Unravelling self-regulation in early childhood: protocol for the longitudinal SPROUTS study

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Abstract

Background Enough is known about self-regulation to establish it as a priority target for education and intervention efforts beginning in early childhood, yet not enough to meaningfully and reliably alter developmental trajectories. Rather than resigning our aspirations, we need more nuanced and integrative understanding of self-regulation abilities and change.

Methods Launching in 2024, SPROUTS is a 3-year longitudinal study of early self-regulation, beginning in the pre-school period (3–5 years old at Wave 1) with retrospective data back to birth and annual data collection across the transition to school period (ages 5–7 years at Wave 3). Data will be collected on children's self-regulation, related abilities, outcomes, as well as prior and current contexts. One nested study within each Wave–that contributes complementary insights via supplementary and in-depth methods and data–will enable further exploration of contemporary issues related to self-regulation.

Discussion Insights generated can potentiate more effective intervention and education efforts by: improving intervention cost-benefit ratios; identifying likely mechanisms of change; easing burdens of unhealthy and antisocial behaviours associated with low self-regulation; and, most importantly, contributing to giving children the best early start to life. These benefits are timely in the context of intense policy and educational interest in fostering children's self-regulation.

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Keywords Self-regulation, Self-control, Executive function, Early childhood, Development, Longitudinal, Preschool, Primary school, Transition to school

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Background to the study

Self-regulation enables important kinds of freedom for children: freedom from needing constant direction from others, from maladaptive impulses and from unproductive distraction. A child adept at self-regulation can resist distractions, sustain their attention, persist with challenging activities, endure temptations, delay gratification, wait their turn and consider the consequences of their actions. They can initiate (e.g., brushing their teeth) and cease behaviours (e.g., stop playing) that conflict with their plans and preferences. However, an estimated one-fifth of children do not show typical expected growth in self-regulation prior to entering school, and a significant proportion of children at age 7 remain at levels of self-regulation expected of 4-year-olds [1]. Indeed, research and comprehensive meta-analyses show at least a doubling of risk of poor academic, health, wellbeing and economic outcomes conferred by low early childhood self-regulation [2–4].

Importantly, self-regulation is malleable [3–6] and any-cause improvements in childhood self-regulation are associated with better outcomes decades later – even for those with initially average or high self-regulation [3, 4]. What matters most then is supporting strong *growth* in *early* childhood self-regulation. This has instigated a raft of diverse early intervention and education efforts aiming to stimulate the development of early self-regulation. Indeed, a recent review of the literature identified 85 intervention studies in preschool settings alone over the last 20 years, adopting 12 fundamentally different approaches (from mediated structured play to mindfulness to music to exergaming), with most showing small effects and few indicating that improvements transmitted to real-world outcomes [6]. As such, the promise that early self-regulation improvements could "reduce a panoply of societal costs, save taxpayers money, and promote prosperity" [4]–via benefits to education, health, fiscal and social outcomes–has not yet been realised. In short, we now understand enough about self-regulation to establish it as a priority target for education and intervention efforts from early childhood, yet not enough to meaningfully and reliably alter developmental trajectories.

Although we understand well the importance of self-regulation and situations in which it is required, there remains low agreement on its nature, functioning, development, assessment and means to stimulate its growth. Here is a telling example: self-regulation is contemporaneously considered to be: a stable capacity [7], yet fluctuating with context [8]; an ability [9], outcome [10] and a process [11]. Given insufficient research that reconciles these perspectives, it remains unclear how self-regulation operates, develops (and by what means we can index and authentically evidence this growth). Further, not enough is known about the developmental mechanisms that stimulate self-regulation growth in a manner that yields flow-on effects to children's real-world behaviours, decisions and outcomes [6].

The *Study of Preschoolers' Self-Regulation and Outcomes, Undertaking Transition to School* (SPROUTS) represents Australia's first longitudinal study of self-regulation in a key window of development and transition–from preschool into early primary school (ages 3 to 7)–which will seek to derive an integrated and more nuanced understanding of self-regulation and its growth. This study will generate evidence and advance understandings of early self-regulation processes, components, trajectories, antecedents and outcomes, and thereby also its likely mechanisms of change. Multiple modern methodological and analytic approaches will be applied to generate unique lines of evidence, including as-yet unknown challenges and unmet possibilities. Together, this will offer insights that could help ensure that our education and intervention efforts are well-positioned to succeed.

Nature of self-regulation

Although the definition and delineation of self-regulation is debated [12], there is emerging agreement that self-regulation enables exertion of control over our attention, cognition, emotions and behaviours, despite contrary impulses, stressors and distractions, in ways that are conducive to our goals, desired outcomes, context and circumstances [2]. Thus, self-regulation is a foundational ability that facilitates the development of broad abilities and outcomes [2, 4]. In the pre-school years, self-regulation allows young children to sustain their play and attention, to persist with challenging tasks, take turns, delay gratification, and initiate and cease behaviours that conflict with immediate preferences or impulses. The evidence supporting this formulation of self-regulation is compelling: early childhood self-regulation abilities robustly predict later health, social, academic and vocational outcomes into adolescence and adulthood [2, 4]. This conception of self-regulation is also that which most often permeates educational curricula, and parents' and educators' acute concerns [13].

Yet even among models consistent with this conception, self-regulation is variously considered to be: an ability that is relatively stable across situations, yet gradually developing over time [7, 9]; fluctuating across the day, owing to changes in stressors, situations and expectations [8, 10]; an outcome of successful mobilisation of other abilities and processes (e.g., higher-order cognitive capacities – namely, executive functions – deployed to manage changes in psychophysiological arousal, the efficacy of which contributes to successful self-regulation) [10, 14]; and/or the process through which children self-regulate, involving recursive evaluations and adjustments

of the current state compared to a goal state [15]. Other accounts articulate the ingredients for successful self-regulation, such as goal setting, capacity to resist impulses, and motivation to persist toward a goal [11]. There is need to reconcile these perspectives, as: an ability that is differentially challenged and enacted across situations, that grows with maturation and experience; as well as a process toward goal attainment, involving dynamic mobilisation and interaction of various abilities and strategies as circumstances and goals change. Comprehensive, integrative evidence of early self-regulation and its growth is needed to provide surer footing for the theories of change on which education and intervention are currently based.

Development of self-regulation

Intervention research supports the malleability of early self-regulation [5, 6]. Longitudinal adult-report ratings of children's self-regulation indicate that, for children rated as becoming more self-regulated by or shortly after entry to school, there are immediate (e.g., school readiness and success) and long-term improvements in outcomes (e.g., health habits, financial health, risky behaviours, relationships, prosocial behaviours) [4]. While most children show self-regulation growth over this period on structured direct assessments, there is wide variation in trajectories and a highly concerning proportion of children who show little self-regulation growth even into early primary school [1]. Other children contravene statistical predictions, with high self-regulation despite multiple risk factors including low income and low parental education levels, or low self-regulation in the context of no apparent risk factors [16]. While it is not straightforward to reconcile this evidence, given that it derives from highly disparate measures and models, clearly we cannot assume even and equitable growth of self-regulation. Rather, we need explicit and intentional experiences, educational and intervention efforts to support early self-regulation development.

Encouraged by this evidence, efforts to intervene on early self-regulation have intensified internationally in recent decades. Self-regulation permeates contemporary education curricula [13] and substantial international efforts seek to effect self-regulation change via intervention [5, 6]. *Early* education and intervention, in particular, have received an inordinate share of this attention based on suggestion that this timing might produce more pronounced, stable and lasting change [17], and yield greater return on investment [18]. Despite the large number and diversity of early self-regulation intervention approaches that have been developed, effects have been routinely small and usually limited to directly trained abilities [6]. The promise of self-regulation improvements potentiating shifts in population-level outcomes – in self-regulation and beyond – remains unfulfilled.

Yet abandoning this pursuit is premature. Evidence for the contemporary importance of self-regulation continues to accumulate, and arguably increase, with new challenges in which children are required to make safe, discerning and productive decisions (e.g., healthy digital diets and citizenship, "big behaviours" upon return to school after COVID-19 lockdowns). Yet prevalent solutions emphasise *other*-regulation approaches (e.g., locking away mobile phones, banning social media), which fail to equip children with self-regulation skills and strategies to successfully navigate these challenges independently later in life.

This background indicates that we need to unravel, challenge, integrate and reconcile disparate models of self-regulation to establish a more nuanced understanding of self-regulation ability and change. This is timely because of a continued rise in intervention efforts, educational curricula and public debates concerning self-regulation – all of which appear destined to continue unabated. This project is thus both urgent and important.

Aims and research questions

The research questions for this study align with the aim of generating an integrated understanding of: self-regulation abilities, growth, fluctuations and outcomes; typical (latent) trajectories of self-regulation change across the transition to school years; and the various predictors and outcomes of self-regulation performance and development. Its guiding research questions are:

1. *What are the typical trajectories of self-regulation change across the transition to school period?* It is anticipated that there will be multiple latent growth trajectories identified, e.g., most prominently rapid growth versus low/no growth. Of additional interest will be robust estimates of the proportion of the sample that comprise each trajectory in early childhood, and potential predictors.
2. *What are the antecedents of self-regulation levels, growth and trajectories?* It is hypothesized that self-regulation will be predicted by factors at the macro, micro and individual levels. Machine learning will allow comprehensive analysis of predictors, from which qualitative follow-up of identified cases will further explore exceptions to these predictions (see Research Question 5).
3. *How does self-regulation fluctuate over the preschool day, and what are precursors of these changes?* While this research question is exploratory in nature, it is broadly expected that children with higher self-regulation will experience fewer and lesser fluctuations in self-regulation across the day, but that

some fluctuation will nevertheless be experienced by all children. Possibly these will be most prevalent around times of tiredness (e.g., before nap time), hunger (e.g., before mealtime) and stress (e.g., transitions, whole- or large-group experiences that require sitting still, taking turns, etc.). Time until a 'return to regulation' is expected to differ, with faster recovery expected at higher levels of child self-regulation.

4. *What outcomes are associated with early self-regulation levels, growth and trajectories?* It is anticipated that self-regulation abilities and growth will replicate (predictors identified in less comprehensive models) and extend (to differing findings and novel predictors) prior findings of associations of self-regulation with various assets and risks. It is anticipated that this will vary by self-regulation growth trajectory, such that self-regulation trajectories moderate, for example, progress in achievement (i.e., early self-regulation ability is more influential for children with low initial academic knowledge).

5. *What are the potential unmeasured circumstances, assets and risks of "diagonal children", whose self-regulation levels and growth do not conform to model predictions?* This will involve an exploratory mixed methods nested study that will be hypothesis generating.

6. *How do different self-regulation measurement operationalisations and approaches, independently or combined, account for the models of self-regulation implied by these data?* It is anticipated that approaches that index a child's self-regulation behaviours in everyday situations, using observation, will capture unique variance that will relate to children's concurrent and subsequent outcomes. It is further hypothesised that combining this with data from a task-based approach will provide better prediction of child outcomes, due to its additional capture of unobserved (e.g., cognitive) components of self-regulation. It is expected that educator-report indices of self-regulation will provide lower predictive strength, given known biases and imprecision in adult-report ratings. Parent-report indices of self-regulation are expected to add no significant additional predictive value, given their limited normative frame of reference [19].

7. *Does self-regulation have a role in phenomena of public interest (e.g., children's digital activities)? In what ways?* It is anticipated that self-regulation will be related to a range of phenomena investigated in the name of public interest, and in various ways (e.g., duration of digital recreation, digital recreation activities selected, and ability to disengage when needed will vary with levels of child self-regulation capacity).

Methods and design
Design and setting
This project entails a single cohort 3-year longitudinal study of self-regulation, beginning in the pre-school period (ages 3–5 years at Wave 1), with annual data collection timepoints thereafter to capture children's transition to school in Wave 2 (mid-2025) or Wave 3 (at ages 5–7, in mid-2026). This research design and timeline are depicted in Fig. 1. Data will be collected on children's self-regulation, related abilities, outcomes and surrounding contexts once per year across 3 years.
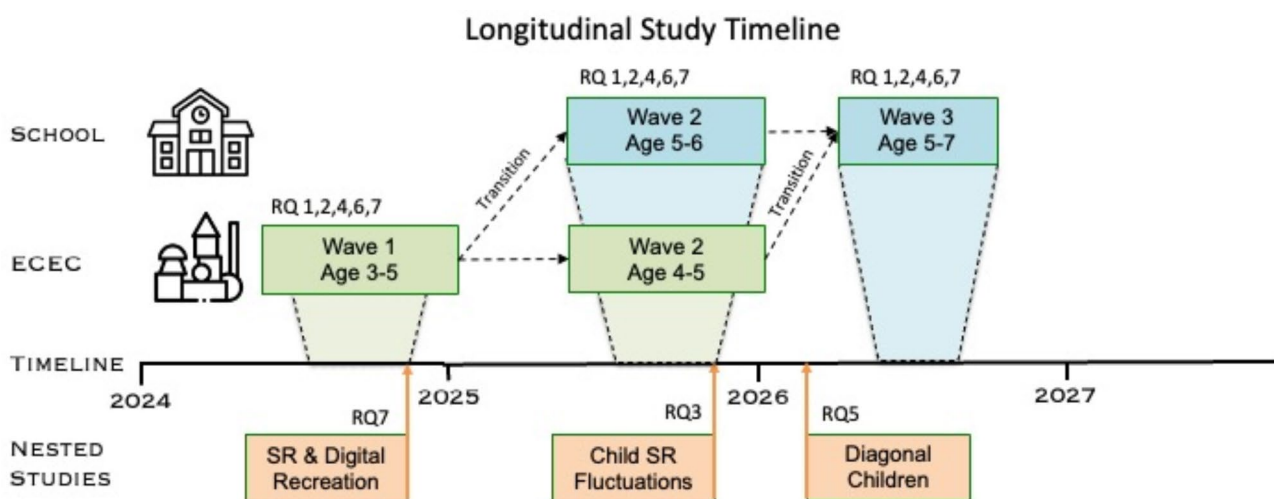

Fig. 1 Longitudinal study timeline, design, waves, nested studies and aligned research questions (RQs)

The longitudinal design further enables exploration of potentials and problems through a nested study at each Wave. Nested studies will be on a topic of public interest that contributes complementary insights through alternative data collection and methods, and will involve a smaller subset of participants either within or outside planned longitudinal data collections. For instance, a nested study in Wave 1 will explore more deeply young children's digital activities (e.g., types, time, co-play, ease of disengagement) and how self-regulation relates to these digital behaviours (a responsive 'public interest' investigation). The Wave 2 nested study will observe children over a typical preschool day to understand their goals, experiences (child-reported, observed) and situational fluctuations in self-regulation (through observer ratings, which have shown strong validity and sensitivity to fluctuation). At Wave 3, a qualitative nested study is planned for children whose self-regulation levels contravene our statistically derived predictions ("diagonal children", e.g., high self-regulation in the context of numerous risk factors) to explore the naturally occurring contexts, abilities and situations that relate to unexpected trajectories of self-regulation. These nested studies will contribute important nuance and insight to the overarching longitudinal data capture.

Participants

Participating children, at initial recruitment, will be 3–5 year olds enrolled in an early childhood education and care (ECEC) service in the Greater Sydney or Illawarra region. These regions are broadly representative of Australian general population demographics, including proportion of the population identifying as Aboriginal and Torres Strait Islander, culturally and linguistically diverse, and socioeconomic diversity (i.e., socioeconomic indices for these local government areas range from decile 1 to 10).

All eligible-aged children in participating ECEC services, along with their caregivers and their ECEC educators, will be invited to participate in the SPROUTS study (www.sprouts-study.com.au). Based on consent rates in previous studies, it is anticipated that approximately 40 ECEC services will be needed to achieve the desired sample size of 500 children. This target of 500 children was determined to ensure sufficient statistical power for the analytic approach requiring the largest sample size for reliable inference: Machine Learning (see *Data Analyses* below).

Given likely dispersion to a larger number of schools than preschools in later waves, it is anticipated that a larger number of schools and teachers will be invited to participate (although exact numbers will not be known until after children's transition to school).

Data collection and measures

Data collection for the longitudinal study will entail annual direct child assessments, as well as parent and educator surveys, collected in the third quarter of each calendar year (for pragmatic benefit, to allow time for ethics approval and recruitment after grant commencement, but also conceptual benefit of capturing data shortly prior to transition to school). For instance, self-regulation will be assessed annually using a multi-source approach (task, questionnaires, observation) given findings that each may make unique contributions to a longitudinally predictive self-regulation index [19]. Data on related abilities will also be collected annually (e.g., executive functions, school readiness, learning), to investigate trajectories and interactions over time. Additional constructs to be captured will be distributed across the study, at relevant waves (e.g., invariant antecedents collected at Wave 1, outcomes after entry to school collected in Waves 2 and 3). These pertain to macro (e.g., ECEC attendance, family resources, area characteristics), micro (e.g., home environment, family and peer relationships), and individual child characteristics, experiences, assets and risks (e.g., age, sex, self-regulation-supportive strategies and abilities, stressful life events) that are variously implicated in young children's self-regulation.

For instance, at baseline this will involve: direct assessment of children's self-regulation, executive functions, and learning; parent-report demographics, home and family characteristics and activities, daily life (e.g., child responsibilities, digital activity), child self-regulation, and child and parent wellbeing; and educator-report on their professional and ECEC characteristics, expectations, child self-regulation and related abilities, relationships, and learning. Elaboration of the constructs and measures for Wave 1 are provided below (* indicates intent to repeat this measurement at each annual wave).

Direct assessments of child self-regulation

*Head-Toes-Knees-Shoulders (HTKS) task HTKS is a self-regulation task that requires a child to respond with the opposite behaviour to what was instructed (e.g., touch their head if asked to touch their toes) [20]. This proceeds across two practice and 10 test trials across three levels, where difficulty–via more complex correspondences between body parts–increases across the levels.

Preschool Situational Self-Regulation Toolkit (PRSIST) assessment The PRSIST assessment is an observational measure of self-regulation that engages children in two routine play activities – a memory card game in a group of four children, and an individual curiosity boxes guessing game. Children's behaviours and responses during these play activities are situated against pre-defined dimensions and progressions of self-regulation, using the PRSIST rat-

ing scale [21]. Ratings are completed by observers trained to reliability using online and in-person approaches and checks.

Direct child assessments of child executive function

*Early Years Toolbox (EYT) Mr Ant Mr Ant is an iPad-based working memory measure [22]. On the screen, children are presented with an image of a cartoon ant with coloured dots in different spatial locations on its body. After their brief presentation, Mr Ant disappears for a short retention interval, after which Mr Ant reappears and the child must recall the locations of the dots by tapping the corresponding locations on the ant's body. Levels increase the number of dots to be recalled. The task continues until completion or a performance-based stop rule.

*EYT Go/No-Go EYT Go/No-Go is an iPad-based measure of inhibition [22]. Children are presented with fish and sharks swimming across the screen, one at a time, and must tap the screen when they see the fish (80% 'go' trials) and inhibit the impulse to respond whenever a shark appears (20% 'no-go' trials).

*EYT Catch-A-Mole Catch-A-Mole is a new iPad-based measure of shifting. Children are introduced to a vegetable patch, from which moles are stealing carrots. The child is told and shown how the mole behaves and is then tasked with protecting the carrots by catching the mole. Each level requires a change in rule (e.g., because the colour of the mole has changed, and those moles behave differently; because it has turned night, and moles do the opposite at night). The task increases in complexity as it proceeds, with a performance-based stop rule.

Assessment of Motivation, Effort, and Self-Regulation (AMES) This is an iPad-based battery of assessments [23]. For the working memory task (eCorsi), squares in a 3×3 grid are highlighted, one at a time, and children repeat the sequence in forward order (Forward Span) and later in backward order (for Backward Span). The sequence to be remembered increases as the task progresses, with a stop rule based on performance. In the shifting and inhibition task (Hearts & Flowers), children tap the same side of the screen (left or right) as a heart and opposite side of the screen when they see a flower. The task increases in complexity as it proceeds, requiring children to shift rules between (and sometimes also within) levels.

Direct child assessments: learning

*EYT Language This is an iPad-based assessment of children's early receptive language abilities. It consists of 100 interspersed items pertaining to phonology, emergent literacy, semantics, syntax and morphology. For example, children are asked to: select the picture that best depicts

a verbal statement provided (e.g., "The dog makes dinner for the cat"); carry out a verbal instruction (e.g., "show me the picture that rhymes with log"); or respond to a question verbally (e.g., "Whose shoes were missing?"). Items are presented in order of increasing difficulty, with age-based start rules and a performance-based stop rule.

*EYT Early Numeracy 2 This is an iPad-based assessment of children's early numeracy abilities [24]. It consists of 79 interspersed items assessing foundational domains of early numeracy knowledge, including number sense, cardinality, counting, numerical operations, and spatial and measurement constructs. Items are presented in order of increasing difficulty, with start rules based on age and a performance-based stop rule.

Parent questionnaire

A parent questionnaire will collect data on children's self-regulation and antecedents, outcomes and correlates that have been implicated in its development. A full list of constructs, measures, example items, sources and scoring are provided in Table 1. The areas and constructs captured in the parent questionnaire are summarised below:

1. Demographic questions: child date of birth, sex, and birth weight; parent date of birth, sex, relation to the child, marital status, highest level of education completed.
2. Questions about family background, household, care arrangements and concerns: child's living arrangements, postcode (to derive area-level SES indices) and income, household composition, child's usual care arrangements, child's country of birth, language(s) spoken at home, presence of a diagnosis, parent developmental concern.
3. Questions about child's daily life: home learning environment, household routine/order, extra-curricular activities, household expectations, child roles and responsibilities, child digital activity.
4. Questions about the child's self-regulation and wellbeing: child's strengths and difficulties, executive function, sleep, life events causing disruption, and recent injuries.
5. Questions about the parent's/carer's wellbeing: parent mental wellbeing, parent executive function, parent anxiety and parenting approaches.

Educator questionnaire

An educator questionnaire will collect data on the child's self-regulation, and antecedents and outcomes implicated in self-regulation development. The areas and constructs captured in the educator questionnaire are summarised below:

Table 1 Study constructs, measures, sources, items and scale

Construct	Measure, Reference	Items, Example, Response Scale
Direct Assessment		
Self-Regulation	Head-Toes-Knees-Shoulders (McClelland et al., 2014) [20] Preschool Situational Self-Regulation Toolkit assessment (Howard et al., 2019) [21]	10 trials per level, max. 3 levels (accuracy-based stop rule) *'Touch your knees'* (correct response is touching shoulders). Correct, self-corrected, incorrect. 10 observer-rated items (rating based on observation of child HTKS performance) *Did the child sustain attention, and resist distraction, throughout the instructions and activity.* 7-point scale with illustrative anchors for 1 and 7.
Executive Function	EYT Mr Ant (Howard & Melhuish, 2017) [22] EYT Go/No-Go (Howard & Melhuish, 2017) [22] EYT Catch-A-Mole (Howard & Melhuish, 2017) Assessment of Motivation, Effort and Self-Regulation: Hearts & Flowers (Obradovic et al., 2018) [23] Assessment of Motivation, Effort and Self-Regulation: eCorsi (Obradovic et al., 2018) [23]	3 trials per level, max. 8 levels (accuracy-based stop rule) Cartoon ant depicted with *n* stickers, followed by a blank screen for 5s, then child taps location(s) where the *n* stickers were on a blank cartoon ant. Correct, incorrect. 75 trials (60 go, 15 no-go) divided into 3 blocks *Tap whenever a fish swims across the screen. Do not tap when a shark swims across the screen.* Correct, incorrect. 8 trials per level, starting level 1 up to max. level 8 *Tap the location the mole will move to next, based on the provided rule about their movement.* Correct, incorrect. 12 congruent trials, 12 incongruent trials, 33 mixed trials *For congruent trials, tap the button on the same side of the screen as the stimulus. For incongruent trials, tap the button on the opposite side of the screen as the stimulus.* Correct, incorrect. 3 trials per level (accuracy-based stop rule) *Tap the sequence in which squares light up, in a 3 × 3 grid.* Correct, incorrect.
Language	EYT Language*	100 items (age-based start rule, accuracy-based stop rule) *Children select a response option for questions that assess e.g., phonology, emergent literacy, semantics, syntax, morphology.* Correct, incorrect.
Numeracy	EYT Early Numeracy (Howard et al., 2021) [24]	79 items (age-based start rule, accuracy-based stop rule) *Children select a response option for questions that assess e.g., numerical concepts and language (e.g., few), matching of digit and quantity, ordinality, cardinality, early numerical operations.* Correct, incorrect.
Parent Questionnaire		
Demographics	Derived from various longitudinal study questionnaires, e.g.: • Australian Bureau of Statistics Census (abs.gov.au/census) [25] • Longitudinal Study of Australian Children (LSAC) (growingupinaustralia.gov.au) [26] • Australian Children of the Digital Age (ACODA) (acoda.org.au) [27]	31 questions capturing child and family demographics: • Child date of birth (DD-MM-YYYY) • Child's sex (M/F/O) • Child's weight at birth (kgs) • Parent (respondent) date of birth (DD-MM-YYYY) • Parent sex (M/F/O) • Parent relationship to child • Parent current relationship status • Parent (and partner) highest level of education • Child postcode (to generate area-level SES index) • Net household income • Number and relation of adults in child's household • Number and relation of children in child's household • Child's care arrangements – which, how many days per week, for how many years • Child's country of birth • Child identification as Aboriginal or Torres Strait Islander • Child's primary language • Child speaking or understanding of other languages • Child disability or diagnosis
Parent Developmental Concern	ACODA (acoda.org.au) [27]	5 items *Do you have any concerns about how the SPROUTS child is developing in any of the following areas? Physical (fine motor) development?* 5-point scale: not at all, slightly concerned, somewhat concerned, moderately concerns, extremely concerned.
Home Learning Activities	LSAC, Activities at Home (growingupinaustralia.gov.au) [26]	7 items *In the last week, on how many days have you or someone in your family done the following with the SPROUTS child? Read to the child a book.* 4-point scale: none, 1–2 days, 3–5 days, 6–7 days.
Household Routine	Confusion, Hubbub and Order Scale (CHAOS) (Matheny et al., 1995) [28]	4 items *It is really disorganised in our home.* True/False

Table 1 (continued)

Construct	Measure, Reference	Items, Example, Response Scale
Child Extracurricular Activities	LSAC, Extracurricular Activities (growingupinaustralia.gov.au) [26]	7 items *Does the SPROUTS child participate in any of the following extracurricular activities? Considering the last 4 weeks, how much time on average per week did they spend engaging in each activity? Music programs or lessons (singing, instrument, musical play).* 5-point scale: does not participate, 30 min, 1 h, 2 h, 3 h+
Parent Expectations	Tightness/Looseness scale (adapted) (Gelfand et al., 2011) [29]	6 items *There are many expectations that children are supposed to abide in our family.* 6-point scale: strongly disagree to strongly agree.
Child Responsibilities	Children Helping Out: Responsibilities, Expectations, and Supports (CHORES, reduced). (Dunn et al., 2014) [30]	22 items *To what extent does the SPROUTS child perform each of the following household chores?* Cleans up after own play. 7-point scale: not expected to do this, cannot do this, does this with a lot of help, does this with some help, does this with supervision, does this on their own when asked, does on their own without being asked more than 50% of the time.
Child Digital Activities	Problematic Media Use Measure – Short Form (PMUM-SF9) (Domoff et al., 2019) [31]	6 items *It is hard for my child to stop using a digital device.* 5-point scale: never, rarely, sometimes, often, always.
Parent Digital Regulations	ACODA (acoda.org.au) [27]	4 items *I set rules or regulate the time spent on a digital device.* 5-point scale: never, almost never, sometimes, often, very often.
Child's Wellbeing	Strengths & Difficulties Questionnaire (SDQ) (Goodman, 1997) [32]	25 items *Considerate of other people's feelings.* 3-point scale: not true, somewhat true, certainly true
Child's Executive Function	Executive Function from Observation & Reflection Tool (EFFORT)* (https://gefi.stanford.edu)	34 items *Pays attention when an adult is explaining or showing something (e.g., by listening carefully and/or watching with appropriate eye gaze/body orientation).* 4-point scale: rarely, sometimes, frequently, almost always.
Child's Sleep	LSAC, behavioural sleep problems (growingupinaustralia.gov.au) [26]	4 items *Does the SPROUTS child have any of these problems on 4 or more nights a week (or more than half the time)? Difficulty getting to sleep.* Yes/No 1 item *How much is the SPROUTS child's sleeping pattern or habits a problem for you?* 5-point scale: no problem at all, a small problem, a moderate problem, a large problem, not sure/don't know.
Food insecurity	Food Insecurity Risk (Hager et al., 2010) [33]	2 items *Within the past 12 months I worried whether our food would run out before I/we got money to buy more.* 3-point scale: never true, sometimes true, often true
Stressful Life Events	LSAC, Stressful Life Events (growingupinaustralia.gov.au) [26]	4 items *Considering each category of life event below, evaluate the degree of disruption and stress you have experienced in relation to that type of event in the last 12 months. Changes in habits and family dynamics (e.g., major changes in eating habits, marriage/divorce, gaining a new family member/pregnancy, changes in sleeping habits).* 101-point scale from 0 = the event was not experienced or has created no stress to me or my household to 100 = has created extremely high levels for me and/or my household.
Injuries	LSAC, Injuries (growingupinaustralia.gov.au) [26]	2 items *During the last 12 months, how many times has the SPROUTS child been hurt, injured or had an accident and needed medical attention from a doctor or hospital?* Number, then checkbox for type of injury (e.g., broken or fractured bones)
Parent Mental Health	Kessler Psychological Distress Scale (K10) (Blake et al., 2024) [34]	10 items *Based on the last 4 weeks, how often did you: feel tired out for no good reason?* 5-point scale: none of the time, a little of the time, some of the time, most of the time, all the time.
Parent Anxiety and Depression	Hospital Anxiety & Depression Scale (HADS-7) (Julian, 2011) [35]	7 items *I feel tense or wound up.* 4-point scale: most of the time, a lot of the time, occasionally, not at all.
Parent Executive Function	Difficulties in Emotion Regulation Scale – Short Form (DERS-SF) (Kaufman et al., 2016) [36]	6 items *When I am upset, my emotions feel overwhelming.* 5-point scale: almost never, sometimes, half the time, most of the time, almost always.
Parent-Child Relationship	Mothers Object Relations Scales (MORS) (Simkiss et al., 2013) [37]	7 items *My child smiles at me.* 6-point scale: never, rarely, sometimes, quite often, very often, always.

Table 1 (continued)

Construct	Measure, Reference	Items, Example, Response Scale
Hostile Parenting	LSAC, Hostile Parenting (growingupinaustralia.gov.au) [26]	5 items *I have been angry with this child.* 10-point scale from 1 = not at all to 10 = all the time.
Parent Rules and Expectations	Items generated for this study	2 items: *What are the top three rules (or expectations) that the SPROUTS child most struggles to adhere to?* 3 open-ended response boxes per item.
Educator Questionnaire		
Demographics	Derived from the Early Start to Self-Regulation study (Howard et al., 2020) [38]	• Educator gender • Educator highest level of education • If qualifications are related to early childhood education • Years in the early childhood sector • Employment type • Role(s) in the early childhood service
Educator Expectations	Tightness/Looseness scale (Gelfand et al., 2011) [29]	6 items *There are many expectations that children are supposed to abide in our room.* 6-point scale: strongly disagree to strongly agree.
Child Self-Regulation	Child Self-Regulation & Behaviour Questionnaire (CSBQ) – self-regulation subscales (Howard & Melhuish, 2017) [22]	17 items *Persists with difficult tasks.* 5-point scale from not true to very true.
Child's Executive Function	Executive Function from Observation & Reflection Tool (EFFORT)* (https://gefi.stanford.edu)	34 items *Pays attention when an educator is explaining or showing something (e.g., by listening carefully and/or watching with appropriate eye gaze/body orientation).* 4-point scale: rarely, sometimes, frequently, almost always.
Teacher-Child Conflict	Student Teacher Relationship Scale (STRS) – conflict subscale (Pianta, 2001) [39]	7 items *This child and I always seem to be struggling with each other.* 5-point scale: definitely does not apply, not really, neutral/not sure, applies somewhat, definitely applies.
Child's Reading	LSAC, Academic Rating Scale – Reading (growingupinaustralia.gov.au) [26]	6 items *Interested in reading (e.g., wants to know the meaning of printed materials).* Yes, No, Unsure.
Child's Early Numeracy	LSAC, Academic Rating Scale – Numeracy (growingupinaustralia.gov.au) [26]	6 items *Able to count the number of a few objects accurately.* Yes, No, Unsure.
Child's Social Maturity	Teachers' Social Maturity Rating Scale (Peterson et al., 2007) [40]	7 items *The child's skill for appropriately standing up for own opinions, needs and rights with peers.* 7-point scale from very much less mature than the average child this age to very much more mature than the average child this age.
Child's School Liking	LSAC, School Liking Scale (growingupinaustralia.gov.au) [26]	4 items *This child enjoys attending preschool/childcare.* 6-poitn scale: never the case, seldom the case, sometimes the case, often the case, very often the case, always the case.

Note. *New assessment (or assessment version) being validated as part of baseline data collection

1. Demographic questions about the educator: qualifications, employment status, years in sector, and role(s).
2. Questions about their classroom expectations: rules and expectations in their classroom.
3. Questions about the child's relationships and adjustment: child's closeness/conflict with the educator, child's social maturity, child's preschool liking.
4. Questions about the child's self-regulation and related abilities: child's self-regulation, classroom regulation, executive function.

Linkage to extant Department of Education data – academic performance, school attendance, suspension, expulsion – is currently being pursued.

Data analyses

Multiple analytic approaches are planned in alignment with particular research questions (e.g., latent profile

analysis to identify growth trajectories, structural equation modeling to evaluate statistical models of antecedents and outcomes, qualitative analyses of ethnographic child and observation data collected across a day). However, the sample size was selected to ensure sufficient statistical power for the analytic approach requiring the largest sample for reliable inference: Machine Learning. We intend to deploy a variety of Machine Learning algorithms that are shown to deliver reliable results on moderately sized datasets, in particular tree-based models (e.g., GBM and XGBoost algorithms using R) [41]. The proposed sample size of 500 – final $n = 405$ after accounting for 10% attrition at each of Waves 2 and 3 – is sufficient to produce reliable estimates from these modelling approaches [42]. For all Machine Learning analyses we will run 10-fold cross validation, hyper parameter tuning and confirm feature importance to derive the best predictive model. We anticipate running an 80/20 train test split of the dataset for training and testing of the models. Additional Machine Learning approaches that typically necessitate even larger samples are possible too, using strategies of dimension reduction of the predictors (e.g., to create an executive function factor) and re-sampling (e.g., bootstrapping) to better understand the distribution of estimates.

Discussion

This study will provide insights into the risk and protective factors that are associated with early childhood self-regulation development. These insights have broad interest given the current early childhood education and early primary school context. That is, self-regulation features prominently in existing education curricula and consciousness, reference to which is only growing. Yet, at present, these resources are often unclear about mechanisms to effectively support children's self-regulation growth. This project will enable more explicit articulation of how these growth and outcome ambitions might be achieved. Of course, longitudinal studies can only *imply* causal mechanisms, effective solutions and strategies; however, many effective approaches to learning and development have originated from such longitudinal insights. Study resourcing requires geographically constrained sampling, although this impact is mitigated by selected regions providing high representativeness of population demographics.

A particular strength of this study is the triangulation of data from multiple sources (direct assessments, questionnaire, extant data), studies (e.g., quantitative longitudinal data, mixed method nested study data) and respondents (i.e., parents, pre/school teachers, children) using established and robust instruments and approaches. This contrasts the common longitudinal study approach of prioritising cost-efficient yet shallower data collection

(e.g., questionnaires with few items per construct) over deeper but more burdensome approaches. To the extent that insights generated by this study potentiate more effective intervention and education efforts, this could: improve current intervention cost-benefit ratios that continue to concern governments, economists and funding bodies; suggest methods for enacting this change, which continue to challenge many psychologists and educators; ease burdens of unhealthy and antisocial behaviours associated with low self-regulation, of concern to health professionals and sociologists; and, perhaps most importantly, contribute to giving children the best early start to life, which is a priority concern for children, parents, educators and society at large. These benefits are timely in the context of intense policy and educational interest in fostering children's self-regulation, internationally.

Abbreviations
ECEC   Early Childhood Education and Care
SPROUTS   Study of Preschoolers' Self-Regulation and Outcomes, Undertaking Transition to School

Author contributions
All named authors contributed to the design of the study and manuscript preparation. SJH was additionally responsible for securing funding for the project. Authorship decisions were made based on the Australian Government's Authorship supplement to the Australian Code for the Responsible Conduct of Research. All authors read and approved the final manuscript.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participant
Ethics approval has been received for the 3-year SPROUTS longitudinal study from the human research ethics committee of University of Wollongong (HREC approval: 2024/020). This approval required submission of an extensive written ethics application and data management plan from the principal investigator (SJH), which was subject to thorough evaluation by a 16-member ethics review panel. Participating families are those who give written parental consent and child verbal assent to participate. Participating educators provide written consent for their participation. Ethics approval for Wave 2 data collection (mid-2025), for children who have transitioned to formal schooling, is currently under consideration by the NSW Department of Education's State Education Research Applications Process (SERAP). An ethics application for the Wave 1 nested study (late-2024), for which separate written consent and child verbal assent will be sought, is under review with University of Wollongong's human research ethics committee.

Consent for publication
Not applicable.

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