychiat.* 2019;64(4):256-64.
3. Charach A, Mohammadzadeh F, Belanger SA, et al. Identification of Preschool Children with Mental Health Problems in Primary Care: Systematic Review and Meta-analysis. *J Can Acad Child Adolesc Psychiatry.* 2020;29(2):76-105.
4. Bevilacqua L, Hale D, Barker ED, et al. Conduct problems trajectories and psychosocial outcomes: a systematic review and meta-analysis. *Eur Child Adolesc Psych.* 2018;27(10):1239-60.
5. Gin K, Stewart C, Jolley S. A systematic literature review of childhood externalizing psychopathology and later psychotic symptoms. *Clin Psychol Psychother.* 2021;28(1):56-78.
6. Séguin JR, Leckman JF. Developmental approaches to child psychopathology: longitudinal studies and implications for clinical practice. *J Can Acad Child Adolesc Psychiatry.* 2013;22(1):3-5.
7. Kessler RC, Amminger GP, Aguilar-Gaxiola S, et al. Age of onset of mental disorders: a review of recent literature. *Curr Opin Psychiatr.* 2007;20(4):359-64.

8. Rioux C, Castellanos-Ryan N, Parent S, et al. Age of Cannabis Use Onset and Adult Drug Abuse Symptoms: A Prospective Study of Common Risk Factors and Indirect Effects. *Can J Psychiat-Rev Can Psychiat.* 2018;63(7):457-64.
9. Glover V. Prenatal stress and the origins of psychopathology: an evolutionary perspective. *J Child Psychol Psychiatry.* 2011;52(4):356-67.
10. Simard M, Lavoie A, Audet N. Enquête québécoise sur le développement des enfants à la meternelle 2017. Québec, QC: Institut de la statistique du Québec, 2018.
11. Carter AS, Wagmiller RJ, Gray SAO, et al. Prevalence of DSM-IV Disorder in a Representative, Healthy Birth Cohort at School Entry: Sociodemographic Risks and Social Adaptation. *J Am Acad Child Adolesc Psychiatr.* 2010;49(7):686-98.
12. McGrath KF, Van Bergen P. Who, when, why and to what end? Students at risk of negative student-teacher relationships and their outcomes. *Educ Res Rev.* 2015;14:1-17.
13. Wang MT, Degol JL, Amemiya J, et al. Classroom climate and children's academic and psychological wellbeing: A systematic review and meta-analysis. *Dev Rev.* 2020;57:21.
14. Rioux C, Castellanos-Ryan N, Parent S, et al. The interaction between temperament and the family environment in adolescent substance use and externalizing behaviors: Support for diathesis-stress or differential susceptibility? *Dev Rev.* 2016;40:117-50.
15. Belsky J, Pluess M. Beyond risk, resilience, and dysregulation: Phenotypic plasticity and human development. *Dev Psychopathol.* 2013;25(4):1243-61.
16. Collishaw S. Annual Research Review: Secular trends in child and adolescent mental health. *J Child Psychol Psychiatry.* 2015;56(3):370-93.
17. Parent S, Lupien S, Herba CM, et al. Children's cortisol response to the transition from preschool to formal schooling: A review. *Psychoneuroendocrinology.* 2019;99:196-205.

18. Fraser WD, Shapiro GD, Audibert F, et al. 3D Cohort Study: The Integrated Research Network in Perinatology of Quebec and Eastern Ontario. *Paediatr Perinat Epidemiol.* 2016;30(6):623-32.

19. Putnam SP, Gartstein MA, Rothbart MK. Measurement of fine-grained aspects of toddler temperament: The Early Childhood Behavior Questionnaire. *Infant Behavior and Development.* 2006;29(3):386-401.

20. Lyons M, Lyons R. Mystero. Montréal, QC: Chenelière Éducation, 1999.

21. Caron L, Parent S, Normandeau S, et al. Les caractéristiques de la collaboration mère-enfant à 48 mois dans deux tâches de numération. *L'annee psychologique.* 2008;108(1):15-50.

22. Rioux C, Murray J, Castellanos-Ryan N, et al. Moderation of parenting by inhibitory control in the prediction of the common and unique variance of hyperactivity-impulsivity and inattention. *Dev Psychopathol.* 2020;32(3):909-21.

23. Nikolaidis A, Paksarian D, Alexander L, et al. The Coronavirus Health and Impact Survey (CRISIS) reveals reproducible correlates of pandemic-related mood states across the Atlantic [preprint]. *medRxiv.* 2020. (doi: 10.1101/2020.08.24.20181123). Accessed September 4, 2020.

24. Rioux C, Lewin A, Odejimi OA, et al. Reflection on modern methods: planned missing data designs for epidemiological research. *Int J Epidemiol.* 2020;49(5):1702–11.

25. Graham JW, Hofer SM, MacKinnon DP. Maximizing the usefulness of data obtained with planned missing value patterns: An application of maximum likelihood procedures. *Multivariate Behav Res.* 1996;31(2):197-218.

26. Rhemtulla M, Hancock GR. Planned Missing Data Designs in Educational Psychology Research. *Educ Psychol.* 2016;51(3-4):305-16.

27. Adiguzel F, Wedel M. Split Questionnaire Design for Massive Surveys. *J Mark Res.* 2008;45(5):608-17.

28. Jorgensen TD, Rhemtulla M, Schoemann A, et al. Optimal assignment methods in three-form planned missing data designs for longitudinal panel studies. *Int J Behav Dev.* 2014;38(5):397-410.

29. Watson N, Wooden M. Identifying factors affecting longitudinal survey response. In: Lynn P, ed. *Methodology of longitudinal surveys*. West Sussex, UK: John Wiley & Sons, 2009:157-82.

30. Eisner NL, Murray AL, Eisner M, et al. A Practical Guide to the Analysis of Non-Response and Attrition in Longitudinal Research Using a Real Data Example. *Int J Behav Dev.* 2019;43(1):24-34.

31. Santé Québec, Jetté M, Desrosiers H, et al. *"En 2001… j'aurai 5 ans!", Enquête auprès des bébés de 5 mois. Rapport préliminaire de l'Étude longitudinale du développement des enfants du Québec (ÉLDEQ)*. Montréal, QC: Ministère de la Santé et des Services Sociaux, Gouvernement du Québec; 1997.

32. Collins LM, Schafer JL, Kam CM. A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychol Methods.* 2001;6(4):330-51.

33. Brandmaier AM, Ghisletta P, von Oertzen T. Optimal planned missing data design for linear latent growth curve models. *Behav Res Methods.* 2020;52(4):1445-58.

34. Hogue CM, Pornprasertmanit S, Fry MD, et al. Planned missing data designs for spline growth models in salivary cortisol research. *Measurement in Physical Education and Exercise Science.* 2013;17(4):310-25.

35. Rhemtulla M, Jia F, Wu W, et al. Planned missing designs to optimize the efficiency of latent growth parameter estimates. *Int J Behav Dev.* 2014;38(5):423-34.

36. Wu W, Jia F, Rhemtulla M, et al. Search for efficient complete and planned missing data designs for analysis of change. *Behav Res Methods.* 2016;48(3):1047-61.

37. Sattler JM, Hoge RD. *Assessment of children: Behavioral, social, and clinical foundations*. 5th ed. San Diego, CA: Jerome M. Sattle Publisher Inc.; 2006.

38. Graham JW, Taylor BJ, Cumsille PE. Planned missing-data designs in analysis of change. In: Collins PE, Sayer AG, eds. *New methods for the analysis of change*. Washington, DC: American Psychological Association, 2001:335-53.

39. Palmer RF, Royall DR. Missing Data? Plan on It! *J Am Geriatr Soc.* 2010;58:S343-S8.

40. Rhemtulla M, Savalei V, Little TD. On the asymptotic relative efficiency of planned missingness designs *Psychometrika.* 2016;81(1):60-89.

41. Harel O, Stratton J, Aseltine R. Designed missingness to better estimate efficacy of behavioral studies-application to suicide prevention trials. *Journal of Medical Statistics and Informatics.* 2015;3(1):1-7.

42. Statistics Canada. Focus on Geography Series, 2016 Census. Ottawa, Ontario: Data products, 2016 Census, 2017, publication no. Statistics Canada Catalogue no. 98-404-X2016001)

Table 1. Sociodemographic Characteristics of Participants in the 3D-Transition Study (2017-2021) at Wave 1

		Respondent 1	Respondent 2[a]
Variable	**%**	**%**	**%**
Child sex: Female	50.1		
Household income			
<40 000 CAD	9.7		
40 000 - 80 000 CAD	23.9		
>80 000 CAD	66.4		
Household with both legal parents	86.1		
Education			
High school not completed		0.7	1.8
High school diploma		8.2	5.7
CEGEP[b] or vocational school diploma		20.7	27.0
University degree		68.1	65.3
Other		2.2	0.4
Ethnicity[c]			
White		81.1	84.8
Native African		4.1	3.0
African American		0.6	0.6
East Asian		2.7	1.4
South Asian		0.4	0.4
Arab-West Asian		5.2	5.5
Latin American		5.5	3.7
Native/Aboriginal		1.1	0.3
Other		3.4	3.0

Abbreviations: CAD, Canadian Dollars.

[a]Respondent 1 = Parent 1; Respondent 2 = Parent 2

[b]CEGEP: technical professional degrees or pre-university degrees required in the province after high school graduation (grade 11) to enter university before age 21; equivalent to 13-14 years of schooling from Grade 1.

[c]Participants were asked whether they were a member of each ethnicity listed, total >100% because participants could identify as more than one ethnicity.

Table 2. Descriptives of participants (a) in the 3D study, (b) who agreed to be contacted for a follow-up, (c) in 3D-Transition (2017-2021), and (d) with cortisol sampling on infant and mother characteristics measured between pregnancy and delivery

Variables	3D (n = 2366)	Contacted (n = 1551)	3D-Transition (n = 939)	Cortisol (n = 383)
Infant female sex (%)	50	49.9	50.1	51.8
Household income (%)				
<40 000 CAD	17.8	16	11.1	13.3
40 000 - 80 000 CAD	31.8	31.3	30.8	28.5
>80 000 CAD	50.4	52.8	58.1	58.1
Married/common law partnership (%)	94.5	95.2	96.2	96.4
Years of schooling[a]	16.56 (3.28)	16.75 (3.23)	17.08 (3.06)	16.92 (3.10)
Mother born in Canada (%)	65.1	67.2	73.6	69.5
White (%)	72.2	74.0	81.1	77.8
Mother age at delivery[a]	31.46 (4.61)	31.6 (4.45)	31.71 (4.25)	31.97 (4.30)

Abbreviations: CAD, Canadian Dollars.
[a]Values are expressed as mean (standard deviation)

Table 3. Comparisons between participants (a) in the 3D study, (b) who agreed to be contacted for a follow-up, (c) in 3D-Transition (2017-2021), and (d) with cortisol sampling on infant and mother characteristics measured between pregnancy and delivery

	Contacted vs. 3D			3D-Transition vs. Contacted			Cortisol vs. 3D-Transition		
Variables	χ^2 value	t value	p	χ^2 value	t value	p	χ^2 value	t value	p
Infant female sex[a]	0.00		.978	0.01		.908	0.81		.367
Household income[b]	13.22		.001	47.81		<.001	3.80		.149
Married/common law[a]	4.63		.031	4.60		.032	0.06		.803
Years of schooling[c]		-3.90	<.001		-4.95	<.001		1.33	.183
Mother born in Canada[a]	8.89		.003	43.78		<.001	5.50		.019
White[a]	7.30		.007	62.07		<.001	4.67		.031
Mother age at delivery[d]		-2.18	.029		-1.24	.216		-1.53	.127

Abbreviations: df, degrees of freedom
[a]df = 1
[b]df = 2
[c]df Contacted vs. 3D = 2316; df 3D-Transition vs. Contacted = 1522; df Cortisol vs. 3D-Transition = 919
[d]df Contacted vs. 3D = 2233; df 3D-Transition vs. Contacted = 1548; df Cortisol vs. 3D-Transition = 936

Table 4. Planned Assessments for Each Cohort From the 3D-Transition Study (2017-2021)

	2017		2018		2019		2020		2021	
Cohort	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Cohort 1	K	G1	G1		G2					
Cohort 2	K − 1	K	K	G1	G1		G2			
Cohort 3			K − 1	K	K	G1	G1		G2	

Abbreviations: G1, Grade 1; G2, Grade 2; K − 1, 1 year before kindergarten; K, Kindergarten.

Table 5. Breakdown of Sets of Items and Their Assignment to Forms in a 3-Form Design

Form	**Set X**	**Set A**	**Set B**	**Set C**
1	X	X	X	N/A
2	X	X	N/A	X
3	X	N/A	X	X

Abbreviations: N/A, not applicable, i.e., set missing from form; X, set included in form.

Table 6. Assignment of the 3-Form Design for Questionnaires Across Assessments and Respondents in 3D-Transition (2017-2021)[a]

	K − 1 Spring		K Fall		K Spring		G1 Fall		G1 Spring		G2 Spring		Assignment
Profile	R1/R3	R2	R1/R3	R2	R1/R3	R2	R1/R3	R2	R1/R3	R2	R1/R3	R2	values[b]
Profile 1	1	2	2	3	3	1	1	2	2	3	3	1	1-17
Profile 2	1	3	2	1	3	2	1	3	2	1	3	2	18-33
Profile 3	2	3	3	1	1	2	2	3	3	1	1	2	34-50
Profile 4	2	1	3	2	1	3	2	1	3	2	1	3	51-66
Profile 5	3	1	1	2	2	3	3	1	1	2	2	3	67-83
Profile 6	3	2	1	3	2	1	3	2	1	3	2	1	84-100

Abbreviations: G1 = Grade 1; G2 = Grade 2; K − 1 = 1 year before kindergarten; K = Kindergarten; R1 = Respondent 1, i.e., parent 1; R2 = Respondent 2, i.e., parent 2; R3 = Respondent 3, i.e., teacher.

[a]Cell numbers (1-3) indicate form assigned.

[b]When participants gave consent to participate in 3D-Transition, a number between 1 and 100 was randomly drawn to assign their profile. The same random number determined their wave-missing profile (see Table 7).

Table 7. Assignment of the Wave-Missing Design for Home Assessments in 3D-Transition (2017-2021)

Profile	%	Assessment				Assignment values[a]
		K − 1	K	G1	G2	
Cohort 1						
1	5	N/A	X	N/A	N/A	1-5
2	5	N/A	N/A	X	N/A	6-10
3	5	N/A	N/A	N/A	X	11-15
4	20	N/A	X	X	N/A	16-35
5	20	N/A	X	N/A	X	36-55
6	20	N/A	N/A	X	X	56-75
7	25	N/A	X	X	X	76-100
Cohorts 2 and 3, no cortisol						
1	5	X	N/A	N/A	N/A	1-5
2	5	N/A	X	N/A	N/A	6-10
3	5	N/A	N/A	X	N/A	11-15
4	20	X	X	N/A	N/A	16-35
5	20	X	N/A	X	N/A	36-55
6	20	N/A	X	X	N/A	56-75
7	25	X	X	X	N/A	76-100
Cohorts 2 and 3, with cortisol sampling						
1	5	X	X	N/A	N/A	1-5
2	5	X	N/A	X	N/A	6-10
3	5	X	N/A	N/A	X	11-15
4	20	X	X	X	-	16-35
5	20	X	X	N/A	X	36-55
6	20	X	N/A	X	X	56-75
7	25	X	X	X	X	76-100

Abbreviations: G1, Grade 1; G2, Grade 2; K − 1, 1 year before kindergarten; K, Kindergarten; N/A, not applicable, i.e., home assessment missing; X, home assessment administered.

[a]When participants gave consent to participate in 3D-Transition, a number between 1 and 100 was randomly drawn to assign their profile. The same random number determined their questionnaire profile (see Table 6).

FIGURE LEGENDS

Figure 1. Examples of (A) cascade and transactional effects starting with externalizing problems, tested in a cross-lagged panel model - full lines represent cascading effects; dashed lines represent transactional effects. (B) the addition of early risk factors - full lines represent early shared risk effects; long dash and dots lines represent cascading and transactional effects that could disappear once shared risk effects are included; (C) family dysfunction as a moderator - long dash and dots lines represent moderation effects. Hypothesized relationships shown; control variables, other cross-lagged regressions and within time covariances not illustrated. 3D-Transition Study (2017-2021).

Figure 2. Examples of (A) model testing the mediating role of stress between preschool externalizing behaviors and teacher-child relationship in K, with cortisol modeled using piecewise latent growth modeling with slope 1 before K entry and slope 2 after K entry, and (B) model testing the mediating role of stress between teacher-child relationship in K and child externalizing behaviors in G1, with cortisol modeled using latent growth modeling and one slope across the K and G1 period. K = Kindergarten. G1 = Grade 1. 3D-Transition Study (2017-2021).

Figure 3. Lessons learned from the 3D-Transition Study (2017-2021).

Figure 1

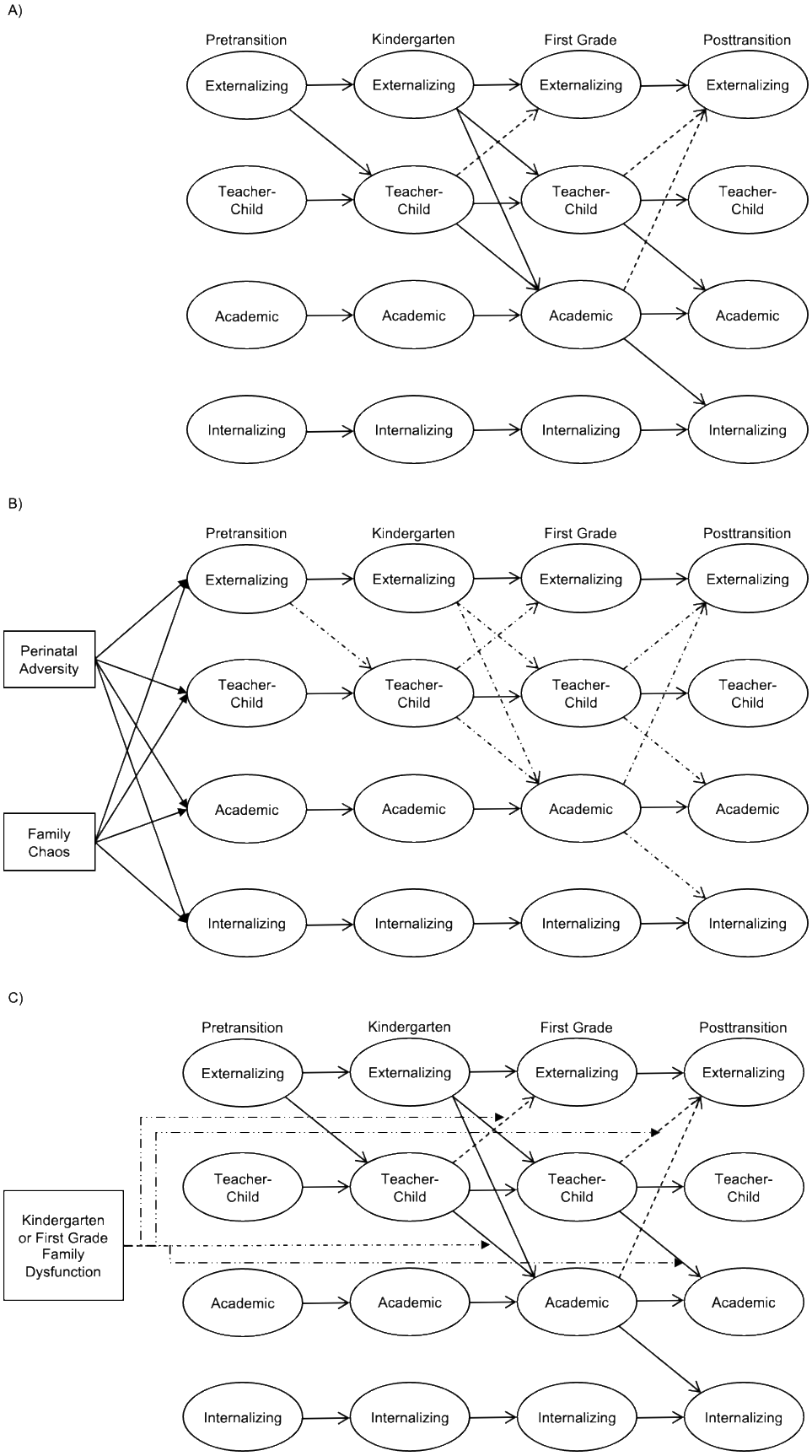
A)
Pretransition
Kindergarten
First Grade
Posttransition
Externalizing
Teacher-Child
Academic
Internalizing
B)
Perinatal Adversity
Family Chaos
C)
Kindergarten or First Grade Family Dysfunction

Figure 2

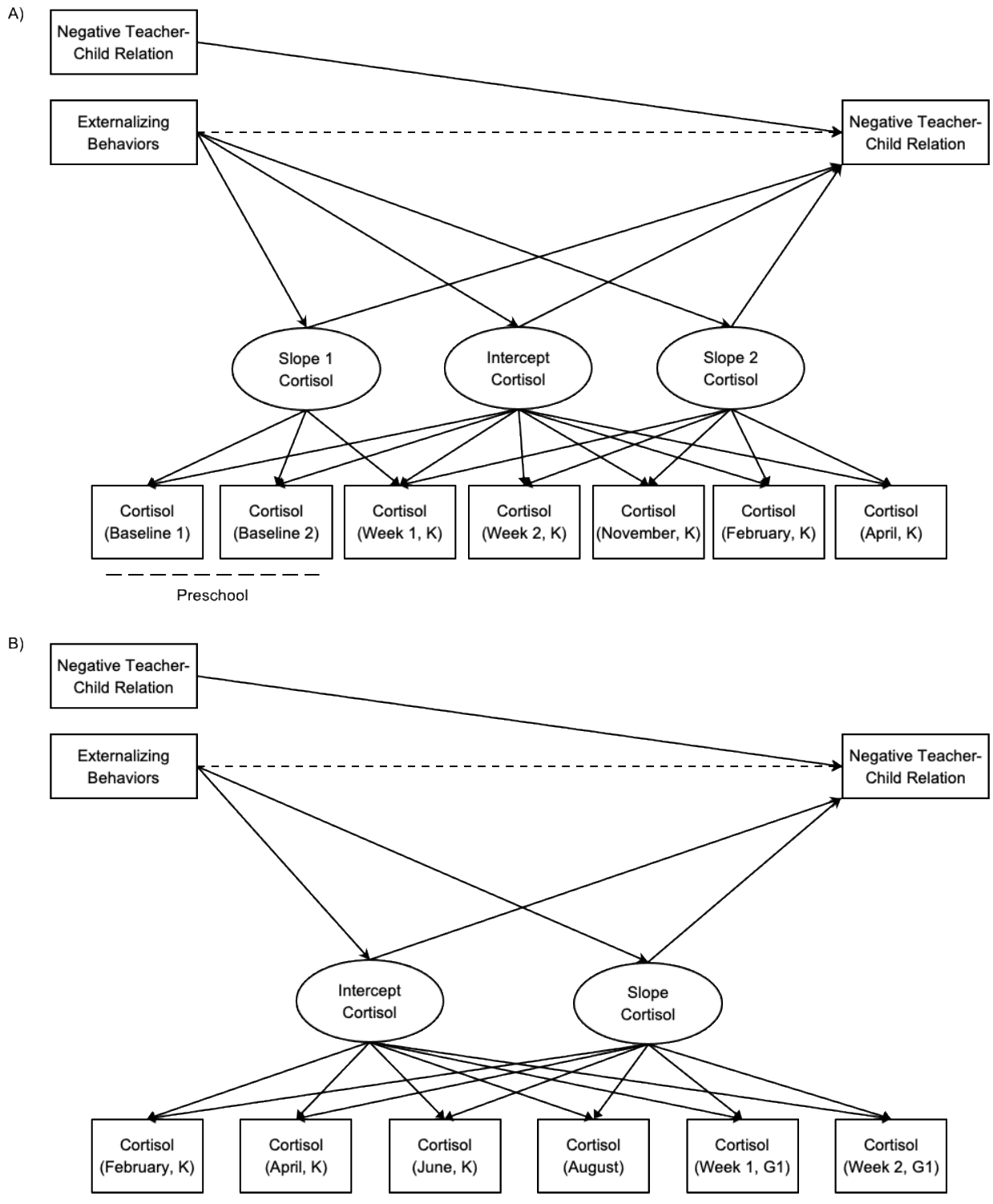
A)
Negative Teacher-Child Relation
Externalizing Behaviors
Negative Teacher-Child Relation
Slope 1 Cortisol
Intercept Cortisol
Slope 2 Cortisol
Cortisol (Baseline 1)
Cortisol (Baseline 2)
Cortisol (Week 1, K)
Cortisol (Week 2, K)
Cortisol (November, K)
Cortisol (February, K)
Cortisol (April, K)
Preschool
B)
Negative Teacher-Child Relation
Externalizing Behaviors
Negative Teacher-Child Relation
Intercept Cortisol
Slope Cortisol
Cortisol (February, K)
Cortisol (April, K)
Cortisol (June, K)
Cortisol (August)
Cortisol (Week 1, G1)
Cortisol (Week 2, G1)

Figure 3

- The three-form planned missing data design reduces the length of a questionnaire by assigning participants to have missing questionnaire items that are missing completely at random, allowing missing data treatments to recover the information without introducing bias.

- The wave-missing planned missing data design reduces participant burden and study costs by assigning participants to miss one or more data collection occasion(s), which are also missing completely at random.

- Examining the cortisol response to the transition to formal schooling requires repeated measures over the school year with sufficiently frequent time intervals to capture rapid recoveries and a sufficiently long follow-up period for recovery to be observed in most children.

- Implementing a variety of strategies to obtain participant feedback could help improve longitudinal study follow-ups and participant engagement.

The 3D-Transition Study: Objectives, Methods, and Implementation of an Innovative Planned Missing Data Design

Charlie Rioux, Sophie Parent, Natalie Castellanos-Ryan, Isabelle Archambault, Michel Boivin, Catherine M. Herba, Sonia J. Lupien, Isabelle Marc, Gina Muckle, William D. Fraser, and Jean R. Séguin

Web materials

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Web Table 1
Complete list of administered cognitive tasks

Task	Domain	Reference	K-1	K	G1
Dimensional Change Card Sort (DCCS) - Standard	Cognitive flexibility	(1)	X	X	
Dimensional Change Card Sort (DCCS) - Advanced	Cognitive flexibility	(1)	X	X	X
Random Object Span Task (ROST)	Visual-spatial working memory	(2)	X	X	X
Digit Span	Working memory	(3, 4)	X	X	X
Block Design	Visuospatial ability and motor skill	(3, 4)	X	X	X
Number Knowledge Test (NKT) Adapted	Number knowledge/School readiness	(5, 6)	X	X	X
Lollipop	School readiness	(7)	X	X	
Beery visual-motor integration (VMI)	Visual-motor integration	(8)	X	X	
Reading test (K-ABC)	Reading	(9)			X
Test of Emotion Comprehension (TEC)	Emotion comprehension	(10)	X	X	X
Theory of Mind	Theory of Mind	(11)	X		
Theory of Mind	Theory of Mind	(12)		X	X
Peabody Picture Vocabulary Test (PPVT)	Receptive vocabulary	(13, 14)	X	X	X

Abbreviations: K − 1, 1 year before kindergarten; K, Kindergarten; G1, Grade 1.

Web Table 2
Constructs Measured in Study Questionnaires of the 3D-Transition Study (2017-2021)[a]

			Parent long	Parent short	Teacher
Child characteristics	Mental health	Externalizing behaviors	X	X	X
		Internalizing behaviors	X	X	X
		Other problems	X	X	X
		Social problems	X	X	X
		Social competence	X	X	X
		Temperament	X	X	
	Academic skills/ school readiness	Exposure to languages	X		
		Autonomy	X	X	
		Life in society	X	X	
		General knowledge	X	X	
		Emotional and interpersonal competency	X	X	
		Socialization	X	X	
		Motor development/skills	X	X	X
		Socioemotional development			X
		Cognitive development			X
		School readiness			X
		School achievement			X
		Student potential			X
		School engagement			X
	Physical health and habits	Sleep	X	X	
		Physical activity	X	X	
		Media use	X	X	
		Nutrition	X	X	
		Physical health	X		X
		Injuries	X		
		Hospitalizations	X		
		Neurological health	X		
		ADHD medication	X	X	

		Other medication	X	
		Neurological antecedents	X	X
		Professional services	X	
	Social network	Friends	X	X
		Support for the school transition	X	
	Daycare and preschool	Participation in daycare	X	
		Daycare history	X	
		Participation in an educational program	X	
Parent and family characteristics	Parent mental and physical health	Stress and mood	X	X
		Substance use	X	X
		Antisociality	X	X
		ADHD	X	X
		Anxiety	X	X
		Physical health	X	X
	Sociodemographic characteristics	Parent education	X	X
		Financial resources	X	
		Employment	X	
		Housing	X	
		Food insecurity	X	
	Resources	Family structure	X	
		Social resources	X	X
		Immigration	X	X
	Parent-child relationship	Parenting	X	X
		Child attachment	X	X
		School preparation	X	X
	Couple	Relationship with current partner	X	X
	Family	Family functioning	X	X
		Family routines	X	X
	Home chaos	Family transitions	X	
	Lifestyle	Sleep pattern	X	X
		Screen time rules and use	X	X

School characteristics	Classroom-level	Teacher self-efficacy			X
		Teacher autonomy support			X
		Teacher structure			X
		Learning support			X
		Teacher-child relation			X
		Teacher characteristics			X
		Teacher expertise			X
		Teacher stability			X
		Teacher-child ratio			X
	School-family collaboration	Collaboration with parents			X
		Parent attitudes toward school	X	X	
		Family/school relations	X	X	

[a]The longer parent questionnaire ranged from 401-614 items depending on the wave of assessment, the short parent questionnaire ranged from 282-403 items, the teacher questionnaire ranged from 157-194 items. With the three-form design (see *Planned missing data design* section), the longer parent questionnaire was shortened by 69 to 108 items (depending on the form and wave of assessment), the shorter parent questionnaire was shortened by 54 to 87 items, and the teacher questionnaire was shortened by 39 to 48 items. Participants were expected to answer 4 to 7 items per minute.

Web Table 3
Missing data profiles for randomization to shorten home visits for participants without cortisol sampling (n = 555)[a]

	Task	
Profile	ROST	Digit Span
1	X	
2		X

[a]X = task administered. A number between one and two was randomly drawn, and they were given the corresponding profile.

Web Table 4
Missing data profiles for randomization to shorten home visits for participants with cortisol sampling (n = 384)[a]

	Working memory tasks		School readiness tasks	
Profile	ROST	Digit Span	Lollipop	NKT
1		X	X	
2		X		X
3	X		X	
4	X			X

[a]X = task administered. A number between one and four was randomly drawn, and they were given the corresponding profile.

References

1. Zelazo PD. The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nat Protoc.* 2006;1(1):297-301.
2. Hongwanishkul D, Happaney KR, Lee WS, Zelazo PD. Assessment of hot and cool executive function in young children: Age-related changes and individual differences. *Dev Neuropsychol*. 2005;28(2):617-644.
3. Wechsler D. Wechsler Preschool and Primary Scale of Intelligence - IV CDN. Toronto, ON: NCS Pearson Inc, 2012.
4. Wechsler D. Wechsler Intelligence Scales for Children – IV CDN. Toronto, ON: NCS Pearson Inc, 2003.
5. Okamoto Y, Case R. Exploring the microstructure of children's central conceptual structures in the domain of number. *Monogr Soc Res Child Dev*. 1996;61(1-2):27-58.
6. Garon-Carrier G, Boivin M, Lemelin JP, et al. Early developmental trajectories of number knowledge and math achievement from 4 to 10 years: Low-persistent profile and early-life predictors. *J Sch Psychol*. 2018;68:84-98.
7. Chew AL. The Lollipop Test: A diagnostic screening test of school readiness. Atlanta, GA: Humanics Limited, 1981.
8. Beery KE, Buktenica NA, Beery NA. Beery-Buktenica Developmental Test of Visual-Motor Integration (6th ed.). Minneapolis, MN: NCS Pearson Inc, 2010.
9. Kaufman N, Kaufman A. Kaufman Assessment Battery for Children. Circle Pines, MN: American Guidance Service, 1983.
10. Pons F, Harris P. Test of Emotion Comprehension – TEC. Oxford, UK: University of Oxford, 2000.

11. Perner J, Leekman S, Wimmer H. Three-year-olds' difficulty with false belief: The case for a conceptual deficit. *Br J Dev Psychol*. 1987;5(2):125-137.

12. Harris PL, Johnson CN, Hutton D, Andrews G, Cooke T. Young children's theory of mind and emotion. *Cogn Emot*. 1989;3(4):379–400.

13. Dunn LM, Dunn DM. Peabody Picture Vocabulary Test–Revised: Manual for forms L and M. Circle Pines, MN: American Guidance Services, 1981.

14. Dunn LM, Thériault-Whalen CM, Dunn LM. Échelle de Vocabulaire en Images Peabody: Adaptation française du Peabody Picture Vocabulary Test-Revised: Manuel pour les formes A et B. Toronto, ON: PSYCAN, 1993.