University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Neurocognitive Development in Children

Study 1: Can Early Infant Cognitive Assessment Predict Neurodevelopmental Outcomes at Age Five? Evaluating a Novel Touchscreen Method in a Community Sample.

Study 2: The Relative Influence of Child and Family Factors on Neurodevelopmental and Psychosocial Outcomes at Age Five in a Community Sample.

Thesis submitted by

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

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1.1 Introduction

Understanding early child development and the factors that shape long-term cognitive and psychosocial outcomes remains a central objective in developmental science and clinical psychology. The early years are a period characterised by profound neurobiological and psychological growth, wherein developmental trajectories are shaped by a complex interplay of biological, psychological, and environmental influences (Gilmore et al., 2018; Johnson, 2001; Shonkoff et al., 2012). Literatures concerned with childhood education have in recent years continually highlighted the need for such systems to adopt a "whole child" approach, recognising the dynamic interdependencies of social-emotional experiences, biological factors, neurocognitive development, and learning (Doss et al., 2019; Immordino-Yang et al., 2019; Osher et al., 2016). This approach underscores the need to consider the holistic development of children, encompassing cognitive, emotional, and social changes that significantly impact future functioning and outcomes across multiple domains (Bornstein et al., 2013; Bowe et al., 2023; Masten & Cicchetti, 2010).

The early identification of developmental risks and the implementation of supportive interventions have consequently become focal points in both research and applied practice (Peacock-Chambers et al., 2017). Despite advancements, accurately assessing child development during infancy and early childhood, and its relevance for later developmental trajectories, remains challenging due to its nonlinear and highly variable nature (Anderson & Reidy, 2012; Johnson et al., 2016). Child development is multifaceted, dynamic, and deeply embedded within the broader context of the family and environment (Gilmore et al., 2018). This thesis comprises two empirical research studies, exploring two interconnected dimensions of early development: the utility of early cognitive assessments in predicting later neurodevelopmental outcomes, and the influence of family-level factors on child psychosocial and cognitive development.

While standardised tools such as the *Bayley Scales of Infant and Toddler Development* (*Bayley-III*) are widely used to assess early neurocognitive development, their predictive validity over time remains variable (Koshy et al., 2024; Rasheed et al., 2023). Numerous studies have highlighted that the *Bayley-III* tends to overestimate developmental functioning and demonstrates only modest predictive validity for later cognitive outcomes, particularly when used before 24 months of age (Anderson & Burnett, 2017; Rasheed et al., 2023; Koshy et al., 2024). These concerns, alongside comparable predictive performance by shorter tools such as the *Denver Developmental Screening Test* and measures of family environment (Rubio-Codina & Grantham-McGregor, 2020), underscore broader limitations of current developmental assessments and provide the context for exploring alternative, scalable approaches. While standardised psychometric assessments remain the gold standard, parent-report screening tools such as the *Ages and Stages Questionnaire (ASQ)* are also commonly used. However, recent longitudinal studies suggest that the *ASQ* demonstrates low sensitivity for identifying children with later cognitive delay, raising concerns about its effectiveness as a standalone screening measure in population-level surveillance (Bowe et al., 2022; Duggan et al., 2023).

Novel approaches which are brief and accessible, such as touchscreen assessments, offer promising alternatives but require empirical validation (Casey et al., 2023; Twomey et al., 2021). Study 1 of this thesis addresses this need, adopting an explorative approach in examining the concurrent and predictive validity of the *CogniTOT* application, a novel touchscreen assessment tool for children aged 18 to 30 months, when compared with the *Bayley-III* and later cognitive outcomes at five years.

As noted, child development also unfolds within a social and relational context. Beyond individual cognitive abilities, a substantial body of research highlights the influence of family environment, parenting stress, and parental psychological well-being on child outcomes (Krauss et al., 2020; Neece et al., 2012; Ponnet et al., 2013). Family systems theory, dynamic systems theory, and ecological models of development emphasise the interaction between child and context (Bronfenbrenner, 1986; Miller et al., 1985; Thelen & Smith, 1994). Importantly, while many models of developmental psychopathology have emerged from clinical or high-risk populations, there is a growing recognition of the need to investigate these processes in general, non-clinical cohorts (Masten & Cicchetti, 2010; Sameroff, 2009). Examining the relative influence of family-level factors compared to child trait characteristics, such as early cognitive abilities, in normative samples is essential for understanding how risk and resilience operate across typical development. Moreover, such evidence is critical for informing early prevention strategies that are applicable beyond high-risk groups and embedded in broader public health systems (Moore et al., 2017). Study 2 of this thesis builds on this understanding by examining how family structural and dynamic factors, such as parental mental health, parenting stress, and family functioning, contribute to both neurodevelopmental and psychosocial outcomes in early childhood.

This literature review aims to provide an integrated synthesis of research on early child cognitive development and the role of family-level factors in shaping developmental outcomes. It will consider evidence relating to the predictive validity of early cognitive assessments, the mechanisms by which family environment influences child functioning, and the combined contribution of these domains to later psychosocial and neurodevelopmental outcomes.

1.1 The Nature of Child Development: Developmental Trajectories and Latent Effects

A substantial body of research indicates that brain development follows a nonlinear trajectory, with children naturally exhibiting unpredictable and nonlinear patterns of learning, alongside unique learning styles shaped by environmental influences. Evidence further suggests that nonlinearity, individual variability, and unpredictability are inherent characteristics of child development and learning processes (Gowda et al., 2024; Johnson, 2001). At a neurobiological level, longitudinal neuroimaging studies have demonstrated that cortical development follows both linear and nonlinear patterns, depending on the brain region and developmental stage. Measures such as cortical grey matter volume and synaptic density exhibit nonlinear trajectories, with regionally specific developmental curves (Gilmore et al., 2012; Kolk, 2022; Tamnes et al., 2010). This nonlinearity is mirrored in cognitive skills such as working memory, executive functioning, and language processing, which often display rapid developmental spurts followed by periods of consolidation or plateau (Mills et al., 2014). In the development of theory of mind, the capacity to understand and infer others' thoughts, beliefs, and emotions, it is understood that children also experience regressions and plateaus, with significant conceptual shifts typically occurring around middle childhood (Leece et al., 2017; Osterhaus & Koerber, 2021). This evidence underscores that predictive models grounded in linear statistical frameworks may be inherently limited, given the dynamic and non-linear nature of child development, wherein outcomes emerge through complex and reciprocal interactions over time (Gowda et al., 2024; Johnson, 2001; Smith & Thelen, 2003).

While the early childhood period in this context represents a crucial timeframe when developmental interventions can have significantly enhanced benefits (Britto et al., 2017; Center on the Developing Child at Harvard University, 2020), the described characteristics present a challenge in the assessment of child development, and thus, in the early identification of neurodevelopmental problems in infants. The concept of latent effects from early insults or injuries is a critical area of study within neurocognitive development. Contrary to previous assumptions about the young brain's resilience due to heightened plasticity, research more recently highlights that early brain insults can have a profound and lasting impact on development, in terms of cognitive and behavioural outcomes, but that such outcomes may not become apparent until later (Westmacott et al., 2009).

Research on paediatric acquired brain injuries suggests that early insults are associated with poorer intellectual and executive function outcomes compared to later insults (Tamnes et al., 2010). Studies have shown that children who experience brain injuries before the age of two often exhibit more severe cognitive deficits compared to those injured later, challenging the notion of early neural flexibility (Anderson et al., 2011; Brandt et al;. 2024). Furthermore, cognitive deficits arising from injuries in early infancy often only emerge in later childhood as these children struggle to meet the demands of their environments, when they are expected to process increasingly complex information, with increasing efficiency (Anderson et al., 2005; Dennis, 2000). This may reflect the fact that the brain, when injured at a stage of incomplete neurological development, may fail to develop optimally; however, the full impact of this disruption only becomes apparent later, when the affected neurodevelopmental systems are required to support adaptive functioning.

For example, following traumatic brain injury (TBI) in infancy, children often fail to keep up with peers in later development due to emerging cognitive deficits. Research has demonstrated a relationship between injury severity and outcomes, and the increased vulnerability of children who sustain TBI in infancy and early childhood to residual cognitive impairment (Anderson et al., 2005). These outcomes have been shown to be consistent over time with the most significant deficits observed in cognitive ability (Anderson et al., 2012). The neurodevelopmental implications for children acutely diagnosed with unilateral neonatal arterial ischemic stroke (AIS) have also been examined longitudinally. Cognitive assessments (Wechsler scales) administered at preschool age (3 years 6 months to 5 years 11 months) indicated no significant differences between participants and the normative sample. However, by school age (6 years 1 month and 12 years 5 months), participants' performances were significantly lower than the normative sample; 69% of participants showed significant declines in 1 or more cognitive domain. Emerging deficits in working memory, processing speed and nonverbal reasoning were indicated in the sample, in line with significant decline in Full Scale IQ scores (Westmacott et al., 2009).

It has been established that for most children, cognitive functions tend to stabilise around seven years of age, and begin to follow more consistent developmental trajectories (Hill et al., 2022). However, as outlined, the effects of early insults may not become fully apparent until later stages of development, as higher-order cognitive functions consolidate, emphasising the challenges delayed manifestation poses in early diagnosis and intervention. Longitudinal monitoring to detect and address these latent effects effectively would be useful (Anderson et al., 2011; Brandt et al., 2024), and is arguably particularly feasible in clinical populations such as those described. However, a broad appreciation of the diverse factors which influence child developmental trajectories is essential.

1.2 Developmental Screening and Surveillance

As noted, the range of factors which have significant implications for neurocognitive development in childhood is broad. In the context of latent vulnerability, a challenge exists in the early identification of deficits to facilitate early intervention, which aims to mitigate negative outcomes. Reliable assessment and screening tools which can be used in early infancy to predict neurodevelopment are required, along with reliable systems which facilitate population screening, and in particular screening for infants who are identified to be at higher risk due to parental and environmental factors.

Despite the prevalence of developmental delays in childhood, occurring in 10% - 15% of preschool children, they are most often identified by routine assessments by primary care physicians, or when concerns are raised by parents or preschool due to emerging deficits (Choo et al., 2019), such that early interventions are provided based on the presence of a developmental delay (Kerstjens et al., 2009). However, this reactive approach limits the potential of early intervention to achieve its most meaningful impact. Increasingly, developmental science and public health models emphasise the importance of identifying children *at risk* of delays, rather than waiting for deficits to become apparent, so that timely, preventive strategies can be implemented during periods of heightened neural plasticity (Bowe et al., 2023; Peacock-Chambers et al., 2017). Ideally, screening and assessment practices should aim to detect subtle early indicators of developmental vulnerability, allowing for the provision of support before difficulties consolidate into enduring challenges. This proactive model of care requires sensitive, developmentally appropriate tools capable of capturing early signs of risk across cognitive, behavioural, and relational domains.

While population based screening programmes are useful in many ways, they are limited in that they do not take into consideration the presence of pre-existing risk factors, thereby increasing the likelihood that the opportunity for pre-emptive intervention in early infancy will be lost. Furthermore, research which has examined the prevalence of screening and surveillance in early childhood has indicated that rates are generally low, and in light of the voluntary nature of same, those most vulnerable to risk factors are least likely to attend (Hirai et al., 2018; Wolf et al., 2018). In the US, despite the American Academy of Paediatrics recommending for decades that universal screening and surveillance be implemented to promote early detection of and intervention for developmental problems, uptake remains low. Recent surveys have estimated that 30.4% of children aged 3 years and under were reported to have received parent-completed developmental screening, while 37.1% (95% CI, 34.4%-39.8%) had received developmental surveillance from a health care professional in the preceding year. Furthermore, factors such as income, household education and family structure remained significantly associated with screening and surveillance after adjustment (Hirai et al., 2018).

In the absence of comprehensive screening programmes informed by child development research and known risk factors for neurodevelopmental outcomes, routine developmental surveillance most commonly occurs through scheduled visits, however, these have been shown to have poor sensitivity (Guevara et al., 2013; Guttmann et al., 2020; Schonwald et al., 2009). Research by Guevara and colleagues (2013) examined the effectiveness of developmental screening in identifying developmental delays. The *ASQ-II* and *Modified Checklist for Autism in Toddlers (M-CHAT)* were used in a randomised controlled, parallel-group trail, where use of these screening tools were more likely to lead to more timely identification of developmental delays, early intervention (EI) referrals, and EI eligibility, when compared with routine developmental surveillance. Despite evidence such as this, in the US and Canada, relevant task forces have not recommended universal screening for speech and language delay and disorders in children aged 5 years or younger, citing insufficient evidence to recommend same in the absence of parent or clinician concerns (Siu, 2015). Research in recent years, however, has not contradicted such findings but rather have reinforced the ongoing need for more evidence. The US Preventive Services Task Force's (USPSTF) stance remains unchanged, highlighting the lack of robust data to support universal screening for asymptomatic children (USPSTF, 2024).

In research which has comparatively examined the validity, reliability, accessibility and applicability of developmental screening tools, the *ASQ* has emerged as the most favourable (Kurbatfinski et al., 2024), and is widely used globally (Singh et al., 2017). However, research documenting the sensitivity and specificity of screening tools generally in identifying development delay is highly variable, including for the *ASQ*, with high sensitivity and specificity typically reported only where severe developmental delay is present (Kurbatfinski et al., 2024; Sheldrick et al., 2020). In an Irish context, and indeed elsewhere, previous research has pointed to issues with the sensitivity of screening tools leading to a failure to identify a high proportion of children developmentally at risk, and subsequently a high proportion of under-referrals for early intervention (Ahsan et al., 2009). The need for the development of more reliable, sensitive tools to detect developmental delay in early infancy is evident. In this context, the current research aimed to evaluate whether novel, touchscreen-based methods such as *CogniTOT* perform better, or at least comparably, to established tools such as the *ASQ* or *Bayley-III*, and whether they offer additional advantages in terms of accessibility, scalability, or early predictive utility.

1.3 Child Neurodevelopmental Assessment: A Review of Current Measures

The *Bayley Scales of infant and Toddler Development (BSID)* have long been one of the most widely used objective measures of early developmental delay, in both research and clinical settings. However, recent research highlights considerable limitations regarding the predictive validity of the *Bayley-III* for forecasting longer-term cognitive and developmental outcomes. A review of the psychometric properties of *Bayley-III* carried out by Anderson & Burnet (2017) investigated concerns that the scales overestimate developmental status, and poorly predict functioning in later childhood. The review reported results which supported these concerns, as it was found the tool under-identified children with developmental delay by overestimating cognitive, language and motor composites of the *Bayley-III*.

The predictive validity of the *Bayley-III* has been examined in a number of studies in varying populations. A large cohort in rural Pakistan were assessed using *Bayley-III* subscales (cognitive, language, motor) at 24 months. Follow-up assessments at age four using the *Wechsler Preschool and Primary Scale of Intelligence III* (*WPPSI-III*) and at age eight with the *Wechsler Intelligence Scale for Children V* (*WISC-V*) revealed minimal predictive power. Specifically, *Bayley-III* scores at two years explained only 15% and 1% of the variance in *WPPSI-III* Full-Scale scores and the *WISC-V Fluid Reasoning Index*, respectively.

Consequently, the authors advised caution when interpreting *Bayley-III* scores as indicators of future intellectual abilities (Rasheed et al., 2023)

Similarly, Koshy et al. (2024) examined *Bayley-III* stability and predictive validity within an Indian cohort, assessed longitudinally at 6, 15, 24, and 36 months, and subsequently at ages 5, 7, and 9 years using the *WPPSI* and *Malin's Intelligence Scale for Indian Children*. Findings indicated weak correlations across assessments, with *Bayley-III* scores at 36 months demonstrating comparatively stronger predictive validity (R^2 between 23.3% to 28.6%) than assessments conducted earlier at 24 months (R^2 between 16% to 25.9%). Thus, despite modest improvements in predictive validity at older assessment ages, overall results underscored limited stability and accuracy of *Bayley-III* for predicting future cognitive outcomes.

Rubio-Codina and Grantham-McGregor (2020) provided complementary findings from a large longitudinal Colombian cohort, initially assessed with the *Bayley-III* between 6-42 months and followed up at 6-8 years using the *WISC-V* and school achievement tests. Predictive validity for cognitive and language domains increased with assessment age, yet remained minimal before 19 months and only reached moderate levels after 31 months. Notably, brief screening tests such as the *Denver Developmental Screening Test* demonstrated comparable predictive validity at older ages, highlighting potential alternatives to the *Bayley-III* in large-scale studies. Additionally, measures of family environment (Family Care Indicators) demonstrated equal or superior predictive validity compared to *Bayley-III* in identifying risks of poor developmental outcomes. Collectively, these studies indicate that the *Bayley-III* possesses limited predictive capability for future cognitive performance, particularly when administered before 24 months, suggesting the necessity of caution and the integration of supplementary measures or later assessments for more accurate predictions of children's developmental trajectories.

While much of the available research examining the predictive validity of the *Bayley-III* in larger cohorts has been conducted in low and middle-income countries, some research from Western, high-income settings provide additional insight. Longitudinal research examining a Danish community sample of 55 children found only weak associations between *Bayley-III* cognitive scores at 9 months and general cognitive outcomes at 3 years, as measured by the *WPPSI-III*. Predictive validity of cognitive scores was demonstrated primarily between 7 and 13 months, but not beyond 13 months, and was variable across language and motor domains. These findings raise questions about the predictive utility of early assessments conducted in the first year of life (Krogh & Væver, 2018). In contrast, findings from a German community sample (n = 53 at follow-up) indicated that *Bayley-III* cognitive scores collected at 18 and 26 months were significantly associated with cognitive outcomes at 50 months as measures by the *WPPSI-III*, with moderate effect sizes observed. Predictive validity was found to improve with age at assessment, as no significant associations were observed at 6 and 9 months, supporting the view that assessments conducted after the first year may offer more stable indicators of later functioning. However, both studies were limited by small sample sizes, which may restrict the generalisability of findings (Klein-Radukic et al., 2022). Nevertheless, the variability in findings underscores the significance of assessment timing and reflects broader concerns regarding the limited stability of cognitive functioning in infancy, particularly before 12 months of age.

Additional findings from clinical samples further illustrate the predictive capacity of the *Bayley-III* in specific populations. A U.S. sample of 77 preterm infants born before 30 weeks' gestation, reported moderate predictive validity of *Bayley-III* scores at 2 years for cognitive and language outcomes at 4 years, with the strongest associations observed for language domains (Bode et al., 2014). Similarly, Spencer-Smith et al. (2015) examined a cohort of very preterm infants in Australia, and found that *Bayley-III* cognitive and language scores at 2 years accounted for significant variance in IQ outcomes at age 4, although the overall predictive strength was moderate. These studies, while informative, reflect clinical populations with elevated neurodevelopmental risk, where early cognitive deficits may be more pronounced and stable over time. Thus, while the *Bayley-III* appears to perform more robustly in identifying developmental risk in preterm populations, the extent to which these findings translate to general community samples remains uncertain. Collectively, the evidence from both community and clinical settings reinforces the view that the predictive utility of the *Bayley-III* is highly dependent on both the age at administration and the developmental risk profile of the sample. This research underscores the need for supplementary assessment tools and sustained developmental monitoring to more accurately identify children at risk for cognitive or psychosocial difficulties. This is particularly important given the influential role early assessments play in shaping parental understanding and determining pathways for clinical or educational intervention.

In addition to poor evidence of the *BSID* predictive validity, in the context of routine screening the requirement of user qualifications for the administration of the *BSID*, now

Bayley-4, represents a further challenge to its use. Specific training is required and the test it is most commonly administered by psychologists, neuropsychologists, or developmental paediatricians. Administration of the *Bayley-4* is also time intensive, with guidelines suggesting the test takes 30-70 minutes to complete (Balasundaram & Avulakunta, 2022). Another limitation of current validated neurodevelopmental assessments is that they rely heavily on children's receptive communication and fine motor skills, such as the *Bayley-4* and the *Griffiths Mental Development Scale* (Luiz et al., 2006). Such assessments are also susceptible to intra-assessor variability as significant child-administrator interaction is required (Twomey et al., 2018).

Although standardised psychometric assessments administered by clinicians remains the gold standard, parent-reported screening questionnaires are also often used to assess developmental status in children, such as the *Ages and Stages Questionnaire (ASQ)* as noted above. At present the use of the *ASQ* has been recommended by the National Steering group for the Revised Child Health Programme during the 24-month public health nursing assessment (Bowe et al., 2022; HSE, 2021). As well as issues with the prevalence and pathways through which screening and surveillance are undertaken, tools commonly used to detect delays in cognitive development have limitations. A recent retrospective, longitudinal study examined the predictive value of the *ASQ* when administered at 24 or 27 months, in identifying children who were found to have low cognitive ability at age 5. Of the 755 infants who participated in this study, the sensitivity of the *ASQ* for identifying low cognitive ability at age 5 was 20.8%, with 91.1% specificity, such that the *ASQ* did not detect the majority of children with low cognitive ability at age 5 years. Significantly, when *ASQ* performance was adjusted for, maternal education and family income were found to be strongly associated with cognitive outcomes in those who participated. However, although the *ASQ* itself has been found not to detect children who will enter into educational settings with low average cognitive ability (Bowe et al., 2022), it remains widely used and relied upon to discriminate between children with typical and atypical development.

A further longitudinal birth cohort study by Duggan and colleagues (2023), assessed the domain specific, concurrent validity of both the *ASQ-3* and the *Bayley-III*, and their predictive ability in detecting developmental delay at 5 years. Results indicated that the tools showed poor concurrent validity. At 24 months the sensitivity of the *ASQ-3* in detecting those with a *Bayley-III* score in the low average range (i.e. <1SD from the cohort mean) was poor. The sensitivity of the cognitive and communication domains were 20.7% and 25% respectively. Neither early screening (*ASQ-3*) nor formal developmental testing (*Bayley-III*) were found to demonstrate validity in predicting cognitive delay at school age. The *Bayley-III* performed better than the *ASQ-3* in this respect, however, results indicated this to be driven by very high specificity, such that the majority of children in the low average range at 5 years were not detected by a *Bayley-III* at 24 months (Duggan et al., 2023).

1.4 The Role of Family and Environmental Factors in Child Development

The research literature, as outlined, has contributed to a growing recognition of the need to conceptualise child development not as a fixed sequence of milestones, but as a dynamic process that can follow multiple pathways. Theoretical frameworks such as family systems theory, dynamic systems theory, and ecological models provide essential insights into the complex interplay of factors influencing early child development. These frameworks highlight the dynamic and relational nature of development, emphasising how children's growth is shaped by interactions with their environment (Bronfenbrenner, 1986). Central to this understanding is the consideration of the relative influence of intrinsic child characteristics, such as neurobiological maturation or early cognitive capacities, versus environmental and relational factors. While children bring innate potentials to their developmental trajectories, the family context plays a powerful role in shaping, amplifying, or buffering these predispositions, supporting a transactional view of development in which nature and nurture are continuously interacting and mutually influential across time.

Family systems theory, for example, posits that the family is a complex system where each member's behaviour affects others. This theory emphasises the importance of understanding family dynamics, such as communication patterns and emotional interactions, in shaping child development (Miller et al., 1985). For instance, a family's cohesion and adaptability can significantly influence a child's socioemotional development and resilience (Olson, 2000). Dynamic systems theory offers a similar, compelling framework for understanding these complexities (Thelen & Smith, 1994). This perspective posits that development emerges through the continuous and reciprocal interaction between the child and their environment. This interaction gives rise to self-organising processes that can result in sudden, qualitative changes in behaviour, often triggered by small shifts in internal or external conditions (Smith & Thelen, 2003). In this view, cognitive abilities are not pre-programmed or hardwired, but are constructed and reconstructed through a continuous process of adaptation and change. Crucially, this dynamic systems perspective also accommodates the wide variability seen in individual developmental trajectories. Children with similar early profiles may diverge markedly in later outcomes depending on environmental inputs, experiences, and internal regulatory processes. It also helps explain how early adverse experiences or delays may not immediately manifest in observable difficulties but can later emerge when the developmental system is challenged, a concept known as "latent vulnerability."

In line with the theoretical frameworks outlined, latent vulnerability has also been observed in relation to maternal factors, in terms of both later cognitive and psychosocial outcomes. Maternal distress during pregnancy and postpartum, can significantly influence early child development, and has been shown to be related to poorer outcomes in cognitive, behavioural, and emotional development domains (Berthelon et al., 2021; Kingston & Tough, 2014). Research specifically examining maternal biological stress signals (elevated cortisol levels) and maternal psychological distress (pregnancy-specific anxiety) has shown these factors to independently predict child anxiety at age 6-9 years (Davis & Sandman, 2012). A systematic review reported a negative association between prenatal and postnatal maternal mental health, and child development at school age. The majority of studies included reported small to medium effect sizes between impaired global, behavioural, cognitive development, and socio-emotional development outcomes, and exposure to prenatal and/or postpartum maternal distress (Kingston & Tough, 2014). Research has also evidenced the importance, and observed effects, of positive mental health on mother and child. Findings suggest that positive maternal mental health is associated with improved birth outcomes, and may be related to parenting which promotes academic achievement and good socio-emotional functioning. It is, thus, suggested that child cognitive development is supported by the presence of positive maternal mental health (Phua et al., 2020).

Although incorporation of such biological and perinatal factors were beyond the scope of the current research, these studies illustrate the broader point that maternal mental health, both in terms of distress and wellbeing, plays a foundational role in shaping long-term developmental outcomes. This provides important contextual grounding for Study 2, which focuses on maternal psychological wellbeing and parenting stress during the preschool years, thereby extending the investigation of these associations beyond the perinatal and infancy stages into a later developmental window.

As well as maternal mental health, the influence of family environmental factors on child development has also been evidenced. Increased anxiety or other stress in the child due to their environment reduces the brains capacity to focus on aspects of brain development which are necessary for future learning and cognitive ability. Survival is instinctively prioritised, which is helpful and effective in the short term, but in the longer term this can have negative implications (Hanson et al., 2014; McLaughlin et al., 2014). Studies have demonstrated that severe deprivation in early childhood can lead to alterations in adult brain structure and cognitive abilities, even when individuals are later raised in nurturing environments (Mackes et al., 2020; Nelson & Gabard-Durnam, 2020). Similarly, early neglect has been linked to cognitive, language, and behavioural deficits, emphasising the critical impact of early experiences on long-term developmental outcomes (Johnson et al., 2010; Spratt et al., 2012). While the current studies did not assess extreme deprivation, the broader literature demonstrates how even subclinical levels of stress within the caregiving environment may shape developmental trajectories in meaningful ways. This supports the rationale for examining normative variation in family dynamics and stress, such as those measured in Study 2, as potentially significant influences even in non-clinical, community-based populations.

Conversely, a rich family environment, for example where the child is exposed to rich language use and cognitive stimulation, promotes children's development and allows them to achieve their full potential (Garcia et al., 2020; Winston & Chicot, 2016). Research has demonstrated, via analysis of free play between children and caregivers, the positive association between caregiver's language richness and child cognitive, language, motor, and social-emotional development (Gao et al., 2023). Research carried out on a large Latin American sample of children examined the influence of factors, including a nurturing environment, on early child development. Measurement of the nurturing environment in this study included, for example, the number of books for children in the home, the number of adults who interacted with the child through play, story-telling, or creative activities, and the frequency of such interactions. A nurturing environment was found to be most significantly associated with child development, and was statistically significant across all domains (cognitive, socio-emotional, motor, language and communication) in all countries under investigation. The nurturing environment was more strongly associated with child development outcomes than socio-economic status, and maternal education. The relationship between a nurturing environment and child cognitive development was statistically significant, where the difference between groups on the low vs the high end of the nurturing environment index also increased with age (Verdisco et al., 2016). Thus, parents' interactions with their children and the quality of the adult-child interaction have important consequences for the socio-emotional and cognitive development of children. The current research draws on these principles by exploring family functioning and emotional climate as potentially modifiable influences on child development, with Study 2 in particular aiming to capture the effects of everyday variation in these domains on both neurocognitive and psychosocial outcomes.

1.5 Rationale for Thesis

Considering the inherent complexities of child development and current challenges in accurately assessing neurodevelopment in infancy, ongoing research efforts have sought to develop effective tools for identifying developmental delays and assessing neurocognitive functioning in childhood. The focus of some research has turned to developing brief, valid and interactive screening measures of early neurodevelopment, with touch-screen technology emerging as a promising medium. Research has been accumulating in recent years, evidencing the feasibility of touchscreen technology in assessing cognitive development in young children (Ahearne et al., 2016; Twomey et al., 2018). Through a series of related studies, the *CogniTOT* application a touchscreen, non-verbal assessment of executive functions, designed for 22–30-month-old toddlers, has been developed by researchers (Casey et al., 2023; Twomey et al., 2018; Twomey et al., 2021). This innovation reflects a growing recognition that traditional tools may be limited in their ability to detect early markers of neurodevelopmental difficulty, particularly in community settings.

While *CogniTOT* exemplifies this innovative approach, the extent to which performance on *CogniTOT* predicts later cognitive outcomes at ages four to five remains uncertain. Understanding the predictive validity of *CogniTOT* is critical, given evidence suggesting subtle cognitive deficits, often overlooked in early childhood, may become increasingly apparent as children reach school age. A key emerging question is whether these tools can move beyond feasibility and engagement to generate clinically meaningful data that enhance the early identification of children at developmental risk.

Moreover, irrespective of *CogniTOT*'s psychometric properties, developmental outcomes at school age are likely influenced by a range of mediating family-level factors. Parental mental health, family functioning, caregiving capacity, and wider environmental contexts directly shape child development trajectories (Moore et al., 2017). These factors must, therefore, be investigated as potential influencing factors in the relationship between early touchscreen-based cognitive assessments and later neurodevelopmental outcomes. This thesis explores both emerging approaches to early cognitive assessment and the broader relational and contextual influences on child development. In doing so, it aims to contribute to ongoing efforts to improve early identification by considering how novel methods might be used alongside an understanding of the child's caregiving environment.

The remainder of this thesis comprises two main empirical studies, which aim to address these gaps. The first study investigates the concurrent and predictive validity of the *CogniTOT* application, a novel touchscreen-based cognitive assessment tool for infants. The second study examines the role of family structural and dynamic factors in influencing developmental trajectories in early childhood by examining their associations with neurodevelopmental and psychosocial outcomes at age five. Each empirical study is followed by a supplementary chapter that provides additional methodological and analytical detail. The thesis concludes with an integrative discussion chapter, which synthesises findings from both studies and reflects on their broader theoretical, empirical, and clinical relevance.

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Chapter 2: Empirical Study 1

Can Early Infant Cognitive Assessment Predict Neurodevelopmental Outcomes at Age Five? Evaluating a Novel Touchscreen Method in a Community Sample.

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Title

Can Early Infant Cognitive Assessment Predict Neurodevelopmental Outcomes at Age Five? Evaluating a Novel Touchscreen Method in a Community Sample.

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Abstract

Early intervention for neurodevelopmental problems is dependent on early, accurate detection and identification of potential problems. However, developmental trajectories are non-linear and variable, thus, challenges exist. Issues with the sensitivity and reliability of screening and assessment tools has also been suggested, leading to a failure to identify a high proportion of children developmentally at risk. This longitudinal study evaluates the concurrent and predictive validity of *CogniTOT*, a novel touchscreen-based cognitive assessment tool, designed for children aged 22-30 months, in predicting later neurodevelopmental outcomes at age five. A community-based sample of 80 typically developing children and 7 children with a history of hypoxic ischemic encephalopathy (HIE) participated in the study. Early *CogniTOT* scores were compared with scores from the *Bayley-III*, and later neurodevelopmental outcomes were assessed using *WPPSI-IV* and *NEPSY-II* subscales. The results demonstrated small to moderate effect size associations between *CogniTOT* subscales, such as *Working Memory* and *Sustained Attention*, and later verbal reasoning and memory tasks. While some associations aligned with expected patterns, others contradicted the anticipated direction, highlighting issues with the tool's scoring logic. These findings underscore the need for refinement in *CogniTOT'*s subscale structure and scoring algorithms. Despite these challenges, the study provides preliminary evidence supporting the utility of touchscreen-based assessments for capturing early cognitive functioning. The findings suggest that such tools may offer a feasible, scalable alternative to traditional assessments, with potential for broader implementation in early childhood developmental screening. Future research should focus on further validating these tools across diverse populations and exploring their potential for early identification of children at risk for neurodevelopmental difficulties.

1. Introduction

Early childhood represents a unique period of neural development characterised by sensitivity, plasticity and growth (Johnson, 2001). Signals from the external environment significantly influence cognitive development in multiple domains, as both brain volume and cognitive function markedly increase (Bowe et al., 2023; Gervain, 2015). However, the trajectory of child development is inherently nonlinear and variable, shaped by both biological maturation and dynamic environmental inputs (Gowda et al., 2024; Johnson, 2001). Neuroimaging and developmental studies have demonstrated that cognitive skills, such as executive functioning and language, develop through rapid growth spurts followed by periods of consolidation, with individual variability reflecting diverse neurodevelopmental pathways (Kolk, 2022; Mills et al., 2014). In general, it is understood that neurodevelopmental patterns tend not to stabilise or follow consistent patterns of development until approximately age 7 (Hill et al., 2022).

This variability poses a significant challenge for the early identification of children at risk of neurodevelopmental difficulties. Thus, the opportunity presented by this period of heightened neuroplasticity will be missed in many cases, as intervention typically occurs only as overt cognitive delay or deficits become evident (Bowe et al., 2023). Additionally, research has shown that early brain injuries or disruptions may not manifest in cognitive deficits until later developmental stages when higher-order functions are more explicitly demanded (Anderson et al., 2005; Westmacott et al., 2009). In children with mild hypoxic ischemic encephalopathy (HIE), for example, neuropsychological difficulties have been shown to emerge at school age (van Kooij et al., 2010). A systematic review of mild HIE outcomes reported abnormal outcomes for 22% of children at 18 months, increasing at 5 years, when 35% were reported to have difficulties in one or more developmental areas (Conway et al., 2018). These "latent effects" highlight the limitations of relying on early behavioural observation alone, and underscore the need for assessment tools that can sensitively capture early indicators of later developmental risk (Brandt et al., 2024).

As well as the challenges posed by characteristic variability and latent vulnerability, issues remain with regard to uptake of available early interventions (Hirai et al., 2018), despite significant findings from empirical research which outlines their effectiveness. As well as early intervention in cases of overt, diagnosed difficulties, positive outcomes related to pre-emptive early intervention during the period of optimal neural plasticity, prior to the emergence of atypical cognitive development and related difficulties, have been demonstrated (Peacock-

Chambers et al., 2017). However, as research has also highlighted, such early intervention is dependent on early, accurate detection and identification of potential problems in order to achieve optimal long term outcomes (Bowe et al., 2023).

Despite their widespread use in both clinical and research contexts, the predictive validity of standardised developmental assessments in infancy for later cognitive outcomes, such as the *Bayley Scales of Infant and Toddler Development, Third Edition (Bayley-III)*, remains inconsistent. While these tools offer reliable composite scores across cognitive, language, and motor domains, their capacity to predict long-term neurodevelopmental outcomes, especially in typically developing children, has been questioned (Anderson and Burnett, 2017). Numerous studies in diverse cohorts have reported poor predictive validity of the *Bayley-III* in predicting later neurodevelopmental outcomes (Krogh & Væver, 2018; Rasheed et al., 2023; Rubio-Codina & Grantham-McGregor, 2020). Better predictive validity has been evidenced in clinical cohorts, such as preterm infants (Bode et al., 2014; Spencer-Smith et al., 2015). However, such research reflects clinical populations with elevated neurodevelopmental risk, where early cognitive deficits may be more pronounced and stable over time, thus, the extent to which these findings translate to general community samples is arguably reduced. This has led to increasing interest in the development of more targeted, sensitive tools that can better assess emerging cognitive capacities, particularly executive functions, which are known to underpin later academic and behavioural outcomes (Anderson et al., 2005; Clark et al., 2016).

A review by Anderson and Burnett (2017) concluded that the *Bayley-III* tends to overestimate developmental functioning, particularly in children with delays, and has limited utility in forecasting outcomes beyond infancy. Recent longitudinal studies have reinforced these concerns. Findings across multiple studies suggest that while predictive accuracy improves slightly with age at assessment, the *Bayley-III* demonstrates limited ability to forecast later cognitive outcomes, particularly when administered before 24 months of age. In a large Pakistani cohort, *Bayley-III* scores at 24 months accounted for only 15% of the variance in *WPPSI-III* scores at age 4 and 1% of the variance in *WISC-V Fluid Reasoning* scores at age 8 (Rasheed et al., 2023). Similarly, longitudinal research in India found that the *Bayley-III* scores at 24 months explained between 16% and 25.9% of the variance in later IQ scores, while assessments at 36 months showed slightly improved but still moderate predictive validity (R^2 = 23.3% to 28.6%) (Koshy et al., 2024). In Western settings, Krogh and Væver (2018) found only weak correlations between *Bayley-III* cognitive scores at 9 months and *WPPSI-III* outcomes at 3 years in a Danish community sample.

Even at older ages, its predictive power remains modest. In some instances, brief screening tools such as the *Denver Developmental Screening Test* have shown comparable or even superior predictive validity (Koshy et al., 2024; Rasheed et al., 2023; Rubio-Codina & Grantham-McGregor, 2020). These limitations are compounded by the *Bayley-III*'s logistical demands; administration requires specialist training, is time-consuming, and is heavily reliant on fine motor and receptive communication abilities. Taken together, these findings underscore that while the *Bayley-III* remains a widely used tool, its predictive utility, particularly in the first two years, is limited, supporting the need for alternative or complementary methods of early developmental assessment.

Other widely used screening tools, such as the *Ages and Stages Questionnaire* (*ASQ*), have similarly demonstrated poor sensitivity in detecting children with later cognitive difficulties (Bowe et al., 2022; Duggan et al., 2023). Failure by screening tools in this context to identify children developmentally at risk has been linked to under-referring to necessary early intervention (Ahsan et al., 2009). Within healthcare systems globally, lack of appropriate assessment tools, shortage of qualified professionals, and training of primary care medical professionals which centres on the treatment of acute illness, rather than evaluation and recognition of developmental delay, have been identified as barriers to assessment (Villagomez et al., 2019). Although these tools are integral to early detection efforts, their limited predictive capacity underscores the need for more developmentally sensitive, accessible, and scalable approaches to early cognitive screening, particularly those that can reliably identify children at risk before school age.

In recent years, the emergence of touchscreen technology has opened new avenues for assessing early cognitive development, offering potential advantages over traditional assessment methods. At present there are no available non-verbal assessment tools for use with children under 3 years, and generally there is a paucity of suitable cognitive assessment tools for children with physical disabilities (Marlow, 2013; Twomey, 2018). Touchscreen-based tools are particularly promising for their capacity to engage young children, reduce reliance on language and fine motor skills, and minimise administrator bias through standardised delivery (Casey et al., 2023; Twomey et al., 2018). Research indicates that typically developing infants can interact purposefully with touchscreen devices, demonstrating task-specific behaviours such as swiping and feature activation at a median age of 24 months (Ahearne et al., 2016).

As such, touchscreen assessments provide a viable platform for scalable, accessible, and low-resource screening of cognitive development in infancy and toddlerhood. Initial feasibility studies have supported the developmental appropriateness of touchscreen platforms. Notably, *Babyscreen*, a precursor to *CogniTOT*, demonstrated that children under three years could complete cognitively engaging tasks on a touchscreen without verbal instruction or extensive adult facilitation. This research demonstrated good 'overall' internal consistency of the tool (α=0.85), however, subscales were subsequently revised by authors who determined that tasks used in this version of the tool were not good measures of the constructs they were purported to assess (Twomey et al., 2018). Subsequent iterations of the tool improved psychometric robustness, with *Babyscreen V.1.5* demonstrating concurrent validity with *Bayley-III* in children aged 18-24 at risk of cognitive delay due to complications at birth (Twomey et al., 2021). Specifically, *Babyscreen V.1.5* scores demonstrated a moderate positive correlation with the *Bayley-III* cognitive composite ($r = .414$, $p < .001$), indicating a meaningful association between the two measures.

Most recently, Casey et al. (2023) validated *Babyscreen V.1.89* in a community sample, reporting moderate correlations with *Bayley-III* scores, sensitivity of 50%, and good specificity (93%) in detecting mild cognitive delay at 24 months. *Bayley-III* cognitive composite scores were moderately correlated with the total number of *Babyscreen V.1.89* tasks completed i.e. total score (r=.358, $p< .001$), indicating moderate concurrent validity. These findings underscore the potential of such tools in real-world early identification settings. Additional detail related to the studies outlined and the development of *CogniTOT* is outlined in Supplementary Chapter 3.

Despite promising feasibility evidence, there is a paucity of research examining the concurrent and predictive validity of touchscreen-based assessments in community-based samples. Existing studies have focused primarily on clinical or high-risk cohorts, limiting the generalisability of findings. Moreover, little is known about whether touchscreen-based performance in infancy is associated with later neurodevelopmental outcomes captured through validated standardised assessments in early childhood. The current study aims to address these gaps by evaluating the concurrent and predictive associations of the *CogniTOT* application in a community-based sample of typically developing children. Specifically, it investigates: (1)

whether *CogniTOT* scores are concurrently associated with scores on the *Bayley-III* at 24–30 months; and (2) whether early *CogniTOT* scores predict performance on neurodevelopmental assessments (*WPPSI-IV* and *NEPSY-II*) at age five.

2. Materials and Methods

2.1 Design

The current study is a follow-up of a cross-sectional observational study which assessed the concurrent validity of two measures of child neurodevelopmental functioning. The *Bayley-III* and the *CogniTOT* application (Liltoda Ltd) were used to assess each child at baseline, between September 2020 and September 2021 when aged 22-30 months (O'Sullivan et al., under review). As the follow-up study was constrained by the scope of demographic and background information collected at baseline, additional variables could not be retrospectively obtained. The current study, thus, adopts a longitudinal quantitative design to examine the validity of the touch-screen screening tool, *CogniTOT*, in predicting neurodevelopmental outcomes in children at age 5 years.

2.2 Participants

Participants were recruited to the current study from a community sample of 126 typically developing children, and a smaller clinical sample of 15 children with HIE in infancy. At baseline, community and convenience sampling was used by O'Sullivan and colleagues (n.d.) to recruit participants. Participants were recruited via posters in the community and staff/faculty emails at University College Cork (UCC). Convenience sampling was used to recruit both typically developing children attending the INFANT Early Life Lab, UCC, for developmental assessment as part of another study, and children with HIE attending INFANT Research Centre, UCC, as part of a large scale study of children with HIE. Children were excluded from participation if they were currently ill or impaired by a known physical health condition, which was determined at the recruitment stage of the current study.

Ethical approval was granted by the Clinical Research Ethics Committee of the Cork Teaching Hospitals (CREC) (see Appendix A). The procedures for participant recruitment in the current study followed the protocol approved by CREC, which were necessarily consistent with the protocol of the baseline study (O'Sullivan et al., under review), wherein participants consented to being contacted again in relation to follow-up research such as the current study. For the current study, parents were contacted by phone and the study was explained to them. They were invited to provide consent for their child to take part in a follow-up assessment of their cognitive abilities. The Participant Information Leaflet (Appendix B) was sent by email to interested participants, along with the Informed Consent form (Appendix B) for information purposes. An appointment time was arranged for each child to attend the research centre for the assessment. Informed consent and age-appropriate assent (Appendix C) was obtained in person prior to the assessment taking place. In total 87 participants were recruited to the current study; 80 from the community sample, and 7 from the HIE sample. No a priori power analysis was conducted, as sample size was determined by the number of participants from the original cohort who were eligible and available for follow-up within the study period.

2.3 Outcome Measures

At baseline, the *Bayley-III* and *CogniTOT* assessments were administered to each child, in person in the research centre. The *Bayley-III,* was used as a standardised measure of early developmental functioning across cognitive, language, and motor domains (See Supplementary Chapter 3).

The *CogniTOT* application is a novel touchscreen, non-verbal assessment of executive functioning, designed for children aged 22-30 months. The version of *CogniTOT* under investigation (version 1.1), based on previous versions of the application tested (Casey et al., 2023; Twomey et al., 2018; Twomey et al., 2021), consists of 30 task items and purports to assess toddlers fundamental cognitive abilities in the following individual cognitive domains*: Processing speed, selective attention, working memory, acquired learning, problem solving, cognitive shift*, and *sustained attention*. Subscales are named in line with the cognitive construct they purport to measure. Each subscale and a sample of corresponding tasks are outlined table 2.1 below. Significantly, lower subscales scores on *CogniTOT* indicate better performance, with the exception of *CogniTOT Total* score and *CogniTOT Sustained Attention*. See Supplementary Chapter 3 for detailed description of the design, scoring and administration of the *CogniTOT* application, as well as Appendix F for a complete overview of each *CogniTOT* task with descriptions.

Table 2.1

CogniTOT subscales and sample of corresponding tasks

Cognitive Construct	Sample description of task items measuring the construct
Processing Speed†	**Task 5:** 9 Stars (3 x 3 grid), 8 Blue, 1 Smiley face yellow star. Press yellow star.

Cognitive Construct	Sample description of task items measuring the construct
Working Memory†	**Task 20**: 5 Boxes: Pink, Blue, Green (left - right). Yellow star falls into pink box (1st in line) and is completely hidden. Press pink box to completely reveal star. Press yellow star.
Problem Solving†	**Task 16:** Blue and Red Bucket. Red Bucket (on right) covers Yellow Star. Swipe up bucket and press yellow star.
Selective Attention†	**Task 6:** 30 stars (6 x 5 grid), 29 blue, 1 smiley face yellow star. Press yellow star.
Acquired Learning†	**Task 17:** Blue and red buckets, with 1 yellow star becoming hidden under blue bucket on left side. Press blue bucket and press yellow star.
Cognitive Shift†	**Task 8:** 30 stars (6 x 5 grid): 1 yellow smiley target star, 29 multi-colored plain distractor stars. Press yellow star.
Sustained Attention†	**Task 30:** Balloons moving onscreen as they do at end of app, for 120 seconds maximum. Task does not contribute to CogniTOT score. Instead provides a separate measure of sustained attention.

Note. Appendix F contains a complete overview of each CogniTOT task with descriptions
†Individual CogniTOT subscales

The consultant clinical neuropsychologist (CMC) chose the neuropsychological assessments, and categorised subtests into cognitive domains for the purposes of the current study. This approach allowed for a more detailed exploration of specific cognitive processes, providing greater sensitivity to subtle domain-specific variations that may not be captured by overall index scores. Neuropsychological outcomes were assessed in the cognitive domains of *verbal reasoning, non-verbal reasoning, receptive language, expressive language, speed of information processing, verbal and non-verbal memory, working memory*, and *perceptual motor abilities*. Table 2.2 outlines each subtest contained in the test protocol, and the related cognitive construct measured. Standardised scores for each subtest were calculated, i.e. a child's raw score on each task was converted into a score relative to age-based normative data, allowing for meaningful comparisons across children and cognitive domains. The *WPPSI-IV* subtest scores are standardised with a mean (standard deviation (SD)) of 10 (3) (Wechsler, 2012). Of the *NEPSY-II* subtests used in the current protocol, all are standardised with a mean (SD) of 10 (3), with the exception of *Design Copying,* which yields a raw score that is converted into percentile ranks and descriptive categories.

Table 2.2

Neuropsychological Subtests and Descriptions

Neurodevelopmental Outcome	Test	Description
Non-Verbal Reasoning	Matrix Reasoning†	Measures fluid reasoning and problem-solving using abstract visual patterns.
Verbal Reasoning	Similarities†	Assesses verbal concept formation and abstract reasoning by identifying similarities between words.
Receptive Language	Receptive Vocabulary†	Evaluates understanding of spoken words by asking the child to point to pictures.
Expressive Language	Picture Naming†	Measures expressive vocabulary by asking the child to name pictured objects.
Processing Speed	Bug Search†	Assesses visual scanning and processing speed through identifying matching symbols.
Non-Verbal Memory	Picture Memory†	Evaluates visual recognition and memory for previously presented pictures.
Working Memory	Comprehension of Instructions‡	Measures auditory attention and working memory by having the child follow multi-step spoken instructions.
Verbal Memory	Narrative Memory‡	Assesses memory for verbally presented stories, focusing on both immediate and delayed recall.
Perceptual-Motor	Design Copying‡	Measures visual-motor integration by having the child reproduce geometric figures.

† Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version);
‡ NEPSY–Second Edition: A Developmental Neuropsychological Assessment

A bespoke demographic questionnaire was developed to collect information about each child and their family (Appendix D). The demographic variables included were those available from the baseline protocol and were selected to capture key family characteristics potentially relevant to child development, such as household structure and parental education. The following variables were derived from this questionnaire for the purposes of analysis:

- Number of siblings
- Family composition (i.e. lone parent or two-parent household)
- Maternal age
- Maternal level of education
- Main language spoken at home (English or other)
- Maternal country of birth (Ireland or other)

- Paternal country of birth (Ireland or other)
- Presence of a diagnosed medical condition in the child

2.4 Procedures

Child neurocognitive assessments were carried out by a trainee clinical psychologist (MB), a psychology research assistant (LO'S) and a psychology graduate (AM) each of whom were trained to undertake the current neuropsychological assessment battery. Multiple training sessions were facilitated by the consultant clinical neuropsychologist (CMC), during which assessors were instructed in standardised administration procedures and practiced test delivery with one another in a controlled, practice environment. Training continued until each assessor demonstrated satisfactory competence and procedural adherence. To further ensure assessment fidelity, the initial assessments were conducted by CMC and observed by the other assessors from an adjacent observation room. Subsequently, each assessor conducted their first participant assessments under observation by CMC, who provided feedback and confirmed administration competency prior to the assessor proceeding independently. These procedures ensured consistency, reliability, and standardisation of the assessment protocol across all administrators. The duration of assessments was approximately 45 minutes.

2.5 Statistical Analysis

Statistical analysis was completed by using IBM SPSS Statistics version 29.0.2.0. Tests of normality were performed using measures of skewness and kurtosis, and where assumptions of normality were not met, appropriate data transformations were applied. Descriptive statistics (e.g., means, standard deviations, ranges and percentages) were calculated for key study variables, including child cognitive assessment scores (*CogniTOT, Bayley-III, WPPSI-IV, NEPSY-II*), and child and family demographic characteristics. Where available, sample characteristics were compared with normative data to aid interpretation.

Pearson's correlation coefficients and independent samples t-tests were used to examine both the concurrent associations between *CogniTOT* and *Bayley-III* scores, and the predictive relationships between these early cognitive assessments and later neurodevelopmental outcomes, as measured by the *WPPSI-IV* and *NEPSY-II.* Specifically, analyses assessed the strength and direction of associations (using correlation coefficients), and compared mean scores across groups (using t-tests), with statistical significance ($p < .05$) and effect sizes (e.g. r, Cohen's d) used to interpret the magnitude and practical relevance of the findings.

Independent samples t-tests were also conducted to assess between-group differences, comparing children who scored one-third of a standard deviation below the mean at baseline and follow-up with those performing within or above the expected range. These analyses were conducted to complement the correlational findings by identifying whether children identified as potentially at-risk based on early cognitive scores demonstrated significantly different outcomes at follow-up. This approach enabled an evaluation of the clinical relevance of early identification thresholds beyond general associations.

One-sided p-values were used in line with the study's directional hypotheses, which predicted that higher *CogniTOT* scores (or lower, depending on subscale scoring direction) would be associated with better performance on validated cognitive measures. The focus was on examining whether *CogniTOT* scores showed meaningful concurrent and predictive associations with scores on the *Bayley-III, WPPSI-IV*, and *NEPSY-II*. As some *CogniTOT* subscales are scored such that lower values indicate stronger performance, the direction of hypotheses and interpretation of associations were based on the specific scoring conventions of each measure. Effect sizes for between-group differences were calculated using Cohen's d to indicate the magnitude of observed effects.

3. Results

3.1 Sample Characteristics

In total 87 children were recruited to this study, from an original sample of 126. Sample characteristics are summarised in table 2.4 below. The *Bayley-III* index composite scores have a standardised mean of 100 (*SD* = 15) (Bayley, 2006). As outlined in Table 2.4, the current sample closely aligned with these normative means across *Cognitive, Language,* and *Motor* domains. *Language* and *Motor* scores were slightly above average, while *Cognitive* scores were in line with the expected mean. Thus, concerns about sampling bias in terms of overall cognitive functioning are reduced.

When the sample representativeness of participants for the current study was assessed, no significant differences were found between the responder and non-responder groups (see Table 2.3). A chi-square test of independence was conducted to compare gender distribution between responders and non-responders. The results showed no significant difference between the groups ($p = .69$).

Independent samples t-tests were conducted to compare *Bayley-III Cognitive, Language,* and *Motor Composite* scores between responders and non-responders. No significant differences were found for cognitive scores, $t(120) = 0.459$, $p = .647$, language scores, $t(118) = -0.727$, $p = .469$, or motor scores, $t(118) = -1.001$, $p = .319$. These findings indicate no significant differences in cognitive performance between the two groups. An independent samples t-test was also conducted to compare scores between responders and non-responders on *CogniTOT*, using the *CogniTOT Total* score. The results indicated no significant difference between the groups, $t(122) = -0.712$, $p = .478$. These findings suggest that cognitive performance did not differ significantly based on response status.

Table 2.3

Sample Characteristics of responders and non-responders from baseline study

Variable	Responders (*n* = 78)	Non-responders (*n* = 46)	*P*
Gender			.69†
Male *n*	33 (42%)	16 (35%)	
Female *n*	45 (58%)	30 (65%)	
Bayley's Composite scores			
Cognitive	99.6 (12.4)	100.8 (15.6)	.65‡
Language	105.9 (15.9)	103.6 (18)	.47‡
Motor	103.3 (12.2)	100.9 (12.6)	.32‡
CogniTOT total score	19.2 (6.6)	18.3 (8)	.48‡

† Pearson Chi-Square Test, ‡ Independent Samples *t*-test

Whilst the cognitive functioning of the sample infants appeared aligned to normative means, the demographics of the family were less typical. Thus, 8.1% of the current sample were lone parents. This is significantly lower than nationally representative data which, in 2022, indicated that 15.5% of children lived in a single parent family unit in Ireland (Department of Children, Equality, Disability, Integration & Youth (DCECIY), 2024). The maternal level of education of the current sample is also higher than population norms, with 87% of mothers reporting to have achieved a Level 8 degree or higher. Nationally, in 2016, 50.6% of children's maternal highest level of education was secondary level, and 8.1% of children had a mother with either no formal education or primary education only (DCECIY, 2024). Directly comparable normative data relating to nationality was not available. However, Census 2022 figures indicate that just over 87% of householders in families stated they were

Irish citizens, while 12% declared non-Irish citizenship, which is comparable to the current sample.

Table 2.4

Sample Characteristics relating to demographic information and family factors, and child neurodevelopmental functioning in infancy

Factor	% (*n*)	*M*(*SD*)
Family		
Maternal Age (years) §		40.1 (3.9)
Lone parent	8.1% (7)	
Mother born in Ireland	84% (44)	
Father born in Ireland	88% (42)	
Main language used at home		
English	93.8% (75)	
Other language	6.3% (5)	
Maternal Level of Education‡		
Level 7 degree and lower	13% (10)	
Level 8 degree and higher	87% (67)	
Number of siblings		1.4 (0.9)
Child		
Sample type		
Community	92% (80)	
HIE†	8% (7)	
Gender		
Male	47% (41)	
Female	53% (47)	
Child with diagnosed medical condition	13% (11)	
Age		
Baseline (months)		26.1 (1.8)
Follow-up (years)		5.5 (0.3)
Bayley's scores		
Cognitive Composite		99.8 (12)
Language Composite		105.4 (16.1)
Motor Composite		103.5 (12.2)

† HIE = hypoxic ischemic encephalopathy

‡ Education levels are categorised as Level 7 and lower (Ordinary degree or below) and Level 8 and higher (Honours degree or above).

§Refers to maternal age at time of follow-up assessment.

3.2 Data Screening and Assessment of Normality

A visual inspection of histograms was conducted for all variables, in conjunction with kurtosis and skewness analyses, to assess the normality of their distributions. Outliers (> 3 standard deviations from subgroup means) were removed from the dataset (n = 4 outliers removed). Tests of normality were conducted using skewness and kurtosis values. All variables were found to be normally distributed, with the exception of *CogniTOT Processing Speed*. A $\log_{10}$ transformation was applied to this variable, after which normality assumptions were met. Full details of this process are reported in Supplementary Chapter 3.

3.3 Concurrent Associations between CogniTOT profile scores and Bayley-III index scores in infancy

To evaluate the concurrent associations of the *CogniTOT* with *Bayley-III*, independent samples *t*-tests were conducted to compare *CogniTOT* scores between children categorised as scoring within, and those below, the expected range on each of the *Bayley-III* composite scales. Two-thirds of a standard deviation below the *Bayley-III* mean scores was taken as the threshold for caseness scores. Group differences across *CogniTOT* domains are summarised in Tables 2.5 to 2.7. Correlational analyses were not conducted for concurrent associations between *CogniTOT* and *Bayley-III* scores, as the primary focus of this phase of analysis was on evaluating potential clinical utility. Group comparisons based on *Bayley*-defined caseness allowed analysis to explore whether *CogniTOT* scores could meaningfully differentiate children performing below the expected range, consistent with early identification aims in applied settings.

There were some statistically significant differences evident between those within, and those below, threshold on the *Bayley's Cognitive Composite* and the *CogniTOT Total Score* and the *Working Memory* subtests (highlighted in the table). Those infants who were 2/3 of a SD below the *Bayley's* mean had lower *CogniTOT Total* scores and less efficient *Working Memory* scores (indicated by higher reaction time scores on the latter subtests). Effect sizes were medium to large here. However, no other group differences were observed in the expected direction. No group differences were evident when the *Bayley's Language Composite* and *Bayley's Motor Composite* index scores were used to divide the groups – although *Working Memory* approached statistical significance (p = 0.76) with a medium effect size (0.5) for the language composite domain. Overall, these findings suggest only the *CogniTOT Total* and *Working Memory* scores have some concurrent association and with the *Bayley's Cognitive Composite* scores.

Table 2.5
CogniTOT Scores by Bayley-III's Cognitive Composite Caseness

Scale	90 and less *M* (*SD*)	91 and above *M* (*SD*)	*t* (*df*)	*p*	E.S.
CogniTOT Total Score	17.1 (5.9)	21 (4.9)	-3 (82)	.002**	-.8
CogniTOT Processing Speed	12.8 (9.8)	22.9 (25)	-1.6 (62)	.054	-.6

Scale	90 and less	91 and above	*t* (*df*)	*p*	E.S.
CogniTOT Selective Attention	38.8 (21.6)	57.2 (40)	-2.1 (62)	.024*	-.5
CogniTOT Working Memory	5.7 (1.6)	4.5 (2.4)	2.1 (65)	.024*	.5
CogniTOT Acquired Learning	100.9 (31.4)	91.3 (37.3)	.8 (62)	.222	.3
CogniTOT Cognitive Shift	20.3 (17.6)	26.2 (24.6)	-1 (79)	.161	-.3
CogniTOT Problem Solving	102.9 (29.1)	107.8 (21.1)	-.7 (64)	.256	-.2
CogniTOT Sustained Attention	68.2 (44.5)	63.7 (35)	.4 (64)	.357	.1

Note. E.S. = Cohen's *d* effect size. Significant results in the expected direction are highlighted.
* $p < 0.05$
**$p < 0.01$

Table 2.6
CogniTOT Scores by Bayley-III's Language Composite Caseness

Scale	90 and less *M* (*SD*)	91 and above *M* (*SD*)	*t* (*df*)	*p*	E.S.
CogniTOT Total Score	20.9 (4.4)	19.7 (5.7)	.7 (75)	.237	.2
CogniTOT Processing Speed	15.3 (9.6)	17.3 (17.8)	.1 (56)	.478	.02
CogniTOT Selective Attention	61.4 (38.6)	47.4 (34.9)	1.0 (56)	.151	.4
CogniTOT Working Memory	5.7 (1.6)	4.5 (2.4)	1.5 (59)	.076	.5
CogniTOT Acquired Learning	93.2 (32.9)	90.5 (34.2)	.2 (56)	.418	.1
CogniTOT Cognitive Shift	24.8 (17.4)	24.3 (22.8)	.1 (72)	.470	.03
CogniTOT Problem Solving	99.7 (28.3)	110.3 (20.4)	-1.3 (58)	.091	-.5
CogniTOT Sustained Attention	70.3 (48.7)	64.4 (33.7)	.5 (58)	.327	.2

Note. E.S. = Cohen's *d* effect size.
* $p < 0.05$
**$p < 0.01$

Table 2.7
CogniTOT Scores by Bayley-III's Motor Composite Caseness

Scale	90 and less *M* (*SD*)	91 and above *M* (*SD*)	*t* (*df*)	*p*	E.S.
CogniTOT Total Score	19.9 (5.2)	19.8 (5.5)	.02 (76)	.493	.007
CogniTOT Processing Speed	15 (12.5)	17.2 (17.3)	-.3 (56)	.392	-.1
CogniTOT Selective Attention	39.1 (23.3)	50.3 (36.3)	-.7 (56)	.254	-.3
CogniTOT Working Memory	4.6 (1.7)	4.7 (2.3)	-.1 (59)	.478	-.03

CogniTOT Acquired Learning	104.4 (37.9)	89.6 (33.4)	.9 (56)	.175	.4
CogniTOT Cognitive Shift	17.7 (17.5)	24.6 (22.3)	-.7 (73)	.230	-.3
CogniTOT Problem Solving	81.6 (25)	111.7 (19.5)	-3.5 (58)	<.001**	-1.5
CogniTOT Sustained Attention	73.3 (48.1)	64.4 (34.7)	.6 (58)	.284	.2

Note. E.S. = Cohen's *d* effect size. * $p < 0.05$; ** $p < 0.01$

3.4 Predictive Associations Between Early Cognitive Assessments and Neurodevelopmental Outcomes at age 5 Years

Correlation analyses were conducted to examine the predictive associations between early cognitive scores on the *Bayley-III* and *CogniTOT*, and later neurodevelopmental outcomes as measured by subscales of the *WPPSI-IV* and *NEPSY-II*. This approach allowed for examining predictive trends across the full range of scores, rather than comparing predefined groups as in the concurrent analyses. All statistically significant associations are presented in Table 2.8.

Overall, analyses suggested small – medium (at best) effect size associations for both *Bayley-III*'s and *CogniTOT* scales with later cognitive outcomes. *Bayley Composite* scores showed modest associations with later verbal, memory, and visuospatial abilities. The *Bayley Language Composite* was most consistently associated with later outcomes, particularly verbal reasoning, language, and memory-based tasks. The *Bayley Cognitive* and *Bayley Motor Composites* also showed significant associations with memory, language, and visual-spatial processing domains. These observed associations were in the expected direction, supporting the theoretical alignment between early cognitive domains and later outcomes. Notably, the *Bayley Motor Composite* demonstrated a somewhat stronger pattern of association with visuospatial outcomes at age five, while the *Bayley Language* and *Bayley Cognitive Composites* were more closely related to verbal and language-based outcomes. Nonetheless, these associations remained modest in size.

A number of *CogniTOT* subscales demonstrated small but statistically significant associations with neurodevelopmental outcomes at age five. In particular, *Working Memory*, *Sustained Attention*, and *Acquired Learning* were positively associated with later performance on verbal, memory, and reasoning tasks, consistent with hypothesised directions. These findings provide preliminary support for the predictive validity of certain *CogniTOT* domains. However, effect sizes were modest, and not all subscales demonstrated associations in the expected direction. Significant associations that aligned with the expected direction of effect are highlighted in Table 2.8. Overall, while results suggest some utility in early touchscreen-based assessment, the strength and consistency of predictive associations remain limited.

To complement correlational analyses, group comparisons were conducted to examine whether early cognitive scores on the *Bayley-III* and *CogniTOT* predicted differences in later outcomes by comparing children scoring below and above normative thresholds at age five. While a small number of significant group differences were observed, particularly in relation

Table 2.8
Significant correlation effect size associations: Bayley-III/CogniTOT and Neurodevelopmental Outcomes at age 5 Years

	Matrix Reasoning†	Bug Search†	Picture Memory†	Similarities†	Receptive Vocabulary†	Picture Naming†	Comprehension of Instructions‡	Narrative Memory‡	Design Copying‡
Bayley-III Composites									
Cognitive				0.25	0.25	0.2			0.3
Language				0.35	0.35	0.27	0.27		0.31
Motor		0.23	0.19						0.29
CogniTOT subscales									
Total									
Processing Speed									
Selective Attention				0.21					
Working Memory							-0.2		-0.21
Acquired Learning									-0.22
Cognitive Shift	0.22			0.26	0.3			0.19	
Problem Solving									
Sustained Attention				0.21					0.33

Note. Highlighted values represent significant associations that aligned with the expected direction of effect.
† Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version)
‡NEPSY–Second Edition: A Developmental Neuropsychological Assessment

to early *Bayley-III* scores and later language outcomes, the findings did not follow a consistent pattern, nor did they add to the findings of the correlational analysis. These results are therefore summarised in Supplementary Chapter 3 for completeness.

4. Discussion

We have presented data from a longitudinal cohort of typically developing children assessed in infancy and followed up at age five. To our knowledge, this is among the first studies to evaluate the predictive associations between a novel, non-verbal touchscreen-based cognitive assessment tool administered in toddlerhood. While previous work has demonstrated the feasibility and concurrent validity of earlier iterations of the tool in high-risk or clinical samples, and a sample of typically developing children, this study expands on those findings by applying the *CogniTOT* application within a community-based sample and assessing its association with later neurodevelopmental outcomes. Key strengths of the study include its longitudinal design, the use of standardised assessments at both time points, and a focus on developmentally appropriate, language-free assessment in early childhood. A number of findings were evident.

4.1 Summary of Key Findings

Concurrent Associations

Findings provide partial support for the concurrent validity of *CogniTOT*, particularly in relation to general cognitive functioning as indexed by the *Bayley-III Cognitive Composite*. Children who scored below the expected threshold on the *Bayley-III* exhibited significantly lower *CogniTOT Total* scores, with a large effect size, suggesting that *CogniTOT* is moderately sensitive to broad cognitive performance in infancy. Additionally, significant group differences were observed in the *Working Memory* and *Selective Attention* subscales of the *CogniTOT*, evidencing the potential of the tool to capture key components of cognitive functioning. However, while overall cognitive ability as assessed by the *CogniTOT Total* score is significant, findings relating to domain specific performance are not robust and should be interpreted with appropriate caution.

The concurrently validity observed in this study improves on findings for other commonly used screening tools. Duggan and colleagues (2023), assessed the domain specific, concurrent validity of both the *ASQ-3* and the *Bayley-III*, where results indicated poor concurrent validity between the tools. At 24 months the sensitivity of the *ASQ-3* in detecting

Bayley-III scores in the low average range (i.e. <1*SD* from the cohort mean) was poor. The sensitivity of the cognitive and communication domains were 20.7% and 25% respectively. The *Denver Developmental Screening Test II*, has also been found to have low sensitivity (14.8%) when compared with *Bayley-III*, even in high risk populations (Mandini, 2020).

In Ireland, the *ASQ* is commonly used. According to HSE guidelines, the *ASQ-3* is recommended for use in developmental screening of children between 1 month and 66 months of age (HSE, 2018), and to date has been rolled out as part of public health nursing assessments for children aged 20-30 months. However, it's not universally administered at every developmental check. Rather, it is part of a broader approach that includes clinical judgment and parental reports. In this context, and in consideration of the enhanced accessibility of *CogniTOT*, it's use may be favourable, or at least similarly reliable, to standardised assessment or established screening tools used in infancy.

Analyses involving the *Bayley-III Language* and *Bayley-III Motor Composites* revealed weaker and more variable associations with *CogniTOT* scores. No *CogniTOT* subscales showed consistent or significant associations with these domains, suggesting that the tool may have limited sensitivity to early language and motor skills, or that the constructs measured are not directly comparable. The effect sizes observed in our study were smaller than those reported in previous research, highlighting the potential differences in how these assessments capture early developmental skills. This discrepancy may stem from the inherent challenges of assessing cognitive and motor abilities in infancy, where developmental variability is high, and error variance is often present due to the rapid and nonlinear nature of infant development.

Additionally, the *Bayley-III* and *CogniTOT* may assess somewhat different constructs at this stage of infancy. While the *Bayley-III* is designed to assess a broad range of developmental milestones, *CogniTOT* focuses more specifically on cognitive abilities, which may not fully overlap with language and motor skills at such an early age. These differences in assessment goals may help explain the limited associations between the two tools at this stage. Given this, it is important to examine predictive associations with later neurodevelopmental outcomes, particularly across emergent cognitive domains, to better understand how early assessments can inform long-term developmental trajectories.

Predictive Associations with Later Neurodevelopmental Outcomes

In terms of predictive associations, early *CogniTOT* scores were modestly associated with several neurodevelopmental outcomes at age five, with small effect sizes observed. Notably, early *Working Memory* and *Sustained Attention* subscales were positively associated with later memory and reasoning tasks, somewhat consistent with the theoretical constructs these subscales aim to measure. *Working Memory*, which assesses the ability to hold and manipulate information in infancy, showed predictive value for later performance in *Comprehension of Instructions*, a measure of working memory, while *Sustained Attention*, which measures attentional control, was associated with later reasoning abilities. These findings provide preliminary support for the predictive validity of certain *CogniTOT* domains. However, the *Cognitive Shift* subscale, which assesses the ability to adapt and shift attention, showed associations in the opposite direction to what was expected based on the tool's scoring logic. This inverse relationship underscores the presence of variability in the findings, indicating that the scoring properties of this subscale may not accurately capture the developmental construct it is intended to measure. While some significant associations aligned with the expected direction of effect, the overall pattern of results lacked consistency, raising questions about the accuracy and reliability of certain subscales in predicting later neurodevelopmental outcomes, thus, suggesting that further exploration of the tool's scoring and conceptual framework may be necessary.

In developing the current tool, through previous iterations, researchers have sought to address issues with the internal consistency of subscales (see Supplementary Chapter 3). Although good overall internal consistency and improvements to psychometric properties have been reported (Casey et al., 2023; Twomey et al., 2018), these analyses suggest that some issues remain with respect to individual *CogniTOT* subscales and what they purport to assess, and may explain some of the unexpected findings in the present study. Most recently, research by O'Sullivan and colleagues (n.d.) examined the overall and domain specific (i.e. subscale) internal consistency of *CogniTOT* in the larger baseline cohort of the current sample. It is reported that strong internal consistency was observed for the *CogniTOT Total* score, $\alpha = 0.893$. However, subdomain internal consistency reportedly varied from low to moderate; problem solving was particularly low ($p = 0.052$), and interitem correlation scores exhibited small effect sizes for each subscale.

That the *Bayley-III* demonstrated stronger predictive associations than the *CogniTOT* is not unexpected, given its established psychometric properties and widespread use. More consistent relationships were observed between *Bayley-III* scores and later outcomes, particularly in the domains of verbal reasoning, language, and memory. These findings are consistent with previous literature, especially with respect to language outcomes (Koshy et al., 2024; Rubio-Codina & Grantham-McGregor, 2020). However, its overall predictive utility remains limited (Krogh & Væver, 2018; Rasheed et al., 2023). In line with these observations, the current study found only modest associations between *Bayley-III* scores and neurodevelopmental performance at age five, reinforcing concerns raised in prior research regarding its limited predictive validity, particularly when administered before 24 months (Anderson & Burnett, 2017).

Altogether, the weak and inconsistent associations between *CogniTOT* subscales and later outcomes, particularly those found in the predictive analyses, are consistent with concerns raised in prior research regarding the challenge of predicting later cognitive functioning from assessments conducted in infancy (Anderson & Burnett, 2017; Rasheed et al., 2023). This reflects broader debates within developmental psychology about the stability of early cognitive constructs and the influence of latent effects, whereby early vulnerabilities may not manifest until later developmental stages when more complex cognitive demands are introduced (Anderson et al., 2005; Westmacott et al., 2009). In practical terms, this means that children with developmental delay will in many cases go undetected, even when gold standard assessment methods are employed. These findings, thus, support broader calls within developmental science for the design of assessments that are both developmentally sensitive and aligned with contemporary theoretical frameworks emphasising neurocognitive plasticity, executive functioning, and environmental influences (Johnson & Marlow, 2016; Mills et al., 2014).

4.2 Limitations and Future Directions

This exploratory study offers valuable initial evidence for the concurrent and predictive associations of *CogniTOT*, a novel touchscreen-based cognitive assessment tool for toddlers. However, a number of limitations must be considered.

The current study's sample size was constrained by the number of participants from the original cohort who were eligible and available for follow-up within the study period. The modest sample size (n = 87) may have limited statistical power, particularly for detecting subtle associations or subgroup effects in the context of assessing multivariate neurodevelopmental outcomes. No a priori power analysis was conducted, meaning the study may have been underpowered to detect smaller effects, and this should be considered when interpreting findings. Though use of a community-based sample enhances the ecological validity of the findings, and while consistent with early validation studies, larger samples are needed to strengthen generalisability. Additionally, variability in task performance may have been influenced by external factors such as familiarity with digital devices or the home environment, which were not directly assessed in this study. Interpretive complexity also arose from inconsistent directionality in some *CogniTOT* subscale associations, highlighting the need for refinement of specific constructs and scoring algorithms – an expected challenge in early-stage tool development. Future research should explore item-level psychometrics, and further evaluate the tool in more diverse and higher-risk samples. Furthermore, although comparisons were made with standardised instruments (*Bayley-III, WPPSI-IV, NEPSY-II*), these tools also have known psychometric limitations, particularly in predicting long-term outcomes from early assessments. Finally, this study did not incorporate environmental or family-level factors, which are known to impact child development. Future research should continue to refine the tool and explore these broader contextual influences.

5. Conclusion

This research joins a series of studies which have consistently demonstrated the capacity of young children to engage with touchscreen tasks that index core executive functions, even in the absence of verbal instructions or adult facilitation. The current study extends this work by evaluating these capacities in a community-based sample and by examining predictive associations over a longer developmental timeframe. It contributes meaningfully to the growing body of evidence supporting the feasibility and acceptability of touchscreen-based assessments in early childhood, and uniquely does so within a non-clinical, longitudinal framework.

The findings of this study offer a nuanced contribution to the evolving literature on early cognitive assessment, particularly with respect to the development and validation of novel, technology-based screening tools such as *CogniTOT*. While predictive associations were modest and varied across domains, the study highlights the potential of such tools to serve as scalable, accessible early indicators of developmental functioning, particularly in contexts where traditional assessments may not be feasible. In line with theoretical and empirical perspectives emphasising the dynamic and nonlinear nature of early development (Gowda et al., 2024; Johnson, 2001; Mills et al., 2014), this study supports the view that cognitive outcomes in early childhood cannot be fully predicted by a single early measurement point. Nonetheless, the results demonstrate that touchscreen-based assessments may have utility in capturing broad indicators of cognitive functioning during infancy. Future work should focus on refining the tool's subscale structure, improving scoring clarity, and validating it across larger and more diverse populations. Additionally, integrating such tools into broader developmental surveillance frameworks may enhance early identification of children at risk for later cognitive difficulties, facilitating timely and targeted intervention efforts.

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Chapter 3: Empirical Study 1 Supplementary Information

1. Additional Background Information – Development of CogniTOT

The *CogniTOT* application represents the latest iteration of a body of research investigating the feasibility and validity of touchscreen-based cognitive assessments for infants and toddlers. Earlier versions of the tool, known as *Babyscreen* (Hello Games, Guildford, UK), were developed and evaluated through a series of pilot and validation studies. Twomey et al. (2018) first demonstrated the feasibility of using a touchscreen interface to assess cognitive abilities in children under three years, showing that tasks requiring cognitive engagement could be completed by children as young as 24 months without the need for verbal instruction or significant adult facilitation. These tasks, comprising *Babyscreen V.1.5*, targeted constructs such as *selective attention, working memory, hidden object retrieval*, and *object permanence*. While *Babyscreen V.1.5.*showed acceptable internal consistency overall (α = 0.85), internal consistency of the subscales was limited, particularly in the aforementioned subscales. Variability in item difficulty, task novelty and complexity were identified as factors influencing item consistency and construct validity (Twomey et al., 2018). For more complex items it was likely that additional cognitive processes would have been recruited by participants, beyond that which would be reasonably expected, thus, compromising interpretability. However, authors highlighted that the development of *Babyscreen V.1.5* tasks were intended as prototypes, conceptually aligned to tasks described in existing literature. Thus, concluding that tasks used in this version of the tool were not good measures of the constructs they were purported to assess. For instance, the *selective attention* task more closely resembled a measure of *processing speed*, as responses to distractor stimuli (commission errors) were not recorded, limiting conclusions about *selective attention*. Likewise, the *working memory* items may have been better characterised as assessing short-term memory, as the task required only the retention, not manipulation, of information to locate the target (Twomey et al., 2018).

Beyond feasibility, subsequent work by Twomey et al. (2021) provided evidence of concurrent validity between *Babyscreen V.1.5* scores and the *Bayley-III* in a clinical cohort of children aged 18-24 months, at risk of developmental delay due to complications at birth. Acceptable internal consistency (α = 0.63) of the tool as an ‘overall’ measure of problem-solving was again reported. *Babyscreen V.1.5* scores demonstrated a moderate positive correlation with the *Bayley-III* cognitive composite (r =.414, p < .001), indicating a meaningful association between the two measures. In contrast, correlations with the *Bayley-III* language (r

= .24, *p* = .038) and motor composites (*r* = .28, *p* = .019) were weaker, suggesting that *Babyscreen* performance aligned more closely with cognitive than with language or motor domains.

Most recently, Casey et al. (2023) validated *Babyscreen V.1.89* in a community sample, reporting moderate correlations with *Bayley-III* scores, sensitivity of 50%, and good specificity (93%) in detecting mild cognitive delay at 24 months. The study included 101 children (mean age = 24.25 months, *SD* = 0.22), and found that cognitive composite scores were moderately correlated with the total number of *Babyscreen* tasks completed ($r = .358$, $p < .001$), indicating moderate concurrent validity. Children with *Bayley-III* cognitive scores below 90 (classified as mild cognitive delay) had significantly lower mean *Babyscreen* scores than those with scores ≥90 ($M = 8.50$, $SD = 4.89$ vs. $M = 12.61$, $SD = 3.68$; $p < .001$), demonstrating the tool's discriminatory capacity. Correlational analyses further showed that the *Babyscreen* score did not correlate significantly with the language composite score ($r = 0.144$, $p = .163$), and showed only a weak correlation with the motor composite score ($r = .249$, $p = .016$), suggesting stronger specificity to cognitive domains than to language or motor development.

These findings supported the utility of the touchscreen platform for early developmental screening and informed the refinement of tasks in the current *CogniTOT* version. Collectively, these studies highlight the growing potential of touchscreen-based assessments as scalable, language-free tools for identifying early cognitive difficulties in young children, and provide additional context to the information presented in the main paper.

2. Additional Methodological Detail

Included in this section is additional methodological information to supplement the paper for Empirical Study 1, in Chapter 2. Further details relating to participants, assessment procedures, and descriptions and selection rationale of outcome measures are provided.

2.1 Procedure

Initial ethical approval was granted by the Clinical Research Ethics Committee (CREC), and approval for the current study was granted by the same committee in February 2024 (Appendix A). Following ethical approval, the researchers were provided with the contact information of those who had participated in the original observational study, and recruitment was conducted as outlined in Chapter 2. There were few expected risks from participating in the study. Assessments took place in a safe and appropriate environment; parents remained present throughout assessments, positioned such that their presence was not distracting to the child. A protocol was in place for participants who became upset or distressed during assessment. Parents would be invited to comfort their child, and the child would be encouraged to re-engage with the assessment as and when appropriate. They would be reminded that their participation was voluntary and that they were free to withdraw without consequence, and a debriefing session would be offered.

A protocol was in place for instances where a child's assessment performance was of concern. Parents would be contacted by phone by a member of the research team, and the results would be discussed with them. Where appropriate and where parental consent was provided, children would be referred to the relevant clinical care pathway in, Cork University Hospital, specifically a referral to the consultant paediatrician at INFANT would be recommended to parents. Following this appointment onward referrals would be facilitated as appropriate to the needs of each child and family.

On completion of the neuropsychological assessment families were provided with a summary report outlining their child's performance, framed in terms of strengths and weaknesses (see Appendix G for report template). Reports explicitly stated that assessments were administered as part of a research study and were not an alternative to a clinical assessment. All assessment reports were completed by the assessor (MB, LO'S or AM) and were each reviewed by the consultant clinical psychologist (CMcC) prior to sending. Data was stored according to GDPR and Data Protection Law.

2.2 Outcome measures

This section outlines the neuropsychological outcome measures administered at both baseline and follow-up. Subtests were selected by the consultant clinical neuropsychologist based on their relevance to the aims of the current study. As *CogniTOT* is a novel assessment tool, particular attention is given to its design, administration, and scoring procedures.

2.2.1 CogniTOT

Administration

The *CogniTOT* application is a tablet-based, non-verbal measure of emerging executive functions (EFs), developed for use with toddlers aged approximately 22–30 months. The version used in this study included 30 interactive tasks (plus 1 demonstration task) delivered via touchscreen interface. Summary details of individual *CogniTOT* tasks are provided in

Appendix F. *CogniTOT* takes approximately 15-20 minutes to complete, and was administered by a trained researcher. During each assessment the child was seated with a parent/guardian present. Demographic information, including the child's age, sex, and previous exposure to touchscreen devices, was recorded at the outset.

Each *CogniTOT* task allowed for up to two attempts. On the first attempt, children were given 30 seconds to complete the task independently. If the child successfully completed the task within that time, the application advanced to a waiting screen until the child initiated the start of the next task. If the task was not completed on the first attempt, the researcher used a demonstration mode within the application, to perform a visual demonstration of the task for the child. Following this, the child was given a second 30-second attempt to complete the task. If the task was not completed on this attempt, they were again shown a waiting screen until they initiated the start of the next task, ensuring the child remained engaged at their own pace.

Scoring

Total CogniTOT score

A total *CogniTOT* score was calculated, based on whether the child passed or failed 28 of the tasks presented. The demonstration task, and the first two task items, were deemed training tasks which screened for meaningful engagement with the tablet, and were not included in the calculation of the total score. The total score represented the number of tasks completed independently on the first attempt, within 30 seconds, and without a visual demonstration by the researcher. Children who failed to complete all three training items (i.e. a score of <3) were considered to have not meaningfully engaged with the task, and their data were excluded from further analysis of test performance.

CogniTOT Subdomain Scoring

Performance on the *CogniTOT* was also examined across seven subdomains of executive functioning, with scoring based on accuracy (i.e., number of errors committed), reaction time, or a combination of both. Table 3.1 outlines the number of tasks pertaining to each individual subdomain, the basis of scoring, and the interpretation of scores. Subdomain scores were only calculated for participants who completed all tasks within the relevant subdomain, ensuring consistency in interpretation.

Table 3.1
Basis and Interpretation of CogniTOT Total and Subdomain Scores

	Number of Tasks	Scoring Range	Scoring Basis	Score interpretation
CogniTOT Total Score	28	0-28	Pass count	Higher = Better
Subdomains				
Processing Speed	5	0-150	Reaction time	Lower = Better
Acquired Learning	6	0-180	Reaction time	Lower = Better
Problem Solving	5	0-150	Reaction time	Lower = Better
Selective Attention	5	0-150	Reaction time and Accuracy	Lower = Better
Working Memory	4	0-8	Accuracy	Lower = Better
Cognitive Shift	3	0-300	Accuracy	Lower = Better
Sustained Attention	1	0-120	Time (total duration (seconds) of continuous attention to targets)	Higher = Better

2.2.2 Bayley-III

The *Bayley Scales of Infant and Toddler Development – Third Edition* (*Bayley-III)* is a standardised, individually administered assessment tool designed to evaluate the developmental functioning of infants and toddlers aged between 1 month and 42 months (Albers & Grieve, 2007). The *Bayley-III* assesses five key domains of development: *Cognitive, Language, Motor, Social-Emotional, and Adaptive Behaviour*. Each domain is measured through a series of structured tasks and observations, producing composite scores for each scale. These composite scores are standardised, with a mean of 100 and a standard deviation (*SD*) of 15, and scores between 85 and 115 are typically considered within the average range. The *Cognitive* scale assesses abilities such as attention, memory, exploration, and problem-solving. The *Language* scale comprises Receptive and Expressive Communication subtests, evaluating the child's understanding and use of language. The *Motor* scale includes Fine Motor and Gross Motor subtests, which assess skills related to hand use, coordination, crawling, and walking. The *Bayley-III* is widely recognised as a gold-standard tool in the assessment of early childhood development. The *Bayley-III* has demonstrated strong internal consistency and test–

retest reliability across its core domains, with reported reliability coefficients ranging from .86 to .93 for composite scores (Bayley, 2006). The *Bayley-III* is used extensively in both clinical and research settings for developmental monitoring, early intervention planning, and diagnostic assessment.

2.2.3 WPPSI-IV and NEPSY-II

Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (WPPSI-IV)

The *WPPSI-IV* is a standardised, individually administered assessment used to comprehensively evaluate the cognitive ability of children aged 2 years, 6 months to 7 years, 7 months. The assessment structure varies by age band, with younger children (2:6–3:11 years) administered a shorter battery of 5 subtests. There are 10 primary and 4 ancillary subtests which can be administered to children in the older age band (4:0–7:7 years). All subtests yield a scaled score with a mean of 10 and a standard deviation (*SD*) of 3. Scaled scores range from 1 to 19, with scores between 8 and 12 considered average. The subtests contribute to primary index scores which represent cognitive functioning in five domains: *Verbal Comprehension, Visual Spatial, Fluid Reasoning, Working Memory, and Processing Speed*. The assessment also produces a Full Scale IQ (*FSIQ*) representing general intellectual ability. Index scores and the *FSIQ* have a mean of 100 and standard deviation of 15.

NEPSY–Second Edition (NEPSY-II)

The *NEPSY-II* is a comprehensive, individually administered neuropsychological assessment designed to evaluate cognitive functioning in children aged 3 to 16 years. It consists of 32 subtests that assess six functional domains: *Attention and Executive Functioning, Language, Memory and Learning, Sensorimotor Functioning, Social Perception, and Visuospatial Processing*. The assessment can be administered flexibly, where subset selection can be tailored to the child's individual needs as relevant to the clinical question. Most subtests yield scaled scores (*M* = 10, *SD* = 3), while others produce percentile ranks or process scores, depending on the nature of the task. The NEPSY-II has demonstrated good psychometric properties, including acceptable internal consistency, test–retest reliability, and validity across its domains (Korkman, Kirk, & Kemp, 2007). The NEPSY-II is especially useful in identifying developmental disorders and neuropsychological difficulties affecting learning and behaviour. The assessment is often used in making accurate diagnoses and intervention planning.

As outlined in the main paper, a select number of subtests from the *WPPSI-IV* and *NEPSY-II* were selected by the consultant clinical neuropsychologist, which aligned with the constructs measured by *CogniTOT*. This allowed for a more detailed exploration of specific cognitive processes, providing greater sensitivity to subtle domain-specific variations that may not be captured by overall index scores. Completing the full battery of each assessment would also not have been appropriate for the current study, as it would have been too time-intensive. Additionally, such an approach would not have aligned with the *CogniTOT* subscales, and therefore, would not have contributed additional meaningful insights into the specific constructs being measured.

2.3 Additional Analyses

This section outlines the procedures undertaken to prepare the data for statistical analysis, including data cleaning, normality testing, and quality assurance checks. Justification for the selection of specific statistical tests is also provided. Furthermore, additional analyses that were conducted to support or supplement the findings in the main paper, but which were not included in the primary results section, are presented and discussed below.

2.4 Data Cleaning

As noted in Chapter 2, a visual inspection of histograms was conducted for all variables to assess the normality of their distributions. The data appeared to be approximately normally distributed across variables (see Appendix E). Prior to conducting tests of normality and statistical analyses, the dataset was further screened for outliers. Outliers were defined as a standardised score on an outcome measure which was more than 3 *SD* above or below the mean. Stem-and-Leaf plots were examined using SPSS 29.0.2.0. For the *CogniTOT* Total Score, three cases were identified as extreme outliers, and for *CogniTOT Cognitive Shift*, one case was identified as an extreme outlier. Given the potential influence of these extreme values on statistical analyses, they were recoded as missing values to correct the distribution before proceeding with further analyses. To ensure that the removal of these cases improved normality, the distribution was re-examined after recoding, confirming that the adjusted data more closely approximated a normal distribution. This approach aligns with best practices for handling extreme outliers that may unduly influence parametric analyses, reducing the potential for Type I error (i.e. finding a false positive result).

2.5 Assessment of Normality

Given the use of parametric statistical analyses in this study, tests of normality were conducted for all test variables. Skewness and kurtosis values, along with results from the Shapiro-Wilk test, were examined to assess the normality of the data. Skewness values between -2 and +2, and kurtosis values between -7 and +7, were interpreted as indicating acceptable levels of variation and a distribution approximating normality (West, Finch, & Curran, 1995). The Shapiro-Wilk test, which is particularly sensitive and well-suited for small sample sizes, was also used. Non-significant scores, $p > .05$, are considered normally distributed. As noted in the main paper, analysis indicated that the data were normally distributed for all variables, with the exception of *CogniTOT* Processing Speed, which exhibited statistically significant skewness and kurtosis (Table 3.2 below). Given that many statistical analyses assume normality, a log10 transformation was applied to the Processing Speed scores to correct for skewness. Following this transformation, skewness and kurtosis values fell within acceptable ranges (skewness = .58; kurtosis = .48), indicating that the transformed data approximated a normal distribution. A new variable was subsequently created using the transformed Processing Speed scores for further analyses requiring normality assumptions. Normality was reassessed post-transformation, confirming that the distribution met the necessary statistical criteria.

Table 3.2
Normality testing results of all outcome measures

Scales	Skewness	Kurtosis
Bayley-III		
Cognitive Composite	-.07	1.11
Language Composite	-.43	-.37
Motor Composite	.5	.8
CogniTOT		
CogniTOT Total Score	-1.4	1.6
CogniTOT Processing Speed	2.5	6.1
CogniTOT Selective Attention	.82	.08
CogniTOT Working Memory	-.18	-.9
CogniTOT Acquired Learning	.57	.1
CogniTOT Cognitive Shift	1.9	4.7
CogniTOT Problem Solving	-.8	.46
CogniTOT Sustained Attention	.05	-1.0
WPPSI†		
Matrix Reasoning	-.22	.61
Bug Search	.39	1.6
Picture Memory	.44	1.0
Similarities	-.98	.61
Receptive Vocabulary	.67	2.6
Picture Naming	.42	-1.0
NEPSY‡		

Comprehension of Instructions	-.12	-.01
Narrative Memory	-.83	1.3
Design Copying	.01	-.9

† Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version);
‡ NEPSY–Second Edition: A Developmental Neuropsychological Assessment

Data was subsequently analysed using parametric tests. The assumption of homogeneity of variance was evaluated prior to conducting independent samples t-tests. This assumption is that variance and distribution of scores on a continuous variable should be equal across independent groups. Levene's Test for Equality of Variances was used to assess this, with a *p*-value of ≤ .05 indicating a violation of the assumption. In such cases, the adjusted t-test result, which does not assume equal variances, was reported instead.

2.6 Quality Assurance Procedures

Quality assurance procedures were employed to ensure the integrity of the data. Procedures included the authors routinely cross-checking scoring of outcome measures during data-collection. The accurate transfer of data from outcome measures to SPSS 29.0.2.0 was also cross-checked. Furthermore, two authors individually checked the data and performed statistical tests, thereafter meeting as a pair to review results. Workings were reviewed as appropriate where inconsistencies or anomalies arose. Each statistical test was performed more than once to ensure consistency in findings.

2.7 Additional Findings

2.7.1 Predictive Associations: Full Correlational Analyses

As outlined in the main paper, Pearson's correlation coefficients were used to examine predictive relationships between early cognitive scores (*Bayley-III* and *CogniTOT*) and neurodevelopmental outcomes at five years (*WPPSI-IV* and *NEPSY-II*). While the main paper reported only statistically significant correlations, Table 3.3 below provides a full account of all correlations examined, including both significant and non-significant results. This comprehensive overview allows for greater transparency and provides additional context for interpreting the pattern of associations. As previously noted, most correlations were small in magnitude, and the overall predictive power of early cognitive assessments was limited.

Table 3.3
Full correlation table of associations between Bayley-III Composites, CogniTOT subscales, and neurodevelopmental outcomes at 5 years

	Matrix Reasoning†	Bug Search†	Picture Memory†	Similarities†	Receptive Vocabulary†	Picture Naming†	Comprehension of Instructions‡	Narrative Memory‡	Design Copying‡
Bayley-III									
Cognitive Composite	-.014	.167	.073	.249*	.254**	.197*	.167	.100	.297**
Language Composite	-.025	.064	.024	.354**	.349**	.267**	.266**	.057	.311**
Motor Composite	.011	.229*	.194*	.134	.153	.061	.067	.003	.294**
CogniTOT									
Total Score	-.017	.160	-.113	-.041	.058	-.136	.157	.080	.164
Log 10 Transformation	-.075	-.127	-.049	.053	-.162	-.009	-.046	.098	.002
Processing Speed									
Selective Attention	.115	.065	.040	.211*	.038	-.009	.107	.036	.068
Working Memory	-.074	-.121	.035	-.116	-.019	-.012	-.203*	.000	-.213*
Acquired Learning	-.158	-.185	-.120	.086	-.205	.032	.090	.060	-.221*
Cognitive Shift	.216*	.110	.027	.255*	.304**	.123	.107	.168	.066
Problem Solving	-.025	-.049	-.139	-.071	-.068	.002	-.177	.044	.110
Sustained Attention	.013	.200	.030	-.207*	-.042	-.175	-.086	-.078	.311**

† Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version);
‡ NEPSY–Second Edition: A Developmental Neuropsychological Assessment
* $p < 0.05$
** $p < 0.01$

2.7.2 Analysis of Group Comparisons at Five Years

As noted in the main paper, to complement the correlational analyses, independent samples *t*-tests were conducted to explore whether early cognitive scores on the *Bayley-III* and *CogniTOT* predicted later performance by comparing children scoring two-thirds of a standard deviation below the mean on outcomes at age five with those performing within or above the expected range. For each of the nine outcome measures from the WPPSI-IV and NEPSY-II, participants were classified into two groups based on performance: those scoring two-thirds of a standard deviation below the normative mean (i.e., scaled scores ≤ 8) and those scoring within or above the expected range (i.e., scaled scores ≥ 9). As the Design Copying subtest yields a percentile range, the raw score was used to group participants for this analyses. Planned comparisons using a more conservative cut-off (i.e., 1 *SD* below the mean; scaled scores ≤ 7 vs. ≥ 8) could not be conducted due to insufficient sample sizes in the lower-performing group across several outcome variables. Thus, the threshold was selected to maintain sufficient group sizes for meaningful statistical comparison

While a small number of significant group differences were identified, particularly within the language domain, these did not follow a consistent pattern across outcome domains. Moreover, the majority of comparisons did not reach statistical significance. *Bayley-III* scores showed a greater number of significant associations with later outcomes than the *CogniTOT*, but effect sizes were generally small to moderate. Overall, these group comparisons offered limited additional insight beyond the correlational findings, and provide only preliminary support for the predictive validity of early assessments. Although some statistically significant associations were observed between early *CogniTOT* subscales (*Cognitive Shift* and *Sustained Attention*) and later verbal reasoning outcomes, these were not in the hypothesised direction and therefore do not support predictive validity. These results provide further context for interpreting the predictive capacity of early cognitive measures and illustrate the limited consistency of group differences across domains. A summary of significant group differences is presented in Table 3.5; *p*-values and effect sizes (Cohen's *d*) are reported together as *p* (*d*).

Table 3.4

Significant between-group differences in early cognitive measures for children scoring below vs. within/above expected range on neurodevelopmental outcomes at 5 years

	Matrix Reason.	Bug Search	Picture Memory	Similarities	Receptive Vocab	Picture Naming	Comp. of Instructions	Narrative Memory	Design Copying
Bayley-III									
Cognitive				0.007 (-0.93)	0.011 (-0.59)		0.045 (-0.79)	0.033 (-0.48)	0.016 (-0.48)
Language				<0.001 (-1.6)	<0.001 (-1.1)	0.010 (-0.67)		0.032 (-0.52)	
Motor				0.117 (-0.45)					<0.001 (-0.77)
CogniTOT									
Total									
Processing Speed			0.015 (0.6)		0.006 (1.0)				
Selective Attention									
Working Memory									
Acquired Learning									
Cognitive Shift				0.002 (-0.6)					
Problem Solving									
Sustained Attention				0.022 (1.0)					0.010 (-0.6)

Values represent one-sided *p*-values and effect sizes (Cohen's *d*) for independent samples *t*-tests. Comparisons are between children scoring ≤ 8 and ≥ 9 on ELF subscales. Only significant findings are presented.

2.8 Researcher Role and Contribution

I commenced working on this research study in 2023. As part of the preparatory work for this project, I completed a literature review to identify and critically evaluate existing cognitive assessment and screening tools used in early childhood, and to situate the current study within the context of child neurocognitive development, a process that is inherently dynamic and particularly challenging to assess in the early years. I was required to submit an application for ethical approval to CREC. I contacted the majority of families from the baseline study to invite them to participate in the current study. I co-ordinated the planning of assessment dates and times for the families whom I contacted, ensuring the availability of test kits and clinical assessment rooms in the hospital. I completed 60 of the 87 neuropsychological assessments with participants. I scored each assessment I completed, and entered each participants data into the database. I cross-checked the scoring of fellow authors scoring at regular intervals throughout data collection. I provided a summary report of results from the neuropsychological assessment to families, and followed up with individual families as required, per the study's procedure. I created an SPSS file to store all data was stored, and entered all data points from the assessments, as well as demographic information, into SPSS. I completed quality assurance checks on all other data points entered on the SPSS file to verify accuracy. I independently ran all statistical analyses and then cross-checked results with my supervisor (CMC). Finally, I prepared the manuscript for this study.

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Chapter 4: Empirical Study 2

The Relative Influence of Child and Family Factors on Neurodevelopmental and Psychosocial Outcomes at Age Five in a Community Sample.

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Title

The Relative Influence of Child and Family Factors on Neurodevelopmental and Psychosocial Outcomes at Age Five in a Community Sample.

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Abstract

This longitudinal study examined the relative contributions of early cognitive functioning and family-level factors to neurodevelopmental and psychosocial outcomes in early childhood. Drawing on a community-based sample of 87 children assessed at two time points (infancy and age five), the study aimed to evaluate whether family structural and dynamic variables enhance the prediction of child outcomes beyond early cognitive ability. Early cognitive functioning was assessed between 22–30 months using the *Bayley Scales of Infant and Toddler Development, Third Edition (Bayley-III)*, and the *CogniTOT* touchscreen assessment. At follow-up, child outcomes were measured using standardised neuropsychological tools (*WPPSI-IV*; *NEPSY-II)* and the parent-reported *Strengths and Difficulties Questionnaire (SDQ)*. Family factors were measured using validated psychometric instruments.

Hierarchical multiple regression analyses revealed that parenting stress emerged as the most consistent and robust predictor of psychosocial functioning, accounting for the largest unique variance in *SDQ Total Difficulties* and *Prosocial Behaviour* scores. Other family dynamic factors, such as emotional expressiveness, also contributed to prosocial outcomes. Early cognitive scores accounted for a significant but modest proportion of variance in later neurodevelopmental outcomes, particularly in language and visuospatial domains. The inclusion of family structural and dynamic variables significantly improved model fit across most neurodevelopmental outcomes, with parenting stress, parental anxiety, and aspects of family environment associated with cognitive performance at age five.

Findings underscore the multifactorial nature of early development and highlight the importance of family context, particularly modifiable dynamic factors, in shaping child outcomes. These results support the integration of family wellbeing assessments into early developmental monitoring and intervention frameworks and point to the value of targeting parenting stress and emotional climate as essential mechanisms for supporting optimal developmental trajectories in early childhood.

1. Introduction

Early childhood development is a multifaceted, dynamic process shaped not only by biological maturation but also by the broader psychosocial and environmental context in which the child is embedded (Gilmore et al., 2018; Gowda et al., 2024; Shonkoff et al., 2012). Parental well-being, family functioning, caregiving capacity, and broader environmental factors have direct effects on child development. As such, they are highly relevant to research investigating predictors of neurodevelopment in early life (Johnson, 2001; Moore et al., 2017). However, most studies to date have employed cross-sectional designs, limiting our understanding of how early family factors shape developmental trajectories over time.

A substantial body of research demonstrates that family structural factors such as socioeconomic status, lone parenthood, and parental education, are significantly associated with child outcomes across cognitive, emotional, and behavioural domains (Letourneau et al., 2013; Masten & Cicchetti, 2010). Beyond structural indicators, family dynamics, including parental psychological distress, parenting stress, and family functioning, are strong predictors of socioemotional development (Berthelon et al., 202; Kingston & Tough, 2014; Neece et al., 2012). Maternal mental health, particularly maternal anxiety and depression, has been linked to less optimal parenting behaviours, diminished emotional availability and increased child behavioural difficulties (Davis & Sandman, 2012; Meadows et al., 2007). Research has indicated that these associations extend beyond diagnosable disorders, with subclinical distress also exerting influence via biological and behavioural mechanisms. Despite this evidence, relatively few studies have examined how these parent and family level variables operate concurrently in the same analytical model, or how their relative influence compares to that of child-level cognitive factors in shaping later outcomes.

Importantly, positive environmental inputs, including cognitive stimulation, responsive caregiving, and emotionally supportive interactions, have been shown to promote favourable developmental outcomes (Gao et al., 2023; Garcia et al., 2020). Language-rich and stimulating home environments are linked to improved language, cognitive, and social-emotional skills, even in contexts of sociodemographic adversity (Verdisco et al., 2016). Conversely, chronic stress and environmental deprivation may impair a child's capacity for learning, self-regulation, and adaptation (Hanson et al., 2014; McLaughlin et al., 2014). However, findings are less consistent in relation to neurocognitive outcomes. While family functioning is widely accepted as a predictor of socio-emotional adjustment, evidence for its role in predicting executive functioning, memory, or processing abilities remains limited and mixed, highlighting a gap addressed in the present study.

Most research examining the impact of maternal mental health on child development has centred on the perinatal period, particularly focusing on maternal depression and anxiety. These early difficulties have been consistently associated with adverse developmental outcomes, including cognitive, language, and motor delays, as well as heightened risk of social-emotional problems that may persist into adolescence (Chen et al., 2025; Shuffrey et al., 2022; Wu et al., 2024). However, fewer studies have examined the impact of maternal mental health throughout early and middle childhood, despite evidence that mental health difficulties during this period can also shape both neurodevelopmental and psychosocial trajectories (Benavides Jiménez, 2023; Schepman et al., 2011). Together, this body of evidence underscores the need to consider maternal mental health not only during the perinatal window, but also throughout the broader developmental period of childhood. The present study addresses this by including maternal mental health measured when children are age five, a period of increasing cognitive and emotional demands.

In the context of parenting stress, research highlights a bidirectional relationship with child outcomes. Longitudinal studies show that elevated parenting stress predicts later behavioural difficulties, while child externalising behaviours, for example, further increase parental stress over time (Chiang & Bai, 2023; Neece et al., 2012). These reciprocal dynamics are particularly evident in families of children with developmental delays, where stress levels tend to be higher and more persistent (Baker et al., 2003; Neece et al., 2012). Parenting behaviours, such as warmth or hostility, are key mediators in this relationship. The strength of these effects can also be moderated by maternal affection, particularly in dyads with high warmth (Chiang & Bai, 2023). These findings highlight the complex, dynamic nature of family processes in shaping child outcomes and underscore the importance of understanding parenting stress within the broader developmental context.

A substantial body of literature also points to the critical role of the broader family environment. Enriched environments marked by emotional support, language-rich exchanges, and cognitive stimulation are consistently associated with better developmental outcomes (Gao et al., 2023; Verdisco et al., 2016). Critically, the quality of adult-child interactions, more so than structural variables like income or parental education, has emerged as a strong predictor of child developmental potential (Garcia et al., 2020; Winston & Chicot, 2016). Supportive family climates, characterised by cohesion, expressiveness, and organisation, are linked to improved cognitive and socioemotional functioning, while environments marked by conflict and disorganisation may impede neurodevelopment and increase behavioural risk (Marsh et al., 2020). Krauss et al. (2020), for example, found that family cohesion and support were predictive of more positive adolescent self-esteem trajectories, reflecting the enduring influence of early family dynamics.

Further, a systematic scoping review by Marsh et al. (2020) found consistent associations between household chaos, defined as environmental disorganisation and confusion, and a range of negative outcomes across cognitive, emotional, behavioural, and physical health domains. The review concluded that household chaos may be a key contextual factor exacerbating developmental disparities, particularly among socioeconomically disadvantaged families. While structural factors are typically less modifiable, these dynamic aspects of the family environment can be addressed through psychological interventions, making them a particularly important focus of research, and early support and prevention efforts. This underscores the importance of examining both structural and dynamic family variables in the same model to evaluate their relative contributions to child outcomes.

Latent vulnerability frameworks suggest that early exposures may not manifest immediately, but emerge later as cognitive and environmental demands increase (Davis & Sandman, 2012). Within this dynamic perspective, individual trajectories are shaped by the interaction between internal regulatory capacities and external supports or stressors (Smith & Thelen, 2003). Despite this, many developmental assessments focus narrowly on individual functioning, failing to capture the complexity of environmental influences, and potentially overlooking the contribution of broader family processes to developmental outcomes. Notably, much of the existing evidence has also been drawn from clinical or high-risk populations. Whether similar patterns of association translate to community samples of typically developing children remains less well understood, and warrants investigation.

Study 2 of this thesis addresses these gaps by examining how family structural (e.g., lone parenting, parental education) and dynamic factors (e.g., parenting stress, maternal mental health, family functioning), alongside early cognitive functioning, contribute to neurodevelopmental and psychosocial outcomes in early childhood. Both child and family level factors are incorporated in the same longitudinal model, allowing for evaluation of their relative influence. By drawing on a community sample, it also offers insight into how these relationships unfold outside of clinical or high-risk settings.

The current study specifically examines: (1) the independent contributions of early cognitive functioning, structural family factors, parenting stress, maternal mental health, and family functioning to child cognitive and psychosocial outcomes at age five; and (2) whether family-level factors enhance the prediction of outcomes above and beyond early cognitive scores. It is anticipated that dynamic family variables will be particularly predictive of psychosocial outcomes, while the role of family functioning in shaping neurodevelopmental outcomes remains a key question of interest.

2 Materials and Methods

2.1 Design

The current study employed a longitudinal, observational design to investigate the outlined research questions. Quantitative data were collected at two time points: early cognitive assessments were conducted between 22 - 30 months of age using standardised measures, and follow-up assessments were completed when children reached five years of age. At follow-up, child neurodevelopmental and psychosocial outcomes were assessed, and parents completed questionnaires capturing family structural factors, and measures of family functioning, parenting stress, and maternal mental health. The demographic and family background information available for this study was determined by the scope of the original data collection protocol, which meant that new variables could not be retrospectively added. This design allowed for the prospective examination of both early predictors (i.e. infant cognitive functioning) and contemporaneous family factors in relation to school-age developmental outcomes, facilitating a more comprehensive understanding of child development within its broader caregiving context.

2.2 Participants

Participants were recruited to the current study in pairs (child and parent) from a community sample of 126 typically developing children and their parents, and a clinical sample of 15 children with hypoxic ischemic encephalopathy (HIE) in infancy and their parents. At baseline, community and convenience sampling was used to recruit participants (September 2020 - September 2021). Participants were recruited via posters in the community and staff/faculty emails at University College Cork (UCC). Convenience sampling was used to recruit children attending the INFANT Research Centre, UCC, as part of other studies. Children were excluded from participation if they were under 4 years, or currently ill or impaired by a known physical health condition. Parents were excluded if they reported experiencing significant mental health difficulties (based on self-report). Inclusion and exclusion criteria were determined at the recruitment stage of the current study.

Ethical approval was granted by the Clinical Research Ethics Committee of the Cork Teaching Hospitals (CREC) (see appendix A). Recruitment procedures for the current study followed the protocol approved by CREC, which were necessarily consistent with the recruitment protocol at baseline, wherein participants consented to being contacted again in relation to follow-up research. Thus, for the current study, parents were contacted by phone and the study was explained to them. They were invited to provide consent for their child to take part in a follow-up assessment of their cognitive abilities, and to participate themselves by completing parental questionnaires relating to family environment and well-being. The Participant Information Leaflet (appendix B) was sent by email to interested participants, along with the Informed Consent form (appendix B) for information purposes. An appointment time was arranged for each child and parent pair to attend the research centre for the assessment. Informed consent and age-appropriate assent (appendix C) was obtained in person prior to the assessment taking place. In total 87 participants pairs were recruited to the current study; 80 from the community sample, and 7 from the HIE sample. No a priori power analysis was conducted, as sample size was determined by the number of participants from the original cohort who were eligible and available for follow-up within the study period.

2.3 Outcome Measures

2.3.1 Child Neurodevelopmental Outcomes

The consultant clinical neuropsychologist (CMC) chose the neuropsychological assessments, and categorised subtests into cognitive domains for the purposes of the current study. This approach allowed for a more detailed exploration of specific cognitive processes, providing greater sensitivity to subtle domain-specific variations that may not be captured by overall index scores. Neuropsychological outcomes were assessed in the cognitive domains of *verbal reasoning, non-verbal reasoning, receptive language, expressive language, speed of information processing, verbal and non-verbal memory, working memory*, and *perceptual motor abilities*. Table 4.1 outlines each subtest and the related cognitive construct measured. Standardised scores for each subtest were calculated, i.e. a child's raw score on each task was converted into a score relative to age-based normative data, allowing for meaningful comparisons across children and cognitive domains. The *WPPSI-IV* subtest scores are standardised with a mean (standard deviation (*SD*)) of 10 (3) (Wechsler, 2012). Of the *NEPSY-II* subtests used in the current protocol, all are standardised with a mean (*SD*) of 10 (3), with the exception of *Design Copying*, which yields a raw score that is converted into percentile ranks and descriptive categories.

Table 4.1
Neuropsychological outcomes subtests and descriptions

Neurodevelopmental Outcome	Test	Description
Non-Verbal Reasoning	Matrix Reasoning†	Measures fluid reasoning and problem-solving using abstract visual patterns.
Verbal Reasoning	Similarities†	Assesses verbal concept formation and abstract reasoning by identifying similarities between words.
Receptive Language	Receptive Vocabulary†	Evaluates understanding of spoken words by asking the child to point to pictures.
Expressive Language	Picture Naming†	Measures expressive vocabulary by asking the child to name pictured objects.
Processing Speed	Bug Search†	Assesses visual scanning and processing speed through identifying matching symbols.
Non-Verbal Memory	Picture Memory†	Evaluates visual recognition and memory for previously presented pictures.
Working Memory	Comprehension of Instructions‡	Measures auditory attention and working memory by having the child follow multi-step spoken instructions.
Verbal Memory	Narrative Memory‡	Assesses memory for verbally presented stories, focusing on both immediate and delayed recall.
Perceptual-Motor	Design Copying‡	Measures visual-motor integration by having the child reproduce geometric figures.

†Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version)
‡NEPSY–Second Edition: A Developmental Neuropsychological Assessment

2.3.2 Child Psychosocial Outcomes

Children's psychosocial functioning at 5 years was assessed using the *Strengths and Difficulties Questionnaire (SDQ)*, a widely used behavioural screening tool for children aged 2-17 years. The 25 item parent-report version of the *SDQ* was administered, with scoring and interpretation based on established normative thresholds (Goodman, 1997). The *SDQ* has been standardised in large UK and US populations (Bourdon et al., 2005; Meltzer et al., 2000). It demonstrates good internal consistency, and test–retest reliability and concurrent validity with measures such as the *Child Behaviour Checklist* (Goodman, 1997; Goodman et al., 2000; Stone et al., 2010).

The *SDQ Total Difficulties* score and the *Prosocial Behaviour* subscale score were used as primary indicators of psychosocial outcomes which respectively capture overall behavioural problems and positive social functioning. These were selected as primary outcome indicators given their strong psychometric properties and clinical relevance. However, exploratory analyses of individual problem subscales (*emotional symptoms, conduct problems, hyperactivity /inattention, peer relationship problems*) were also planned, and results were to be reported separately if differential patterns of association emerged across these domains.

2.3.3 Historical Child Factors – Early Cognitive Functioning

At baseline, the *Bayley-III* and *CogniTOT* assessments were administered to each child, in person in the research centre. The *Bayley-III,* was used as a standardised measure of early developmental functioning across cognitive, language, and motor domains (See Supplementary Chapter 3).

The *CogniTOT* application is a novel touchscreen, non-verbal assessment of executive functioning, designed for children aged 22-30 months. The version of *CogniTOT* under investigation (version 1.1), based on previous versions of the application tested (Casey et al., 2023; Twomey et al., 2018; Twomey et al., 2021), consists of 30 task items and purports to assess toddlers fundamental cognitive abilities in the following individual cognitive domains*: Processing speed, selective attention, working memory, acquired learning, problem solving, cognitive shift*, and *sustained attention*. Subscales are named in line with the cognitive construct they purport to measure. Each subscale and a sample of corresponding tasks are outlined table 4.2 below. Significantly, lower subscales scores on *CogniTOT* indicate better performance, with the exception of *CogniTOT Total Score* and *CogniTOT Sustained Attention*. See Supplementary Chapter 3 for detailed description of the design, scoring and administration of *CogniTOT*, and Appendix F for an overview of each task with descriptions.

Table 4.2

CogniTOT subscales and sample of corresponding tasks

Cognitive Construct	Sample description of task items measuring the construct
Processing Speed†	**Task 5:** 9 Stars (3 x 3 grid), 8 Blue, 1 Smiley face yellow star. Press yellow star.
Working Memory†	**Task 20**: 5 Boxes: Pink, Blue, Green (left - right). Yellow star falls into pink box (1st in line) and is completely hidden. Press pink box to completely reveal star. Press yellow star.
Problem Solving†	**Task 16:** Blue and Red Bucket. Red Bucket (on right) covers Yellow Star. Swipe up bucket and press yellow star.
Selective Attention†	**Task 6:** 30 stars (6 x 5 grid), 29 blue, 1 smiley face yellow star. Press yellow star.
Acquired Learning†	**Task 17:** Blue and red buckets, with 1 yellow star becoming hidden under blue bucket on left side. Press blue bucket and press yellow star.
Cognitive Shift†	**Task 8:** 30 stars (6 x 5 grid): 1 yellow smiley target star, 29 multi-colored plain distractor stars. Press yellow star.
Sustained Attention†	**Task 30:** Balloons moving onscreen as they do at end of app, for 120 seconds maximum. Task does not contribute to CogniTOT score. Instead provides a separate measure of sustained attention.

Note. Appendix F contains a complete overview of each CogniTOT task with descriptions
†Individual CogniTOT subscales

2.3.4 Family Structural Factors

A bespoke demographic questionnaire was developed to collect information about each child and their family (Appendix D). The selection of variables was informed by the literature review and the study aims, focusing on family composition, parental background, and environmental context relevant to child development. Some demographic information had been gathered at baseline and could not be supplemented retrospectively, while additional relevant variables were collected at follow-up within the scope of the approved protocol. The following demographic and family structural variables were derived from this questionnaire for analysis:

- Number of siblings
- Family composition (i.e. lone parent or two-parent household)
- Maternal age
- Maternal level of education
- Main language spoken at home (English or other)
- Maternal country of birth (Ireland or other)

- Paternal country of birth (Ireland or other)
- Presence of a diagnosed medical condition in the child

2.3.5 Family Dynamic Factors

Validated psychometric measures were used in the current study to assess the independent contribution of the following dynamic parent and family factors, known to influence child development:

- Parent Mental Health: *Depression Anxiety Stress Scales – 21 items (DASS-21).* A widely used self-report instrument which measure negative emotional states in adults, specifically depression, anxiety, and stress (Lovibond & Lovibond, 1995). The *DASS-21* has demonstrated strong psychometric properties across community and clinical populations, including high internal consistency and convergent validity with other measures of psychological distress (Henry & Crawford, 2005). Additionally, the demographic questionnaire asked whether parents had a diagnosed mental health condition, which was considered a categorical variable for analysis (i.e. yes or no).

- Parenting Stress: *Parenting Stress Index – Short Form (PSI-SF).* A 36-item parent-report measure designed to assess the magnitude of stress experienced by parents in the context of their parenting role (Abidin, 1995; 2012). The *PSI-SF* is derived from the full-length *Parenting Stress Index* and retains strong psychometric properties. Widely used tool in clinical and research settings, it has demonstrated good internal consistency, test-retest reliability, and validity in both normative and clinical populations (Abidin, 1995; Haskett et al., 2006).

- Family Environment: *Family Environment Scale (FES)* – six subscales: *Cohesion*, *Expressiveness*, *Conflict*, *Active Recreational Orientation*, *Organisation*, and *Control*. The selected subscales comprehensively capture family dynamics relating to emotional climate, communication patterns, and organisation of the family environment. The *FES* has demonstrated good internal consistency and construct validity in both clinical and non-clinical populations (Moos & Moos, 2002).

Figure 1 below summarises the predictor and outcome variables. Additional detail relating to measures is provided in Supplementary Chapter 5.

Outcome Variables

Psychosocial
SDQ Total Difficulties
SDQ Prosocial Behaviour

Neurodevelopmental
WPPSI-IV subscales: Matrix Reasoning; Bug Search; Picture Memory; Similarities; Receptive Vocabulary
NEPSY-II subscales: Comprehension of Instructions; Narrative Memory; Design Copying

Predictor Variables

Early Cognitive Functioning
Bayley-III Composite Scores: Cognitive, Language and Motor Composites
CogniTOT subscales: Processing speed; Working Memory; Problem Solving; Selective Attention; Acquired Learning; Cognitive Shift; Sustained Attention

Family Structural Factors
Maternal Age; Paternal Age; No. of siblings; Family Composition; Child medical condition; Gender.

Family Dynamic Factors
DASS Anxiety; DASS Depression; DASS Stress; PSI Total Score; FES Cohesion, Expressiveness, Conflict, Active Recreational Orientation, Organisation, and

Figure 1 Outcome and Predictor Variables by Category

2.4 Procedures

Child neurocognitive assessments were carried out by a trainee clinical psychologist (MB), a psychology research assistant (LO'S) and a psychology graduate (AM) each of whom were trained to undertake the current neuropsychological assessment battery. Multiple training sessions were facilitated by the consultant clinical neuropsychologist (CMC), during which assessors were instructed in standardised administration procedures and practiced test delivery with one another in a controlled, practice environment. Training continued until each assessor demonstrated satisfactory competence and procedural adherence. Initial assessments were conducted by CMC and observed by assessors from an adjacent observation room. Subsequently, each assessor conducted their initial assessments under observation by CMC, who provided feedback and confirmed administration competency prior to assessors proceeding independently. These procedures ensured consistency, reliability, and standardisation of the assessment protocol across all administrators. The duration of assessments was approximately 45 minutes, during which time questionnaires were completed by the parent.

2.5 Statistical Analysis

Statistical analysis was completed by using IBM SPSS Statistics version 29.0.2.0. Tests of normality were performed using measures of skewness and kurtosis, and where assumptions of normality were not met data transformations were applied where appropriate. Sample characteristics were compared with normative data where available to aid interpretation.

Exploratory correlational analyses were conducted to examine the relationships between child psychosocial outcomes, child neurodevelopmental outcomes at age five, and predictor variables (see Figure 1). These preliminary analyses were used to identify relevant predictor variables for each outcome for subsequent analyses. To determine the relative contribution of structural versus dynamic family factors in predicting child outcomes, significant associations were entered into hierarchical multiple regression models. Separate models were conducted for each child outcome measure: *SDQ Total Difficulties*, *SDQ Prosocial Behaviour*, and each *WPPSI-IV* and *NEPSY-II* subscale.

The sequence of steps for each regression model were informed by the research question, such that in Step 1, child cognitive scores at 24 months were entered to account for baseline neurodevelopmental functioning; in Step 2 (regression models for psychosocial outcomes only), neurodevelopmental outcomes at 5 years were added to assess their unique contribution to psychosocial outcomes; in Step 3 (or Step 2) family structural factors were added, and in Step 4 (or Step 3) family dynamic factors were added, to independently assess their additional explanatory value. This approach enabled the evaluation of whether family-level variables accounted for significant variance in child outcomes beyond early cognitive functioning, and whether family structural and dynamic factors were unique in their contributions, in line with the research questions. An overview of the regression models is provided in Figure 2.

Psychosocial Outcomes	Neurodevelopmental Outcomes
Model 1:	Model 1:
Child Early Cognitive Functioning: CogniTOT Total and Subscale scores; Bayley-III Composite Scores.	Child Early Cognitive Functioning: CogniTOT Total and Subscale scores; Bayley-III Composite Scores.
Model 2:	Model 2:
+ Child Neurodevelopmental Outcomes: WPPSI-IV and NEPSY-II subscales.	+ Family Structural Factors: Maternal Age; Paternal Age; No. of siblings; Family Composition; Child medical condition; Gender.
Model 3:	Model 3:
+ Family Structural Factors: Maternal Age; Paternal Age; No. of siblings; Family Composition; Child medical condition; Gender.	+ Family Dynamic Factors: Maternal Mental Health (DASS-21); Parenting Stress (PSI-SF); Family Environment (FES subscales); Parent diagnosed mental health condition.
Model 4:	
+ Family Dynamic Factors: Maternal Mental Health (DASS-21); Parenting Stress (PSI-SF); Family Environment (FES subscales); Parent diagnosed mental health condition.	

Figure 2 Hierarchical Multiple Regression Models for Psychosocial and Neurodevelopmental Outcomes

All *p*-values were two-tailed with statistical significance cut-off set at < 0.05. Effect sizes for bivariate associations were reported as Pearson's correlation coefficients (r), providing an estimate of the strength and direction of each relationship. For categorical predictor variables, independent samples *t*-tests were conducted to assess between-group differences in outcome variables, and effect sizes were calculated using Cohen's d to evaluate the magnitude of observed differences.

3. Results

3.1 Sample Characteristics

In total 87 child and parent pairs were recruited to this study, from the baseline sample of 126. Sample characteristics are summarised in table 4.4 below. The *Bayley-III* index composite scores have a standardised mean of 100 ($SD = 15$) (Bayley, 2006). As outlined in Table 4.4, the current sample closely aligned with these normative means across cognitive, language, and motor domains. Language and motor scores were slightly above average, while cognitive scores were in line with the expected mean. Thus, concerns about sampling bias in terms of overall cognitive functioning are reduced.

When the sample representativeness of participants for the current study was assessed, no significant differences were found between the responder and non-responder groups (see Table 4.3). A chi-square test of independence was conducted to compare gender distribution between responders and non-responders. The results showed no significant difference between the groups (p = .69). Independent samples t-tests were conducted to compare *Bayley-III Cognitive, Language,* and *Motor Composite* scores between responders and non-responders. No significant differences were found for cognitive scores, $t(120) = 0.459$, $p = .647$, language scores, $t(118) = -0.727$, $p = .469$, or motor scores, $t(118) = -1.001$, $p = .319$. These findings indicate no significant differences in cognitive performance between the two groups. An independent samples t-test was also conducted to compare scores between responders and non-responders on *CogniTOT*, using the *CogniTOT Total* score. The results indicated no significant difference between the groups, $t(122) = -0.712$, $p = .478$. These findings suggest that cognitive performance did not differ significantly based on response status.

Table 4.3

Sample characteristics of responders and non-responders from baseline study

Variable	Responders (n = 78)	Non-responders (n = 46)	p
Gender			.69†
Male n	33 (42%)	16 (35%)	
Female n	45 (58%)	30 (65%)	
Bayley's Composite scores			
Cognitive	99.6 (12.4)	100.8 (15.6)	.65‡
Language	105.9 (15.9)	103.6 (18)	.47‡
Motor	103.3 (12.2)	100.9 (12.6)	.32‡
CogniTOT total score	19.2 (6.6)	18.3 (8)	.48‡

† Pearson Chi-Square Test, ‡ Independent Samples t-test

Whilst the cognitive functioning of the sample infants appeared aligned to normative means, the demographics of the family were less typical. Thus, 8.1% of the current sample were lone parents. This is significantly lower than nationally representative data which, in 2022, indicated that 15.5% of children lived in a single parent family unit in Ireland

(Department of Children, Equality, Disability, Integration & Youth (DCECIY), 2024). The maternal level of education of the current sample is also higher than population norms, with 87% of mothers reporting to have achieved a Level 8 degree or higher. Nationally, in 2016, 50.6% of children's maternal highest level of education was secondary level, and 8.1% of children had a mother with either no formal education or primary education only (DCECIY, 2024). Directly comparable normative data relating to nationality was not available. However, Census 2022 figures indicate that just over 87% of householders in families stated they were Irish citizens, while 12% declared non-Irish citizenship, which is comparable to the current sample. Finally, 10.7% of parents reported having a diagnosed mental health condition, notably lower than national prevalence estimates. A National Survey (Aware, 2024) recently reported that 21% of adults have received a depression diagnosis. The OECD/European Observatory on Health Systems and Policies (2019) similarly estimate that 1 in 5 adults in Ireland are living with a mental health disorder.

Table 4.4
Sample characteristics relating to demographic information and family factors, and child neurodevelopmental functioning in infancy

Factor	% (*n*)	*M* (*SD*)
Family		
Maternal Age (years) §		40.1 (3.9)
Lone parent	8.1% (7)	
Mother born in Ireland	84% (44)	
Father born in Ireland	88% (42)	
Main language used at home		
English	93.8% (75)	
Other language	6.3% (5)	
Maternal Level of Education‡		
Level 7 degree and lower	13% (10)	
Level 8 degree and higher	87% (67)	
Number of siblings		1.4 (0.9)
Parent with diagnosed mental health condition	10.7% (9)	
Child		
Sample type†		
Community	92% (80)	
HIE	8% (7)	
Gender		
Male	47% (41)	
Female	53% (47)	
Child with diagnosed medical condition	13% (11)	
Age		
Baseline (months)		26.1 (1.8)
Follow-up (years)		5.5 (0.3)
Bayley's scores		
Cognitive Composite		99.8 (12)
Language Composite		105.4 (16.1)
Motor Composite		103.5 (12.2)

† HIE = hypoxic ischemic encephalopathy
‡ Education levels are categorised as Level 7 and lower (Ordinary degree or below) and Level 8 and higher (Honours degree or above).
§Refers to maternal age at time of follow-up assessment.

Although some family structural factors were not typical, scores relating to child and dynamic family factors suggest the current sample was generally typical of community samples. At five-year follow-up, children in the current sample performed broadly within normative ranges on neurodevelopmental assessments (*WPPSI-IV, NEPSY-II*), with most subtests aligning with the expected mean of 10 (*SD* = 3). Psychosocial outcomes (*SDQ Total* and *SDQ Prosocial Behaviour*) were similarly aligned with normative expectations. Maternal wellbeing scores reflected expected values for non-clinical populations. *DASS* subscale scores were within normal to mild ranges, though *Anxiety* and *Stress* scores were slightly elevated. *PSI Total Stress* scores were within the normative range, though slightly below normative means (Abidin, 1995; 2012), suggesting lower than typical parenting stress levels. In relation to family environment, *FES* subscale scores were broadly consistent with norms observed in community samples (Moos & Moos, 2002). These findings are summarised in table 4.5 below.

Table 4.5
Summary of mean child neurodevelopmental and psychosocial outcomes, and dynamic family factors, and corresponding normative population means

Variable	*M* (*SD*)	Normative Population *M* (*SD*)
Child Neurodevelopmental Outcomes		
Matrix Reasoning	8.3 (2.9)	10 (3) †
Bug Search	9.9 (2.6)	10 (3) †
Picture Memory	10.5 (2.7)	10 (3) †
Similarities	12.6 (2.9)	10 (3) †
Receptive Vocabulary	9.9 (2.2)	10 (3) †
Picture Naming	11.1 (3.2)	10 (3) †
Comprehension of Instructions	11.9 (2.2)	10 (3) ‡
Narrative Memory	11.1 (2.9)	10 (3) ‡
Design Copying	7.9 (2.2)	50^{th} percentile‡
Child Psychosocial Outcomes		
SDQ Total Score	8.2 (5.3)	8.4 (5.8) §
SDQ Prosocial Behaviour	8.3 (1.8)	8.6 (1.6) §
Dynamic Family Factors		
DASS Anxiety	3.5 (4.7)	1.97 (2.9) ¶
DASS Depression	3.6 (5.0)	3.75 (4.1) ¶
DASS Stress	9.6 (7.8)	4.98 (4.9) ¶
FES Cohesion	8.3 (0.8)	6.7 (1.5) #
FES Expressiveness	6.8 (1.5)	5.5 (1.6) #

Variable	*M* (*SD*)	Normative Population *M* (*SD*)
FES Conflict	1.8 (1.7)	3.2 (1.9) #
FES Active Recreational Orientation	6.8 (1.6)	5.3 (2) #
FES Organisation	6.4 (2)	5.5 (1.9) #
FES Control	3.7 (2)	4.7 (1.8) #
PSI Total Stress	66.1 (18.4)	78 (12) ††

Note. SDQ = Strengths and Difficulties Questionnaire, DASS = Depression, Anxiety and Stress Scale – 21, FES = Family Environment Scale, PSI = Parenting Stress Index – Short Form

† WPPSI-IV; Wechsler, 2012

‡ NEPSY-II; Design Copying subtest normative data are reported as age-adjusted percentile ranks; the 50th percentile reflects average performance in the normative population (Korkman, Kirk, & Kemp, 2007).

§ Meltzer et al., 2003

¶ Henry & Crawford, 2005

Moos & Moos, 2002

†† Abidin, 1995; 2012

3.2 Data Screening and Assessment of Normality

Visual inspection of histograms (Appendix E) was conducted, and skewness and kurtosis values were evaluated, to assess distribution normality. Outliers (scores > 3 standard deviations from the subgroup mean) were removed from child neurodevelopmental outcome variables (*n* = 3). Variables were found to be approximately normally distributed, with the exception of *CogniTOT Processing Speed* and *DASS Depression*. A $\log_{10}$ transformation was applied to the *CogniTOT Processing Speed* variable, after which normality assumptions were met. The *DASS Depression* variable (skewness = 2.54; kurtosis = 8.95) was not transformed, as raw scores were retained for interpretive clarity, and the distribution was consistent with expectations of positive skew in depression scores within non-clinical community samples. Follow-up non-parametric analyses (Spearman's rho) yielded comparable results, supporting the validity of the original findings.

A small number of extreme values were identified for *FES Cohesion*, *DASS Depression*, and *DASS Anxiety* variables (*n* = 4). These were retained, as they were considered valid reflections of natural variability within the sample. Sensitivity analyses indicated their inclusion did not meaningfully affect results. Further detail regarding these processes are provided in Supplementary Chapter 5.

3.3 Exploratory Bivariate Analyses and Multivariate Analyses

3.3.1 Predictors of Child Psychosocial Outcomes

Exploratory correlational analyses were conducted to identify potential predictors of child psychosocial outcomes (see Figure 1 for overview of outcome and predictor variables). Only one historical cognitive factor (*CogniTOT Cognitive Shift*) was associated with socioemotional outcomes at 5 years. Cross-sectionally, a number of associations were observed between neurocognitive functioning and both psychosocial outcome measures (*SDQ Total Score* and *SDQ Prosocial Behaviour*), where effect sizes were small to medium (see Table 4.6 below).

Table 4.6
Significant associations between Psychosocial Outcomes and Child Neurodevelopmental Outcomes, Family Structural Factors and Family Dynamic Factors

	SDQ Total Score	SDQ Prosocial Score
WPPSI		
Matrix Reasoning		
Bug Search	-.33	
Picture Memory	-.23	
Similarities	-.21	.22
Receptive Vocabulary		
Picture Naming		
NEPSY		
Comprehension of Instructions	-.3	.31
Narrative Memory		.25
Design Copying		
Bayley-III Composites		
Cognitive		
Language		
Motor		
CogniTOT		
CogniTOT Total		
CogniTOT Processing Speed		
CogniTOT Selective Attention		
CogniTOT Working Memory		
CogniTOT Acquired Learning		
CogniTOT Cognitive Shift	-.233	.27
CogniTOT Problem Solving		
CogniTOT Sustained attention		
DASS-21		
Anxiety	.4	
Depression	.41	
Stress	.41	
FES		
Cohesion		
Expressiveness		.24
Conflict	.38	
Active Recreational Orientation		
Organisation	-.31	
Control		
PSI Total Stress	.75	-.42
Maternal Age	-.23	
Paternal Age		
Number of siblings	-.37	
Gender		
Child with diagnosed medical condition		
Family Composition (i.e. Lone or two parent family)		
Parent with diagnosis of mental health condition	-0.76†	

Note. WPPSI = Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version), NEPSY = NEPSY–Second Edition: A Developmental Neuropsychological Assessment, SDQ = Strengths and Difficulties Questionnaire, DASS-21 = Depression, Anxiety and Stress Scale – 21, FES = Family Environment Scale, PSI = Parenting Stress Index – Short Form
† Independent Samples *t*-test; Cohens *d* effect size. Other figures shown are Pearson correlation *r* values.

In relation to *SDQ Total* there were significant associations with family structural factors (maternal age and number of siblings), with small to medium effect sizes observed. The *SDQ Total* was also associated with family dynamic factors: each *DASS-21* subscale showed medium effect sizes; *FES Conflict* and *Organisation* also showed medium effects; *PSI Total Stress* showed a large effect size, indicating a strong link between higher parenting stress and greater child difficulties. For *SDQ Prosocial Behaviour*, no associations were observed with family structural factors. However, among dynamic family factors, *FES Expressiveness* showed a small effect size, and *PSI Total Stress* showed a medium effect size. These associations are summarised in Table 4.6.

To examine the relative contribution of child neurodevelopmental, family structural, and family dynamic factors to child psychosocial outcomes, two separate hierarchical multiple regression analyses were conducted using *SDQ Total Difficulties* and *SDQ Prosocial Behaviour* scores as outcome variables. Beyond bivariate analyses, hierarchical regression allowed for the evaluation of each predictor domain's incremental contribution to the outcome, while controlling for variables entered in earlier blocks. Predictor variables were entered based on theoretical and empirical rationale, with particular interest in the contribution of family dynamic factors as outlined in section 2.4.

For the *SDQ Total Difficulties* outcome, 13 variables showed significant correlations. To preserve statistical power, reduce model complexity, and minimise multicollinearity, only variables with medium or larger effect sizes ($r \geq .30$) were included in the regression analysis. Additionally, *DASS Depression* was selected as the representative indicator of maternal mental health due to high intercorrelations among the *DASS-21* subscales, which precluded their simultaneous inclusion, and its conceptual relevance and empirical support linking maternal depression to child socioemotional outcomes (Kingston & Tough 2012; Shuffrey et al., 2022). These decisions align with best practice recommendations for linear regression, which suggest a minimum of 10 participants per predictor variable (Field, 2018), given the sample size (n = 87). Predictor variables which showed significant associations were entered in blocks in the order outlined in Figure 2. For the *SDQ Total Difficulties* outcome, no historical cognitive factors with a medium or larger effect size were significant, thus, the blocks were as follows: Block 1 – Neurodevelopmental outcomes at 5 years; Block 2 – Family structural factors; Block 3 – Family dynamic factors.

Results of the hierarchical multiple regression illustrated that neurodevelopmental outcomes at age five significantly explained 14% of the variance in *SDQ Total Difficulties* scores, with performance on tasks such as *Bug Search* and *Comprehension of Instructions* demonstrating significant negative associations with behavioural difficulties. This indicates that better processing speed and working memory skills were associated with fewer behavioural difficulties, supporting the expected direction of effect. The addition of family structural factors substantially improved model fit, with the number of siblings emerging as a significant negative predictor of psychosocial difficulties accounting for an additional 11% of the variance. The inclusion of family dynamic factors in the final block led to the largest increase in explained variance, to 60%, indicating that such factors explain an additional 35% of the total variance in *SDQ Total Difficulties* scores. The final regression model was statistically significant and indicated that child neurodevelopmental functioning, family structural characteristics, and family dynamic factors each contributed to the prediction of psychosocial outcomes. Of the predictors, *PSI Total Stress* had the largest standardised beta coefficient, indicating it was the strongest unique predictor of children's behavioural and psychosocial adjustment within this sample. These results are summarised in Table 4.7.

Table 4.7
Results of hierarchical regression analyses predicting SDQ Total Scores

	Stand. Beta	Adjusted r^2	F	p
Block 1		0.14	7.62	<0.001
Bug Search†	-0.28*			
Comprehension of Instructions‡	-0.24*			
Block 2		0.25	9.75	<0.001
Bug Search†	-0.24*			
Comprehension of Instructions‡	-0.25*			
Number of Siblings	-0.34**			
Block 3		0.6	15.81	<0.001
Bug Search†	-0.12			
Comprehension of Instructions‡	-0.15*			
No. of Siblings	-0.15*			
FES Conflict	0.11			
FES Organisation	-0.02			
DASS Depression	0.11			
PSI Total Stress	0.55**			
Parent Diagnosed Mental Health Difficulty	-0.01			

SDQ = Strengths and Difficulties Questionnaire, DASS = Depression, Anxiety and Stress Scale – 21, FES = Family Environment Scale, PSI = Parenting Stress Index – Short Form
†Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version);
‡NEPSY–Second Edition: A Developmental Neuropsychological Assessment
* $p < 0.05$
** $p < 0.01$

For *SDQ Prosocial Behaviour* all 6 variables which demonstrated statistically significant associations were included in the regression analysis. One historical cognitive variable was significant (*CogniTOT Cognitive Shift*), however, no family structural factors were significant, thus, the blocks were as follows: Block 1 – Historical cognitive factors; Block 2 – Neurodevelopmental outcomes at 5 years; Block 3 – Family dynamic factors.

Results of the hierarchical multiple regression illustrated that the *CogniTOT Cognitive Shift* variable explained a significant percentage of the variance in *SDQ Prosocial Behaviour* scores, although small at 6%. The addition of current neurodevelopmental functioning significantly accounted for a further 6% of the variance. The inclusion of family dynamic factors in the final block increased the explained variance to 21%, indicating that such factors explain an additional 9% of the total variance in *SDQ Prosocial Behaviour* scores. The final regression model was statistically significant and indicated that child neurodevelopmental functioning, both historic and current, and family dynamic factors each contributed to the prediction of psychosocial outcomes related to prosocial behaviours. Of the predictors associated with *SDQ Prosocial Behaviour,* the *PSI Total Stress*, again, had the largest standardised beta coefficient, indicating it was the strongest unique predictor of this outcome within this sample. These findings suggest that while early cognitive factors play a role, family stress and emotional climate variables accounted for more variance in psychosocial outcomes. These results are summarised in Table 4.8.

Table 4.8
Results of hierarchical regression analyses predicting SDQ Prosocial Behaviour scores

	Stand. Beta	Adjusted r^2	F	p
Block 1		0.06	6.0	0.017
CogniTOT Cognitive Shift	0.27*			
Block 2		0.12	3.48	0.012
CogniTOT Cognitive Shift	0.23*			
Similarities†	-0.01			
Comprehension of Instructions‡	0.25			
Narrative Memory‡	0.1			
Block 3		0.21	4.35	<0.001
CogniTOT Cognitive Shift	0.14			
Similarities†	-0.03			
Comprehension of Instructions‡	0.18			
Narrative Memory‡	0.09			
FES Expressiveness	0.09			
PSI Total Score	-0.33**			

SDQ = Strengths and Difficulties Questionnaire, FES = Family Environment Scale, PSI = Parenting Stress Index – Short Form
†Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version);
‡NEPSY–Second Edition: A Developmental Neuropsychological Assessment
* $p < 0.05$
** $p < 0.01$

3.3.2 Predictors of Child Neurodevelopmental Outcomes

Exploratory correlational analyses were conducted to identify potential predictors of child neurodevelopmental outcomes at 5 years (see Figure 1 for overview of outcome and predictor variables). Overall, findings suggest a degree of continuity between cognitive functioning in infancy and neurodevelopmental outcomes at age five. However, these associations were modest in strength, with effect sizes ranging from small to medium at best. A number of significant associations were observed across the neurodevelopmental outcomes, highlighting the relevance of both early child characteristics and family factors. Notably, early *Bayley-III Cognitive, Language,* and *Motor Composite* scores were positively associated with later reasoning, memory, and language abilities, supporting their predictive validity. Specific *CogniTOT* subscales, particularly *Cognitive Shift* and *Sustained Attention*, also demonstrated significant associations, though to a more limited extent. More pervasive and consistent associations were observed between neurodevelopmental outcomes and family factors, especially dynamic variables such as parenting stress and aspects of the family environment. Although based on cross-sectional data, these outcomes were independently and objectively assessed by a trained assessor who was blind to parent-reported family variables, lending greater confidence to the robustness of these associations.

Among the family dynamic variables, higher levels of parental stress (*PSI Total Stress*) and anxiety (*DASS Anxiety*) were negatively associated with child cognitive outcomes, particularly those involving verbal reasoning and working memory. Similarly, higher levels of family conflict were associated with lower reasoning performance, whereas positive family traits such as expressiveness and cohesion were modestly associated with better outcomes across several domains. Significant associations were also found for structural family characteristics. Older maternal and paternal age, and a higher number of siblings, were negatively associated with verbal abilities. Certain categorical comparisons (i.e. lone vs. two-parent households, presence of a child medical condition) also demonstrated significant group differences in reasoning, memory and language outcome domains. These associations are summarised in Table 4.9.

To examine the relative contribution of historical cognitive factors (*Bayley-III* and *CogniTOT* scores), family structural, and family dynamic factors to child neurodevelopmental outcomes at age five, a series of hierarchical multiple regressions were conducted. This analysis

Table 4.9
Significant Associations between Child Neurodevelopmental Outcomes at 5 years and Early Cognitive Functioning, Family Structural Factors and Family Dynamic Factors

	Matrix Reasoning†	Bug Search†	Picture Memory†	Similarities†	Receptive Vocabulary†	Picture Naming†	Comprehension of Instructions‡	Narrative Memory‡	Design Copying‡
Bayley-III Composites									
Cognitive				.25	.25				.3
Language				.35	.35	.27	.27		.3
Motor		.23							.29
CogniTOT									
Total									
Processing Speed									
Selective Attention									
Working Memory									
Acquired Learning									
Cognitive Shift				.26	.3				
Problem Solving									
Sustained Attention									.33
DASS-21									
Anxiety				-.41	-.26		-.21		
Depression									
Stress				-.24	-.23				
FES									
Cohesion						.22			
Expressiveness		.27		.25			.29	.26	
Conflict	-.28								
Active Recreational Orientation									
Organisation									
Control									
PSI Total Stress		-.28			-.24				
Maternal Age						-.26			
Paternal Age						-.4			
Number of siblings						-.23			
Gender									
Child with diagnosed medical condition	.806§			1.005§					
Family Composition			-.815§					.845§	
Parent with diagnosis of mental health condition									

DASS-21 = Depression, Anxiety and Stress Scale – 21, FES = Family Environment Scale, PSI = Parenting Stress Index – Short Form
†Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version); ‡NEPSY–Second Edition: A Developmental Neuropsychological Assessment
§ Independent Samples *t*-test; Cohens *d* effect size. Other figures shown are Pearson correlation *r* values

allowed for the evaluation of each predictor domain's incremental contribution to the outcome, while controlling for variables entered in earlier blocks. All variables that demonstrated statistically significant bivariate associations with neurodevelopmental outcomes were included in regression analyses. As with psychosocial outcomes, predictor variables were entered based on theoretical and empirical rationale, in the following order: Block 1 – Early cognitive functioning; Block 2 – family structural factors; Block 3 – family dynamic factors (see also Figure 2). Given the breadth of outcome variables (nine subscales), a summary of key findings from these regression analyses is presented, and detailed regression outputs are contained in Supplementary Chapter 5.

Adjusted R^2 values for each regression model are summarised in Table 4.10. For some outcomes, not all blocks included variables due to the limited number of significant predictors identified at earlier stages of analysis. In such cases, these blocks are denoted as non-significant (N.S.). Findings indicated that predictor variables accounted for a significant proportion of variance in neurodevelopmental outcomes, for the majority of outcome variables (i.e. *WPPSI-IV* and *NEPSY-II* subtests), with the addition of each block.

Early cognitive functioning accounted for a significant proportion of variance in outcomes on six of the nine neurodevelopmental subtests, spanning several domains. In Block 1, it modestly predicted later processing speed and memory abilities, explaining 4% to 6% of the variance in these outcomes. Stronger predictive value was observed for language and visuospatial reasoning, with early cognitive functioning accounting for 17% to 20% of the variance in these domains. The inclusion of family structural factors in Block 2 significantly improved model fit and predicted variance in five of the nine outcomes. However, the additional variance explained was modest to moderate, ranging from 3% to 13%. Similarly, family dynamic factors added in Block 3 significantly contributed to variance in seven of the nine outcomes, with incremental increases of 2% to 10%.

These findings indicate that neurodevelopmental outcomes at age five are shaped by a range of early child and family-level influences. While early cognitive functioning demonstrates some predictive value, the contribution of family structural and dynamic factors significantly enhances explanatory power across multiple domains. This underscores the multifactorial nature of neurodevelopment and supports the value of integrative models that incorporate both child and environmental predictors.

Table 4.10

Adjusted R^2 analyses of predictor variables for child neurodevelopmental outcomes at 5 years

	Matrix Reasoning†	Bug Search†	Picture Memory†	Similarities†	Receptive Vocabulary†	Picture Naming†	Comp. of Instructions‡	Narrative Memory‡	Design Copying‡
Block 1 Early Cognitive Functioning	*N.S.*	0.04*	*N.S.*	0.17**	0.19**	0.05	0.06*	*N.S.*	0.20**
Block 2 Early Cognitive Functioning Family Structural Factors	0.06*	*N.S*	0.04*	0.22**	*N.S.*	0.18*	*N.S.*	0.04*	*N.S.*
Block 3 Early Cognitive Functioning Family Structural Factors Family Dynamic Factors	0.10**	0.14**	*N.S.*	0.30**	0.21**	0.20*	0.13**	0.09**	*N.S.*

Note. N.S = non-significant, denoting blocks for which there were no significant predictor variables identified for the corresponding outcome to enter into the block for regression analysis.

†Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version)

‡NEPSY–Second Edition: A Developmental Neuropsychological Assessment

* $p < 0.05$

** $p < 0.01$

4 Discussion

This study explored the relative contributions of early cognitive functioning, family structural characteristics, and family dynamic factors to children's neurodevelopmental and psychosocial outcomes at age five, using a longitudinal community-based sample. While previous research has emphasised the importance of early caregiving and environmental influences, few studies have examined these variables alongside early cognitive functioning within a longitudinal design. By evaluating these predictor domains within the same analytic models, this research moves beyond a focus on perinatal influences, highlighting the sustained relevance of family-level factors throughout early childhood, and the relative weight of structural versus dynamic family variables. The inclusion of independently administered, standardised assessments of child outcomes, and validated parent-report measures, strengthens the study's methodology, reducing the risk of shared method variance. The findings offer new insight into the multifactorial nature of child development and highlight the relevance of both early individual developmental markers and the broader caregiving environment in shaping child outcomes.

4.1 Summary of Key Findings

Dynamic family factors, particularly parenting stress, emerged as the strongest and most consistent predictors of both psychosocial and neurodevelopmental outcomes. While early cognitive functioning demonstrated modest predictive value, especially for reasoning and visuospatial outcomes, family variables, particularly those reflecting emotional climate and relational stress, substantially enhanced explanatory models.

In relation to psychosocial outcomes, parenting stress, as captured by the *PSI Total Stress* score, was the most robust predictor of both *SDQ Total Difficulties* and *Prosocial Behaviour*. Given the conceptual basis of the *PSI* as a measure of perceived stress in the parenting role, it may also reflect strain in the parent-child relationship and can be interpreted as a proxy for relational quality. Its predictive strength across both outcomes underscores its relevance in capturing emotional dynamics within the caregiving environment. These findings are consistent with literature highlighting the role of parental strain in shaping child socioemotional development (Chiang & Bai, 2023; Neece et al., 2012), and support the inclusion of parenting stress in early screening frameworks. The magnitude of effect observed here reinforces the value of evaluating family stress as a proximal influence, particularly given its explanatory power exceeded that of neurocognitive measures.

Neurodevelopmental outcomes were shaped by a broader range of influences. Early cognitive functioning (as measured by *Bayley-III* and *CogniTOT*) predicted later performance on tasks of reasoning, language, and visuospatial skills. However, effect sizes were modest, and predictive value varied across subdomains. Notably, family dynamic factors, particularly parenting stress, and family cohesion and expressiveness, contributed additional explanatory value in several cognitive domains. This pattern highlights the limitations of relying solely on infant cognitive assessments to predict later functioning, and supports a more holistic approach to developmental surveillance. These findings are in alignment with ecological and dynamic systems theories (Bronfenbrenner, 1986; Smith & Thelen, 2003), which emphasise the reciprocal influence between children and their caregiving environments, as well as extending research which highlights the limitations of assessments in infancy in forecasting longer-term outcomes (Koshy et al., 2024; Rasheed et al., 2023).

Family environment, as measured by the *FES*, also demonstrated meaningful associations. Higher conflict and lower cohesion or organisation were associated with poorer cognitive and behavioural outcomes, supporting previous findings that disorganised or emotionally strained home environments can hinder regulatory and cognitive development (Marsh et al., 2020). In contrast, family expressiveness, characterised by open communication and emotional availability, was positively associated with prosocial behaviour, suggesting that emotionally open communication may promote empathy and social competence (Garcia et al., 2020; Winston & Chicot, 2016).

Family structural factors such as the number of siblings and maternal education also emerged as significant, albeit less influential, predictors. Children from households with more siblings demonstrated fewer behavioural difficulties, possibly reflecting enhanced opportunities for social interaction and cooperative play, thus, supporting social development. While maternal education was high across the sample, findings still align with literature indicating that structural factors, though less modifiable, remain relevant contributors to developmental trajectories (Letourneau et al., 2013; Masten & Cicchetti, 2010).

The relative strength of dynamic over structural predictors was evident across both sets of outcomes. While structural factors explained additional variance in some neurodevelopmental domains, dynamic variables, especially *PSI Total Stress*, accounted for more substantial increases in explained variance. This pattern is particularly noteworthy given that dynamic factors are more amenable to intervention. Furthermore, the independent contribution of these family variables, even after accounting for early cognitive ability, underscores their importance in child development frameworks.

In terms of children's psychosocial functioning, the findings that parenting stress accounted for the largest proportions of variance across models may reflect the more immediate impact of parenting strain on relational dynamics. These results suggest that stress in the context of the parenting role may be a more proximal influence on child behaviour than underlying mood symptoms. Findings, however, also align with research suggesting that even in the absence of clinically diagnosed mental health disorders, subclinical distress among mothers can influence child outcomes. The significance of the *DASS Depression* subscale as a predictor of psychosocial difficulties supports this assertion and resonates with prior work indicating the pervasive influence of maternal mood on children's emotional and behavioural functioning (Davis & Sandman, 2012; Kingston & Tough, 2014). Though, compared with parenting stress, depressive symptoms, for example, may be more likely to indirectly influence dynamics through behaviours such as reduced warmth or increased hostility.

While the cross-sectional nature of the family variables limits interpretation of directionality, the strong association between parenting stress and lower prosocial behaviour highlights the need to consider the role of relational strain and the broader caregiving environment in early social functioning. While this study did not assess bidirectional processes directly, prior research has highlighted the reciprocal nature of parent–child interactions. Bidirectional effects are well documented (Neece et al., 2012) and support the rationale for intervention approaches that target both parent and child processes, which are likely to yield benefits for both.

The observed association between *FES Expressiveness* and *SDQ Prosocial Behaviour* suggests that emotionally open and communicative environments may promote social competence. This supports evidence that positive relational processes within the home can serve as protective factors for children's psychosocial adjustment. The *PSI Total Stress* score, while not a direct attachment measure, may reflect aspects of the parent–child relationship, such as relational strain or reduced emotional availability. Elevated stress levels could indicate difficulties in the caregiving relationship that may impact developmental outcomes. Taken together, these findings can be interpreted within an attachment-informed framework, whereby family expressiveness may represent a relational strength, and parenting stress a potential vulnerability. This highlights the importance of emotional quality in the caregiving environment for promoting positive developmental trajectories.

It is important to note that family and child predictors were assessed using different methods and sources, with trained assessors administering child cognitive assessments and parents completing family questionnaires. This methodological separation mitigates potential bias from shared informant effects, particularly in the interpretation of associations between family variables and child cognitive outcomes.

4.2 Limitations and Future Directions

This study is not without limitations. First, while early cognitive data were collected prospectively, family predictors and child outcomes at follow-up were assessed concurrently, limiting causal interpretations. Though cross-sectional respondent bias was mitigated by the study design i.e. neurocognitive outcomes were independently assessed in a standardised manner, future research should incorporate repeated measures of family functioning and child outcomes across developmental stages to better examine temporal dynamics. Second, assessment of psychosocial outcomes relied on parent-report. This introduces potential reporting bias, especially where parental stress or mental health difficulties are present (Däschle et al., 2023). Future studies may benefit from multi-informant designs including teacher reports or observational assessments to triangulate findings, and the inclusion of paternal as well as maternal mental health data which was beyond the scope of this study.

Third, the sample, while drawn from the community, was not nationally representative. High maternal education levels and lower rates of lone parenting may have influenced the generalisability of findings. The achieved sample size was constrained by the number of participants from the original study who were eligible and available at follow-up, and no a priori power analysis was conducted. As such, the study may not have provided sufficient statistical power to detect smaller effects, underscoring the need for caution in interpreting findings where effect sizes were small. Larger and more socioeconomical diverse samples would support broader application of results. Finally, while exploratory regression models were theoretically informed and statistically appropriate, replication in larger samples is needed to validate these patterns. Inclusion of additional ecological variables, such as community resources, peer relationships, or cultural norms, may also enhance explanatory power in future studies.

5. Conclusion

The current study contributes to a nuanced understanding of early childhood development by demonstrating that family-level variables, particularly those reflecting parenting stress and emotional climate, make significant contributions to child developmental outcomes, above and beyond early cognitive functioning. These findings support integrative approaches that recognise the family environment as a central and modifiable influence on children's cognitive and psychosocial development. Unlike many structural or biological risk factors, dynamic family variables are amenable to change through psychological and social interventions, underscoring their relevance as targets for early, preventative support.

The results further affirm the importance of including family wellbeing assessments in early developmental monitoring frameworks. Addressing parental stress and strengthening the caregiving environment may offer practical opportunities to enhance child outcomes, particularly during the highly sensitive preschool period. This research affirms the value of a holistic, systems-oriented approach to child development, recognising the family environment not as a peripheral context, but as a central and modifiable influence shaping developmental outcomes. By integrating both child and family-level predictors, it highlights the multifactorial nature of development and the importance of attending to the caregiving environment in efforts to support optimal outcomes for young children.

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Chapter 5: Empirical Study 2 Supplementary Information

1. Additional Methodological Detail

Included in this section is additional methodological information to supplement the paper for Empirical Study 2, in Chapter 4. Some information relating to participants, assessment procedures, and outcome measures, which are also relevant to this study have been previously outlined in Supplementary Chapter 3. Where relevant, the reader will be directed to refer to previous sections in lieu of repetition of information.

1.1 Procedure

Ethical approval was granted by the Clinical Research Ethics Committee (CREC; Appendix A). Procedures relating to participant recruitment, child neurodevelopmental assessment, and related protocols regarding child distress, and assessment follow-up and feedback, have been outlined in Chapters 2 and 3.

The current study additionally recruited parent participants as outlined in the main paper. There were few expected risks to parents from participating in the study. Parent questionnaires were completed concurrently to child assessments. The researcher was available to parent participants during this time to answer questions relating to questionnaires. Where possible, parents were asked to wait until the child assessment was completed to ask questions, so as not to distract their child during assessment i.e. to avoid interfering with assessment validity. Additional time was allowed for parents to complete questionnaires if they were not completed within the time of the child's assessment; the researcher was available to engage with the child during this time, to allow for parents to complete questionnaires without distraction. Participants would be reminded that their participation was voluntary and that they were free to withdraw without consequence, and a debriefing session would be offered.

While it was not envisaged that participation would increase parental distress, data were collected related to symptoms of depression, anxiety and stress. The *DASS-21* and the *PSI-SF* are not a diagnostic tools, but are indicative of participants' level of mood disturbance, thus, it may be possible through their use to identify participants who are clinically at risk of mental health problems. Participant scores were appropriately monitored by the research team, and a protocol was in place for instances where scores were of concern. Specifically, where a profile score of 1.5 standard deviation above normative sample means for depression and anxiety (on *DASS-21*) was observed by a member of the research team, a response would be prompted. The participant would be contacted by phone by a qualified member of the research team, to further explore their concerns. Where appropriate, participants would be signposted to sources of support within the HSE or other services. Data was stored according to GDPR and Data Protection Law.

1.2 Outcome measures

The neuropsychological outcome measures administered at both baseline and follow-up have been outlined in section 3.3 in Supplementary Chapter 3. This section outlines the additional psychosocial outcome measures used in this study, and measures used to assess dynamic family factors.

1.2.1 Strengths and Difficulties Questionnaire (SDQ)

The *SDQ* is a widely used behavioural screening tool designed for children and adolescents aged 2 to 17 years (Goodman, 1997). It is available in several versions, including parent-report, teacher-report, and self-report (for children aged 11 and over). In the current study, the 25-item parent-report version of the *SDQ* was utilised, which includes five subscales: *Emotional Symptoms, Conduct Problems, Hyperactivity/Inattention, Peer Relationship Problems,* and *Prosocial Behaviour.* Each subscale consists of five items rated on a 3-point Likert scale (0 = Not true, 1 = Somewhat true, 2 = Certainly true), reflecting the frequency or severity of specific behaviours over the past six months. The *SDQ Total Difficulties* Score is calculated by adding the scores of the four difficulty subscales (i.e. all except *Prosocial Behaviour*), yielding a total score ranging from 0 to 40, with higher scores indicating greater psychosocial difficulties. The *Prosocial Behaviour* subscale, scored separately, reflects strengths in prosocial functioning such as kindness and helpfulness, with higher scores indicating more positive behaviours.

The *SDQ* is recognised for its utility in both clinical and research settings, offering a brief yet comprehensive snapshot of child behavioural and emotional functioning. It has been widely validated across multiple populations and age groups and is often used for population-based screening, early detection of difficulties, and monitoring of psychosocial development over time. The tool has been standardised in large populations in the US and UK (Bourdon et al., 2005; Meltzer et al. 2003). The *SDQ* demonstrates good internal consistency, with reported Cronbach's alpha values typically ranging from .70 to .80 for the *SDQ Total Difficulties* score, and slightly lower for individual subscales (Goodman, 2001; Stone et al., 2010). Test–retest reliability and concurrent validity with other established behavioural measures (e.g. the *Child*

Behaviour Checklist) have also been demonstrated (Goodman, 1997; Goodman et al., 2000). Scoring and interpretation are based on established normative thresholds, which allow for the categorisation of scores into normal, borderline, or abnormal ranges (Goodman, 1997). This facilitates comparisons with community samples and provides clinically meaningful insight into behavioural functioning.

1.2.2 Depression Anxiety Stress Scales – 21 items (DASS-21)

The *DASS-21* is a widely used self-report instrument designed to measure negative emotional states in adults, specifically depression, anxiety, and stress (Lovibond & Lovibond, 1995). The *DASS-21* is a shortened version of the original 42-item scale and comprises three subscales, each consisting of seven items that assess the severity of symptoms related to their respective domains. The *Depression* scale evaluates dysphoria, hopelessness, and low self-esteem; the *Anxiety* scale measures autonomic arousal, situational anxiety, and subjective feelings of panic; and the *Stress* scale captures chronic non-specific arousal such as tension, agitation, and difficulty relaxing.

Each item is rated on a 4-point Likert scale ranging from 0 (“Did not apply to me at all”) to 3 (“Applied to me very much or most of the time”), with higher scores indicating greater levels of distress. The *DASS-21* has demonstrated strong psychometric properties across community and clinical populations, including high internal consistency and convergent validity with other measures of psychological distress (Henry & Crawford, 2005). It is particularly well-suited for use in community-based research due to its brevity, clarity, and ability to capture a broad spectrum of emotional difficulties. The *DASS-21* is not intended to provide clinical diagnoses but is valuable for identifying individuals experiencing elevated levels of emotional symptoms and for evaluating outcomes in intervention and epidemiological research.

1.2.3 Parenting Stress Index – Short Form (PSI-SF)

The *PSI-SF* is a 36-item parent-report measure designed to assess the magnitude of stress experienced by parents in the context of their parenting role (Abidin, 1995; 2012). The *PSI-SF* is derived from the full-length *Parenting Stress Index* and retains strong psychometric properties, making it a widely used tool in both clinical and research settings. The measure yields a *Total Stress* score, as well as scores across three subscales: *Parental Distress (PD),* which reflects stress directly associated with the parenting role; *Parent-Child Dysfunctional*

Interaction (PCDI), which assesses the parent's perception of the child not meeting their expectations; and *Difficult Child (DC),* which evaluates child temperament and behaviour characteristics that may contribute to parenting stress.

Responses are rated on a 5-point Likert scale ranging from "Strongly Agree" to "Strongly Disagree." Higher scores indicate greater levels of stress. The *PSI-SF* has demonstrated good internal consistency, test-retest reliability, and validity in both normative and clinical populations (Abidin, 1995; Haskett et al., 2006). In non-clinical samples, *PSI Total Stress* scores typically range from 65 to 70, with scores above the 85th percentile indicating clinically significant levels of parenting stress. In the current study, only the *PSI Total Stress* score was used in analyses as a general indicator of parenting-related stress. This allowed for a concise yet comprehensive reflection of overall parental stress levels within the sample.

1.2.4 The Family Environment Scale (FES)

The *FES* (Moos & Moos, 2002) is a widely used instrument designed to assess the social-environmental characteristics of families. It consists of 90 true–false items and provides standardised scores across ten subscales, grouped into three underlying indices: Relationship, Personal Growth, and System Maintenance. The Relationship index includes three subscales: *Cohesion* (the degree of commitment, help, and support family members provide for one another), *Expressiveness* (the extent to which family members are encouraged to express their feelings openly), and *Conflict* (the amount of openly expressed anger and conflict among family members). The Personal Growth index comprises *Independence* (emphasis on self-sufficiency and decision-making), *Achievement Orientation* (focus on achievement and competition), *Intellectual–Cultural Orientation* (interest in political, intellectual, and cultural activities), *Active–Recreational Orientation* (participation in social and recreational activities), and *Moral–Religious Emphasis* (emphasis on ethical and religious issues). The System Maintenance index includes *Organisation* (importance of clear structure and planning in family activities) and *Control* (the extent of rules and procedures governing family life).

In the current study, six *FES* subscales were administered: *Cohesion*, *Expressiveness*, *Conflict*, *Active Recreational Orientation*, *Organisation*, and *Control*. These subscales were selected to capture a comprehensive picture of family dynamics, particularly as they relate to emotional climate, communication patterns, and the structural organisation of the family environment. Scaled scores were calculated for each subscale, allowing for comparison with general population norms. The *FES* has demonstrated good internal consistency and construct validity in both clinical and non-clinical populations (Moos & Moos, 2002), and has been shown to be a reliable tool for assessing the family context in developmental and psychological research.

2. Additional Analyses

This section details the procedures undertaken to prepare the dataset for statistical analysis, including data cleaning, assessment of normality, and quality assurance checks. Justification for the selection of statistical tests is also provided. In addition, supplementary analyses that support or elaborate on the findings presented in the main paper are included here. In particular, further detail is provided relating to regression analyses results for child neurodevelopmental outcomes, which were summarised in the primary results section.

2.1 Data Cleaning and Outlier Handling

Prior to conducting tests of normality and statistical analyses, in addition to the visual inspection of histograms conducted, the dataset was screened for outliers. Outlier handling was tailored to the nature and context of each variable, although they were consistently defined as standardised scores on an outcome measure that were more than 3 standard deviations above or below the mean. Stem-and-leaf plots were examined using SPSS version 29.0.2.0.

For the *CogniTOT Total* score $n = 3$ outliers were removed (i.e. re-coded as missing values). These outlier values did not appear to reflect meaningful developmental variability, as they were substantially beyond the expected range for typically developing children and were not consistent with other indicators of the child's developmental profile. As such, they were deemed likely to distort the distribution and were excluded to preserve the validity of the analyses. In contrast, a small number of outliers ($n = 4$) were identified in parent and family related variables, including *DASS Depression, DASS Anxiety*, and *FES Cohesion*. These were retained in the dataset, as they were judged to reflect meaningful variability in psychological and family functioning within a community sample, rather than data entry error or aberrant responding. Sensitivity analyses confirmed that inclusion of these outliers did not materially alter the overall pattern of results. This approach aligns with best practices that recommend context-sensitive handling of extreme values (Field, 2018).

2.2 Assessment of Normality

Tests of normality were conducted for all test variables, given the use of parametric statistical analyses. For many variables, the Shapiro–Wilk test yielded statistically significant results (p

< .05), indicating potential non-normality. However, given that the test is highly sensitive in larger samples and often flags minor, non-meaningful deviations (Ghasemi & Zahediasl, 2012), these results were interpreted in conjunction with visual inspection and skewness/kurtosis metrics. In cases where both visual and numerical evidence supported approximate normality, variables were retained in their original form for parametric analysis. Skewness values between -2 and +2, and kurtosis values between -7 and +7, were interpreted as indicating acceptable levels of variation and a distribution approximating normality (West, Finch, & Curran, 1995). For most variables, skewness and kurtosis values were within acceptable limits, indicating sufficient normality for parametric testing. However, two exceptions were observed. As described in Chapter 3 section 3.4.2, a log10 transformation was applied to the *Processing Speed* variable to correct for skewness; the new variable was used for subsequent parametric tests.

The *DASS Depression* subscale exhibited non-normality, with skewness and kurtosis values of 2.54 and 8.95, respectively. While this exceeded conventional thresholds for normality, a transformation was not applied. This decision was guided by several considerations: (1) parametric tests such as Pearson's correlation are robust to moderate violations of normality, particularly with larger sample sizes (Norman, 2010); (2) retaining untransformed scores supports interpretive clarity, particularly when using norm-referenced psychological measures; and (3) positively skewed depression scores are typical in non-clinical community samples and reflect the expected distribution of distress in general populations (Henry & Crawford, 2005).

To ensure the robustness of findings, non-parametric analyses were also conducted. Spearman's rho correlations were calculated to examine the associations between *DASS Depression* scores and child psychosocial outcomes. Results closely mirrored those obtained from Pearson's correlations. Specifically, the correlation between *DASS Depression* and *SDQ Total Score* remained significant with both Pearson's $r = .409$, $p < .001$ and Spearman's $\rho = .433$, $p < .001$. For the *SDQ Prosocial Subscale*, both Pearson's $r = –.104$, $p = .344$ and Spearman's $\rho = –.054$, $p = .625$ indicated non-significant associations. The consistency in the pattern and strength of correlations between parametric and non-parametric tests suggests that the non-normal distribution of the *DASS Depression* variable did not substantially influence the results. This supports the decision to retain untransformed scores in the main analysis to preserve clarity and interpretability. Data was subsequently analysed using parametric tests.

2.3 Quality Assurance Procedures

Quality assurance procedures were employed to ensure the integrity of the data. Procedures included the authors routinely cross-checking scoring of both child and parent completed outcome measures during data-collection. The accurate transfer of data from outcome measures to SPSS 29.0.2.0 was also cross-checked. Furthermore, two authors individually checked the data and performed statistical tests, thereafter meeting as a pair to review results. Workings were reviewed as appropriate where inconsistencies or anomalies arose. Each statistical test was performed more than once to ensure consistency in findings.

2.4 Hierarchical Regression Analyses: Child Neurodevelopmental Outcomes at Age Five

As outlined in the main paper, a series of hierarchical multiple regressions were conducted to examine the extent to which early cognitive functioning, family structural factors, and family dynamic variables predicted child neurodevelopmental outcomes at age five across nine *WPPSI-IV* and *NEPSY-II* subscales. Building on the summary presented in Table 4.10 of the main paper, this section presents the full regression models for each outcome, allowing for a more detailed exploration of the predictors and their unique contributions. Predictor variables were entered in blocks, reflecting a theoretically informed sequence whereby infant cognitive functioning was considered the most proximal predictor, followed by family structure, and then dynamic family factors, which reflect more immediate psychosocial influences on child development (i.e. Block 1 – Early cognitive functioning; Block 2 – family structural factors; Block 3 – family dynamic factors). All variables with significant bivariate associations with each outcome were included in the relevant regression model.

The adjusted R^2 values across outcomes illustrate considerable variation in the proportion of explained variance. Across the full set of models, the strongest total variance explained was observed for *Similarities* (adj. $R^2 = .30$), followed by *Receptive Vocabulary* (.21) and *Picture Naming* (.20). These results align with the broader literature suggesting that verbal and language outcomes are particularly sensitive to both early cognitive ability and environmental influences.

For several outcomes, including *Similarities*, *Receptive Vocabulary*, and *Design Copying*, early cognitive scores alone accounted for a modest but significant proportion of variance. This suggests some predictive utility of infant cognitive assessments, particularly for verbal and visuospatial domains. The addition of family structural variables resulted in improved model fit for select outcomes, such as *Picture Naming* and *Narrative Memory*, indicating that demographic and contextual characteristics (e.g., parental age, family composition) provide additional explanatory power in understanding children's cognitive functioning. The inclusion of family dynamic variables in the final block further improved prediction in multiple domains. For example *Bug Search*, *Similarities,* and *Comprehension of Instructions* all showed meaningful increases in explained variance when measures of parental well-being and family functioning were added. Notably, parenting stress (*PSI-SF*) and family expressiveness (*FES*) emerged as consistent contributors across several models, underscoring the influence of the home environment and caregiver wellbeing on child neurodevelopmental trajectories.

Taken together, these analyses highlight the multifactorial nature of child cognitive development, showing that while early cognitive performance contributes to later outcomes, the child's social and familial context plays an important and additive role. These findings offer a more granular understanding of the predictive pathways explored in this study and provide a foundation for further hypothesis generation in future research. Full regression models for each outcome are provided in Tables 5.1 to 5.9 below.

Table 5.1

Results of hierarchical regression analyses predicting WPPSI-IV Matrix Reasoning scores

	Stand. Beta	Adjusted r^2	F	p
Block 1		0.06	6.0	0.016
Child Medical Condition	-0.26*			
Block 2		0.10	5.67	0.005
Child Medical Condition	-0.22*			
FES Conflict	-0.24*			

Note. WPPSI-IV = Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version), FES = Family Environment Scale
* $p < 0.05$

Table 5.2

Results of hierarchical regression analyses predicting WPPSI-IV Matrix Reasoning score

	Stand. Beta	Adjusted r^2	F	p
Block 1		0.04	4.25	0.043
Bayley's Motor Composite	0.23*			
Block 2		0.14	5.2	0.003
Bayley's Motor Composite	0.2			
FES Expressiveness	0.23*			

	Stand. Beta	Adjusted r^2	F	p
PSI Total Stress	-0.23*			

Note. WPPSI-IV = Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version), FES = Family Environment Scale, PSI = Parenting Stress Index – Short Form
* $p < 0.05$

Table 5.3

Results of hierarchical regression analyses predicting WPPSI-IV Picture Memory scores

	Stand. Beta	Adjusted r^2	F	p
Block 1		0.04	4.26	0.042
Family Composition	0.22*			

Note. WPPSI-IV = Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version)
* $p < 0.05$

Table 5.4

Results of hierarchical regression analyses predicting WPPSI-IV Similarities scores

	Stand. Beta	Adjusted r^2	F	p
Block 1		0.17	5.9	0.001
CogniTOT Cognitive Shift	0.28*			
Bayley's Cognitive Composite	-0.07			
Bayley's Language Composite	0.42**			
Block 2		0.22	6.24	<0.001
CogniTOT Cognitive Shift	0.26*			
Bayley's Cognitive Composite	-0.05			
Bayley's Language Composite	0.36*			
Child Medical Condition	-0.26*			
Block 3		0.3	5.51	<0.001
CogniTOT Cognitive Shift	0.18			
Bayley's Cognitive Composite	0.003			
Bayley's Language Composite	0.28			
Child Medical Condition	-0.24*			
DASS Anxiety	-0.27*			
DASS Stress	-0.01			
FES Expressiveness	0.15			

Note. WPPSI-IV = Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version), DASS = Depression, Anxiety and Stress Scale - 21, FES = Family Environment Scale
* $p < 0.05$
** $p < 0.01$

Table 5.5

Results of hierarchical regression analyses predicting WPPSI-IV Receptive Vocabulary scores

	Stand. Beta	Adjusted r^2	F	p
Block 1		.19	6.84	<0.001
CogniTOT Cognitive Shift	0.33**			
Bayley's Cognitive Composite	-0.07			
Bayley's Language Composite	0.41**			
Block 2		0.21	4.15	0.001
CogniTOT Cognitive Shift	0.3*			
Bayley's Cognitive Composite	-0.05			
Bayley's Language Composite	0.38*			
DASS Stress	-0.13			
DASS Anxiety	-0.07			
PSI Total Stress	-.05			

Note. WPPSI-IV = Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version), DASS = Depression, Anxiety and Stress Scale - 21, PSI = Parenting Stress Index – Short Form
* $p < 0.05$
** $p < 0.01$

Table 5.6

Results of hierarchical regression analyses predicting WPPSI-IV Picture Naming scores

	Stand. Beta	Adjusted r^2	F	p
Block 1		0.05	3.47	0.069
Bayley's Language Composite	0.27			
Block 2		0.18	3.49	0.015
Bayley's Language Composite	0.25			
No. of siblings	-0.17			
Paternal Age	-0.34			
Maternal Age	-0.02			
Block 3		0.20	3.31	0.013
Bayley's Language Composite	0.24			
No. of siblings	-0.2			
Paternal Age	-0.35*			
Maternal Age	0.03			
FES Cohesion	0.2			

Note. WPPSI-IV = Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (UK Version), FES = Family Environment Scale
* $p < 0.05$

Table 5.7

Results of hierarchical regression analyses predicting NEPSY-II Comprehension of Instructions scores

	Stand. Beta	Adjusted r^2	*F*	*p*
Block 1		0.06	5.81	0.018
Bayley's Language Composite	0.27*			
Block 2		0.13	4.67	0.005
Bayley's Language Composite	0.23*			
DASS Anxiety	-0.14			
FES Expressiveness	0.14*			

Note. NEPSY-II = NEPSY–Second Edition: A Developmental Neuropsychological Assessment, DASS = Depression, Anxiety and Stress Scale - 21, FES = Family Environment Scale
* $p < 0.05$

Table 5.8

Results of hierarchical regression analyses predicting NEPSY-II Narrative Memory scores

	Stand. Beta	Adjusted r^2	*F*	*p*
Block 1		0.04	4.46	0.038
Family Composition	-0.23*			
Block 2		0.09	5.0	0.009
Family Composition	-0.22*			
FES Expressiveness	0.25*			

Note. NEPSY-II = NEPSY–Second Edition: A Developmental Neuropsychological Assessment, FES = Family Environment Scale
* $p < 0.05$

Table 5.9

Results of hierarchical regression analyses predicting NEPSY-II Design Copying scores

	Stand. Beta	Adjusted r^2	*F*	*p*
Block 1		0.2	4.65	0.003
Bayley's Cognitive Composite	0.02			
Bayley's Language Composite	0.25			
Bayley's Motor Composite	0.19			
CogniTOT Sustained Attention	0.35**			

Note. NEPSY-II = NEPSY–Second Edition: A Developmental Neuropsychological Assessment
* $p < 0.05$

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Chapter 6: Integrative Discussion

1. Overview of the Research Aims and Approach

This thesis aimed to examine predictors of child neurodevelopmental and psychosocial outcomes through two complementary studies, using a longitudinal community-based sample of children assessed in infancy and followed up at age five. Study 1 focused on evaluating the concurrent validity and predictive associations between a novel touchscreen-based cognitive assessment tool, *CogniTOT*, and neurocognitive functioning, as assessed through standardised tools such as the *Bayley-III*, *WPPSI-IV*, and *NEPSY-II*. Specifically, this study sought to determine whether early *CogniTOT* scores were predictive of later neurodevelopmental outcomes, such as verbal reasoning, memory, and executive functioning, and to examine how well *CogniTOT* measures aligned with established developmental frameworks.

Study 2 investigated how family structural and dynamic factors, such as parenting stress, maternal mental health, and family functioning, contribute to neurodevelopmental and psychosocial outcomes in early childhood, focusing on how these variables might interact with early cognitive functioning to influence developmental trajectories. In doing so, this study aimed to identify critical environmental and familial predictors of child development, grounded in ecological and dynamic systems theories. Together, these studies contribute to advancing knowledge on the role of both early cognitive assessments and family dynamics in shaping developmental outcomes, with an emphasis on how early interventions can be informed by these factors. The extended discussion presented here provides an integrative synthesis of the two studies, reflecting on how the findings contribute to theoretical models of development, clinical practice, and policy, particularly in relation to early intervention and the design of more sensitive, accessible assessment tools.

2. Integrating and Contextualising Findings Across Studies

Together, the two studies demonstrate that early developmental outcomes are shaped by a dynamic interplay between individual cognitive functioning and broader family and environmental contexts. Study 1 provided evidence of the modest but meaningful concurrent validity between *CogniTOT* and the *Bayley-III Cognitive Composite*, suggesting that touchscreen-based tools may provide scalable and accessible measures of early cognitive functioning. However, the study also highlighted significant limitations in the predictive power of both the *CogniTOT* and *Bayley-III* tools, with modest and inconsistent associations observed between infant cognitive scores and neurodevelopmental outcomes at age five.

Findings resonate with broader concerns in the literature regarding the limitations of early cognitive assessments in predicting longer-term outcomes, in both typically developing and higher risk populations (Anderson & Burnett, 2017; Rasheed et al., 2023). As highlighted in the current research, the non-linear nature of early development, latent vulnerabilities, and variability in developmental trajectories pose inherent challenges to early prediction (Davis & Sandman, 2012; Gowda et al., 2024). Development in infancy and toddlerhood is characterised by rapid change, periods of regression and consolidation, and marked individual variability, rendering static assessments of limited prognostic value (Johnson, 2001; Mills et al., 2014). Neurodevelopmental outcomes are influenced by a constellation of biological, psychological, and environmental factors which interact dynamically over time (Doss et al., 2019; Shonkoff et al., 2012; Sameroff, 2009). This complexity means that early assessments may be vulnerable to false positives or negatives, with children either over-pathologised or, conversely, overlooked due to the absence of overt delay at the time of screening. This is especially true for the vast majority of children in the "normal" range and even "low-average" performers. Early assessment tools may be more accurate at the extremes of development, where delays or advanced development are more easily detectable. However, the latent effects of early vulnerabilities, coupled with neuroplasticity and dynamic changes during this period, make it much more difficult to predict outcomes for the majority of children who appear to be developing typically or within the low-average range.

In this context, the value of early assessment tools may lie less in their ability to offer precise forecasts and more in their utility as part of broader surveillance strategies that capture evolving developmental patterns. Increasingly, developmental science is shifting away from deterministic models of early screening and toward longitudinal monitoring frameworks that account for developmental plasticity and environmental modulation (Guralnick, 2017; Johnson & Marlow, 2016). This approach aligns with public health models that advocate for tiered surveillance, combining universal developmental monitoring with targeted assessments for children at elevated risk (Sheldrick & Perrin, 2013). Within clinical psychology, such models support a shift from one-off assessments to ongoing developmental formulation, where early tools, such as the touchscreen-based assessment evaluated in Study 1, serve as adjuncts to clinical judgment, helping to flag areas of concern that warrant continued observation rather than definitive diagnostic conclusions.

Moreover, the adoption of developmentally appropriate, scalable tools holds potential for improving early identification within underserved or low-resource settings, where access to specialist assessment is often limited (Twomey et al., 2018; Villagomez et al., 2019). Tools that are non-verbal, engaging, and require minimal training to administer may help bridge gaps in services by enabling earlier, routine surveillance at the primary care or community level, particularly when embedded within collaborative interagency models. Importantly, such tools should be interpreted within a broader ecological framework, where child functioning is understood in relation to contextual variables, including family dynamics and parental wellbeing, rather than in isolation. This integrated approach has been increasingly endorsed in clinical developmental psychology, where there is growing recognition of accurate identification and early intervention being dependent on consideration of assessments themselves, as well as important contextual factors (Guralnick, 2017; Shonkoff & Garner, 2012).

In the Irish context, this aligns with current efforts to enhance early identification and developmental surveillance within community services, particularly in light of the *Progressing Disability Services for Children and Young People* (*PDS*) programme. This national initiative emphasises a family-centred, interdisciplinary approach to care and acknowledges the importance of early intervention pathways that can flexibly respond to developmental concerns as they emerge. However, challenges remain regarding long wait times and limited access to specialist assessments (Oireachtas Library & Research Service, 2021), highlighting the potential value of scalable, low-burden tools that can be integrated into primary care and early years settings to inform ongoing developmental formulation. As such, incorporating tools like *CogniTOT* may help support clinicians in navigating the increasing demand for developmental evaluations within overstretched systems, by facilitating structured, repeatable, and developmentally appropriate screening that complements clinical expertise.

Study 2 addressed a critical limitation of Study 1 by incorporating family-level variables into developmental prediction models. Consistent with ecological and systems-oriented frameworks (Bronfenbrenner, 1986; Thelen & Smith, 1994), findings from Study 2 confirmed that family dynamics, especially parenting stress and maternal mental health, were stronger predictors of both psychosocial and neurocognitive outcomes than early cognitive functioning alone. In hierarchical regression analyses, parenting stress emerged as the most robust predictor across multiple domains, even after accounting for early cognitive performance and structural variables such as parental education or family composition. Importantly, Study 2 demonstrated that by enriching the explanatory model with measures of family functioning, such as cohesion, expressiveness, and conflict, significant additional proportions of the variance in child outcomes were explained. These findings support prior research showing that emotionally responsive caregiving environments buffer against adverse outcomes, even in contexts of stress or adversity (Garcia et al., 2020; Marsh et al., 2020). Notably, associations between family expressiveness and child prosocial behaviour suggest that relational warmth and open emotional communication are protective factors with developmental significance.

A novel contribution of Study 2 is the emphasis on the dynamic interplay between family functioning and parenting stress as predictors of child development, specifically highlighting how family expressiveness and cohesion contribute to positive child outcomes in the context of parental stress. This underscores the importance of considering not only the structural aspects of family life but also the emotional quality of family interactions when predicting developmental trajectories in children. By examining these factors in a community sample, Study 2 provides new insights into the mechanisms that support healthy child development even in the face of adversity, extending the literature on the protective role of family dynamics beyond clinical or high-risk populations.

From a clinical psychology perspective, these findings underscore the value of attending to relational dynamics in both assessment and intervention. Interventions aimed at improving family communication and cohesion, such as attachment-based or systemic family therapies, may have cascading benefits across multiple domains of child functioning (Kehoe et al., 2020; Toth et al., 2013). Furthermore, these results align with evidence that relational qualities of the home environment, rather than structural factors alone, are more predictive of children's socioemotional competence (Gao et al., 2023; Winston & Chicot, 2016). Indeed, children growing up in emotionally expressive, structured, and low-conflict environments tend to show greater resilience to external stressors and better adaptive functioning, even in the presence of parental psychological distress (Morris et al., 2007; Phua et al., 2020).

Clinically, these findings advocate for the inclusion of family systems variables in developmental formulations and case conceptualisation, particularly when working with young children presenting with behavioural or emotional difficulties. The data suggest that interventions solely focused on the child may be limited in their efficacy unless the broader emotional ecology of the family is also addressed. In line with ecological and transactional models of development (Bronfenbrenner, 1986; Sameroff, 2009), this research highlights how child outcomes emerge from ongoing interactions between individual capacities and the relational context, emphasising the clinician's role in supporting the caregiving environment as a modifiable and therapeutically potent mechanism of change.

3. Relevance to Clinical Psychology and Practice

The findings have clear relevance for clinical psychology, particularly in the areas of early assessment, intervention, and family-centred care, some of which have been referenced. First, the limited predictive power of standardised tools observed in Study 1 suggests that sole reliance on early cognitive scores may be insufficient for identifying children at risk for later difficulties. Instead, clinicians should consider integrating family-focused variables, such as parenting stress, mental health, and relational functioning, into routine developmental screening. This may involve the use of brief screening tools for parenting stress, maternal mental health, and family functioning during routine developmental assessments. Instruments such as the *Parenting Stress Index* (Abidin, 2012) or the *Family Environment Scale* (Moos & Moos, 2002) may offer accessible means of capturing relevant dimensions of family life, particularly when administered alongside standardised child assessments.

Where concerns arise, clinicians may use these data to inform broader systemic interventions, such as parenting support, stress management, or family therapy, in addition to direct work with the child. Such practices are particularly relevant in the Irish context, where access to child mental health and developmental services is often constrained, and identification processes may rely heavily on brief observations or one-time assessments within primary care or educational settings (Oireachtas Library & Research Service, 2021). The current findings support calls for more integrative, developmentally attuned service models in Ireland that recognise the centrality of the caregiving system in both the emergence and remediation of developmental difficulties. Within such models, clinicians might adopt a tiered formulation approach that includes both individual and systemic factors, ensuring that interventions are responsive to the full complexity of children's lived developmental environments.

Relatedly, the findings speak to the transactional nature of development. Bidirectional associations between parenting stress and child behavioural difficulties, as referenced in Study 2, reinforce the view that child and caregiver influence each other over time in mutually reinforcing cycles (Baker et al., 2003; Neece et al., 2012;). Although causality cannot be inferred from the current design, the consistency of these associations underscores the need for developmental models that incorporate temporal reciprocity and feedback loops. The overall findings, thus, highlight the importance of supporting parental wellbeing and reducing parenting stress as a central strategy in promoting child development. Interventions that target parental stress, enhance family cohesion, and support emotionally expressive parenting may be particularly effective in promoting both cognitive and socioemotional development, even in the absence of diagnosable mental health difficulties. This aligns with preventative frameworks in clinical psychology, which emphasise early identification and low-threshold interventions to mitigate risk trajectories (Peacock-Chambers et al., 2017).

The findings from both studies suggest the need for flexibility and innovation in assessment strategies. The *CogniTOT* tool represents a promising example of scalable, non-verbal, and child-friendly technology that may be particularly useful in low-resource settings or with children who have verbal, motor, or attentional difficulties. However, ongoing refinement and psychometric validation are needed before it can be integrated into clinical protocols.

4. Developmental Trajectories and Latent Effects

These findings also support the concept of latent vulnerability, which suggests that early exposures may not yield immediate deficits but can become salient as developmental demands increase with age (Anderson et al., 2012; Brandt et al., 2024). This was particularly evident in the predictive value of early family environment factors for later executive and memory-related functions; early caregiving environments were associated with later cognitive functioning, highlighting how early experiences shape emerging capacities. Within this framework, it is proposed that early adversity or suboptimal relational contexts may alter the structure and functioning of neural systems involved in self-regulation, attention, and memory, creating a neurocognitive profile that may remain latent until triggered by developmental transitions, environmental stressors, or increased environmental demands, such as those encountered during the transition to formal schooling (Gilmore et al., 2012; Mills et al., 2014).

Importantly, this concept also extends to children who have experienced early neurological insult or injury, such as those in the HIE subgroup within this thesis, where neurodevelopmental effects may not be readily observable in infancy. Study 1 found that early cognitive assessments, including the *Bayley-III* and *CogniTOT*, demonstrated only modest predictive validity for later neurodevelopmental outcomes. This is consistent with research showing that children with early brain injury, including mild HIE may present within the average range in early childhood, yet later demonstrate difficulties with higher-order functions as demands increase (Anderson et al., 2005; van Kooij et al., 2010; Westmacott et al., 2009). These "sleeper effects" are characteristic of vulnerability and highlight the need for developmental monitoring that extends beyond the infancy period.

From a clinical psychology perspective, these findings emphasise the importance of adopting a developmental formulation that is sensitive to both relational and biological risks, even when early functioning appears typical. Children who experience early neurological disruptions may benefit from anticipatory guidance and continued surveillance, not because deficits are certain to emerge, but because the likelihood of later challenges may be increased in subtle or domain-specific ways. Furthermore, the impact of such early biological vulnerabilities may be shaped by concurrent environmental factors, such as parenting stress or family cohesion, which either buffer or exacerbate latent risk trajectories (Bick & Nelson, 2017).

The findings from Study 1 also reinforce the latent vulnerability perspective by demonstrating that performance on early cognitive assessments, including both the *Bayley-III* and *CogniTOT*, had only modest predictive utility for later functioning. This aligns with broader evidence that early assessments, particularly those conducted before the consolidation of core executive functions, may not fully capture future vulnerabilities (Anderson et al., 2005; Johnson & Marlow, 2016). In this sense, the weak and inconsistent associations observed between early cognitive measures and later outcomes may not necessarily reflect measurement limitations alone, but may also point to the developmental reality that early vulnerabilities require time, and context, to become behaviourally evident. This interpretation does not imply determinism, but rather supports the view that early relational experiences shape the scaffolding upon which later cognitive and behavioural capacities are built. It underscores the importance of identifying modifiable environmental factors early and targeting these through interventions that support family functioning and reduce stress, in order to bolster children’s resilience and adaptive capacities over time. Within an Irish context, where structured developmental follow-up is not routinely embedded into primary care, the findings advocate for longitudinal, formulation-driven models that remain sensitive to latent trajectories of vulnerability and change.

5. Policy Implications and Future Directions

The findings have practical implications for policy and service provision. In particular, the centrality of parenting stress as a predictor of child outcomes suggests that early years services should prioritise support for parental wellbeing. Integrating validated screening tools for parenting stress and family functioning into routine child health assessments could facilitate earlier identification of families who may benefit from additional support. In line with recommendations from Marsh et al. (2020), family environments marked by disorganisation or conflict may function as early risk markers, offering actionable targets for intervention. Further, the results affirm the need for policy initiatives that promote mental health access for mothers, including those not meeting diagnostic thresholds. Subclinical symptoms may still have profound effects on parenting and child development. Accordingly, universal and tiered supports that enhance parental wellbeing, strengthen caregiver-child relationships, and promote stable caregiving environments may reduce long-term risk and support positive developmental trajectories (Kingston & Tough, 2014; Verdisco et al., 2016).

Future research should seek to replicate the current findings in more diverse and representative samples, particularly in contexts of socioeconomic disadvantage or high-risk clinical populations. Longitudinal designs incorporating repeated measures of child and family variables would also allow for more robust examination of developmental trajectories and causal pathways. Further, this thesis highlights the potential value of more nuanced, contextually grounded assessment methods, such as ecological momentary assessment (EMA), in capturing fluctuations in family dynamics, parenting stress, and child behaviour in real-time. While beyond the scope of the current studies, future research could benefit from integrating EMA with observational, behavioural, and self-report measures to yield a richer, multi-informant understanding of the dynamic interplay between child characteristics and the family environment (Hamilton et al., 2020).

In sum, this thesis contributes to the evolving literature on early development by demonstrating that while early cognitive assessments offer valuable information, they must be situated within the broader context of family life. It highlights the enduring relevance of relational processes and the need for integrative, family-centred approaches to early identification and intervention. The findings underscore that in supporting child development, it is not only the child who must be seen, but the family system as a whole.

6. Conclusion

This thesis has explored early childhood development through two complementary lenses: the predictive utility of novel cognitive assessment tools in infancy, and the influence of family structural and dynamic factors on neurodevelopmental and psychosocial outcomes. Together, the findings provide a compelling argument for a multidimensional and contextually grounded approach to developmental science, one that recognises the complex, reciprocal relationships between child characteristics and their caregiving environment.

The results from Study 1 offer preliminary evidence supporting the concurrent validity of a novel, touchscreen-based tool, *CogniTOT*, as a non-verbal, scalable measure of general cognitive functioning in infancy. Although predictive associations were limited, particularly at the subscale level, these findings underscore the potential of innovative digital tools to augment existing assessment practices. As traditional assessments such as the *Bayley-III* continue to demonstrate only modest predictive power in community samples, there is a pressing need to develop tools that are both sensitive and practical for wide-scale early screening. In this regard, *CogniTOT* represents a promising step forward, particularly for use in low-resource or linguistically diverse settings, though continued refinement and validation of such methods will be essential to achieving this aim.

Study 2 extends this focus by demonstrating that child outcomes at age five, both cognitive and psychosocial, are strongly shaped by family-level factors, especially parenting stress and the emotional climate of the home. These findings resonate with dynamic systems theory and ecological models of development (Bronfenbrenner, 1986; Smith & Thelen, 2003), which emphasise the mutual influence between the child and multiple layers of their environment. Clinically, they highlight the limitations of child-only assessments and support a shift toward holistic, family-centred models of care. Importantly, the predictive significance of family variables, above and beyond early cognitive functioning, suggests that psychosocial risk may be better captured by assessing relational and environmental processes rather than relying solely on developmental test scores.

Contemporary research makes it increasingly clear that cognitive development is not a uniform or predictable progression. Taken together, this body of work supports a model of child development that is dynamic, multifactorial, and context-sensitive. It reinforces the importance of early identification and intervention, while cautioning against static interpretations of early test results. A developmental systems perspective, one that integrates cognitive, emotional, and relational domains, provides a more accurate and clinically relevant framework. For clinical psychology, this has clear implications: early assessments should inform ongoing developmental formulation and interdisciplinary care planning, ensuring that children at risk for later difficulties are identified not only through their test scores, but through a broader understanding of their caregiving ecology.

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Appendices

Appendix A Ethical Approval Letter

COISTE EITICE UM THAIGHDE CLINICIÚIL
Clinical Research Ethics Committee of the Cork Teaching Hospitals

University College Cork
Lancaster Hall
6 Little Hanover Street
Cork
Ireland

Tel: +353-21-4901901
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CREC Review Reference Number: ECM 4 (i) 06/02/2024
& ECM 3 (a) 05/03/2024

Date: 16th February 2024

Professor Deirdre Murray
Consultant Paediatrician
Department of Paediatrics
Cork University Hospital
Wilton
Cork

Study Title: Elf Study. Early Learning and Neurocognitive Function Study.

Dear Professor Murray

The following document has been approved:

Study Protocol	Version 2.0 dated 14th February 2024.

Full approval is now granted to carry out the above study. The date of this letter is the date of authorization of the study.

Please keep a copy of this signed approval letter in your study master file for audit purposes. The study must be carried out in accordance with General Data Protection Regulation and Health Research Regulation 2018/2021.

You should note that ethical approval will lapse if you do not adhere to the following conditions:

1. Submission of an Annual Progress Report/Annual Renewal Survey (due annually from the date of this approval letter). We would encourage you to keep note of this date as the CREC will not issue a reminder.

2. Report unexpected adverse events, serious adverse events or any event that may affect ethical acceptability of the study

3. Submit any change to study documentation (minor or major) to CREC for review and approval. Amendments must be submitted on an amendment application form and revised study documents must clearly highlight the changes and contain a new version number and date. Amendments cannot be implemented without written approval from CREC.

4. Notify CREC of discontinuation of the study

5. Submit an End of Trial Declaration Form and Final Study Report/Study Synopsis when the study has been completed.

Yours sincerely

____

Professor David Kerins
Chairman
Clinical Research Ethics Committee
of the Cork Teaching Hospitals

The Clinical Research Ethics Committee of the Cork Teaching Hospitals, UCC, is a recognised Ethics Committee under Regulation 7 of the European Communities (Clinical Trials on Medicinal Products for Human Use) Regulations 2004, and is authorised by the Department of Health and Children to carry out the ethical review of clinical trials of investigational medicinal products. The Committee is fully compliant with the Regulations as they relate to Ethics Committees and the conditions and principles of Good Clinical Practice.

Appendix B Participant Information Leaflet and Informed Consent Form

Study Title: "**E**arly **L**earning and neurocognitive **F**unction Study (ELF study)"

Parent/Guardian Information leaflet

Dear Parent/Guardian,

We are writing to you from the INFANT Research Centre, to invite you to take part in a research study which is a follow-up to one you and your child previously participated in approximately two years ago.

INTRODUCTION

You and your child are being invited to take part in a research study. Before you decide whether to take part it is important for you to understand why we are doing this research and what is involved. You should understand enough about its risks and benefits to make an informed judgment. This process is known as informed consent. This Parent Information Leaflet gives detailed information about the research study. A study researcher will discuss the study in detail with you on the day of the assessment. When you are sure you understand the study and what will be expected of you and your child, you will be asked to sign this form if you wish to participate. Please take time to read this leaflet, and if you want to, discuss it with your family or friends. Please feel free to ask us if anything is not clear, or if you would like more information. Thank you for taking the time to read this.

ABOUT THE STUDY

You and your child previously participated in a research project conducted by the INFANT Centre/UCC approximately 2 years ago. Your infant's cognitive skills (ability to think and solve problems) were assessed using a novel touchscreen assessment, the CogniTOT test. The purpose of this study is to find out more about how your child is doing now, several years later, in terms of their cognitive skills such as memory, attention and speed of information processing. We also want to determine if how they did on the CogniTOT test as an infant is related to their cognitive skills today. There are several questionnaires involved in this study and we are asking you as the parent(s) to complete. The questionnaires will help to understand how your feelings, behaviours, and your family environment, support your child's development.

WHY HAVE I BEEN ASKED TO TAKE PART?

You and your child have been asked to take part in this study because you participated in a previous study conducted by the INFANT Centre/UCC. When your child was 24-30 months of age, researchers completed an assessment of skills and development with your child (the CogniTOT tablet task, which involved your child looking at interactive shapes (e.g. a star) and colours, and selecting an answer by touching the screen, and the Bayley's Scales of Infant Development, which assessed your child's thinking, language, motor and other skills using a variety of tasks involving objects such as a toy car, a teddy bear, blocks and rubber ducks, and stimulus books of pictures).

DO I HAVE TO TAKE PART?

We are very grateful to you for considering your and your child's participation in this study, but we understand if you decide not to enroll. The decision to take part is completely up to you; you are under no obligation to participate. You do not have to take part in this study. If you decide not to take part, it won't affect you or your child's current or future medical care. You can change your mind about taking part in this study any time you like. Even if the study has started, you can still opt out. You don't have to give a reason. If you do opt out, it won't affect the quality of the medical care you or your child get now or in the future. If you decide after your child has been assessed, and after you have completed the parent/guardian questionnaires, you will have two weeks to let us know. We will then remove your contribution i.e. your data from the overall data set. If you do decide to take part, you will be asked to sign the consent form at the end of this information leaflet and your child will be asked to sign an age-appropriate assent. You will be given a copy to keep.

WHAT WILL HAPPEN IF MY CHILD AND I TAKE PART?

If you choose for you and your child to participate, you will be asked to attend for an appointment (approx 1 hour) at INFANT Research Centre, University College Cork. The INFANT Research Centre at UCC is a quiet and child friendly environment for us to assess your child's development.

Developmental Assessment:

The developmental assessment will be carried out by a member of the research team and will be an assessment of your child's cognition (learning and understanding) for their age. This assessment will contain some tests from two assessments commonly used to assess intelligence and cognitive abilities in children, such as their memory, attention, and problem solving skills. The two assessments that the subtests will be used from are the *Wechsler Preschool and Primary Scale of Intelligence (WPPSI)* and *NEPSY 2* (NEPSY is an acronym, NE for Neuro, and PSY for Psychology.).

Questionnaires:

During the study we will ask you the parent(s) to complete six brief questionnaires. These questionnaires ask questions about you, your family life, and your child. Some questionnaires will ask you about parenting stress, and about whether you experience symptoms of depression and anxiety. Some questionnaires will ask about your family environment and relationships within your family. Finally, some questionnaires will ask about your child, their behaviour, and their strengths and difficulties. There will also be one questionnaire which asks you for basic demographic information about you and your child. A list of the questionnaires you will be asked to complete is provided below:

- Parenting Stress Index - Short form (PSI-SF)
- Depression Anxiety and Stress Scale – 21 (DASS-21)
- Family Environment Scale (FES)*
- Strengths and Difficulties Questionnaire (SDQ)

**Please note that for these questionnaires you will be asked to complete only some sections.* (note: leading asterisk printed)

We will ask you to fill in these questionnaires during your child's appointment. If you have any questions about the questionnaires, or need some support to complete them, a member of the research team will guide you. It is estimated that it will take you approximately 30 – 45 minutes to complete these questionnaires.

WHAT HAPPENS TO THE INFORMATION COLLECTED?

By participating in this study, information from you and your child (also called "personal data") will be collected for the purposes mentioned above in this Parent Information Leaflet. This personal data includes, for example:

- Information that directly identifies you and your child (such as name, date of birth)
- Information collected from your child's developmental assessment
- Information collected from your child's CogniTOT touchscreen assessment
- Information from parental questionnaire's
- Information contained in the results after analysis.

To ensure confidentiality, the data generated during the study is **coded** with a unique Study ID Number that your child will be allocated once recruited to the study. Any information that leaves the clinical site will be labelled with this ID Number. Every person that has access to the uncoded data (that is kept at Cork University Hospital) is subject to professional secrecy and confidentiality.

All information management will adhere to the Data Protection Act and GDPR.

Data that directly identifies you and your child (uncoded data) including the list or key linking your child's study number to your child is stored in a locked filing cabinet separate to study documentation.

Only study personnel can match your child's name to the unique Study ID Number. Data may be accessed by the study Sponsor (UCC) and their representatives to check if the study is conducted properly and that your rights are being respected. If such an audit occurs all personal information made available for inspection will be handled in the strictest confidence and in accordance with legal data protection requirements. All information collected about you and your child will be kept private and confidential and will be stored in a secure web-based database in INFANT UCC. The information will be pseudo-anonymised and any information that could identify you or your child **will not be stored** on the database. Only anonymized data will be shared with the study collaborators for analysis and possible publications.

WHAT HAPPENS TO THE INFORMATION FROM THE STUDY?

UCC is the study's Sponsor and will act as the data controller for this study. Any personal data which you provide to the University will be treated with the highest standards of security and confidentiality, in accordance with Irish and European Data Protection legislation. Your uncoded data will only be accessible to the study researchers and site staff. Sponsor quality representatives (Monitors and Auditors) may also have access so that they can check if the study is being conducted to the best standards. Any personal data you provide to us during the study will be processed fairly and lawfully. Signing the Informed Consent Form means that your and your child's personal data will be used for the purposes outlined in this Parent Information Leaflet (PIL).

The clinical site, the study investigators and members of the study team will use your personal data within the scope defined above. If the research team have a concern about your child, they must act in accordance with Children First, National Guidance for the Protection and Welfare of Children (2017). Any incidental/adverse findings which come to light during the study assessments will be discussed with you and will be conveyed to the Principal Investigator who will refer you and your child to the relevant clinical care pathway.

THE PURPOSE AND LEGAL BASIS FOR COLLECTING YOUR AND YOUR CHILD'S DATA.

Any personal data you provide to us during the study will be processed fairly and lawfully. Signing the Informed Consent Form means that your and your child's personal data will be used for the purposes outlined in this Parent Information Leaflet (PIL). You are entitled to withdraw your consent at any time. Personal data collected during this study and the results of the study may be presented for scientific purposes. However, you or your child will never be identified individually during these presentations. Your or your child's identity will not be revealed in any reports or publications. The clinical site staff, the study investigators and the members of the study team will use the personal data within the scope defined above. If the clinical site staff, study researcher or study team wish to use your and your child's data for a purpose other than the purpose specified, the researcher must contact you again to give you more information and ask your permission to use your and your child's data for the new purpose.

The General Data Protection Regulation (GDPR) allows us to process your data because the research is of substantial public interest (Articles 6(1) (e) and 9(2) (a) (j) of the GDPR). We have also sought your consent to process your data in accordance with the Health Research Regulations.

If you require further information on the legal basis for processing your personal data, please contact UCC's Data Protection Officer – details below.

Your Rights:

You have various rights under data protection law, subject to certain exemptions, in connection with our processing of your and your child's personal data, including the right:

to find out if we use your or your child's personal data, access your or your child's personal data and receive copies of your and your child's personal data.

to have inaccurate/incomplete information corrected and updated.

in certain circumstances, to have your and your child's details deleted from systems that we use to process your and your child's personal data or have the use of your and your child's personal data restricted in certain ways.

to object to certain processing of your and your child's data by UCC.

to exercise your right to data portability where applicable (i.e. obtain a copy of your and your child's personal data in a commonly used electronic form)

to withdraw your consent to the processing of your and your child's data at any time without giving a reason by notifying your decision to the study researcher. If you withdraw your consent for data processing, your and your child's participation in the study stops and no further data will be collected from you. Your study researcher will present you with the options you have concerning your and your child's personal data.

along with study withdrawal, you have the right to request the deletion of data about you and your child, if the data is no longer necessary for the purposes of processing or there is no other legal ground for their further processing.

If you wish to exercise any of these rights, please address your request to the study researcher or the Data Protection Officer, University College Cork (details below).

INSURANCE

UCC as the Sponsor of this research study has appropriate insurance in place if you are harmed as a result of participation in this study. If your child is harmed and this is due to someone's negligence, then you may have grounds for a legal action for compensation against the hospital where your child is being treated. The normal Health Service Executive complaints mechanisms will be available to you if appropriate.

WHAT WILL HAPPEN TO THE RESULTS OF THIS RESEARCH?

Results of this research will be submitted to UCC by the psychology researchers as part of their masters and doctoral theses. Results of this research study may also be published in academic journals and presented at scientific meetings. This may help others to learn from what we found in this research study. However, you or your child will never be identified individually during these presentations and will not be revealed in any reports or publications. Names or anything else identifiable to you or your child will not be released or published. A copy of the signed informed consent and assent forms if applicable will be scanned and included in your child's medical notes.

FOR HOW LONG WILL THIS DATA BE KEPT?

We will keep identifiable information about you and your child from this study for a period of 10 years after the study has concluded, as per UCC Code of Research Conduct Version 2.4. The data will be stored securely at the INFANT Centre, UCC in a study specific folder on a UCC secure server. A pseudo anonymised database (where participants are assigned unique numbers and there is no identifiable information) will be stored on researcher's password protected encrypted computers at UCC. We would like your permission to allow us to store your and your child's de-identified data for future related research for a period of 25 years. Further research analyses may be performed but this will be subject to further ethics approval if applicable.

QUERIES OR COMPLAINTS

If you have any complaints in connection with our processing of personal data pertaining to you or your child, you can contact UCC's Data Protection Officer (DPO): **Information Compliance Manager Office of Corporate & Legal Affairs, University College Cork, College Road, Cork**

E: gdpr@ucc.ie Tel: +353 21 4903949

You also have the right to lodge a complaint with the Data Protection Commission if you are unhappy with our processing of your personal data. Details of how to lodge a complaint can be found on the Data Protection Commission's website (www.dataprotection.ie), or by telephoning 1890 252 231.

FUTURE USE OF DATA COLLECTED

We would like to use the anonymised data collected as part of this study for future related research studies without your further consent. Related studies mean studies looking at neurodevelopmental outcomes. The assessments performed in this study mainly are about understanding neurodevelopmental outcomes, and by this we mean a child's developmental milestones such as the age that a child gains certain skills like walking or talking. Any further research would have approval from a Research Ethics Committee before your or your child's data could be used. You can indicate in the consent form attached to this leaflet whether you consent or not to the data being used in future related research studies.

WHAT HAPPENS IF I NEED SUPPORT AFTER THE ASSESSMENT?

After the assessment appointment a member of the research team will meet you, to ensure that you and your child are feeling well, and will be available to answer any questions you might have. If you have any concerns following participation in the research, you may contact the research team whose contact details are provided below. You will be provided with a written feedback summary outlining your child's participation in the assessment. This will be sent to you by post. If your child's performance during the assessment is of concern, you will be notified as soon as possible by phone and the results discussed with you. Where appropriate, and with your consent, your child will be referred to the relevant clinical care pathway.

ARE THERE ANY BENEFITS OR DISADVANTAGES TO TAKING PART?

There are no direct benefits for you or your child to taking part. It is hoped that the findings from this research will benefit children and their families, as it contributes to the development of a good early identification tool for potential developmental problems in childhood. We don't anticipate any risks or disadvantages to taking part. You will be invited to remain in the room with your child throughout the assessment, which will take place in a quiet, child-friendly room. Our researchers have lots of experience in dealing with children, however, if your child does not want to participate, or gets tired or upset the assessor will stop the assessment. A subsequent appointment may be arranged on another day if appropriate and if you are happy to continue in the study. A member of the research team will be there to support you and your child throughout.

WHO HAS REVIEWED AND APPROVED THIS STUDY?

All research in Ireland is carefully reviewed by an independent group of people, called a Research Ethics Committee, to protect your safety, rights, wellbeing and dignity.

This study has been approved by the Clinical Research Ethics Committee (CREC) of the Cork Teaching Hospitals.

IF I HAVE QUESTIONS ABOUT THIS STUDY, WHO DO I CONTACT?

The study will be fully explained to you and any questions answered before you decide if you want to take part. If you have any further questions regarding this study you can contact the Principal Investigator Prof Deirdre Murray, Consultant Paediatrician, Cork University Hospital d.murray@ucc.ie or Megan Blackburne by email **114421028@umail.ucc.ie/**

Thank you very much for your interest in this research study. We are very grateful for your time and consideration of our invitation.

Parent/Guardian Informed Consent Form

Study Title: "**E**arly **L**earning and neurocognitive **F**unction Study (ELF study)"

Participant Study Number: ____________________________ **Participant/Maternal MRN (If applicable):**_______	**Principal Investigator:** *Prof Deirdre Murray* ***Tel:*** +353(0)21 4205082 *Email: d.murray@ucc.ie*

Please read accompanying information sheet and take time to consider the information.
Please initial each section to show you have read and understood each statement.
If you agree for you and your child to take part, please sign the bottom of the form.

	Please initial	
1 I have read the information leaflet about this study and have been given a copy to keep. The information has been fully explained to me and I have been able to ask questions and have them answered satisfactorily. I understand the purpose of the study, any risks involved, and what me and my child's participation will involve.	**Yes**	**No**
2 I am aware that **my child's** participation is voluntary, and I can withdraw my consent at any stage. I am aware that my decision not to continue participation at any stage will not restrict mine or my child's access to health care services normally available to me.	**Yes**	**No**
If I withdraw from the study, I may request that **my child's** data be deleted. I understand it may not always be possible to delete coded personal data (already collected) to preserve the integrity of the study.	**Yes**	**No**
I understand that in accordance with Children's First legislation, if there is a concern about me or my child, the research team are mandated to report this.	**Yes**	**No**
I agree for my child to participate in this research study and to undergo the developmental assessments as explained to me.	**Yes**	**No**
I am aware that confidentiality of records concerning m **my child's** involvement in this study will be maintained according to national and EU Data Protection Laws. When required by law, the records of this study may be reviewed by government agencies, ethics committee and sponsors of the study and I give my permission for these individuals to access my child's records.	**Yes**	**No**
I understand that the sponsors and Investigators have such insurance as is required by law in the event of injury resulting from this research.	**Yes**	**No**
I understand that my child's anonymised data will be stored in password protected electronic files, on a shared study specific folder accessible only to the research team.	**Yes**	**No**
I am aware of resources that are available to me where I can receive support, for my child, if partaking in the study results in any distress.	**Yes**	**No**

I give permission for all anonymised information collected from my child to be stored for possible future related research *without my further consent being required* but subject to approval of a Research Ethics Committee.	**Yes**	**No**
I give permission to the research team to contact me in the future for follow up information regarding my own and my child's health or for related research.	**Yes**	**No**
I consent that data collected for this study may be used, now or in the future, and understand that I will not benefit financially if this research leads to the development of a new treatment, drug, or device.	**Yes**	**No**
I give permission for **my child's** medical records to be reviewed and information to be taken from them to be analysed in confidence by the study team, if required.	**Yes**	**No**
I, the undersigned, consent to my child's personal data being processed as part of this research study.	**Yes**	**No**
I, the undersigned, consent to **my child** participating in this study. I understand if I have any further questions, I can contact the Investigator listed above. If I have further queries concerning my rights in connection with the research, I can contact the Clinical Research Ethics Committee of the Cork Teaching Hospitals, Lancaster Hall, Little Hanover Street, Cork (Tel 021 4901901).	**Yes**	**No**
FUTURE CONTACT I give permission to the research team to contact me in the future for follow up information regarding my own and my child's health or for related research.	**Yes**	**No**
STORAGE AND FUTURE USE OF INFORMATION		
I give permission for the information - assessment results to be stored for *possible future research **related*** to the current study including commercial or collaborative research ***with my further consent being required*** and only if the research is approved by a Research Ethics Committee.	**Yes**	**No**
I give permission for the identifiable data to be stored for 10 years after the study has concluded	***Yes***	***No***

Parent's/Guardian's Signature	Date:
Parent's/Guardian's Signature	Date:
Consent obtained by (Researcher's Signature)	Date:

Appendix C Assent Form

Assent Form (6-8 Year Olds)

For use in conjunction with the Parent(s) Information Leaflet and Informed Consent Form.

Short Title: The ELF Study.

Study Title: Early Learning and neurocognitive function Study.

Hi there!

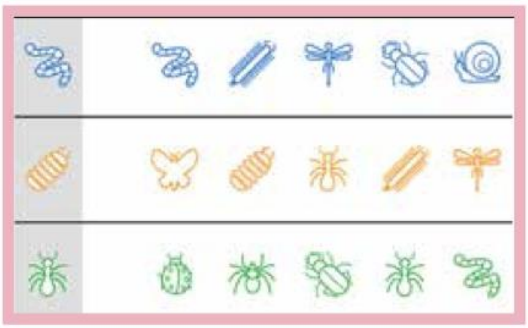
We are doing a study about children's thinking and learning skills. What you need to know about the study is on this piece of paper. It is completely OK if you don't want to take part. No one will be upset.

Why are we doing this study?

We are doing this study to learn more about how children think and learn. When you were smaller, you helped with a study by playing games on a tablet. We would like to look back at the games you did before, and to do some new checks and games to see how you are thinking and learning now.

What will happen during this study?

In this study we will do checks on how you learn, remember, and think. For these checks, you will look at pictures in books as well as doing some quizzes on a page. We will also ask you some questions. We will give your mam/dad/guardian some questions to answer too.



Are there good and bad things about this study?

Yes! The good thing is we would like to learn more about how children think, and to make new ways to test their thinking, so we can try and find the children who might need some extra help. Taking part in the study is completely safe and there are no bad things that we know of. If you would like to take part you will come into the INFANT research centre for approximately 1 hour with your mam/dad/guardian to do the checks and games.

Can I ask questions?

If you want to ask us anything that you are not sure about then we will be very happy to talk to you. You can ask your parents if there is something on this page that you don't understand or you can ask the researcher who gave you this piece of paper.

What if I don't want to be in the study?

If you or your parents do not want, you to take part then that is OK, and no one will be upset. You can also change your mind about taking part any time you like and if you do change your mind then that is OK too. The care you get from your doctors and nurses won't change.

ASSENT SHEET FOR PARTICIPANT IN OBSERVATIONAL STUDY
Study Name: The ELF Study

Study Number: ______________________	**Study Contact:** Prof Deirdre Murray **Contact details:** d.murray@ucc.ie

This assent form must be used in conjunction with the appropriate parent consent form. On its own, it does not provide informed consent for a minor to take part in the study.

<u>Please circle Yes or No:</u>

1. The study person has explained the study to me.	**Yes**	**No**
2. All my questions have been answered.	**Yes**	**No**
3. I know what this study is about and what I need to do.	**Yes**	**No**
4. It's okay to collect information about me from my parent(s)	**Yes**	**No**
5. It's okay for me to have learning checks as part of this study	**Yes**	**No**
6. Can we keep and use your learning checks and information, collected in this study and in other studies like this one?	**Yes**	**No**

My name is: ____ Date: ______________

Parent's signature: __________________________________ Date: ______________

Name of person explaining the study: ____________________ Date: ______________

When completed: 1 for the parent, 1 for the researcher site file.

Appendix D Demographic Information Questionnaire

Participant Demographic Information

Child Information

Please answer the following questions about your child:

Age:

Gender:

No. of siblings:

Who lives with the child in their main residence (majority of days of the week)?

Does your child have any diagnosed medical conditions?

Yes ☐

No ☐

If yes, please explain:

Does your child have any diagnosed learning or developmental difficulties?

Yes ☐

No ☐

If yes, please explain:

Is your child currently engaged with HSE Primary Care or Child and Adolescent Mental Health service (CAMHS) or a similar private service?

Yes ☐

No ☐

If yes, please explain:

Is your child currently engaged with a HSE Children's Disability Network Team (CDNT team) or similar private service for therapies; for example speech therapy, physiotherapy, occupational therapy, art, play or music therapy? Yes/No

Yes ☐

No ☐

If yes, please explain:

Thank you

Please return this form to the researcher.

Participant Demographic Information

Parent Information

Please answer the following questions about you:

Age:

Gender:

No. of children:

Who lives with the child in their main residence (majority of days of the week)?

Do you have any diagnosed mental health condition?

Yes ☐

No ☐

If yes, please explain:

Are you currently engaged with HSE Primary Care or Adult Mental Health service (or similar private service)?

Yes ☐

No ☐

If yes, please explain:

Parent 1 (Person filling questionnaire):
What is the highest level of education/training Parent 1 has completed? (Please circle)

i. No formal education/training
ii. Primary school/equivalent
iii. Junior certificate/equivalent
iv. Leaving certificate/High school diploma/A Levels/equivalent
v. Training college/Trade/Technical school training
vi. University graduate (BA or BS)
vii. Graduate school degree: Master's or Doctorate degree (MD, PhD)

Is Parent 1 employed?
Yes No

What best corresponds to Parent 1's current work situation: (please circle)

i. Working full time
ii. Working part time
iii. Not working and not looking for work
iv. Unemployed and looking for work.
v. Disabled or retired and not looking for work.
vi. Currently studying

What is Parent 1's occupation (e.g. retail store manager, secondary teacher, civil engineer, stay at home parent etc)

Was Parent 1 born in Ireland?

Parent 2 (if applicable):
Parent 2 Age: _______________ Parent 2 Sex: ______________
What is the highest level of education/training Parent 2 has completed? (Please circle)

i. No formal education/training
ii. Primary school/equivalent
iii. Junior certificate/equivalent
iv. Leaving certificate/High school diploma/A Levels/equivalent
v. Training college/Trade/Technical school training
vi. University graduate (BA or BS)
vii. Graduate school degree: Master's or Doctorate degree (MD, PhD)

Is Parent 2 employed?
Yes No
What best corresponds to Parent 2's current work situation: (please circle)

i. Working full time

ii. Working part time
iii. Not working and not looking for work
iv. Unemployed and looking for work
v. Disabled or retired and not looking for work
vi. Currently studying

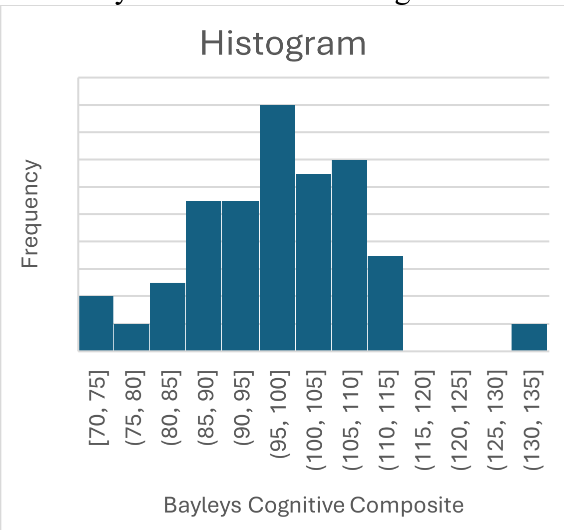
What is Parent 2's occupation (e.g. retail store manager, secondary teacher, civil engineer, stay at home parent, etc)?

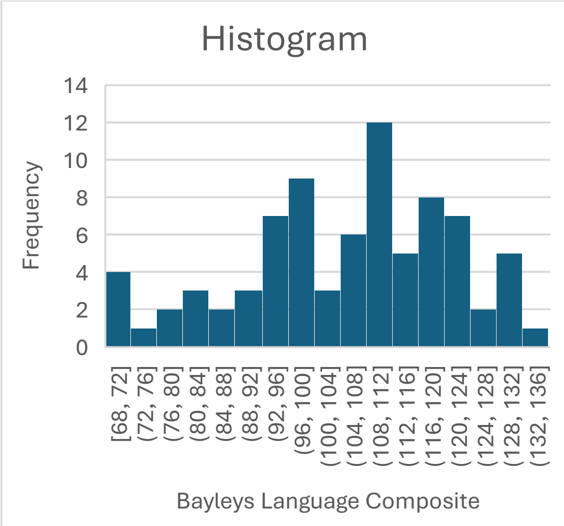
Was Parent 2 born in Ireland?

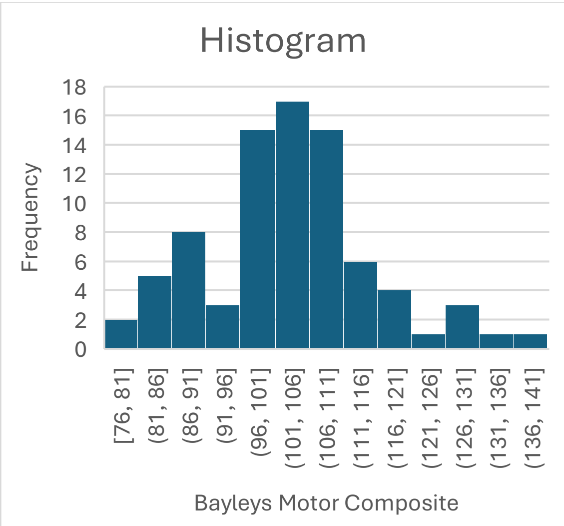
Thank you. Please return this form to the researcher.

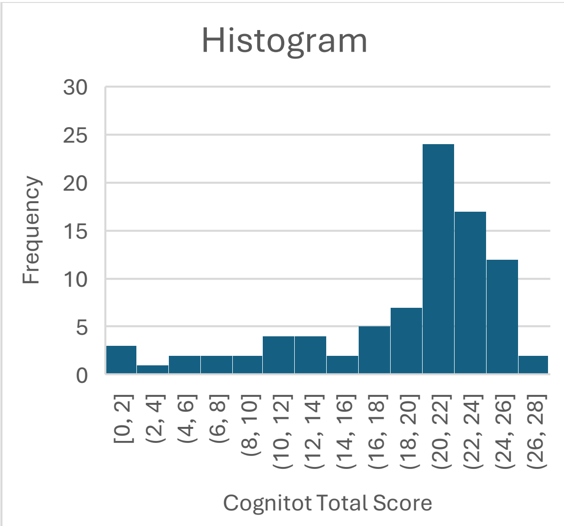
Appendix E Normality Distribution Histograms

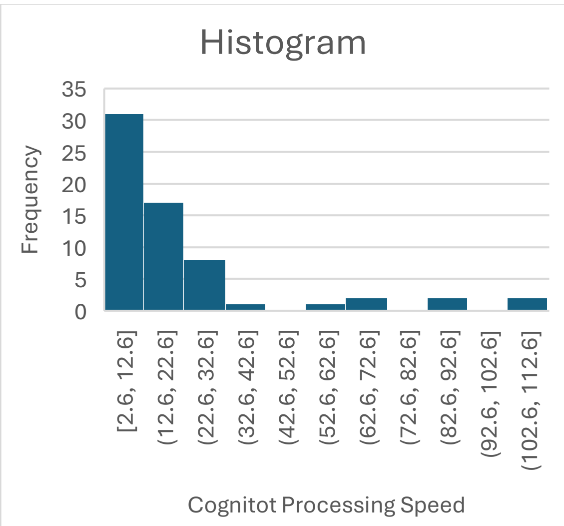
Normality Distribution – Histograms

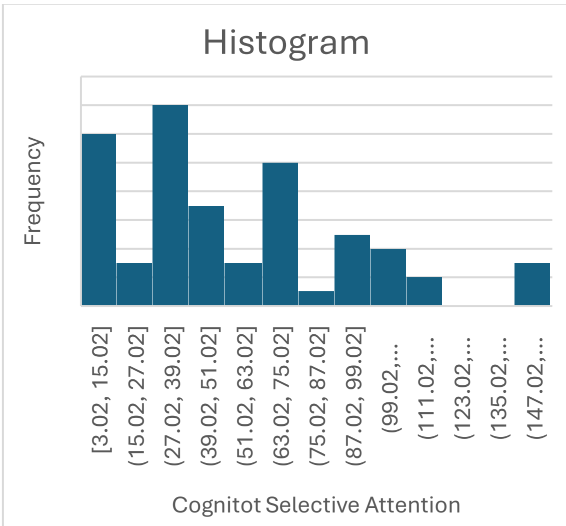


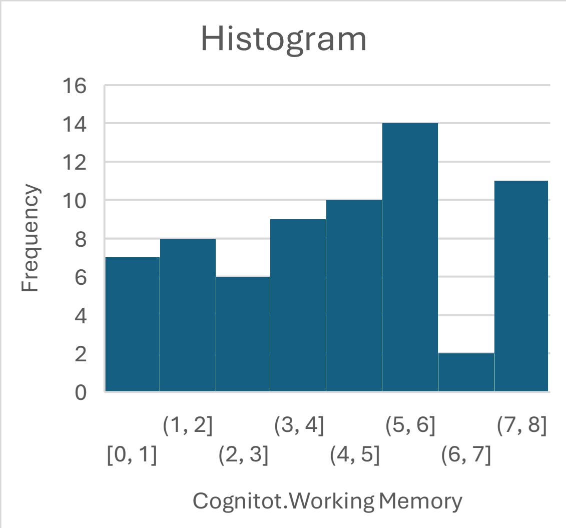


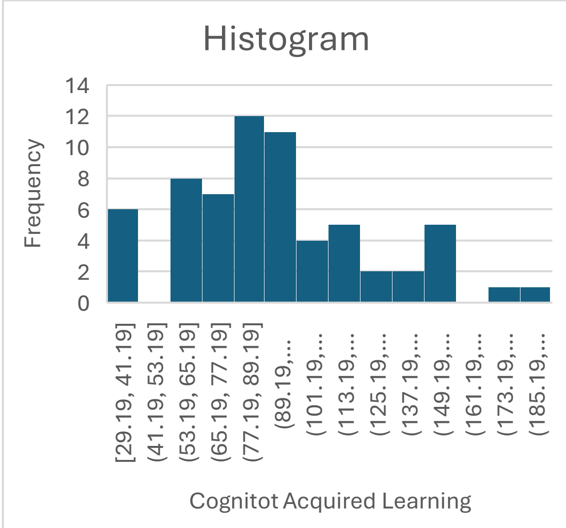


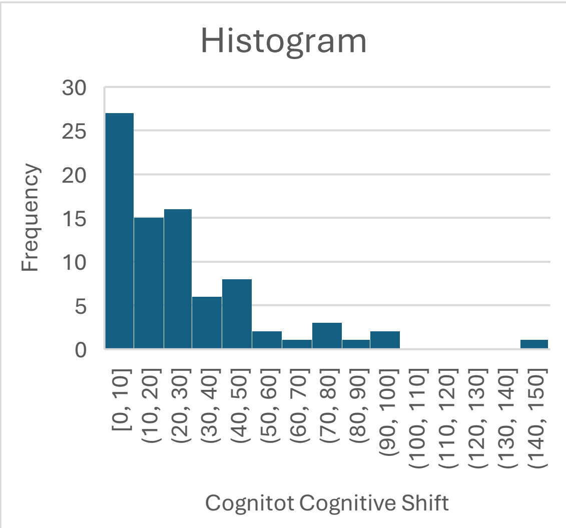


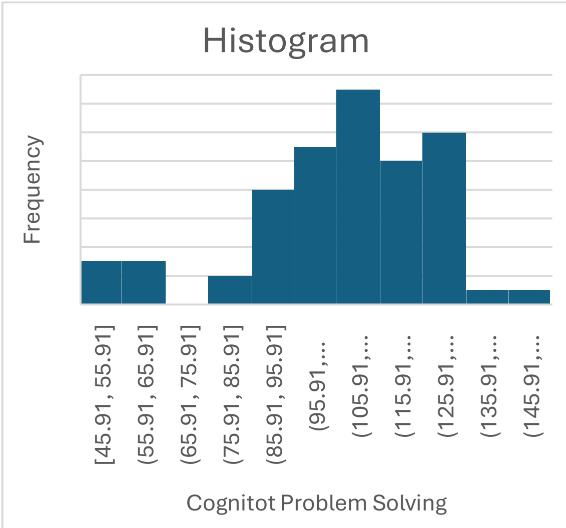


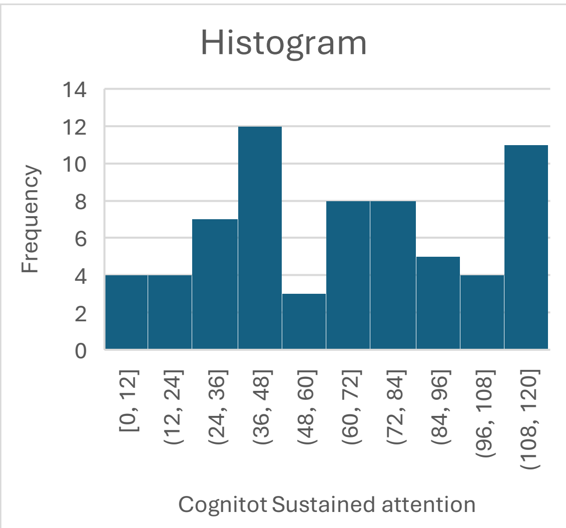


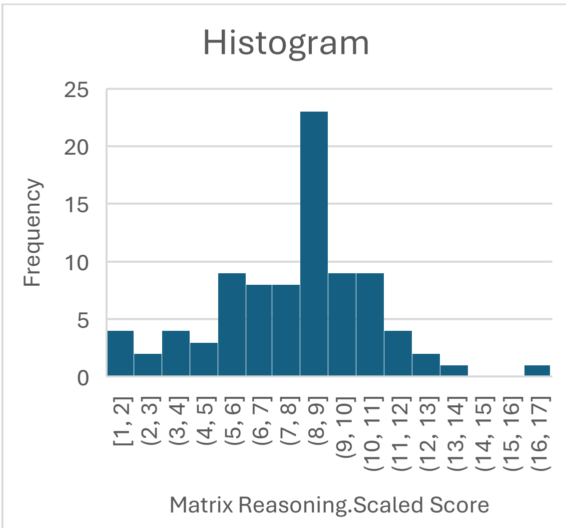

Histogram
Frequency
Cognitot.Working Memory

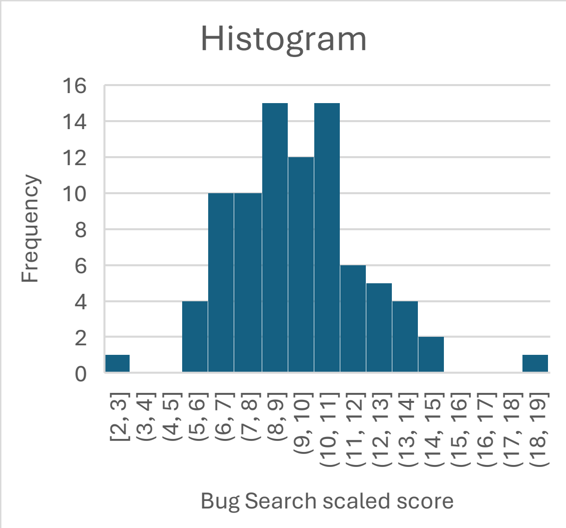

Histogram
Frequency
Cognitot Acquired Learning


Histogram
Frequency
Cognitot Cognitive Shift


Histogram
Frequency
Cognitot Problem Solving


Histogram
Frequency
Cognitot Sustained attention


Histogram
Frequency
Matrix Reasoning.Scaled Score


Histogram
Frequency
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14
12
10
8
6
4
2
0
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(3, 4]
(4, 5]
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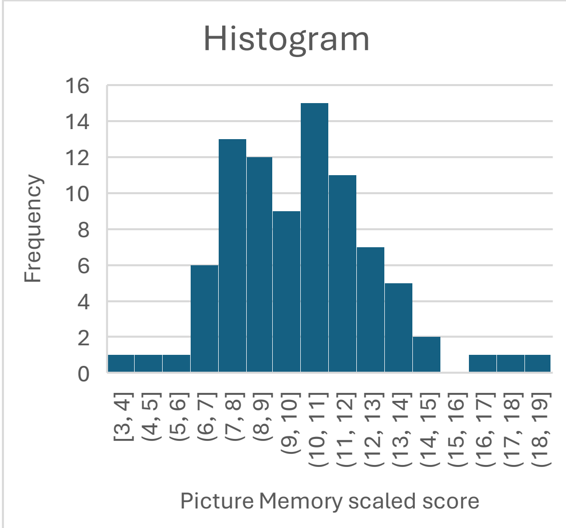
(18, 19]
Bug Search scaled score


Histogram
Frequency
16
14
12
10
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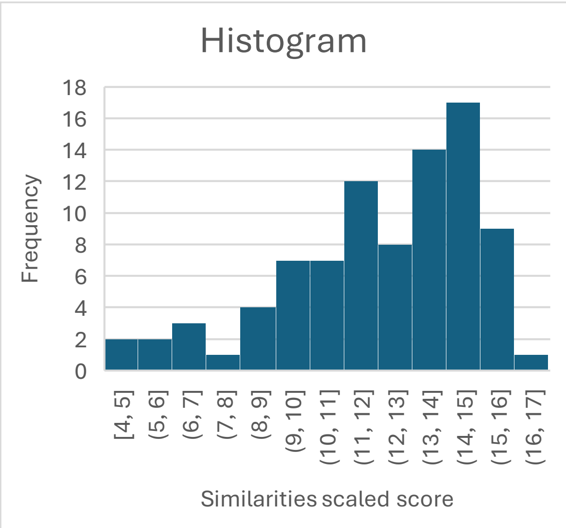
(17, 18]
(18, 19]
Picture Memory scaled score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Frequency
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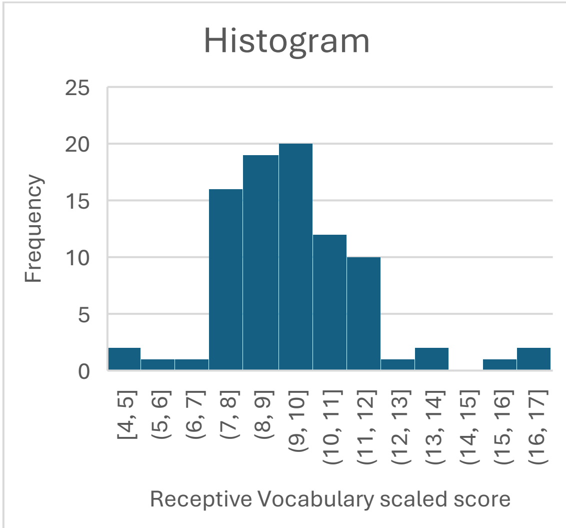
Similarities scaled score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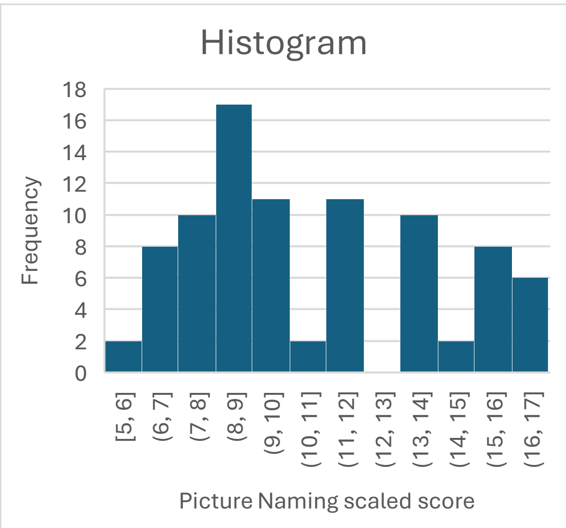
Receptive Vocabulary scaled score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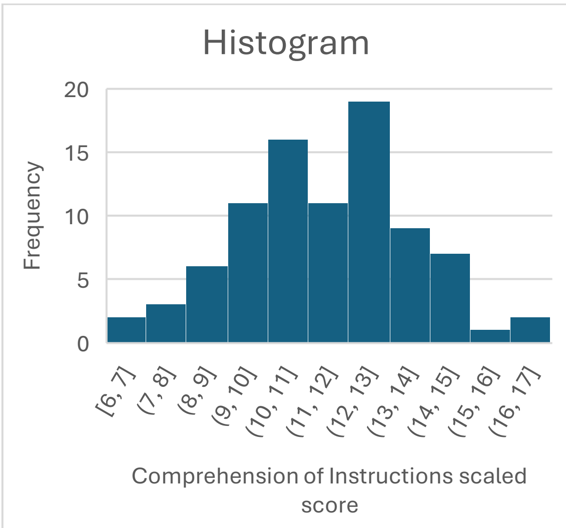
Picture Naming scaled score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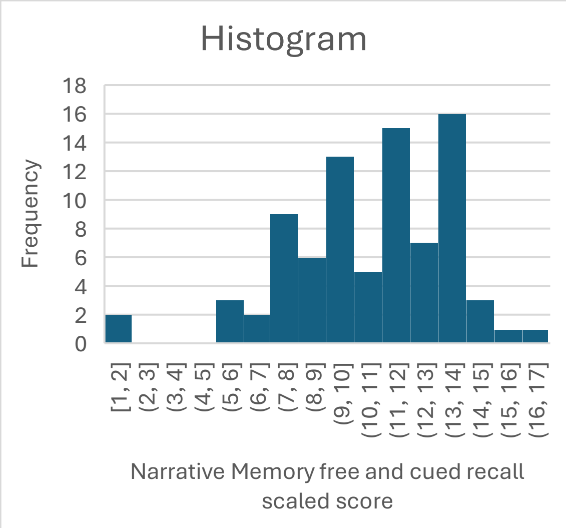
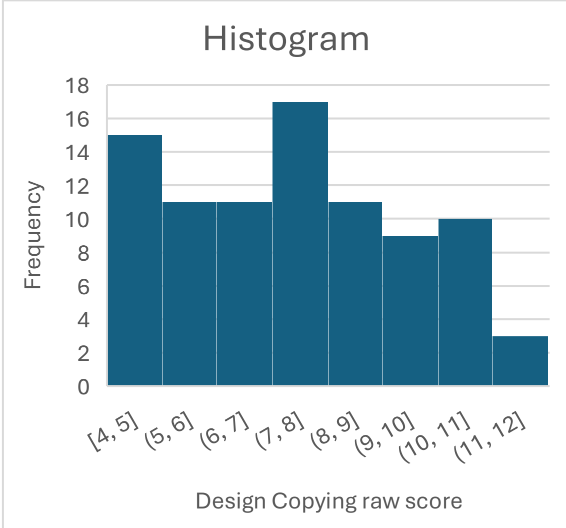
Comprehension of Instructions scaled score





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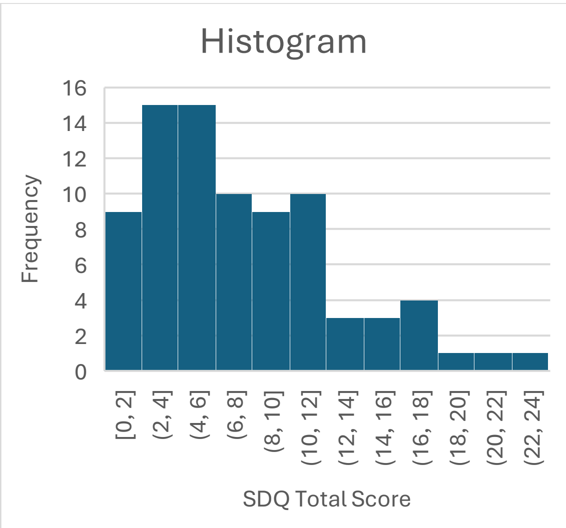
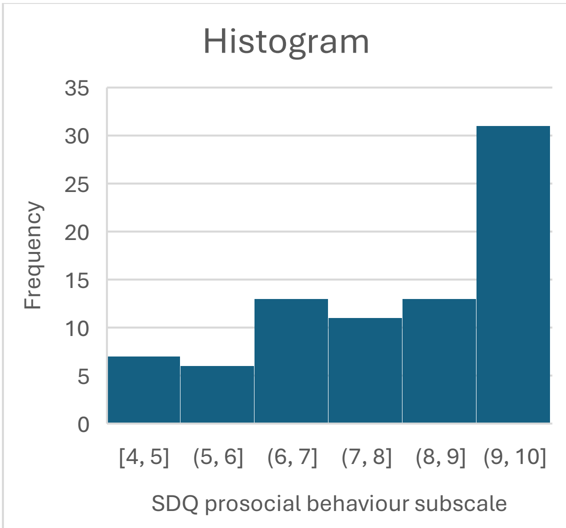
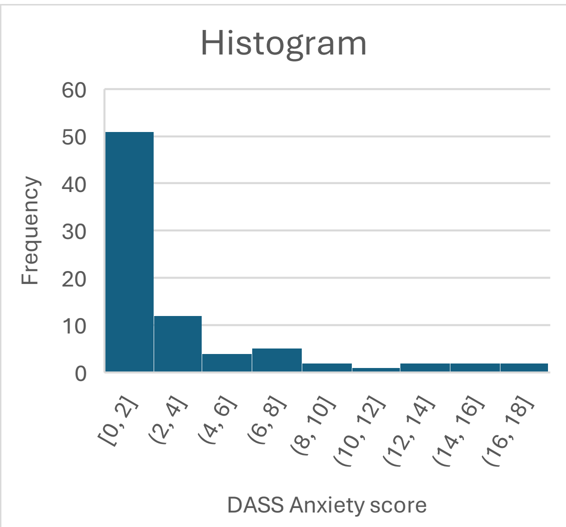
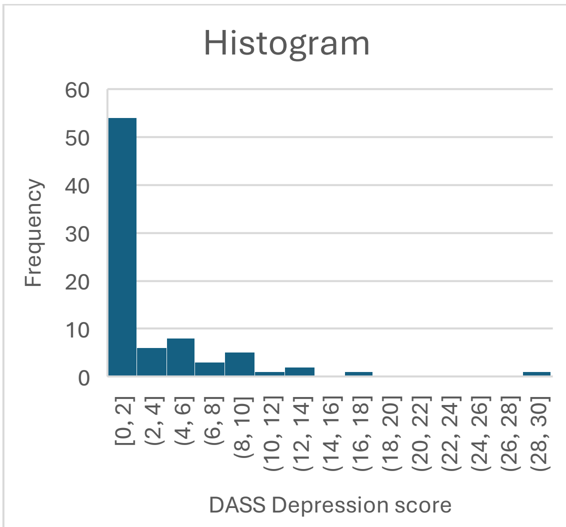
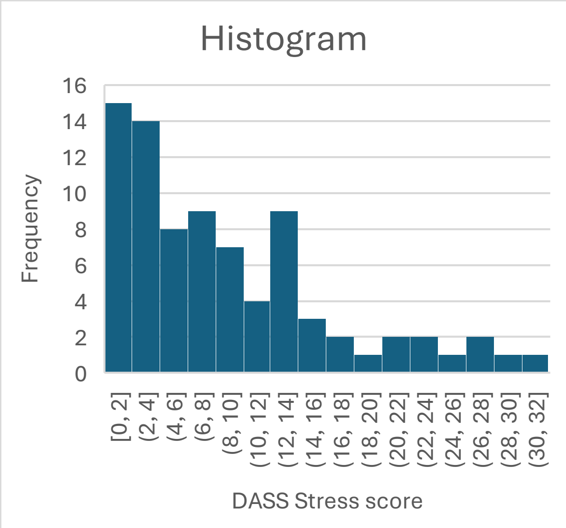
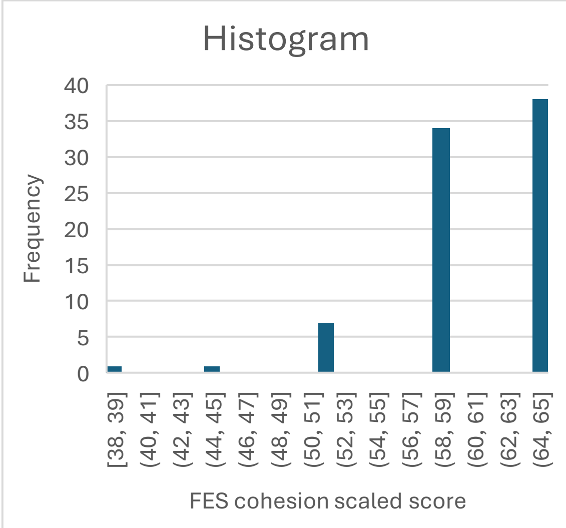


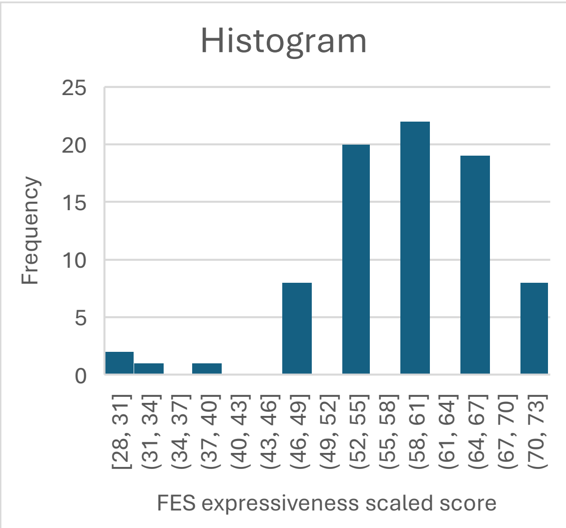


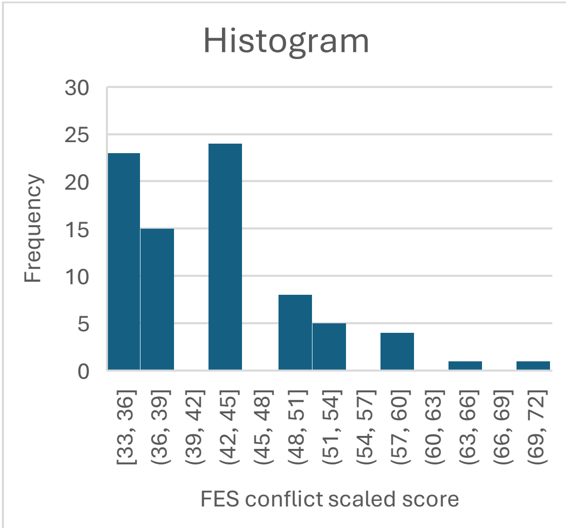


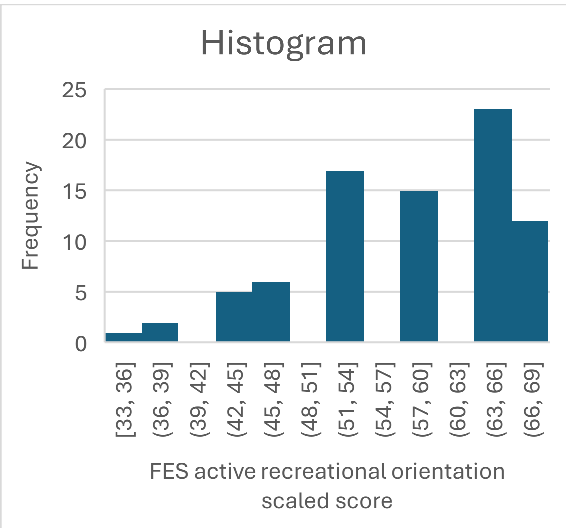


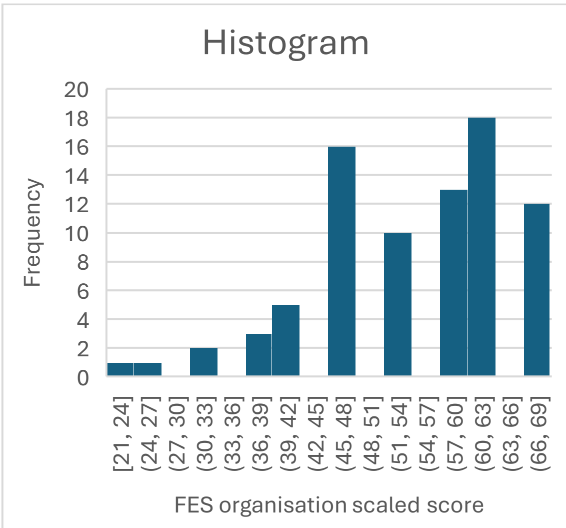

Histogram
Frequency
DASS Stress score

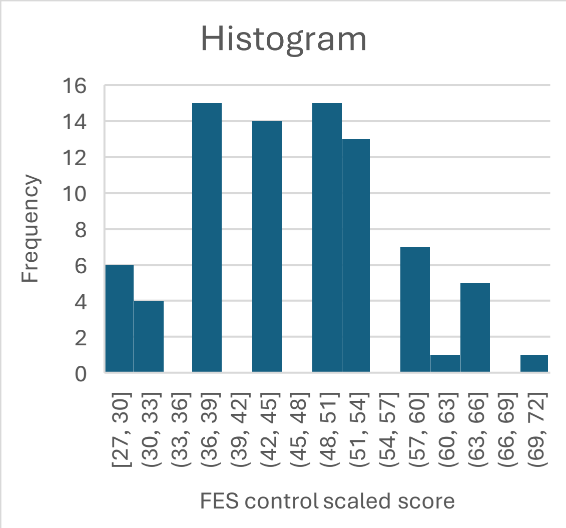

Histogram
Frequency
FES cohesion scaled score


Histogram
Frequency
FES expressiveness scaled score


Histogram
Frequency
FES conflict scaled score


Histogram
Frequency
FES active recreational orientation scaled score


Histogram
Frequency
FES organisation scaled score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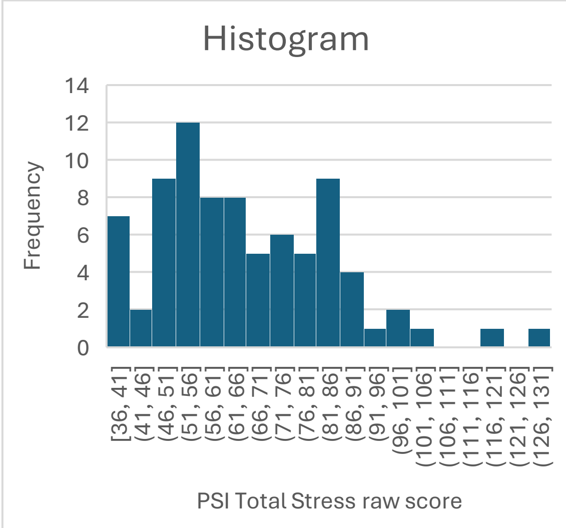
(69, 72]
FES control scaled score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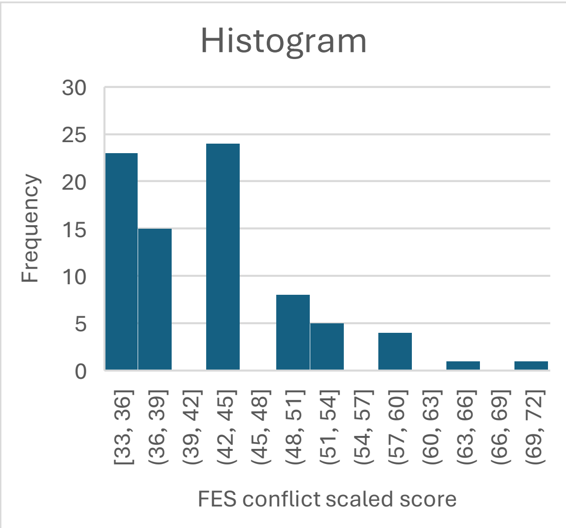
PSI Total Stress raw score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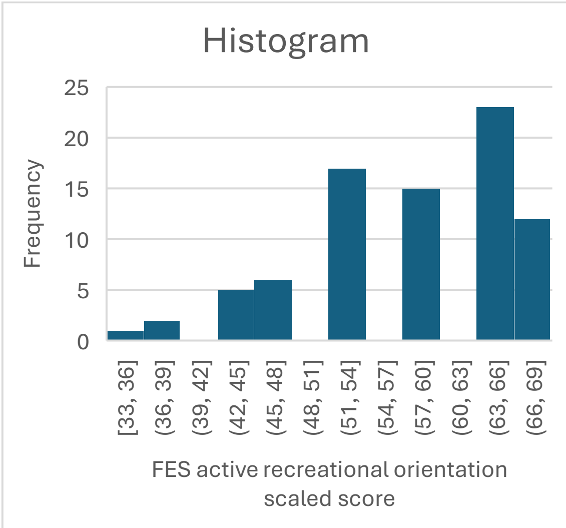
(63, 66]
(66, 69]
(69, 72]
FES conflict scaled score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(45, 48]
(48, 51]
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(54, 57]
(57, 60]
(60, 63]
(63, 66]
(66, 69]
FES active recreational orientation scaled score

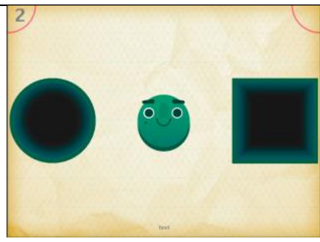
Appendix F CogniTOT Overview

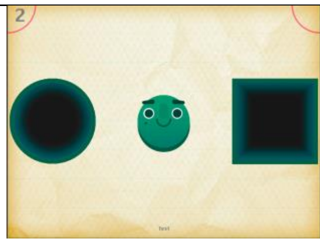
Overview of demo and 30 tasks with descriptions:

Task	Description	Screenshot of task
Demo	**Stimuli**: 1 yellow smiley star **Demo Phase:** A single star appears with device in demo mode. Tester says "Look" and completes the demo by pressing down on the star firmly and with clear intention.	
Task 1	**Stimuli**: 1 yellow smiley star **CogniTOT Score Criteria (Y/N):** Pass= yellow star pressed within 30s, on first attempt	
Task 2	**Stimuli**: 2 yellow smiley stars **CogniTOT Score Criteria (Y/N):** Pass= two stars pressed within 30s, on first attempt	
Task 3	**Stimuli**: 3 stars: 1 yellow smiley star, 2 blue plain distractor stars. **CogniTOT Score Criteria (Y/N):** Pass= yellow star pressed within 30s	
Task 4	**Stimuli: Motor screening task:** 6 yellow target stars presented at different locations on screen, one at a time in a pre-determined flowing sequence.	
Task 5	**Construct:** Selective Attention; Processing Speed **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt.	
Task 6	**Construct:** Selective Attention; Processing Speed **Stimuli:** 30 stars (6 x 5 grid): 1 yellow smiley target star, 29 blue plain distractor stars.	

	CogniTOT Score Criteria (Y/N): Pass= yellow smiley star pressed within 30s, on first attempt.	
Task 7	**Construct:** Selective Attention; Processing Speed; Cognitive Shift **CogniTOT Score Criteria (Y/N):** Pass= blue smiley star pressed within 30s, on first attempt.	
Task 8	**Construct:** Selective Attention; Processing Speed; Cognitive Shift **Stimuli:** 30 stars (6 x 5 grid): 1 yellow smiley target star, 29 multi-colored plain distractor stars. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt.	
Task 9	**Construct:** Cognitive Shift **CogniTOT Score Criteria (Y/N):** Pass= blue plain star pressed within 30s, on first attempt.	
Task 10	**Construct:** Acquired Learning **CogniTOT Score Criteria (Y/N):** Pass= blue plain star pressed within 30s, on first attempt.	
Task 11	**Construct:** Problem-Solving **Stimuli:** Red sliding door and 1 yellow star (hidden behind door) **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt.	
Task 12	**Construct:** Acquired Learning **Stimuli:** Existing task 14. Red sliding door, two yellow stars (one visible, one hidden behind door). **CogniTOT Score Criteria (Y/N):**	

	Pass= two yellow smiley stars pressed within 30s	
Task 13	**Constructs:** N/A **Stimuli:** Yellow target star with face hidden behind blue window (transparent with star partially visible). **CogniTOT Score Criteria (Y/N):** Pass= one yellow smiley star pressed within 30s	
Task 14	**Constructs:** N/A **Stimuli:** Yellow target star with face fully hidden behind blue window (opaque with star hidden). **CogniTOT Score Criteria (Y/N):** Pass= one yellow smiley star pressed within 30s.	
Task 15	**Constructs:** N/A **Stimuli:** Two blue windows (opaque on left, transparent on right) **CogniTOT Score Criteria (Y/N):** Pass= 2 yellow stars pressed within 30s in test phase (only 1 attempt).	
Task 16	**Constructs:** Problem-Solving **Stimuli**: Blue and red buckets, with 1 yellow star becoming hidden under red bucket on right side. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt	
Task 17	**Constructs:** Acquired Learning **Stimuli**: Blue and red buckets, with 1 yellow star becoming hidden under blue bucket on left side. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt	

Task 18	**Constructs:** Acquired Learning **Stimuli**: Blue and red buckets, with 1 yellow star becoming hidden under blue bucket initially on left side, which then moves to the right. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt	
Task 19	**Constructs:** N/A **Stimuli**: 3 Boxes: Pink, Blue, Green (left – right). 1 yellow star drops into blue box in middle and remains visible at top of box. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt.	
Task 20	**Constructs:** Working Memory **Stimuli**: 5 Boxes. Pink, Blue, Green, Purple, Yellow (left – right). 1 yellow star drops into pink box (1^{st} in line) and becomes fully hidden. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt. Note: error rate accounted for in scoring for working memory	
Task 21	**Construct:** Problem-Solving **Stimuli:** Two holes (one circular and one square) on left and right of the screen. Shapes and holes have green colour. A total of 6 shapes (circle or square) appears on center of screen individually, in alternate order, to be sorted into the correct category hole (circle to circle hole, vice-versa). **CogniTOT Score Criteria (Y/N):** Pass= at least 3 shapes successfully sorted, within 30s, on first attempt or second attempt for scoring.	

Task 22	**Constructs:** Working Memory **Stimuli**: Large clockface (counts down from 3 seconds and disappears). 5 Boxes: Pink, Blue, Green, Purple, Yellow (left – right). 1 yellow star drops into yellow box (5th in line) and is fully hidden. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt. Note: error rate accounted for in scoring for working memory.	
Task 23	**Constructs:** Working Memory **Stimuli**: Large clockface (counts down from 5 seconds and disappears). 5 Boxes: Pink, Blue, Green, Purple, Yellow (left – right). 1 yellow star drops into blue box (2nd in line) and is fully hidden. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt. Note: error rate accounted for in scoring	
Task 24	**Constructs:** Working Memory **Stimuli**: Large clockface (counts down from 8 seconds and disappears). 5 Boxes: Pink, Blue, Green, Purple, Yellow (left – right). 1 yellow star drops into green box (3rd in line) and is fully hidden. **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt. Error rate accounted for in scoring for working memory.	
Task 25	**Construct:** Acquired Learning **Stimuli:** Two holes (one circular and one square) on left and right of the screen. Shapes and holes have green colour. A total of 6 shapes (circle or square) appears	

	on center of screen individually, in alternate order, to be sorted into the correct category hole (circle to circle hole, vice-versa). **CogniTOT Score Criteria (Y/N):** Pass= at least 3 shapes successfully sorted, within 30s, on first attempt or second attempt for scoring.	
Task 26	**Construct**: Problem-Solving **Stimuli:** 1 purple button and 1 yellow star (only becomes visible when purple button is held down). **CogniTOT Score Criteria (Y/N):** Pass= yellow smiley star pressed within 30s, on first attempt	
Task 27	**Construct:** Problem-Solving. **CogniTOT Score Criteria (Y/N):** Pass = two yellow smiley stars pressed within 30s, on first attempt.	
Task 28	**Construct:** Acquired Learning **Stimuli:** 1 purple button, 1 red sliding door, with 2 hidden yellow stars (first star becomes visible when purple button is held down, the second star is hidden behind red sliding door). **CogniTOT Score Criteria (Y/N):** Pass= two yellow smiley stars pressed within 30s, on first attempt	
Task 29	**Constructs:** Selective Attention, Processing Speed. **Stimuli:** Grid of 30 (6 x 5 array) stars onscreen; 5 are yellow target stars randomly distributed across the grid; the remaining 25 are blue distractor stars. Task does not contribute to CogniTOT score, instead provides a separate measure of selective attention and processing speed.	

Task 30	**Construct:** Sustained Attention **Stimuli:** Balloons moving onscreen as they do at end of app, for 120 seconds maximum. Task does not contribute to CogniTOT score. Instead provides a separate measure of sustained attention.	

Appendix G Participant Feedback Report Template

The Department of Paediatrics & Health,
Irish Centre for Fetal and Neonatal Translational Research (INFANT); UCC,
Room 2.06, 2nd Floor, Cork University Hospital,
Wilton,
Co. Cork
Ireland

Neurodevelopmental Report

PRIVATE & CONFIDENTIAL

This information is purely for research purposes

This document is subject to the Freedom of Information Act 2014

Name:
D.O.B:
Chronological Age:
Date of Assessment:
Date of Report:

Dear PARENT(/S) NAME,

Thank you for enrolling NAME in the ELF study. As you know approximately 2 years ago your child took part in the CogniTOT Study, which aimed to assess your child's cognitive skills (ability to think and solve problems) using a novel touchscreen assessment, the CogniTOT test. The ELF Study aims to find out more about how your child is doing now, several years later, in terms of their cognitive skills such as memory, attention and speed of information processing. We also want to determine if how they did on the CogniTOT test as an infant is related to their cognitive skills today.

Part of the ELF study involved a neurodevelopmental assessment with your child, which we completed on DATE, when NAME was X years and Y months old. The aim of this report is to provide you with feedback on NAME's performance on this assessment. [Qualitative description of child's engagement during assessment; any other notable information as relevant to the Assessment]

About the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) and the Developmental Neuropsychological (NEPSY) Assessments

The *WPPSI* and *NEPSY* are individually administered tools, which assess current developmental functioning of infants and young children. NAME was asked to complete several activities which examined a number of cognitive skills as described in the table below. Assessment tools such as the *WPPSI* and *NEPSY* compare the score that a child achieves on each test to children his/her own age; this gives us the scaled score which is reported below for each subtest that your child completed. Some tasks NAME was asked to perform may have seemed very easy while some tasks may have seemed very difficult. No child is expected to do well on every activity or subtest.

It is important to note that a complete cognitive assessment includes many more subtests for each neurodevelopmental domain than were administered at this study assessment. As this assessment was completed for research purposes, only some subtests were administered from each Index of the assessment tools. Thus, the profile contained in this report is *indicative* of your child's functioning in each domain, rather than a definitive neurodevelopmental assessment. Please bear this in mind.

Scores on the *WPPSI* subscales are categorised as follows with categories based on what would be expected for the wider population of children of the same age:

- Extremely low
- Borderline
- Low Average
- Average
- High Average
- Superior
- Very Superior

The range of scaled scores is 1-19. Scores of 7-12 are typical (Average range).

Scores on the *NEPSY* subscales are similarly categorised as follows:

- Well Below Expected Level
- Below Expected Level
- Borderline
- At Expected Level
- Above Expected Level

The range of scaled scores is 1-19. Scores of 8-12 are typical (Average range).

The below table outlines the subtests administered during this assessment, the corresponding neurodevelopmental domain and a description of the neurodevelopmental domain and subtest.

Neurodevelopmental Domain	**Subtest**	**Description**
Non-Verbal Reasoning	Matrix Reasoning[1]	Assesses your child's ability to solve problems and puzzles through pictures and diagrams without the use of language. This subtest asked your child to select one of four possible pictures that fit into the sequence or pattern of pictures that was shown to them.
Verbal Reasoning	Similarities[1]	Measures logical thinking, verbal concept formation and verbal abstract reasoning. Here, your child was asked to verbally describe how two objects or concepts were similar.
Receptive Language	Receptive Vocabulary[1]	Measures your child's ability to identify correct responses to spoken words, in this instance, by selecting a picture that represents the word spoken by the examiner.
Expressive Language	Picture Naming[1]	Expressive language is the “output” of language, the ability to express oneself through verbal communication. Your child was asked in this subtest to name a variety of objects shown to them in pictures.
Processing Speed	Bug Search[1]	Processing speed describes the fluency with which the brain receives, understands, and responds to information. In this subtest your child was asked to match as many bug pictures as possible in a certain amount of time.
Non Verbal Memory	Picture Memory[1]	Nonverbal memory is what makes it possible to retain and remember content without words. In this subtest your child

		was shown pictures and asked to recall them a moment later.
Working Memory	Comprehension of Instructions[2]	This is a skill that allows us to work with information without losing track of what we're doing. This subtest is designed to assess the ability to receive, process, and execute oral instructions of increasing syntactic complexity.
Verbal Memory	Narrative Memory[2]	This allows us to assess your child's memory for organized verbal material under free recall and cued recall. The child listens to a story and is then asked to repeat the story. The child is then asked questions to elicit missing details from his/her recall of the story.
Perceptual-Motor	Design Copying[2]	Perceptual motor development involves brain functions necessary to plan and make decisions from simple to more complex. This subtest is designed to assess motor and visual-perceptual skills associated with the ability to copy two-dimensional geometric figures.

[1]WPPSI

[2]NEPSY

WPPSI and NEPSY Assessment Results

It is important to remember that your child's performance on the day of assessment can be influenced by different factors (e.g., attention, motivation, interests, mood at the time). This assessment was administered as part of a research study and is not an alternative to a clinical assessment.

WPPSI Results

Subtest	**Scaled Scores***	**%ile**	**Range**
Matrix Reasoning		-	Average
Bug Search		-	Low Average
Picture Memory		-	Average
Similarities		-	Superior
Receptive Vocabulary		-	Average
Picture Naming		-	High Average

* *The range of scaled scores is 1-19. Scores of 7-12 are typical (Average range).*

NEPSY Results

Subtest	**Scaled Scores***	**%ile**	**Range**
Comprehension of Instructions		-	
Narrative Memory		-	
Design Copying	-		

* *The range of scaled scores is 1-19. Scores of 8-12 are typical (Average range).*

Overall Summary:

[Provide summary of assessment]

It was a pleasure to meet with both you and NAME. On behalf of the ELF Study team I would like to thank you sincerely for your participation in this study. If you have any questions in relation to this report, please do not hesitate to contact us through the details below.

Yours sincerely,

____

Assessor: Megan Blackburne

Title: Psychologist in Clinical Training

Principal Investigator: Prof Deirdre Murray

Tel: +353(0)21 4205082

Email: d.murray@ucc.ie

Appendix H Journal Author Guidelines

Journal Name: British Journal of Developmental Psychology
Source:
https://bpspsychub.onlinelibrary.wiley.com/hub/journal/2044835x/homepage/forauthors.html

BJDP AUTHOR GUIDELINES
Sections

1. SUBMISSION
Authors should kindly note that submission implies that the content has not been published or submitted for publication elsewhere except as a brief abstract in the proceedings of a scientific meeting or symposium.

New submissions should be made via the Research Exchange submission portal. You may check the status of your submission at any time by logging on to submission.wiley.com and clicking the "My Submissions" button. For technical help with the submission system, please review our FAQs or contact submissionhelp@wiley.com.

All papers published in the *British Journal of Developmental Psychology* are eligible for Panel A: Psychology, Psychiatry and Neuroscience in the Research Excellence Framework (REF).

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This journal will consider for review articles previously available as preprints. Authors may also post the submitted version of a manuscript to a preprint server at any time. Authors are requested to update any pre-publication versions with a link to the final published article.

2. AIMS AND SCOPE

- The *British Journal of Developmental Psychology* publishes full-length, empirical, conceptual, review and discussion papers, as well as brief reports, and **Registered Reports**, in all of the following areas:

- motor, perceptual, cognitive, language, neural, clinical, personality, social and emotional development across the lifespan from infancy to adulthood
- atypical development, including developmental disorders, learning difficulties/disabilities, and sensory impairments;
- the impact of genetic, biological, familial, interpersonal, educational, societal, and cultural factors upon human psychological development;
- theoretical approaches to development,
- and especially, research and theories involving underrepresented populations.

3. MANUSCRIPT CATEGORIES AND REQUIREMENTS

The following types of paper are invited:

- papers reporting original empirical investigations;
- theoretical papers which may be analyses of, or commentaries on, established theories in developmental psychology, or presentations of theoretical innovations, extensions or integrations;
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