Stress-Adapted Is Not Impaired: Investigating Short-term and Working Memory Modalities in Children Facing Adversity



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~

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Authorship Statement

This thesis follows the integrated thesis format. All empirical chapters (Chapters 3–5) are either submitted or in preparation for submission to peer-reviewed journals. These chapters were developed in collaboration with my supervisor, Professor Emma Cohen, who provided guidance in an advisory capacity, and Dr. Arran Davis, who contributed additional analytical and computational support. I am the primary author of all work presented, and I am responsible for the intellectual development, practical implementation, and writing of the thesis.

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Abstract

Millions of children worldwide grow up facing severe adversity, including poverty, violence, displacement, and social marginalisation. While traditional deficit models associate such experiences with impaired cognitive development, recent evolutionary-developmental perspectives propose that children exposed to harsh environments may develop adaptive cognitive strengths tuned to their local demands. However, empirical evidence remains limited, particularly across diverse socio-ecological contexts.

This thesis engages with this emerging field, contributing empirical evidence to the Hidden Talents Framework, which argues that adversity may shape—rather than simply damage—the development of specific cognitive capacities. Focusing on short-term and working memory, this research investigates how adversity influences memory performance across three modalities: abstract, social, and motor. Using a combination of experimental tasks and ethnographic fieldwork, four studies were conducted with over 500 children aged 6–10, across five socio-ecological contexts in southern Italy and central Mozambique. In Italy, children from two high-stress environments (Scampia and a Roma camp) were compared to peers in a lower-stress setting (Pozzuoli). Children in high-stress conditions performed more poorly—or equally—on conventional abstract memory tasks. However, they showed comparable or superior performance on tasks involving socially or physically meaningful stimuli. A cross-cultural replication in Mozambique confirmed this pattern: children from a higher-stress rural village demonstrated enhanced social memory compared to peers in a more stable town environment.

These findings support a pluralistic model of cognitive development under adversity. While some cognitive functions appear vulnerable to environmental stress, others—particularly those with ecological relevance, such as social and motor memory—may be preserved or even

enhanced. The thesis highlights the importance of broadening assessment practices to recognise context-specific competencies, challenging normative benchmarks derived from Western, educated, and industrialised populations. It contributes to an evolving scientific and policy discourse that seeks not only to mitigate risk, but to identify and build upon the developmental strengths of children growing up in adversity.

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1 Introduction

Millions of children across the globe grow up in poverty, violence, displacement, and social marginalisation (WHO, 2024). The mainstream idea within the social and psychological sciences holds that early age exposure to such forms of acute and/or prolonged stress can compromise cognitive and behavioural development in children, who are consequently considered impaired compared to their safely nurtured peers. This deficit-oriented perspective is supported by decades of research linking early-life adversity with a broad array of detrimental outcomes, including disrupted brain development, impaired memory, emotion regulation difficulties, increased risk of psychopathology, and lower academic achievement (e.g., Anne Lown et al., 2011; Brito et al., 2016; Kim et al., 2013; Lorant et al., 2003; Perez & Widom, 1994). Although these studies have shed light on the negative effects of adversity on development, more recent work has questioned the universality of these outcomes.

Research on resilience has shown that not all individuals raised in high-stress environments exhibit impairments. Many achieve more typical development *despite* these exposures, often supported by protective factors such as stable caregivers or strong peer networks (see Benard, 1995; Goldstein & Brooks, 2013; Masten, 2001). While this work has expanded our understanding of developmental variability under stress, it still often retains the idea that normative Western development is the best possible outcome.

An emerging body of research adds to these consolidated models by suggesting that *deficit* and *resilience* represent only part of the overall picture. The Hidden Talents Model suggests that adverse environments may not only be sites of risk and impairment, but also of adaptation (Ellis et al., 2017, 2023; Frankenhuis & Nettle, 2020). Rather than merely surviving despite stress, individuals may develop specific cognitive and behavioural skills *because* of it. This

perspective fits within a broader evolutionary-developmental framework, which posits that natural selection has shaped humans to be sensitive to the surrounding environment, particularly during the developmental period, in ways that promote adaptive strategies that increase their chances of survival (Bjorklund & Ellis, 2014; Ellis & Del Giudice, 2014; Frankenhuis & de Weerth, 2013). From this perspective, individuals who grow up in challenging environments develop cognitive and behavioural phenotypes that should not be seen solely as signs of deficiency or maladaptation. Rather, they may display unique adaptations that enable them to navigate and solve problems specific to their ontogenetic niche. However, such adaptations may diverge from conventional Western norms or prevailing definitions of skill, talent, or achievement, and thus remain "hidden" if unrecognised or undervalued by broader society (Ellis et al., 2017).

This evolutionary perspective offers compelling theoretical insights and the potential for new, context-sensitive interventions, but progress in the field remains limited largely due to a lack of empirical studies. This shortage arises from considerable methodological and ethical challenges (Ellis et al., 2017; Frankenhuis et al., 2020). In particular, given that it is not ethically acceptable to manipulate early life stress in humans (i.e., expose children to high-stress conditions), most of the existing literature on stress-adapted skills primarily relies on animal models such as rodents and birds (e.g., Avital & Richter-Levin, 2005; Chin et al., 2009; Leong & Packard, 2014). Even when experimental manipulation is feasible with human participants, the simulated conditions usually fall short of replicating the severity of real-life adversity, limiting external validity. Observing behaviour in naturalistic settings may offer a more ecologically valid alternative, yet this approach often sacrifices experimental control. Moreover, conducting fieldwork in harsh and unpredictable environments can pose significant logistical challenges and safety risks for researchers.

Navigating these challenges and opportunities, this research aims to uncover potential stress-adapted skills in children growing up in high-stress environments. Specifically, it focuses on short-term memory and working memory (hereafter referred to as STM and WM). STM refers to the temporary storage and retrieval of information, while WM encompasses not only the storage and retrieval, but also the active manipulation of information, which is crucial for more demanding cognitive tasks in the present moment (see Chapter 2).

These memory systems play a vital role in children's cognitive development and are integral to a range of core cognitive functions such as learning, comprehension, problem-solving, executive functions, and general intelligence (Cowan, 2014). Extensive research indicates a negative correlation between exposure to adversity and performance on conventional STM and WM tasks (e.g., Brand et al., 2000; Bremner et al., 1993; Evans & Schamberg, 2009; Hart & Rubia, 2012; Klein & Boals, 2001; Tine, 2014). However, this general narrative glosses over considerable nuance. There is also evidence that early adversity can lead to specific enhancements in memory, such as improved STM and WM in stress-exposed individuals (Nweze et al., 2020), or improvements in specific WM components like rapid tracking and memory updating, even when other areas remain impaired (Young et al., 2018). Furthermore, conventional cognitive assessments often rely on abstract, decontextualised stimuli, overlooking other functionally important aspects of memory (see section 2.2). Recent studies have identified additional memory modalities, particularly *social* and *motor* memory (e.g., Meyer et al., 2012; Smyrnis et al., 2014), that may be especially salient in contexts where tracking others' behaviour or responding physically to dynamic environments is critical, yet remain underexplored.

These studies raise new questions about whether memory performance varies not only across environments, but also across memory modalities. Against this background, the present

research investigates whether children raised in high-stress settings differ in their performance on STM and WM tasks depending on the type of stimuli, and whether modality-specific advantages emerge in line with the predictions of the Hidden Talents Model. The three modalities explored are abstract, social, and motor. *Abstract* refers to the capacity to remember information that does not have immediate relevance to a specific problem, environment, or task (e.g., recalling a string of random digits), *social* involves remembering socially meaningful stimuli (e.g., faces of other individuals), and *motor* concerns the retention and reproduction of physical movements (e.g., performing a series of dance or martial arts moves).

To investigate this, the research focuses on children from three environments in the Naples metropolitan area that vary in levels of environmental stress (see Chapter 3). In Scampia, children contend with high criminal presence, widespread drug dealing, and persistent socio-economic insecurity. The Roma camp presents an extreme context of deprivation, marked by poverty, informal housing, unsanitary conditions, and profound social marginalisation. The town of Pozzuoli serves as a comparison site, offering relatively greater infrastructure, safety, and social stability. In addition, the social memory study was replicated in Mozambique, comparing children from Nhandar, a rural community affected by poverty, infrastructural neglect, and a history of paramilitary violence, and children from Gorongosa, a relatively wealthier and stable town.

The research design combines four structured cognitive studies with ethnographic fieldwork conducted in parallel across all sites. Study 1 examined the relationship between early-life adversity and performance on conventional STM and WM tasks. An extensive body of research, often grounded in the deficit model, predicts that children from high-stress environments—such as those in this study (i.e., Scampia neighbourhood and the Roma camp)—would perform significantly worse on STM and WM tasks than children from lower-

stress environments (i.e., Pozzuoli). Accordingly, we hypothesised that children from Scampia and the Roma camp would demonstrate lower performance on conventional STM and WM assessments compared to their Pozzuoli counterparts.

In contrast, both evolutionary-developmental literature on stress-exposed children and insights from fieldwork suggest that individuals living in high-stress contexts may develop *enhanced* memory capacities for socially relevant information (e.g., memory of previous encounters and individual recognition, see Ellis et al., 2017 for a review). Therefore, in Study 2 we hypothesised that Scampia and Roma children would score significantly higher in STM and WM tasks involving *social* stimuli when compared to their Pozzuoli peers.

Study 3 investigated whether children growing up under adversity show differences in STM and WM for *motor* information. Emerging research proposes the existence of an additional memory system specifically responsible for temporary storing and manipulating information related to body movements (Smyrnis et al., 2014; Wu & Coulson, 2014). However, this memory domain remains largely unexplored, particularly among children and in populations exposed to environmental adversity.

Study 4 replicated the social memory investigation in a different cultural context in Mozambique, testing the same hypothesis. Children from the high-stress rural community of Nhandar were predicted to outperform children from the relatively more stable environment of Gorongosa on tasks involving social stimuli.

Supporting these core cognitive-developmental studies, the ethnographic fieldwork included long-term immersion, participant observation, and interviews across all the research sites involved. This helped to ensure the ecological validity of the research and guided our interpretations of the quantitative findings.

This thesis makes several novel contributions. First, it integrates ethnographic qualitative fieldwork with quantitative cognitive assessments for uncovering and providing a more ecologically grounded understanding of potential stress-adapted skills. Second, it focuses on children, while cognitive research on memory predominantly focuses on adults, thereby contributing to a more developmental understanding of STM and WM. Third, it extends the study of memory beyond conventional tasks by incorporating ecologically relevant social and motor domains. Fourth, it examines these domains across multiple cultural and environmental contexts, strengthening the external validity of its findings. Finally, to our knowledge, this is the first study to assess and compare motor STM and WM in children from both high- and low-stress environments.

2 Exploring Childhood Stress and Memory: A Review of Two Core Variables

This chapter explores the core constructs central to this thesis: childhood stress and memory. It builds a conceptual and empirical foundation for the research questions pursued in the subsequent chapters, and clarifies how the present work contributes to, and diverges from, existing literature.

The chapter is organised into two main sections. The first reviews major theoretical perspectives and empirical studies concerning the impact of stress on children's development. Three main clusters of research are discussed: the deficit model, the traditional resilience model, and the adaptive response model. In addition to outlining their contributions, this section also critically examines their limitations, which ultimately shaped the aims of this research.

The second section turns to short-term memory and working memory, which are the key dependent variables in the cognitive-developmental studies that follow. I trace their conceptual evolution, examine their central components, and expand the discussion to include also social and motor memory systems, two additional domains assessed in this research alongside conventional "abstract" STM and WM.

2.1 Understanding the Impact of Stress on Child Development

This section reviews major theoretical perspectives from psychology, developmental science, and evolutionary theory on the impact of stress during childhood. It identifies three interrelated

clusters of research that, while not mutually exclusive, provide distinct ways of understanding psychological development under adversity.

1. The *deficit model*:

The deficit model is the dominant framework in psychology and the social sciences, and emphasises the numerous cognitive, behavioural, and physical impairments resulting from stress exposure in children. Although having the merit of recognising and trying to alleviate the potential damages caused, the deficit model remains incomplete by focusing solely on the negative outcomes of stress exposure (Ellis et al., 2017; Frankenhuis & Nettle, 2020).

2. The *traditional resilience model*:

A second strand of research emphasises *resilience,* showing that children exposed to high-stress environments do not necessarily experience compromised development, and that some can even "overcome the odds" (e.g., Fernando & Ferrari, 2013; Goldstein & Brooks, 2013; Schetter & Dolbier, 2011; Werner & Smith, 1992). However, resilience research tends to frame these outcomes as deviations from expected dysfunction, often retaining the deficit model's underlying assumptions about what constitutes normative development.

3. *The adaptive responses model*:

A third, more recent cluster is grounded in evolutionary-developmental theory and moves beyond charting the absence of impairments. This literature explores the idea that individuals exposed to harsh or unpredictable environments may develop cognitive and behavioural strategies that are advantageous in those contexts. Several theoretical traditions have contributed to this perspective, including life history theory, tightness–looseness theory, and identity fusion research (e.g., Gelfand et al., 2006; Hill, 1993; Whitehouse & Lanman, 2014). While these frameworks differ in scope and emphasis, they share the idea that adversity can shape context-specific competencies. Within this broader theoretical landscape, the Hidden

Talents Model seeks to identify domains in which children exposed to adversity may show intact or enhanced performance, particularly in skills that are ecologically relevant but often unmeasured or overlooked in conventional cognitive assessments (Ellis et al., 2023).

2.1.1 The Deficit Model

The modern Western notion of childhood fragility (see Appendix A), coupled with extensive research on the adverse impacts of stress (see Fink, 2007, 2016) has contributed to the emergence and consolidation of an array of perspectives broadly referred to as the *deficit model* (see Ellis et al., 2017). This posits that growing up in high-stress environments may impair typical neurocognitive development, leading to deficits across cognitive, emotional, and behavioural domains compared to their peers raised in safer and more stable environments (e.g., Evans et al., 2013; Juster et al., 2010; Lupien et al., 2009; Pechtel & Pizzagalli, 2011; Shonkoff et al., 2012). This belief is a core tenet of multiple stress and development theories, including the allostatic load model (e.g., Danese & McEwen, 2012; McEwen & Stellar, 1993), the cumulative risk model (e.g., Appleyard et al., 2005; Evans & Kim, 2007), and the family stress model (e.g., Conger & Elder, 1994; Masarik & Conger, 2017).

Types of Early-Life Stressors

The notion that adversity can significantly disrupt development is currently one of the most widely accepted and pervasive perspectives in behavioural and psychological science, as well as in applied fields such as education and the humanitarian discourse (e.g., Agaibi & Wilson, 2005; Alisic et al., 2014; D'Andrea et al., 2012; Denov, 2010; Derluyn et al., 2004; Singer et al., 1995). This perspective shapes research and interventions aimed at preventing or reducing early-life stress, defined as the inability of an individual to cope with exposure to one or more stressful events during early life, potentially leading to prolonged physiological and psychological strain (Pechtel & Pizzagalli, 2011).

Understanding the types of stressors children may experience is essential to assessing their potential developmental consequences. One of the most influential contributions in this field is the *Adverse Childhood Experience (ACE) study* (Felitti et al., 1998), which identified ten categories of early-life stressors grouped into three domains: abuse (physical, emotional, or sexual), neglect (physical or emotional), and household dysfunction (mental illness, substance abuse, incarcerated relative, domestic violence, and divorce). The ACE study found a graded association between the number of these exposures and the likelihood of developing health-risk behaviours in adulthood, including substance abuse, physical inactivity, severe obesity, depression, and suicidal behaviour.

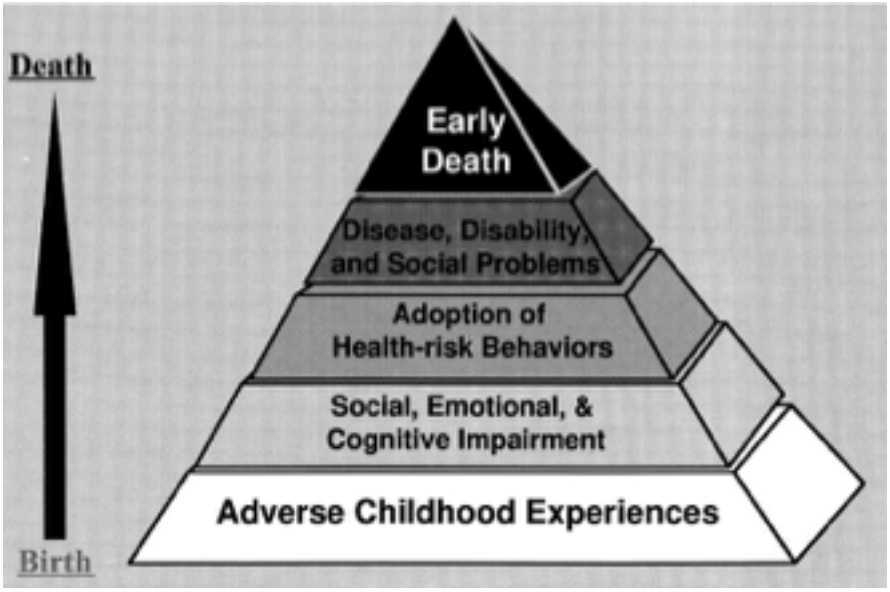


Figure 1. The potential influence of adverse childhood experiences during the lifespan. Reproduced from Felitti et al., 1998.

Other research identified additional potential childhood stressors such as separation from the caregivers, relocation to a new home or school, social deprivation, illness and hospitalisation, exposure to natural disasters, or bereavement (e.g., Brown et al., 2009; Durkin et al., 1993). There is also considerable evidence of the additive and cumulative effects of the various stressors identified, with the likelihood of children developing impairments or

psychopathologies being strongly associated not only with the presence of stressors, but also with their number, severity, and duration over time (Cloitre et al., 2009; Danese & McEwen, 2012; Evans, 2003; Hodges et al., 2013; McEwen, 1998; Suliman et al., 2009).

Early Development and Long-Term Impacts

The developmental effects of adversity can begin as early as the prenatal period. For instance, insufficient maternal nutrition during pregnancy can impair foetal development, resulting in compromised brain growth and subsequent cognitive deficits (Walker et al., 2007). Moreover, exposure to maternal stress during gestation has also been linked to long-term changes in the physiological stress responses of offspring, increasing vulnerability to environmental challenges later in life (Barbazanges et al., 1996; Green et al., 2011; Le Moal, 2007).

After birth, the range of potential impacts broadens considerably. Among the various sources of adversity that children may face, low socioeconomic status (SES)[1] has consistently been identified as a major risk factor. Children from low-SES backgrounds are more likely to experience challenges arising from financial instability, limited access to health and educational resources, and higher exposure to environmental hazards (Bradley & Corwyn, 2002; Evans, 2004). These conditions can adversely affect various aspects of children's development. For instance, research suggests a correlation between low socioeconomic status and alterations in the development of prefrontal brain regions, which may in turn be associated with weaker executive functions in children from these backgrounds (Meaney et al., 2010; Noble et al., 2015). Executive functions, including short-term memory and working-memory, are fundamental to a wide range of developmental outcomes. Multiple studies have found a

[1] Various indicators are used to measure *socioeconomic status*, with the most common being household income, level of parental education, and occupational status (Bradley & Corwyn, 2002).

correlation between these cognitive systems and critical life outcomes such as academic success (e.g., St Clair-Thompson & Gathercole, 2006), social competence (e.g., Barkley, 2001), problem-solving skills (see Diamond, 2013), and mental health (e.g., Willcutt et al., 2005). Although many of these findings are correlational, they are often interpreted as evidence that early adversity can disrupt cognitive development—particularly executive functions—which in turn contributes to later difficulties in academic, social, and emotional domains.

Additional studies have identified more direct associations between specific forms of adversity—such as childhood abuse—and a broad range of psychiatric and behavioural outcomes in later life, including but not limited to depression (Brown et al., 1999; Infurna et al., 2016; Penza et al., 2003), anxiety (Lindert et al., 2014; Neumann et al., 1996; Shackman et al., 2007), alcohol and drug abuse (Anne Lown et al., 2011; Shin et al., 2010; Strine et al., 2012), higher aggressivity and violent behaviour (McKinney et al., 2009; Milletich et al., 2010; Seghorn et al., 1987), suicidal behaviour (Swogger et al., 2011), and academic difficulties (Perez & Widom, 1994). Some studies have also linked specific adverse experiences to the disruption of particular cognitive processes. For instance, early exposure to sexualisation was associated with reduced math performance, an effect attributed to a decrease in working memory capacity (Pacilli et al., 2016).

Merits and Criticisms of the Deficit Model

As reviewed in the previous sections, a substantial body of research indicates that growing up in a high-stress environment is associated with a range of cognitive, emotional, and behavioural challenges (Brumbach et al., 2009; Eamon, 2001; McLoyd, 1998; Miller et al., 2011; Raver et al., 2013). The deficit model has made important contributions to advancing our understanding of these negative outcomes. Firstly, it acknowledges the existence of childhood stress and its potentially harmful consequences. Secondly, it establishes a theoretical framework for

identifying, categorising, and studying the causes and negative consequences of acute and/or prolonged stress on children. Empirically, the model has helped demonstrate that specific stressors (e.g., neglect or exposure to violence) may differentially affect specific functions (e.g., working memory or attention). Furthermore, it has revealed that the incidence of detrimental behaviours such as smoking, alcohol abuse, or depression is disproportionately higher among adults who experienced early-life adversity. As a result, a more comprehensive understanding of how medical, psychiatric, and social issues may be interconnected throughout the lifespan has been advanced.

Nonetheless, the deficit model has been criticised as a simplistic and incomplete portrayal of stress-exposed children (Ellis et al., 2017, 2023), with limited understanding of how these effects emerge across different systems or developmental stages (Noll & Shalev, 2018). More importantly, the deficit model overlooks the possibility that certain cognitive and behavioural responses categorised as *maladaptive* (e.g., heightened vigilance, impulsivity) may actually be adaptive in the environment where they developed (Frankenhuis & de Weerth, 2013). Recognising this possibility challenges the binary categorisation of either adaptive or maladaptive function, and highlights the intricate interplay between the individual, their environment, and the strategies they employ. Furthermore, not all children exposed to ontogenetic stress exhibit impaired development. Many of them "overcome the odds" and develop strengths and coping strategies known as *resilience* (Benard, 1995; Floyd, 1996; Todis et al., 2001; Werner & Smith, 1992).

2.1.2 The Traditional Resilience Model

In psychology, *resilience* refers to the ability to achieve positive outcomes despite exposure to factors that threaten the adaptation or development of individuals (Masten, 2001). Research on

resilience has evolved considerably over time, shaped by changing theoretical perspectives and methodological innovations.

The Evolution of Resilience Studies

Systematic research on resilience emerged in the 1970s within the field of developmental psychopathology, which investigates patterns of adaptation and maladaptation across the lifespan (Cicchetti & Curtis, 2006). This line of inquiry built upon prior work by Norman Garmezy, who conducted research on mental disorders during the 1940s and 1950s. Garmezy and his colleagues also examined children whose parents had mental illness, with a particular focus on those affected by schizophrenia (Garmezy & Rodnick, 1959). They observed that many children considered at risk for psychopathology did not display impairments but rather demonstrated positive developmental outcomes. These findings led Garmezy to develop an interest in resilience, and by the early 1970s he and his team had shifted their focus to examining competencies in children facing various risk factors, such as parental mental illness, poverty, and other challenging life experiences.

Since then, resilience research has progressed through four main waves (Masten & Cicchetti, 2016; Wright et al., 2013). Initially, researchers focused on describing and assessing the uniqueness of resilience, attempting to identify which characteristics distinguished individuals who, despite experiencing adversity, did not display any signs of impairment (Cohler, 1987). During this phase, terms such as "invincible" or "invulnerable" were often used to describe people who demonstrated resilience, as they were seen as exceptional (Pines, 1975). This wave of research facilitated the identification of protective factors associated with resilience (Masten & Obradovič, 2006), spanning individual, family, or community level (Garmezy et al., 1984; Rutter, 1979). For instance, women who were institutionalised in childhood were found to fare

better in adulthood if they had experienced positive school environments, suggesting that these experiences served as a protective factor against early adversity (Rutter & Quinton, 1984).

The second wave shifted attention from describing protective factors to the processes that underlie resilience (Richardson, 2002). Researchers sought to understand how different factors interact over time and across systems to shape both pathological and positive outcomes (Masten et al., 1990). This approach emphasised that resilience arises from multiple interdependent processes and led to greater consideration of biological, social, and cultural elements. Second-wave researchers also noted the contextual specificity of protective factors, highlighting which protect whom and under what conditions (Wright et al., 2013). For example, the Rochester Child Resilience Project (RCRP, Cowen et al., 1990), conducted with 4th-6th-grade urban children in Rochester (New York, USA) who had experienced significant life stress, found that children who had at least one supportive adult in their lives, who provided emotional support and encouragement, were more likely to show resilience and overcome the negative effects of life stress. Similarly, research among Finnish employees found individuals with high levels of personal resilience, measured in terms of optimism and self-esteem, experienced lower levels of mental distress one year later, indicating that optimism and self-esteem can serve as protective factors against the negative effects of adversity over time (Mäkikangas et al., 2004). These findings highlight the importance of understanding how protective factors interact with risk factors to promote resilience, and can inform interventions aimed at fostering resilience in children facing adversity.

A significant shift toward more empirical approaches aimed at promoting resilience in individuals facing adversity characterises the third wave of resilience research. Two complementary goals have typically been pursued: reducing risk factors and strengthening protective factors, with theoretical frameworks and interventions being applied across broad

settings such as families (e.g., Bellin & Kovacs, 2006; Patterson, 2002; Riley et al., 2008), and schools (e.g., Henderson & Milstein, 2003; Morrison & Allen, 2007; Thomsen, 2002). Interventions have also been tailored to specific populations, such as adolescent experiencing depression (e.g., Shochet et al., 2001) or youth at risk for substance abuse and suicide (e.g., Forman & Kalafat, 1998). In other cases, interventions have addressed environmental challenges, for example by helping rural communities cope with drought (e.g., Rockström, 2003).

Currently, the fourth wave of resilience research adopts a multidisciplinary approach, fuelled by recent theories and research methods (Masten & Cicchetti, 2016), including contributions from neuroscience (e.g., Greenberg, 2006) or genomics (e.g., Maul et al., 2020). Resilience is now widely recognised as a dynamic process that emerges from the interplay between individual characteristics and environmental influences, reflecting humans' ability to adapt to their surroundings and resulting in a wide range of potential adaptations and significant variability in response (Masten & Cicchetti, 2016).

Merits and Criticisms of the Traditional Resilience Model

Studies within the traditional resilience model have significantly advanced our understanding of how children can overcome adversity. A key merit of this approach is its demonstration that exposure to early-life stress does not inevitably lead to compromised development. Furthermore, research has identified various protective factors such as strong social support networks, effective coping strategies, and positive school experiences that can shield individuals from the potential negative impacts of stress and promote resilience. These findings have informed the development of interventions aimed at supporting “at-risk” children, emphasising the importance of building and maintaining nurturing relationships and environments.

However, the traditional resilience model has also faced criticism, particularly concerning conceptual inconsistencies and definitional ambiguities. For example, heterogeneity in the types of risk exposures and outcomes considered, instability in resilience across different contexts and over time, and persistent challenges in measurement have contributed to a lack of consensus regarding the construct itself (Luthar & Cicchetti, 2000).

Further criticism focuses on the model's predominant emphasis on individual traits, which can oversimplify the dynamic interplay between the individuals and their environments. Systemic, structural, and cultural factors—such as community resources and cultural practices—also play significant roles in shaping resilience within broader ecological contexts (Southwick et al., 2014; Ungar, 2011).

Additionally, conventional models typically stipulate two conditions for classifying an individual as resilient: (i) exposure to an objective and demonstrable *risk*, and (ii) evidence of a *positive* developmental outcome despite such exposure (Masten, 2001). Yet both conditions are subject to cultural and contextual interpretation. What counts as a "risk factor" or a "positive outcome" can vary widely across social and cultural settings, and research—particularly in psychology and child development—has often reflected Western ethnocentric assumptions in defining both.

An illustrative example comes from child reintegration efforts in post-war Sierra Leone. During the country's civil war (1991-2002), several humanitarian organisations sought to demobilise more than 10,000 child soldiers who had been engaged in the conflict and reintegrate them with their biological parents (Richards, 1996; Zack-Williams, 2001), guided by the Western assumption that being raised by non-biological parents constitutes a risk factor for children's development (e.g., Cooper et al., 2009; Jensen et al., 2017; Sun, 2003). However, in Sierra Leone fosterage was a common and culturally valued practice in which children are raised by

extended kin or unrelated adults for purposes such as social apprenticeship or vocational training (Shepler, 2014). For some of these former child soldiers, returning to biological families—especially after having been coerced into harming them—resulted in stigmatisation, exclusion, and even re-enlistment into armed groups (Richards, 1996; Shepler, 2014).

This case illustrates how definitions of "risk" and "protective" factors are often shaped by culturally specific norms and practices, underscoring the necessity of moving beyond singular cultural viewpoints to enhance our understanding of stress and its impact on child development. Similar concerns arise in defining what counts as a *positive* developmental outcome (Masten, 2001). While academic success or psychological well-being may be taken as standard indicators of resilience in Western research, other cultures may value competence in traditional knowledge, social adaptability, or survival skills as equally legitimate outcomes.

Together, these critiques highlight the limitations of resilience models that are normative, individualistic, or culturally narrow, and underscore the need for broader frameworks that take seriously the ecological and cultural specificity of both adversity and adaptation. This shift in perspective sets the stage for the next section, which focuses on models that move beyond impairment or typical development, and instead explores approaches that consider the emergence of context-specific adaptations.

2.1.3 Adaptive Responses to Stress

While the concept of resilience has contributed to our understanding of how some individuals cope with adversities to achieve a "typical" development, recent frameworks have begun to shift the focus from coping to adapting. These approaches highlight the evolutionary and ecological plasticity of human development, proposing that exposure to adversity may lead to functionally adaptive traits that are well-suited to specific environmental conditions (e.g., Ellis et al., 2017; Sternberg, 2021; Whitehouse et al., 2017). Such models challenge assumptions

rooted in Western, Educated, Industrialised, Rich, and Democratic contexts (Henrich et al., 2010), suggesting that developmental outcomes should be evaluated in relation to ecological demands rather than universalised standards. Among the most prominent of these frameworks are the Adaptation-Based Approach to Resilience and the Hidden Talents Model (Ellis et al., 2017, 2023), both of which argue that exposure to harsh and unpredictable environments may catalyse the development of fine-tuned, context-specific adaptive skills in children—not despite adversity, but because of it.

These frameworks inform the theoretical foundation of this thesis. They underscore the view that human development is inherently adaptive, shaped by selection pressures over evolutionary time to respond flexibly to environmental variation—including stress and unpredictability.

Evolutionary Adaptations to Environmental Instability

The split between *Homo* and *Pan* genera occurred approximately 6 Ma (Glazko & Nei, 2003; Reich et al., 2006), coinciding with the onset of dramatic and increasingly extreme global environmental oscillations (deMenocal, 2004). During this period, Earth's systems experienced repeated fluctuations in rainfall, temperature, vegetation, water basins size, sea level, glacial and interglacial cycles, atmospheric composition, fire regimes, volcanic activity, and wind patterns (Kiefer et al., 2009; Maslin et al., 2015; Shultz & Maslin, 2013; Toggweiler et al., 2006; Trauth et al., 2005). Collectively, such shifting environmental conditions exerted powerful selection pressures that shaped the evolutionary trajectories of early hominins.

Three major hypotheses have been proposed to explain how these climatic fluctuations influenced human evolution (Bobe & Behrensmeyer, 2004). The classic *savanna hypothesis* and its subsequent iterations suggest that climate-driven habitat changes—particularly the expansion of African grasslands—played a pivotal role in the divergence of hominins from

other apes, eventually leading to the emergence of the genus *Homo* (Bartholomew & Birdsell, 1953; Dart, 1953; Jolly, 1970; Klein & Edgar, 2002). Building on this, Vrba (1985, 1988, 1995) argues that the appearance of hominins in the late Miocene and the subsequent rise of *Homo* in the late Pliocene were part of a broader pattern of faunal evolution closely tied to the episodes of global climate change. A more recent perspective is Potts' (1998) *variability selection hypothesis*, which posits that the most important selective pressure in human evolution was not adaptation to any one habitat, but rather environmental unpredictability itself. According to this view, traits such as bipedalism, brain encephalisation, or complex social mechanisms in certain late Pleistocene *Homo*—particularly *H. sapiens*—may have evolved not in response to specific stable habitats, but under conditions of profound ecological changes. Natural selection, in this framework, would have favoured developmental plasticity and cognitive-behavioural flexibility—traits that allowed early *Homo* to survive across diverse and changing environments. This hypothesis has been supported by subsequent research documenting complex ecological variability in environments occupied by early hominins (e.g., Anton et al., 2014; Bobe & Behrensmeyer, 2004; Potts, 2013). Environmental unpredictability and high-stress conditions not only influenced biological adaptations, but also likely spurred social and/or technological innovations, for example in hunter-gatherer societies (see Pereda et al., 2017). Such innovations, in turn, may have been crucial for the survival of *Homo sapiens* (Hoffecker, 2005).

Drawing on this evolutionary foundation, Frankenhuis and Amir (2022) suggest that stressful childhood environments were common across human history and may have favoured the development of phenotypic plasticity—the capacity for organisms to adjust their development in response to local environmental cues. This principle extends to modern developmental contexts, where children exposed to adversity may develop adaptive strategies tailored to the

demands of their environments. Importantly, these adaptations are not limited to the physical domain but also extend to social and behavioural strategies.

For example, the theory of *normative tightness-looseness* explores how groups vary in the strength of their social norms and the degree to which deviations are sanctioned (Gelfand et al., 2006). Adverse and unpredictable environments often foster tighter social norms, where behavioural expectations are clearly defined and strictly enforced. This tightness serves several adaptive functions: it reduces uncertainty by establishing clear conduct standards, enhances coordination by making behaviour more predictable, and minimises conflict by discouraging norm violations, which can be particularly costly in already difficult conditions. Strict norm enforcement can benefit both individuals and groups by providing a sense of belonging and access to resources, while enhancing group cohesion and efficiency (Gelfand et al., 2006, 2017; Harrington & Gelfand, 2014). From an evolutionary perspective, such benefits reflect a group-level dimension of human adaptability, as tightness can helps communities cope with adversity and increase their chances of survival.

Harsh environments can also promote sharing and cooperation, which enhance group functioning through increased social cohesion, resource sharing, and collective problem-solving. For example, societies facing greater resource scarcity, such as unpredictable climate-related food supply, may develop extensive sharing practices beyond individual households, which serves as an adaptive strategy to pool risk and reduce the likelihood of food shortages (Ember et al., 2018). Food sharing may then lay the foundation for other cooperative behaviours, such as forming marital bonds or forging political alliances (Gintis et al., 2005; Patton, 2005).

A particularly intense form of group-level cohesion is seen in identity fusion, a type of bonding in which personal and social identities become simultaneously activated and experienced as

one (Gómez et al., 2011; Swann et al., 2009; Swann & Buhrmester, 2015). Fused individuals tend to develop a profound sense of psychological oneness with their group, wherein the boundaries between personal and social identity blur, leading to strong emotional ties similar to kinship[2]. Identity fusion can emerge from intense, often dysphoric (i.e., painful and frightening) experiences (Whitehouse et al., 2017). Such experiences, which may include a broad range of events, from Brazilian Jiu Jitsu belt whipping (Kavanagh et al., 2019) to participation in violent revolutionary conflict (Whitehouse et al., 2014), can become deeply entrenched as defining memories for both individuals and their fellow group members. Fused individuals are more likely to prioritise group welfare over personal safety and may even engage in self-sacrificial behaviours when the group is under threat. From an evolutionary perspective, identity fusion may represent a behavioural strategy evolved for the survival of ancestral groups in high-risk collective activities such as hunting and intergroup conflicts (Whitehouse et al., 2017; Whitehouse & Lanman, 2014).

These examples illustrate how humans have evolved complex adaptive strategies to enhance survival under adverse conditions. They show that adaptability extends beyond individual-level traits like cognition or temperament to include group-level strategies such as norm enforcement, cooperation, and identity fusion. Returning to developmental strategies specifically, we now turn to the Adaptation-Based Approach to Resilience and the Hidden Talents Model, which emphasise how exposure to harsh and unpredictable environments can foster the development of context-specific adaptive skills, particularly in children.

[2] Unlike conventional group identification, which is based on depersonalised categorical affiliation and a relative de-emphasis of personal identity (Sedikides & Brewer, 2001; Tajfel & Turner, 1985), identity fusion arises from relational bonds that are projected onto the group, producing a powerful sense of oneness (Rosenberg, 1987).

Adaptation-Based Approach to Resilience and Hidden Talents Model

The *adaptation-based approach to resilience* (ABAR, Ellis et al., 2017) aligns with the evolutionary perspectives discussed above—and diverges from both the deficit model and traditional resilience approaches—by proposing that individuals may develop adaptive strategies in response to recurring problems in their environment.

Development and Core Concepts of the ABAR

The ABAR was initially rooted within the *life-history theory* (LHT) framework but extends beyond its foundational premises. LHT seeks to explain how organisms enhance their fitness (i.e., survival and reproduction) by making trade-offs in how they allocate limited resources available toward growth, reproduction, and maintenance (see Belsky, 1999; Charnov, 1993; Del Giudice et al., 2016; Figueredo et al., 2006; Flatt & Heyland, 2011; Hill, 1993). However, the application of LHT to within-species variation, especially in humans, has been challenged, with critics arguing that empirical support for consistent trade-offs is limited, and that human traits shaped by developmental stress often defy the neat patterns predicted by LHT (see Nettle & Frankenhuis, 2020; Sear, 2020; Zietsch & Sidari, 2020). This has prompted calls to acknowledge a broader range of context-sensitive adaptive responses, beyond canonical life history strategies.

Central to the ABAR is the idea that the effectiveness of a particular strategy depends on the physical and social factors of an individual's environment, thus a strategy that confers success in one context may lead to disadvantage in another (Ellis & Del Giudice, 2019). Consequently, organisms that exhibit adaptive phenotypic plasticity—the capacity of a single genotype to produce context-sensitive phenotypes—possess an evolutionary advantage, as they can thrive and reproduce across diverse ecological conditions. In humans, this plasticity may underlie the development of stress-adapted skills: physical, cognitive, and behavioural skills that are

particularly effective in navigating harsh and unpredictable environments (Ellis et al., 2017; Frankenhuis & de Weerth, 2013). Importantly, such skills need not reflect an underlying life history strategy but may emerge as stand-alone adaptations to specific environmental demands.

Two key concepts define the ABAR: the *specialization hypothesis* and the *sensitization hypothesis*. The specialization hypothesis posits that individuals develop specialised adaptive abilities that are particularly well-suited to the challenges of their specific ontogenetic niche (Frankenhuis & de Weerth, 2013). The sensitization hypothesis further suggests that such skills find optimal expression in conditions resembling those in which they were acquired (Ellis et al., 2017). Both ideas are grounded in the assumption that early development is a critical window for adaptation. This is supported by research in evolutionary developmental psychology, which proposes that natural selection has shaped childhood as a particularly plastic and sensitive period for developing context-appropriate strategies (Belsky et al., 1991; Bjorklund & Ellis, 2014; Ellis & Del Giudice, 2014; Fawcett & Frankenhuis, 2015). Across most of human history prior to modernity, childhood was consistently the stage of life facing the highest mortality rates, with estimates often reaching 40–50% (Parsons, 2000; Volk & Atkinson, 2008). Comparable figures are observed also among modern hunter-gatherer societies, often used as proxies for pre-agricultural populations (Ellis et al., 2017; but see Laland & Brown, 2011 for the limitations of this approach). Consequently, the "expected childhood environment" throughout much of human evolutionary history was far from uniformly nurturing and safe; instead, it unfolded under conditions of greater threat and deprivation than in most modern industrialised settings. This variability across spaces and times likely favoured the evolution of phenotypic plasticity, through which children's development is tailored to different conditions (Frankenhuis & Amir, 2022).

Supporting this, studies in non-human animals—particularly rodents and birds—demonstrate that early-life stress can enhance a range of cognitive and behavioural skills such as attention, perception, learning, and memory (see Ellis et al., 2017). For instance, avian research on marsh tits (*Parus palustris*), mountain chickadees (*Poecile gambeli*), and tufted titmice (*Parus bicolor*) shows that developmental exposure to stress-related cues, such as food scarcity or unpredictability, can promote improved spatial memory and superior food-caching ability, thereby increasing survival in resource-limited conditions (Hurly, 1992; Pravosudov & Clayton, 2001; Pravosudov & Grubb, 1997). Similarly, embryonic exposure to elevated yolk corticosterone in species such as barn swallows (*Hirundo rustica*), European starlings (*Sturnus vulgaris*), and great tits (*Parus major*) produces smaller offspring with more mature flight muscles, lower wing loading, and faster take-off speeds—traits that enhance evasion and predator avoidance in risky environments (Chin et al., 2009; Crino & Breuner, 2015). Comparable mechanisms have also been documented in rodents: Wistar rats (*Rattus norvegicus*) exposed to early maternal deprivation followed by unpredictable stress in adulthood exhibit enhanced hippocampal performance in contextual fear conditioning and improved contextual memory, suggesting that early adversity may calibrate neurocognitive systems toward survival in threatening environments (Zalosnik et al., 2014).

Although evidence from humans is still limited, an emerging body of research has identified approximately 20 stress-adapted skills that appear to develop more robustly following early exposure to adversity including, for example enhanced learning about animal danger (Barrett et al., 2016), reward-oriented problem-solving (Suor et al., 2017), and procedural learning (Dang et al., 2016). For broader reviews of potential stress-adapted skills in humans, see Ellis et al. (2017, 2023).

The Hidden Talents Model

The adaptation-based approach to resilience has been further developed into the *Hidden Talents Model* (Frankenhuis et al., 2020), which provides the theoretical foundation for the research questions and hypotheses explored in this thesis. Like traditional resilience frameworks, the HTM focuses on the strengths of stress-exposed individuals, offering a more inclusive perspective than the mainstream deficit model. However, it differs in its questions and approach. While traditional resilience research asks what makes children capable of achieving positive outcomes *in spite* of adversities, the HTM investigates precisely which skills are promoted *due to* such exposure. Additionally, conventional measures of resilience often reflect dominant W.E.I.R.D. values (e.g., academic achievement), overlooking the adaptive strategies developed outside of these contexts, which can remain unrecognised or "hidden". At its core, the HTM acknowledges that certain skills may provide a significant adaptive advantage in the contexts where they developed (Ellis et al., 2017; Frankenhuis & de Weerth, 2013). It also recognises that some of these abilities may be socially questionable or even stigmatised in one society but nonetheless have value and utility in other cultural contexts. For example, behaviours such as fighting or stealing, while viewed negatively in most contemporary Western settings, may be considered essential for survival in others and be associated with traits such as courage or resourcefulness[3].

By embracing a broader and more culturally grounded view of adaptation, the HTM offers not just a more inclusive perspective, but a distinctive account of how adversity shapes development. Rather than framing stress exposure solely in terms of risk or resilience, the

[3] For instance, in some Ugandan communities, acts such as corruption and theft may be culturally accepted or even valued when perceived to benefit one's family or community. As such, embezzling government funds may be viewed as a sign of intelligence and cunning rather than a moral violation (Bukuluki, 2013).

model seeks to identify the mechanisms through which specific environmental demands shape children's cognition, behaviour, and life outcomes. Furthermore, the HTM emphasises that these stress-adapted abilities are not just survival strategies, but potential assets that can be harnessed to promote success across domains such as education, work, relationships, and civic life (Ellis et al., 2017; Frankenhuis & de Weerth, 2013).

The HTM and Adaptive Intelligence

The HTM recognises the importance of looking beyond culturally specific, often Western-biased norms when evaluating human development. This perspective is informed by the work of scholars who have long argued that cognitive and behavioural sciences must expand their definitions of intelligence and development to recognise the diversity of adaptive skills shaped by environmental context (see Sternberg, 2014).

A core premise of the HTM aligns with the widely accepted view that intelligence is defined, at least in part, as the ability to adapt to the environment (see Sternberg, 2014, 2019). In this light, the HTM frames certain context-specific strategies as expressions of adaptive intelligence: skills that may not be universally valued but are nonetheless functional—and sometimes essential—within specific ecological contexts (Ellis et al., 2023).

To illustrate, a study conducted by Sternberg and colleagues (2001) in a rural village in Western Kenya assessed both the academic intelligence and practical knowledge of medicinal plants among 85 children. Although they demonstrated extensive understanding of over 100 local herbal remedies, their practical intelligence scores were trivially or significantly negatively correlated with their academic intelligence as measured by conventional tests. Similarly, a study by Grigorenko et al. (2004) found that Alaskan Yup'ik children from rural communities (n = 136) outperformed their urban peers (n = 125) on a practical intelligence test involving everyday-life local knowledge (e.g., herb gathering and preparation, fishing, hunting, and

weather understanding), while scoring lower on a conventional intelligence test. Had these studies only relied on standard cognitive assessments, rural communities' children would have been considered impaired compared to their urban counterparts, leading to an incomplete evaluation of their cognitive abilities. These findings highlight the importance of considering the cultural and environmental contexts in which cognitive abilities are assessed, and of acknowledging the value of adaptive intelligence in everyday life.

Nonetheless, forms of adaptive knowledge and skills—such as extended plants knowledge among rural Kenyan children or the ability to construct fish racks among the Yup'ik—are not necessarily hidden talents. According to HTM researchers, the distinction between hidden talents and other forms of adaptive intelligence lies in their relationship with stress. While locally relevant knowledge and skills may be adapted to a particular environment, they may not necessarily emerge in response to harsh conditions, and their acquisition processes may differ from those involved in hidden talents. These arise specifically in response to challenges posed by harsh, unpredictable environments, with stress playing a central role in shaping these abilities (see Ellis et al., 2023).

Challenges and Limitations in HTM Research

Although the Hidden Talents Model offers a compelling new perspective on children's development under adversity, the framework remains in its early stages, with empirical research relatively nascent and requiring further methodological and theoretical refinements (Frankenhuis et al., 2020).

A key limitation concerns the populations and methods used. Ethical constraints make it impossible to experimentally expose children to high levels of adversity, and as a result, much of the foundational work on stress-adapted skills has been conducted on non-human animal models (see Ellis et al., 2017). While these studies have provided valuable insights, they cannot

replace the need for human data. Some initial research involving mild exposure to stress has been conducted on humans, but the body of work is still relatively sparse and fragmented. Among these studies, research has also focused on participants from *Western, Educated, Industrialized, Rich, and Democratic* populations (W.E.I.R.D., Henrich et al., 2010), often consisting of university students (e.g., Dittmann et al., 2020; Mittal et al., 2015; Na & Chan, 2016). Such samples represent only a small portion of the global human population and results cannot be generalised cross-culturally.

Another major challenge lies in the measurement of adaptation. While the HTM proposes that adversity can promote the development of context-specific cognitive and behavioural skills, most studies have focused on performance in standardised cognitive tasks rather than real-world outcomes. For instance, Masten and colleagues (2008) found that 49 maltreated children aged between 8 and 15 years from Connecticut displayed faster reaction times compared to controls when identifying emotional facial expressions, particularly for fearful faces. However, it remains unclear whether such abilities translate into meaningful advantages in daily life, such as enhanced social navigation, safety, or access to resources (Frankenhuis et al., 2020).

In addition, isolating the specific contributions of different dimensions of adversity—such as harshness versus unpredictability—remains a methodological difficulty. In real-world conditions, these factors often co-occur, complicating efforts to link particular stressors to specific cognitive outcomes. Greater precision in the measurement of adversity and the use of formal modelling may help to address this issue in future research (Frankenhuis et al., 2020).

The interaction between adaptation and impairment also complicates interpretation. Exposure to adversity may simultaneously impair some capacities while enhancing others. For example, children exposed to violence might develop heightened vigilance or faster threat detection (Shackman et al., 2007) but struggle with executive functioning or emotional regulation

(Pechtel & Pizzagalli, 2011). These trade-offs can remain undetected in conventional designs unless both stress-adapted and safety-adapted measures are included, or within-subject comparisons are used (Frankenhuis et al., 2020).

Moreover, most studies have a very narrow focus, examining isolated skills in small or homogeneous samples. For instance, Raver et al. (2015) found that a higher level of exposure to verbal aggression among parents predicted greater accuracy in recognising emotions among 1025 children of 58 months of age from North Carolina and central Pennsylvania. Similarly, Vandenbroucke and colleagues' (2016) reported that 90 kindergarteners aged between 5.3 and 6.4 years from Belgium, born to very young mothers and exposed to maternal smoking during pregnancy and low family SES, performed better on a response shifting task. While such studies offer compelling evidence of potential hidden talents by showing that particular skills may emerge under specific conditions, their limited scope and cultural specificity prevent generalisation across settings, populations, or developmental stages, thereby constraining broader theoretical conclusions.

A further conceptual challenge concerns the boundary between stress-adapted skills, as defined by the HTM, and more general forms of adaptive or practical intelligence documented in cross-cultural psychology. Studies such Sternberg et al.'s (2001) research in rural Kenya or Grigorenko et al.'s (2004) work with Yup'ik communities are usually cited as examples of cultural adaptation rather than stress adaptation, but in practice the line may be less clear-cut. For instance, Sternberg's participants lived in contexts where most children suffered from parasitic infections that interfered with daily functioning, and therefore their extensive herbal medicine knowledge could also be seen as a skill shaped by chronic stress exposure. Recognising this ambiguity opens an important research avenue: future studies could examine how much locally relevant knowledge develops through cultural transmission, how much

through exposure to adversity, and how the two processes interact. Clarifying this distinction would refine the theoretical scope of the HTM and strengthen its integration with broader work on adaptive intelligence.

In summary, while there is some preliminary support for the HTM, much is still unknown and major questions remain. Do similar hidden talents emerge in children exposed to comparable stressors across different cultural or ecological contexts? Do they emerge only beyond a certain threshold of stress exposure? Does their development depend on the age at which stress occurs? And do such adaptations emerge gradually or rapidly? Answering these questions will require broader, cross-cultural samples, more comprehensive assessments of cognitive and behavioural skills, and longitudinal designs. Future research with more diverse populations and across a broader range of abilities will be crucial to establishing this nascent approach on a firmer empirical footing, and to refining its contributions in relation to other models of development under adversity.

2.1.4 Concluding Perspectives on Development Under Stress

To conclude, research based on the deficit model has played a vital role in identifying the risk factors that threaten typical child development and in documenting their detrimental effects. This work has inspired a range of preventive and therapeutic interventions aimed at avoiding exposure to potentially traumatic experiences, and at healing when such exposure has already occurred (e.g., Alvord & Grados, 2005; Davies & Webb, 2000; Fazel & Stein, 2002; Peek, 2008; Rak & Patterson, 1996). Studies grounded in the traditional resilience framework have further contributed to the field by demonstrating that not all children exposed to adversity experience impairment. These insights have informed interventions aimed at reducing exposure to risk factors, and strengthening protective factors that buffer the effects of stress. Research on adaptive strategies has extended this picture by exploring how challenging

environments can foster context-specific adaptations. This work shows that stress-exposed individuals may develop behavioural strategies that enhance survival or functioning within their specific contexts, for example through group cohesion and cooperation. Finally, the HTM complements these frameworks by proposing that developmental stress does not necessarily lead to impairment or test resilience, but can also foster unique stress-adapted abilities. Its goal is to identify and map such abilities with greater precision, thereby informing policy and practice interventions that work with—rather than against— the lived adaptations of stress-exposed individuals (Ellis et al., 2017, 2023). Importantly, the HTM does not dismiss the real harms caused by early adversity. Rather, it adds a more proactive dimension by focusing on how we can recognise and build upon children's existing strengths. This approach broadens the aims of interventions from "healing" to also promoting positive adaptation through the cultivation of stress-adapted skills (Frankenhuis & Nettle, 2020).

Among the various domains where hidden talents may emerge, this thesis focuses on STM and WM for two main reasons. First, these systems are central to children's cognitive development, and support a range of fundamental cognitive functions including learning, comprehension, problem-solving, executive functions, and overall intelligence (Cowan, 2014). Second, while research has consistently found that exposure to acute and/or chronic stress is associated with poorer performance on conventional STM and WM tasks (e.g., Brand et al., 2000; Bremner et al., 1993; Evans & Schamberg, 2009; Farah et al., 2006; Hart & Rubia, 2012; Klein & Boals, 2001; Tine, 2014), recent studies suggest a more nuanced picture (see 2.2.3). Some findings indicate that stress-exposed individuals may exhibit preserved or enhanced memory capabilities, indicating a complex interaction between stress and memory performance (e.g., Nweze et al., 2020; Young et al., 2018). Given the centrality of STM and WM in cognitive functioning and the emerging evidence for their potential enhancement under adversity, they represent especially promising candidates for investigating possible stress-adapted skills in

children growing up in high-stress environments. STM and WM will be the focus of the next part of the chapter.

2.2 Memory in the Moment: Understanding Short-Term and Working Memory

This section introduces the two core cognitive constructs investigated in the empirical studies of this thesis: short-term memory and working memory. It also provides a focused overview of how they have been conceptualised and measured in psychological research, with particular attention to their relevance for assessing cognitive functioning under conditions of adversity. The section also outlines how additional understudied memory modalities—notably social and motor memory—have been incorporated into this research to explore whether stress-adapted cognitive abilities may manifest in domains not typically captured by conventional tasks.

2.2.1 Development of the Concept

Memory is the cognitive ability to encode, retain, and retrieve information across time (Weisberg & Reeves, 2013; but see Sutton et al., 2010). It enables individuals to engage with their environment both immediately and over extended periods, supporting a wide range of perceptual, cognitive, and behavioural functions (see Gathercole, 1998; Glenberg, 1997; Klein, 2015).

The first major conceptual distinction within memory systems dates back to William James (1890), who proposed a separation between transient *primary memory* (short-lived, conscious content) and *secondary memory* (more permanent, unconscious). However, for much of the early twentieth century, the dominant view remained that memory was a unitary system (see Baddeley, 2007). This view began to shift in 1949 with the work of Donald Hebb, who

proposed a biological distinction: short-term memory depended on temporary electrical activity in the brain, while long-term memory relied on more enduring neurochemical changes.

One of the most influential models was proposed by Atkinson and Shiffrin (1968), who conceptualised memory as a linear sequence of stores: information enters through sensory memory, moves into a short-term memory (STM) system for temporary retention and encoding, and is subsequently transferred into long-term memory (LTM). In this formulation, STM was a unitary system, responsible both for short-term storage and for mediating the flow of information into long-term storage.

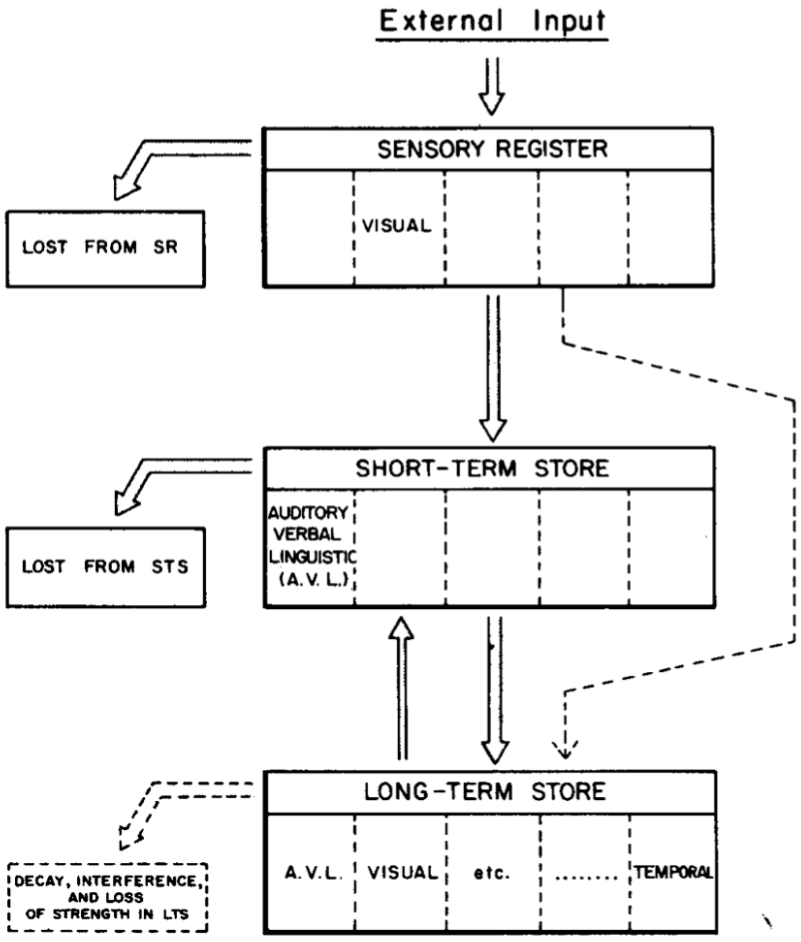


Figure 2. Atkinson and Shiffrin's Model of Memory. Reproduced from Atkinson and Shiffrin (1968).

In its initial formulation, this model exhibited certain shortcomings (Baddeley, 2007). It assumed that duration in short-term storage directly determined the likelihood of long-term encoding, an assumption not consistently supported by empirical data. It also implied that deficits in short-term memory would necessarily impair long-term storage and broader cognition. However, neuropsychological findings contradicted these expectations, prompting revisions to the original model. For example, patients with bilateral damage to the temporal lobes and hippocampi performed poorly on long-term memory tasks but retained intact short-term memory (Baddeley & Warrington, 1970), while other cases presented the reverse pattern: impaired short-term memory alongside preserved long-term recall (Shallice & Warrington, 1970). These dissociations provided compelling evidence for distinct memory systems.

Subsequent theories proposed alternative or complementary accounts of memory structure. For example, the levels of processing model (Craik & Lockhart, 1972) argued that the depth of encoding—rather than the storage system—determined retention, while other models, such as Tulving's (1995) serial–parallel–independent (SPI) framework and the Memory NEo-Structural Inter-Systemic (MNESIS) model (Eustache & Desgranges, 2008), sought to integrate encoding, storage, and retrieval across multiple interacting systems.

Over time, these theoretical developments have shaped research across various domains, including language processing (e.g., Daelemans et al., 1999), learning (e.g., Gathercole & Alloway, 2008), emotions (e.g., Reisberg & Hertel, 2003), and collective memory (e.g., Halbwachs, 2020). Through these studies, the concept of memory has evolved from a single-process notion into a complex and differentiated system, central to understanding both individual and socially shared aspects of cognition.

2.2.2 Baddeley and Hitch's Model

To address the limitations of the Atkinson and Shiffrin's model, Baddeley and Hitch (1974) introduced a multi-component model of "working memory" that redefined the structure of temporary memory processes. In their framework, the functions previously attributed to a general "short-term memory" were redistributed across distinct subsystems. The *visuo-spatial sketchpad* temporarily processes and stores visual and spatial information, for example remembering the route from home to work. The *phonological loop* manages auditory information and consists of two components: the phonological store (which holds sounds briefly) and the articulatory rehearsal process (which refreshes that information). This system supports the retention of items such as digits in a phone number. Overseeing these subsystems is the *central executive*, which plays a coordinating role by directing attention and regulating the interaction between the phonological loop and the visuo-spatial sketchpad (Baddeley & Logie, 1999).

In 2000 Baddeley introduced a fourth component, the *episodic buffer*, to account for features of working memory that could not be explained by the original model—particularly the integration of semantic information and the formation of multimodal representations. The episodic buffer is responsible for temporarily binding information across the phonological loop, visuo-spatial sketchpad, and long-term memory, such as linking a name to a face or forming coherent episodic representations. This refinement, along with earlier and subsequent developments (Baddeley, 1986, 2000, 2003), has made the Baddeley and Hitch's model one of the most widely applied frameworks in both experimental research and applied settings, including education and clinical practice.

Central to this model is a clear distinction between short-term memory and working memory. STM refers to the temporary storage and retrieval of information, serving as a repository for

data that needs to be promptly accessed. In contrast, working memory involves not only storage and retrieval, but also the active manipulation of momentary information for ongoing cognitive tasks. This capacity to actively manipulate stored information, rather than only recalling it, is what fundamentally distinguishes WM from STM (for further details, see Baddeley et al., 2020). This distinction is also supported by neuroscientific research, which reveals that these two memory systems recruit partly distinct neural systems. WM tasks predominantly engage the dorsolateral prefrontal cortex, associated with executive control and manipulation, while STM tasks rely more on the ventrolateral prefrontal cortex, which is not typically involved in manipulation (see Diamond, 2013). Moreover, WM assessments have demonstrated stronger correlations with intellectual aptitudes—particularly fluid intelligence—than STM measurements, and possibly even more than measures of any other particular psychological construct (Cowan, 2001). Nonetheless, the conceptual boundary between STM and WM remains debated, with some researchers arguing that the distinction is largely task-dependent rather than structurally inherent (Aben et al., 2012). In this thesis, we align with the distinction outlined above, using the term "short-term memory" to refer to the temporary storage and retrieval of information, and "working memory" to encompass the temporary storage, retrieval *and manipulation* of information.

2.2.3 Assessing STM and WM: Capacity and Constraints

STM and WM are fundamental components of everyday cognitive functioning, enabling individuals to hold, manipulate, and act upon information in real-time. However, these capacities operate within well-documented cognitive limits. Early insights into these boundaries can be traced to the pioneering work of Holmes (1871), who noted constraints on the number of verbal items that could be accurately recalled after a single exposure (Richardson, 2007). Ebbinghaus (1885) later investigated the number of trials required to

memorise sequences of nonsense syllables, showing that the number increased with sequence length. In a landmark study, Miller (1956) proposed that immediate memory could hold approximately seven familiar units or "chunks" of information, plus or minus two. For example, while a sequence like 1–9–4–5 might be remembered as four separate digits, it can also be encoded as a single chunk—"1945", a familiar year—thereby using one slot in memory instead of four. Later research, however, has proposed a more conservative estimate of 3-4 chunks, particularly under conditions that minimise rehearsal or long-term memory support (see Cowan, 2001). Still, capacity alone does not fully explain performance in STM and WM tasks. Various cognitive mechanisms also influence how well information is retained and recalled, even within these limits (Baddeley, 2003; Cowan, 2010). For instance, information may be lost through decay, the gradual fading of memory traces over time (Barrouillet et al., 2004). Other factors include rehearsal (e.g., silently repeating the digits to be remembered), retrieval from long-term memory (e.g., when a digit sequence resembles a familiar phone number), and temporal distinctiveness (i.e., items presented with clear temporal spacing are often easier to recall than those shown in rapid succession) (Craik & Watkins, 1973; Ricker et al., 2014; Rose et al., 2014). Performance can also be shaped by the properties of the stimuli themselves, such as phonological complexity (Service, 1998) and familiarity (Shen et al., 2018). Additionally, how STM and WM are defined—and which tasks are used to assess them—can substantially shape research outcomes (Aben et al., 2012).

In experimental research, STM is typically assessed using simple tasks that require immediate storage and recall of information, whereas WM is usually evaluated with tasks that additionally involve manipulation or concurrent processing either through complex span paradigms (e.g., operation or reading span) or through backward span tasks (Conway et al., 2005; Richardson, 2007; St Clair-Thompson, 2010). For instance, the *Digit Span Task*, which evaluates the phonological loop, presents sequences of numerical digits to be repeated in the same order

(forward span, for STM) or in reverse (backward span, for WM) (for a detailed discussion, see Jones & Macken, 2015). Similarly, the *Corsi's Block Tapping Test*, designed to assess the visuo-spatial sketchpad, requires participants to reproduce sequences of spatially distributed block taps demonstrated by the experimenter (Corsi, 1973; Kessels et al., 2000).

These standard assessments of STM and WM normally utilise abstract stimuli such as numbers, words, or geometric figures—stimuli that are not anchored to the specific context in which participants are situated. However, emerging research suggests that performance in memory tasks differs depending on the nature and context of the stimuli involved (e.g., Bae et al., 2014; Choi et al., 2025; Gilmore et al., 2019; Greene, 2016; Lin et al., 2021; Marsh, 2003; Pratte et al., 2017). This has led some scholars to propose the existence of additional or domain-specific memory processes not fully captured by the traditional verbal–visuo-spatial dichotomy (e.g., Meyer et al., 2012; Smyrnis et al., 2014). As discussed in Section 2.2.5, these insights challenge long-standing assumptions about memory architecture and underscore the need to broaden both theoretical models and assessment approaches.

2.2.4 Developmental Factors Affecting WM and STM Capacities

STM and WM are dynamic cognitive systems that undergo significant developmental changes from childhood through adulthood, influenced by a combination of biological maturation, environmental exposure, and experiential demands (Cansino et al., 2013; Cowan, 2016; Hedden & Gabrieli, 2004; Mitchell & Cusack, 2018; Park & Payer, 2006; Verhaeghen et al., 2019). Research suggests that WM improves steadily throughout childhood and adolescence, peaks around the age of 30 (Hartshorne & Germine, 2015; Johnson et al., 2010), and remains stable until approximately the age of 45, when it begins to decline (Alloway et al., 2004). Conversely, others have suggested that WM remains relatively stable throughout adulthood (Alloway & Alloway, 2013). Similarly, STM develops progressively as children age, reaches

adult-like levels by adolescence, and starts to decline in the 20s (Brockmole & Logie, 2013; Fandakova et al., 2014). Engagement in cognitively demanding activities appears to moderate these trajectories, indicating that STM and WM development can be shaped by experience (Cockcroft, 2015).

A significant body of research has also examined the impact of stress on memory functions (Bremner & Narayan, 1998; Goodman et al., 2010; Pechtel & Pizzagalli, 2011; Roozendaal et al., 2009; Schwabe et al., 2022; Wolf, 2009). Consistent with the deficit model, many studies associate early-life adversity with impairments in STM and WM. For instance, Evans and Schamberg (2009) reported that infants from lower SES families typically exhibit poorer WM and inhibitory control, as measured by the A-not-B task. Farah et al. (2006) observed that socioeconomic disadvantage, often accompanied by higher stress levels, is associated with deficits in various cognitive functions, including WM. Similarly, Gustafsson et al. (2013) found that exposure to intimate partner violence, as reported by the mothers, significantly predicted impairments in children's short-term, working, and deliberate memory. Experiencing violence may influence memory even in adulthood, as shown by Bogliacino et al. (2017), who reported that greater exposure to violence considerably reduced STM and cognitive control in individuals actively recalling emotional states associated with such experiences.

However, more recent studies challenge the idea that stress exclusively impairs memory. Nweze et al. (2020), studying children in Nigeria who had experienced parental deprivation, found that although they scored lower than non-deprived peers on inhibition tasks and comparably on set-shifting, they significantly outperformed them in WM. In another study, Young et al. (2018) reported that participants who experienced higher levels of stress demonstrated enhanced performance in specific WM components, such as rapid tracking and

memory updating under conditions of uncertainty, but also showed impairments in WM retrieval and capacity when faced with distractions.

Adding to the complexity of the relationship between STM, WM, and stress, recent studies have shown an association between these memory systems and resilience, defined as the capacity to effectively overcome challenges that could potentially disrupt normal development or functioning (Masten, 2014). Wingo (2010) found that African American adults from disadvantaged backgrounds who were classified as resilient, had higher nonverbal WM scores compared to their less resilient peers, though no difference was observed in verbal WM. Avci et al. (2013) reported that among adolescents exposed to poverty and trauma, WM was more strongly associated with resilience measures in males. A study by Bemath et al. (2020) explored this relationship in South African emerging adults from disadvantaged circumstances, using a mixed-methods design. Quantitative results revealed a significant positive correlation between verbal STM (specifically, digit recall) and spiritual resilience resources, interpreted as language-based spiritual practices such as prayer and scriptural reflection that support adaptation through culturally meaningful belief systems. Most other relationships between WM components and resilience were non-significant. However, qualitative findings suggested that working memory may contribute indirectly to resilience by supporting behaviours such as goal-setting, self-talk, and flexible problem-solving. These processes were shown to be supported and shaped by culturally embedded routines and systemic resources, highlighting the importance of context in understanding how STM and WM can underpin adaptation under adversity.

Taken together, these findings indicate that while stress exposure is often associated with impaired STM and WM performance, it may also lead to specific enhancements, particularly those that support fast and flexible adaptation in harsh and unpredictable environments. This

dual pattern suggests that stress-adaptation mechanisms are more nuanced than previously assumed. STM and WM may act both as vulnerable targets and as adaptive assets, depending on context, task demands, and individual trajectories. Furthermore, their relationship with resilience appears to be bidirectional: STM and WM may support adaptive coping by enabling individuals to generate and evaluate creative responses to adversity, while resilience processes may in turn scaffold the preservation or development of STM and WM under adversity. Although this reciprocal link is supported by empirical studies (e.g., Bemath et al., 2020; Zhao et al., 2023), further research is needed to clarify the underlying mechanisms and causal directions.

In the following section, we turn to the emerging (and much more limited) research on social and motor STM and WM, and connect this to the theoretical approach and research aims of this thesis.

2.2.5 Exploring Supplementary STM and WM Systems: Social and Motor Memory

This section aims to describe how STM and WM differ in processing social and motor information compared to conventional stimuli like digit strings or geometric figures. This exploration raises a key question: while extensive research highlights the negative impact of stress on STM and WM in children using conventional abstract tasks, does this also apply to social and motor memory? This question has led us to investigate STM and WM using social and motor information alongside conventional “abstract” stimuli. The distinction among these memory modalities becomes pivotal for understanding the impact of early-life adversity on memory, a theme developed in more detail in the empirical chapters that follow.

Social Memory

One of the distinctive features of human beings is the capacity to navigate complex social environments (Gintis, 2000; Henrich et al., 2004), where the ability to process, recall, and utilise social information, including personal identity, emotions, status, and the nature of relationships, is essential in daily interactions (Adolphs, 2003; Crick & Dodge, 1994; Herrmann et al., 2007; Meyer & Lieberman, 2012). According to the *social brain hypothesis* (Dunbar, 1998), this cognitive sophistication evolved in response to the demands of managing intricate social relationships, which exerted selective pressure for the development of larger and more complex brains in primates, including humans' ancestors. While not always explicitly framed in evolutionary terms, recent cognitive neuroscience research aligns with this view by showing that when processing social information, STM and WM rely on a functionally specialised system supported by distinct neural circuits and optimised for navigating interpersonal contexts.

For example, Meyer et al. (2012) investigated the neural underpinning of social working memory by examining how the brain responds as the amount of social information held in working memory increases (i.e., social load). Sixteen participants (M_{age} = 20 years) from the University of California – Los Angeles community were presented with the names of two, three, or four of their friends and asked to mentally rank them along a trait dimension while holding this information in memory during a delay period. Functional MRI results revealed that two brain networks showed increased activation as social load augmented: (i) medial frontoparietal regions associated with social cognition (e.g., perspective-taking), and (ii) lateral frontoparietal regions typically linked to non-social working memory tasks. Importantly, only the medial frontoparietal activity was correlated with individual differences in trait perspective-taking, suggesting that social working memory engages neural systems specific to mentalising in addition to traditional working memory networks.

A related fMRI study by Thornton and Conway (2013) explored whether working memory processes social and non-social information through different neural mechanisms. Sixteen female participants from the Princeton University community completed a modified n-back task, where both working memory load and the type of the stimuli (faces vs. shapes) were manipulated. Results showed that increased working memory load activated the frontoparietal control network across both conditions. However, social stimuli also recruited regions typically involved in social cognition and face processing (e.g., fusiform face area, medial prefrontal cortex). Intriguingly, within the frontoparietal network, the effect of load was attenuated for social stimuli compared to non-social stimuli, indicating more efficient processing. These findings suggest that memory may operate more efficiently when processing socially relevant information, supporting the notion of domain-specificity within memory systems. This underscores the value of complementing conventional assessments—which typically rely on abstract, decontextualised stimuli—with tasks that incorporate socially meaningful content, in order to better capture the scope of working memory functioning.

Further research suggests that social working memory may be linked to broader social competencies such as empathy and theory of mind—associations not typically observed in studies of standard WM. For example, Xin and Lei (2015) examined the interaction between the frontoparietal control network (FPC) and the default mode network (DMN) during WM tasks requiring externally directed attention and social WM tasks. The study, conducted with thirty-four Chinese university students (17 female; M_{age} = 22, SD_{age} = 1.6 years, range: 18–26 years), found that during social WM tasks, the FPC-DMN anti-correlation was stronger than during identity recognition tasks, suggesting that the top-down signals from the FPC suppress the DMN to support social WM and empathy. Participants with higher levels of trait empathy performed more accurately (though not faster) in the social WM task. Interestingly, the FPC coupled with the dorsal attention network but decoupled from the DMN to focus attention on

externally oriented social WM tasks and suppress irrelevant spontaneous thoughts. These results suggest that heightened competition between the FPC and DMN during social WM tasks may support individual differences in empathic ability.

In a subsequent study, He and colleagues (2019) investigated the development of social working memory capacity and its relationship with theory of mind (ToM) in Chinese preschoolers. The study involved two experiments with 3- to 6-year-olds. In Experiment 1, 64 children (M_{age} = 4.7 years, SD_{age} = 1.67 years, 33 females) completed a social WM task using point-light biological motion (BM) displays selected from the database created by Vanrie and Verfaillie (2004), a method previously used to estimate social working memory capacity in adults. Each stimulus consisted of 30 frames displayed twice in succession and presented on a 14-inch laptop.

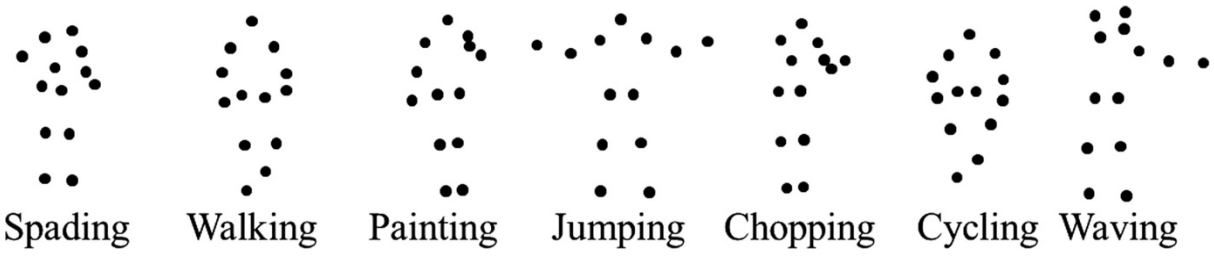


Figure 3. Illustration of sample frames depicting biological motion stimuli utilised in the experiments. Reproduced from He et al. (2019).

Results showed that social WM capacity steadily improved with age, with the sharpest increase observed between 4 and 5 years. Experiment 2 tested whether social WM capacity could predict ToM performance better than non-social WM. Children were asked to memorise upright or inverted biological motion stimuli, and only the upright animations were considered socially meaningful. ToM was assessed using a Mandarin version of a validated scale. Findings confirmed the hypothesis: only social WM capacity significantly predicted ToM scores,

particularly among 4-year-olds. These findings suggest that social WM capacity may play a role in the development of ToM in preschoolers.

Taken together, these studies add to growing evidence of the existence of a specialised memory system for social information. Across experimental paradigms and age groups, social information appears to be processed and maintained differently than non-social content. Moreover, neuroimaging findings further reinforce this distinction by identifying brain networks specifically engaged during social WM tasks.

Given this evidence, the present research investigates social memory as a potential stress-adapted skill. This focus aligns with the Hidden Talents Model, which proposes that certain cognitive strengths—such as social memory—may develop in response to harsh or unpredictable environments, particularly where navigating complex social dynamics is essential for adaptation and survival (Ellis et al., 2017, 2023).

Motor Memory

Further nuancing the picture of WM, recent research has investigated its role in the processing of motor information. Traditionally, movement-related information was assumed to fall within the visuo-spatial sketchpad, the WM subsystem responsible for visual and spatial processing (e.g., Baddeley, 1986; Logie, 1995; Srimal & Curtis, 2008). However, some studies have challenged this view, suggesting that remembering, planning, and executing bodily movements may rely on specialised mechanisms that are at least partially independent from those used for visual or spatial representations. This evidence points to the existence of a domain-specific system for motor information.

For example, Smyth and colleagues (1988) investigated memory for short sequences of whole-body movement patterns, spatial positions, and words using a memory span paradigm with UK

university students. Across five experiments, participants were asked to recall items in order while either passively observing or performing concurrent secondary tasks such as articulatory suppression, movements towards external spatial targets, or body-related actions. The results revealed that memory for familiar movement patterns was unaffected by verbal interference or spatial targeting tasks, but was significantly disrupted by concurrent body-related movements. Notably, this body movement interference did not impair performance on standard verbal or spatial span tasks. These findings suggest that memory for replicating body movements (e.g., mimicking a ballet step) engages distinct cognitive resources from those used in verbal rehearsal or in guiding actions toward spatial targets (e.g., reaching for a glass).

In another study, Smyrnis et al. (2014) provided converging neurophysiological evidence using a sample of ten Greek adults (M_{age} = 35 years, range: 29-44 years, 3 females). Participants performed two tasks: in the first, they used a joystick-controlled cursor to quickly reach a peripheral targe; in the second, a new target appeared for 250 milliseconds, either in the same location (50% probability) or a different one, and participants indicated whether its location matched the first by pressing "yes" or "no." Amplitude spectrum analysis revealed distinct neural signatures, with reduced alpha (8–12 Hz), and increased beta (13–30 Hz) and gamma (30–45 Hz) band activity in memory versus non-memory conditions. Alpha differences were confined to the frontal midline, beta differences extended across the right hemisphere and midline central areas, and gamma differences were localised to the right occipitoparietal region. Notably, beta and gamma bands showed increased activity in movement- compared to perception-related memory tasks in the central midline. These results suggest distinct spatio-temporal connectivity patterns in motor versus perceptual visuo-spatial working memory.

Building on this, Wu and Coulson (2014) contributed to the growing body of evidence supporting the existence of a specialised WM subsystem dedicated to transiently storing body

movements, complementing the phonological loop and visuo-spatial sketchpad. They developed the “movement span task”, a specialised tool crafted to evaluate individuals' ability to recall and reproduce seemingly meaningless configurations of bodily movements. In their study, 90 adult participants (52 females) from the University of California – San Diego viewed short videos of seemingly meaningless movements, presented in sets varying in size from one to five items. Immediately following this encoding phase, participants were tasked with reproducing in order as many of these movements as they could recall. Participants also completed standard verbal and visuo-spatial WM tasks, as well as a gesture classification task assessing their ability to judge whether hand gestures matched accompanying speech. Performance on the gesture task was significantly correlated with movement span scores, but not with traditional verbal or visuo-spatial WM tasks. These findings offer preliminary support for the existence of a functionally independent memory system specialised for motor information—a kind of “motor sketchpad”—and underscore the importance of recognising and studying this additional memory system dedicated to body movements.

2.2.6 Towards New Frontiers of STM and WM: Exploring Uncharted Territories

The research reviewed in this section underscores the multifaceted nature of short-term and working memory. These cognitive constructs hold paramount importance in human cognitive development and, since the work of neo-Piagetian researchers (e.g., Barrouillet & Gaillard, 2011; Case, 1978; Pascual-Leone, 1970), have been recognised as fundamental to children's learning, reasoning, problem-solving, executive functions, and general intelligence (Baddeley et al., 2020; Cowan, 2014; Engle et al., 1999; Jaeggi et al., 2008; Passolunghi & Siegel, 2001). Reflecting this long-standing recognition, a short-term memory digit span task was incorporated as early as 1905 by Binet and Simon into their pioneering intelligence test battery,

and measures of STM and WM remain central to contemporary intelligence assessments for both children (e.g., Wechsler Intelligence Scale for Children, WISC-V, Wechsler, 2014) and adults (e.g., Wechsler Adult Intelligence Scale, WAIS-5, Wechsler, 2024).

However, while extensive studies have primarily focused on the traditional components of STM and WM—namely, the visuo-spatial sketchpad and the phonological loop—recent studies have begun to reveal additional memory systems specifically dedicated to processing social and motor information. These remain significantly underexplored, particularly with respect to child development. Traditionally, the relationship between stress exposure and memory performance has been interpreted through a deficit lens, emphasising cognitive impairments in response to adversity. Yet, as reviewed in the first section of this chapter, emerging research suggests a more nuanced picture, where certain aspects of STM and WM may be preserved or even enhanced in individuals growing up in harsh and unpredictable environments.

Building on this evolving framework, and in response to the challenges mentioned above, the present research investigated STM and WM in primary school-age children across five communities (including both primary and replication samples) characterised by different levels of environmental adversity. This includes populations from non-W.E.I.R.D. settings and combines conventional memory tasks with novel assessments targeting social and motor memory. By doing so, the research aims to contribute to a more differentiated understanding of how memory systems develop in diverse ontogenetic niches, and to identify potential stress-adapted cognitive abilities consistent with the framework of the Hidden Talents Model. The following chapters examine these possibilities through four empirical studies, including a replication study.

3 Modality Matters: Differences in Abstract and Social Memory Skills in Children from High-stress and Low-stress Environments

Submitted to *Cognitive Science*

Modality matters: differences in abstract and social memory skills in children from high-stress and low-stress environments

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Abstract

Although adverse ontogenetic environments are associated with potential impairments in children's memory, recent research suggests that individuals can develop specialised skills to navigate such settings. We conducted two studies on short-term memory (STM) and working memory (WM) among 404 children (191 females, M_{age} = 8.28 years, SD_{age} =1.49 years) from three environments in Naples, Italy: two identified as "high-stress" (Scampia and Roma camp) and one "low-stress" (Pozzuoli). In Study 1, conventional abstract stimuli were used to assess STM and WM. Compared to the Pozzuoli control group, Roma children exhibited significantly lower scores, while Scampia children performed similarly. In Study 2, which used social stimuli, Roma children showed similar STM but lower WM performance compared to Pozzuoli children, while Scampia children outperformed Pozzuoli peers in both STM and WM. These findings highlight the complexity of memory development, supporting the idea that memory function can adapt to environmental challenges during development, and that impairments only partially define the experiences of children in these contexts.

Key words: Evolutionary Anthropology, Adaptation, Children, Memory, Hidden Talents Model, Harsh and Unpredictable Environments

Statements and Declarations

Data Availability Statement: The data supporting the findings of this research will be accessible upon publication.

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1. Introduction

Millions of children worldwide face adversities such as social insecurity, poverty, conflict, or displacement (WHO, 2024). These conditions are widely recognised as developmental risk factors, and are often linked to impairments in cognition, behaviour, and mental health (e.g., Anne Lown et al., 2011; Brito et al., 2016; Kim et al., 2013; Lorant et al., 2003; Perez & Widom, 1994; Schwabe & Wolf, 2010; Shin et al., 2010; Strine et al., 2012). Although there is robust evidence on the potential developmental risks posed by adversity, this is only part of the picture. Many children also demonstrate *resilience* and development considered typical by Western standards (see Benard, 1995; Goldstein & Brooks, 2013; Masten, 2001).

More recently, approaches informed by evolutionary-developmental theory have shifted the focus from resilience to adaptation. These perspectives propose that humans respond adaptively to adversity through strategies that increase their survival, for example through group cohesion and cooperation (see Ember et al., 2018; Gelfand et al., 2006; Whitehouse et al., 2017). A novel and more fine-grained framework, the *Hidden Talents Model* (see Ellis et al., 2022), suggests that high-stress environments may also foster particular cognitive and behavioural skills that are adaptive within these contexts. The model aligns with broader theories of developmental plasticity, which describe how organisms adjust neurocognitive development in response to environmental input (Bjorklund & Ellis, 2014; Ellis & Del Giudice, 2014; Frankenhuis & Amir, 2022; Frankenhuis & de Weerth, 2013).

This reframing has opened new avenues for research into context-specific development. For example, traits like impulsivity or risk-taking, often deemed maladaptive in formal education settings, may serve important problem-solving functions in unpredictable environments. Unlike resilience models, which emphasise typical development in spite of adversity, the HTM

focuses on context-specific cognitive and behavioural skills that emerge as adaptive responses, and often remain “hidden” unless formally recognised or assessed (Ellis et al., 2017, 2023).

Despite its conceptual potential, empirical research on stress-adapted skills remains limited due to significant methodological and ethical challenges (Ellis et al., 2017; Frankenhuis et al., 2020). Experimental manipulation of early-life stress is not ethically viable in human populations, and much of the literature relies on other animal models (e.g., Calandreau et al., 2011; Chaby et al., 2015; Farine et al., 2015). Even where laboratory studies simulate stress, the conditions often diverge substantially from real-world adversity, limiting external validity (e.g., Dickerson & Kemeny, 2004). Naturalistic research in high-stress environments offers an alternative path, but comes with its own constraints related to research control, logistics, and risk to researchers.

1.1 Short-Term and Working Memory

Among the cognitive skills potentially shaped by early adversity (for a review, see Ellis et al., 2017, 2023), the studies reported here focus on short-term memory (STM) and working memory (WM). STM refers to the temporary storage and retrieval of information, serving as a repository for data that needs to be promptly accessed. WM involves not only storage and retrieval, but also the active manipulation of momentary information for more demanding cognitive tasks (Alloway et al., 2004; Baddeley, 2012; Baddeley et al., 2020; Baddeley & Hitch, 1974; Gathercole et al., 2004). This operationalisation is commonly employed in research and aligns with the task structure utilised in the present study (although the distinction continues to be a topic of debate, see Aben et al., 2012).

The decision to examine these memory systems stems from their central role in children's cognitive development, and their contribution to fundamental cognitive functions such as learning, comprehension, problem-solving, and general intelligence (Cowan, 2014). Evidence

of adaptive developmental differences in STM and WM could therefore inspire further research and applications in child development. Additionally, like other executive functions, STM and WM are closely linked to the prefrontal cortex (Diamond, 2013; Friedman & Robbins, 2022), a brain region that undergoes protracted development from childhood through early adulthood (e.g., Giedd et al., 1999; Tanaka et al., 2012). Given this extended neural maturation, STM and WM are likely significantly shaped by environmental influences, including stress exposure (Farah et al., 2006). Consistent with this view, numerous studies indicate a negative relationship between exposure to acute and/or prolonged stress and performance on conventional STM and WM tasks (e.g., Brand et al., 2000; Bremner et al., 1993; Evans & Schamberg, 2009; Hart & Rubia, 2012; Klein & Boals, 2001; Tine, 2014). However, recent research has provided a more nuanced insight, including enhanced WM in stress-exposed individuals (Nweze et al., 2020), or improvements in specific WM aspects like rapid tracking and memory updating, but impairments in others, such as WM in the presence of distractions (Young et al., 2018). These studies have raised new questions about the variability and complexity of STM and WM systems within individuals and across diverse developmental contexts.

1.2 The Present Research

Building on these theoretical and empirical foundations, we conducted two natural experimental studies with primary school-aged children across three sites in Naples, Italy: two high-stress environments (Scampia and Roma camp) and one lower-stress control environment (Pozzuoli). To complement cognitive data, we also administered the Perceived Stress Scale for Children (PSS-C, White, 2014) to measure participants' subjective experience of stress, and carried out ethnographic fieldwork to contextualise developmental conditions across the three sites.

Study 1 employed conventional memory span tasks involving abstract stimuli (e.g., digit strings, geometric figures). Based on prior research, we hypothesised that children from Scampia and the Roma camp would score lower than those from Pozzuoli on these tasks.

In Study 2, we adapted this span paradigm to include socially meaningful stimuli—specifically, unfamiliar faces. This decision was driven by three considerations. First, most cognitive research is based on Western, educated, industrialised, rich, and democratic samples (W.E.I.R.D., Henrich et al., 2010), which tend to experience relatively stable and predictable environments, socio-economic security, and widespread access to formal education. As a result, commonly studied variables and assessment tools may fail to capture skills developed outside these contexts. Second, neuroscientific research suggests the existence of STM and WM systems dedicated to processing social information (e.g., Meyer et al., 2012), which are typically overlooked in conventional STM and WM assessment. Third, some studies have suggested that exposure to adversity may enhance certain social skills, such as better incidental memory for faces (Dietze et al., 2022), increased accuracy in discerning trustworthiness among peers (Pitula et al., 2017), or greater empathic accuracy (Kraus et al., 2010). Similar patterns have also been observed in early childhood, where caregiving adversity predicted stronger memory for specific types of social or emotional information (Rifkin-Graboi et al., 2018, 2021, 2023). We therefore identified social STM and WM as plausible domains of "hidden talents". In contrast to the abstract memory tasks, we hypothesised that children from Scampia and the Roma camp would outperform their Pozzuoli peers on social memory tasks. Age and sex were included as covariates to examine their influence on performance, though they were not central to our hypotheses.

2. The Research Sites

This study was conducted across three distinct environments in the Naples metropolitan area: Scampia, a Roma camp, and the comparatively lower-stress area of Pozzuoli. To assess structural adversity, we refer to the Italian National Institute of Statistics (Istat) Index of Social and Material Vulnerability (IVSM), which integrates indicators such as education levels and economic hardship (see SOM 1). According to the latest data, Scampia exhibits significantly higher vulnerability (121.4) than Pozzuoli (104.1) and Giugliano in Campania (105.3), the latter being the municipality of the Roma camp. The overall score for the city of Naples is 104.9. While the IVSM provides valuable insight into municipal-level disparities, it can mask important variation within and between urban zones, and does not fully capture the specific forms of adversity experienced by the populations in this study. For instance, Scampia's informal labour economy excludes many residents from formal employment statistics (Orientale Caputo, 2012), and the extreme conditions of the Roma camp—severe poverty, overcrowded shelters, poor sanitary conditions, and unmet medical needs—are not separately captured in Giugliano's census data. To complement the IVSM and gain a better understanding of these environments, the first author (a native Italian) conducted nine months of ethnographic fieldwork across the three sites, including schools, community centres, religious events, advocacy meetings, and volunteer work with NGOs supporting Scampia and the Roma communities. Additionally, over 100 semi-structured interviews were conducted with parents, teachers, educators, social workers, healthcare professionals, law enforcement officers, clergy members, local workers, former and current gang members, and politicians. This provided firsthand insight into the social and structural challenges shaping children's development, and informs the contextual descriptions that follow.

Pozzuoli. A coastal city in the metropolitan area of Naples, Pozzuoli serves as the lower-stress comparison site in this study. With approximately 76,000 inhabitants, it is typically middle-class and a popular tourist destination, renowned for its Roman remains and extensive coastline. Pozzuoli benefits from well-developed infrastructure and public services including healthcare, education, policing, sanitation, public transportation, and entertainment. The local administration has received multiple awards for improving urban living standards (see Cronaca Flegrea, 2024; Olcesi, 2017).

Fieldwork revealed a relatively stable and resource-rich setting for children, with structured daily routines, well-equipped schools, and access to multiple extracurricular activities. Teachers described the academic setting as largely supportive, despite occasional individual challenges. Pozzuoli residents expressed relatively high trust in local institutions and services, distinct from the pervasive mistrust reported in Scampia and the Roma camp. Nearly half of the adult population has completed secondary or higher education (Istat, 2011), and economic stability is reflected in secure employment opportunities for many parents. Although some families face financial difficulties—especially due to rising living costs in Italy (Colombarolli, 2024; European Commission. Directorate-General for Economic and Financial Affairs, 2024)—parental concerns centred on children's future academic or employment prospects, not basic safety or access to primary services, topics far more prominent in discussions with parents from Scampia and the Roma camp.

While Pozzuoli offers a relatively secure and structured environment, certain families still face economic difficulties, and some interviewees reported challenges related to youth delinquency and unemployment. Nevertheless, Pozzuoli's stronger structural support, educational opportunities, and general sense of security clearly distinguish it as a lower-stress environment compared to the other sites in this study.

Scampia. Situated in the northern periphery of Naples, Scampia is the most notorious among the city's high-deprivation neighbourhoods. Officially home to around 40,000 people (though many more live in informal housing), the area is marked by systemic neglect, high unemployment, and a long-standing presence of organised crime. Known for its incomplete public housing—particularly the "Vele" complex—Scampia became a stronghold of the Camorra criminal organisation in the 1980s and evolved into one of Europe's largest open-air drug markets (Bertone & Leiduan, 2024; Di Costanzo & Ravel, 2013; Saviano, 2006).

Scampia drew international attention due to the 2004–2005 feud between the Di Lauro clan and the *Scissionisti* splinter group, which triggered over 100 killings and long-lasting instability (Di Costanzo & Ravel, 2013; Saviano, 2006). Although the conflict officially ended in 2005, it fractured territorial control across multiple rival groups, a fragmentation that persists today. Residents describe a social environment in which clan affiliations still shape daily life and require ongoing monitoring of local power dynamics, an aspect that potentially sharpens children's memory for socially relevant information.



Figure 1. Wall along Via del Gran Paradiso, Scampia. The inscription on the wall reads: "Welcome to Baghdad", a reference likely intended to evoke war-zone imagery.

Scampia's notoriety drew international media attention, inspiring books, films, and television series (e.g., Saviano's 2006 best-seller *Gomorrah* and the homonymous Netflix series). Media exposure did little to reverse Scampia's structural decline, but solidified its image as a centre of crime and deprivation—a stigma that persists to this day (Marelli, 2021).

The area continues to suffer from infrastructural decay, physical isolation, and limited access to essential services. Unemployment stands at 46% (compared to a city-wide 21%), and only 21% of adults have a high school diploma (Istat, 2011). Essential services remain scarce, with few shops and supermarkets, and no public cultural and recreational spaces, except for those run by modest voluntary associations. Many families rely on informal employment and face intergenerational poverty. Aligned with observations in comparable contexts, residents tend to prioritise immediate gains over long-term investments in education or other ventures (see Griskevicius et al., 2011), an inclination that aligns with the lure of criminal activities which offer swift earnings. To illustrate, a *vedetta* (lookout)—the entry-level position within the criminal network—can make 100-200€ per day, a sum that could take weeks to earn in typical formal jobs accessible to many residents. Furthermore, criminal networks also provide legal assistance in case of arrest and extend monthly financial aid to the families of incarcerated members, making it a compelling alternative to the slow and uncertain returns of formal education and employment.

Compounding these challenges, Scampia lies within the "Land of Fires", a region associated with illegal toxic waste dumping and widespread environmental contamination (Di Gennaro & Fagnano, 2015; Legambiente, 2003; Saviano, 2006). This has contributed to severe health issues for residents, including respiratory diseases, cancers, and congenital disorders (Beccaloni et al., 2020; Buonaugurio, 2019; Greco, 2016; Rocco et al., 2016; Senior & Mazza,

2004). Notably, Scampia itself contains an illegal landfill that is frequently alight, intentionally or not, releasing toxic fumes.

Children growing up in Scampia thus face multiple overlapping stressors: criminal violence, economic marginalisation, toxic exposure, and institutional neglect. These adversities have been consistently shown to negatively affect cognitive development, particularly executive functions like short-term and working memory (Aurino et al., 2020; Bogliacino et al., 2017; Brooks-Gunn & Duncan, 1997; Calderón-Garcidueñas et al., 2015; Evans & Schamberg, 2009; Farah et al., 2006; Hackman et al., 2014; Ioar et al., 2024; Lopuszanska & Samardakiewicz, 2020; Mooney et al., 2021). To date, however, no study has systematically examined cognitive outcomes in this context.

Roma camp. Located on the outskirts of Giugliano in Campania, northwest of Naples, the Roma camp is home to a predominantly Bosnian-descent community migrated to Italy in the late 1990s and early 2000s. After years in informal settlements, they were relocated in 2013 to a municipal camp near a methane extraction site, only to face respiratory illness from toxic emissions. Following another displacement to a flood-prone former fireworks factory, and subsequent eviction orders, the European Court of Human Rights ruled in 2019 that their living conditions constituted severe human rights violations (The European Court of Human Rights, 2019). Yet, no durable relocation plan has since been implemented.

Most families now reside in an unauthorised settlement built on a disused paint factory. The camp houses about 70 families—roughly 420 people, over half of whom are minors. Residents live in makeshift structures and caravans without sanitation, drawing electricity and water from informal hookups. Waste accumulates around the site, and winters are endured by burning

wood, tires, or scrap materials for heat. These circumstances unfold amidst the toxic environment of the “Land of Fires”, with the camp frequently engulfed by toxic fumes.



Figure 2. Scorched remains and smoky aftermath of burnt waste near the Roma camp.

Beyond environmental and material hardship, the Roma community faces severe institutional exclusion. Roma are often portrayed not as a marginalised group needing support, but as a social “problem” to be managed (Sigona, 2005), which continues to shape public policy and reinforce barriers to integration and access to basic rights (Sigona, 2003). According to Arrevutammoce, the NGO providing primary support to the community, nearly 80% of residents lack formal IDs, which blocks access to healthcare, social services, and legal employment. Adults in the camp do not hold regular work contracts. Some collect scrap for resale, others engage in illicit activities, often involving minors. Arrevutammoce estimates that around 95% of adult residents have criminal records, with over 30 individuals from the community incarcerated at the time of the research.

Many children suffer from untreated conditions such as malnutrition, scabies, or lice, and paediatric visits have confirmed high medical need. Interpersonal interactions are marked by

pronounced violence, reflecting power-based dynamics that shape children's daily lives. Blurred boundaries between adult and child spheres prematurely expose minors to alcohol, smoking, violence, and sexuality. Although formally enrolled in school, the children were not attending at the time of this research. Arrevutammoce has stepped in by organising summer schooling programs and is working to integrate them into schools across Giugliano (for further details, see Paone, forthcoming [Appendix B]).

Childhood in the camp unfolds amid overlapping adversities: poverty, marginalisation, health neglect, and violence. Again, the influence of these conditions on children's memory has not been studied in this context.

3. Experimental Studies

The conditions in both Scampia and the Roma camp create highly uncertain and uniquely challenging developmental environments that may significantly shape the cognitive development of children growing up in these areas. Multiple studies link the kinds of stressors they routinely face (e.g., violence, neglect) to various developmental impairments, including STM and WM deficits (e.g., Evans & Schamberg, 2009; Klein & Boals, 2001; Tine, 2014). To empirically investigate STM and WM development in children from these environments and compare them to a relatively lower-stress control group (Pozzuoli), we conducted two complementary studies. Study 1 used conventional abstract stimuli to measure STM and WM in children aged 6 to 10 across the three study sites, while Study 2 focused on social stimuli to assess these memory systems in the same groups. Additionally, in both studies, we used the Perceived Stress Scale for Children (PSS-C, White, 2014) to evaluate the children's self-reported stress levels and provide a quantitative measure of stress exposure in these environments. We hypothesised that children from the high-stress environments would perform worse on conventional memory tasks (Study 1), but better on social memory tasks

(Study 2). These hypotheses and study designs were pre-registered on AsPredicted (Study 1: https://aspredicted.org/dj24-jp5s.pdf; Study 2: https://aspredicted.org/sk2m-pg5q.pdf). Below we report Study 1 and Study 2, followed by an exploratory analysis comparing effect sizes across the study samples and memory task modalities ("abstract" and "social").

3.1 Study 1 – Conventional Assessment of STM and WM ("Abstract" Memory)

3.1.1 Method

Participants

Data were collected from 404 children across the three populations (191 females, M_{age} = 8.28 years, SD_{age} = 1.49 years), spanning the first to last grades of Italian primary school, which typically includes children aged 6 to 10 years. The sample included 167 children from Scampia (89 females, M_{age} = 8.25 years, SD_{age} = 1.50 years), 190 from Pozzuoli (87 females, M_{age} = 8.22 years, SD_{age} = 1.48 years), and 47 from the Roma camp (15 females, M_{age} = 8.63 years, SD_{age} = 1.49 years). Sample sizes were determined via power analysis, which indicated that 125 participants from both Scampia and Pozzuoli would be needed to have a power of at least 0.8 to detect differences in memory test span scores of 0.3 points or greater between the two environments (see SOM 2). Given the smaller population and recruitment challenges presented by the living conditions and non-school attendance of Roma children, we aimed to include as many children as possible from the camp who were within the target age range. Consequently, the Roma sample size was relatively small, which reduced the statistical power to detect differences with the control group.

Although analysis focused on children aged 6 to 10, to avoid excluding classmates from participation, we allowed eight five-year-olds and one eleven-year-old from Scampia, eight

five-year-olds from Pozzuoli, and two five-year-olds from the Roma camp to participate, though their data were excluded from analyses. Furthermore, data from participants who failed a prior comprehension check assessing their ability to follow task instructions were excluded from analysis (see Measures for details on the task, and SOM Table S1 for details on exclusion by test). Participants completed four tasks (see below for details). The refined sample sizes after exclusions are presented in Table 1.

Table 1. Demographic information of participants across tasks.

Environment	**Task type**	***n***	n_{female} **(%)**	M_{age} **(years)**	SD_{age} **(years)**
Scampia	Verbal STM	157	83 (52.9)	8.35	1.41
	Verbal WM	154	81 (52.6)	8.38	1.41
	Visuo-spatial STM	156	83 (53.2)	8.35	1.42
	Visuo-spatial WM	156	83 (53.2)	8.35	1.42
Pozzuoli	Verbal STM	180	83 (46.1)	8.34	1.42
	Verbal WM	169	77 (45.6)	8.41	1.42
	Visuo-spatial STM	181	84 (46.4)	8.33	1.42
	Visuo-spatial WM	179	84 (46.9)	8.34	1.43
Roma	Verbal STM	45	13 (28.9)	8.76	1.38
	Verbal WM	39	12 (30.8)	8.75	1.39
	Visuo-spatial STM	45	13 (28.9)	8.76	1.38
	Visuo-spatial WM	43	11 (25.6)	8.71	1.38

Participants in Scampia and Pozzuoli were recruited through the schools they attended in their respective neighbourhood/city, while Roma children from the camp in Giugliano in Campania were recruited through an NGO, and completed the experiment in a collaborating school in Scampia. Oral consent to participate in the research was obtained from the institutions where the studies took place and from the teachers. Written consent was obtained from the parents/guardians of the children. In the Roma camp, where literacy levels are lower, the

participant information was read aloud and the consent process was explained verbally to ensure full understanding before obtaining written consent. Assent was also obtained from the children before the beginning of the session. As a token of appreciation for their participation, children received stickers and a "Young Researcher" certificate. This research was approved by the relevant Departmental Research Ethics Committee of the University of Oxford.

Procedure

The sessions took place individually in a quiet room at the school, during school hours. All sessions were administered by the lead author. Children were briefly removed from class, provided this had the class teacher's approval. The session began with the administration of the Perceived Stress Scale for Children (White, 2014), followed by the assessment of a specific memory modality. Task order was counterbalanced across participants, with half beginning with Study 1 and the other half with Study 2 (reported below). Study 1 entailed four tasks evaluating Verbal STM, Verbal WM, Visuo-spatial STM, and Visuo-spatial WM. The order of the tasks was partially counterbalanced, with half of participants starting with the verbal tasks and the other half with the visuo-spatial tasks.

For children from Pozzuoli and Scampia, tasks were administered in Italian by the first author (a native Italian speaker). For Roma children, the tasks were administered in the Romanes language, and the first author worked with a translator to facilitate effective communication. An initial translation was performed by a bilingual individual fluent in both Italian and Romanes, followed by back-translation into Italian by a second bilingual speaker to ensure accuracy and resolve any ambiguities or context-specific nuances. Demographic information about participants (i.e., age, sex, and place of origin) was collected from the school.

Measures

Stress Perception

Defining stress has proven to be challenging, with no universally accepted definition (Levine, 2005). Similarly, gauging stress levels in children presents several difficulties, leading to the proposal of various tools and methodologies. To try to quantify the potential stress arising from the environment in which children live, we employed the Perceived Stress Scale for Children (White, 2014), which is derived from the adult version (Cohen et al., 1983). This scale is generally used as a screening tool to identify children with anxiety and stress disorders, and is acknowledged as a reliable measure of an individual's stress perception at a given moment, and across various age ranges and languages. Designed for use with participants aged 5 to 18, it offers a more concise, less invasive, and simple assessment compared to other tools we evaluated (e.g., Bernstein et al., 1994; Spence, 1998; Spielberger et al., 1973). The scale explores various areas related to the child's perception of stress, including time constraints, school performance, friendship quality, parent/guardian relationships, experiences of conflict and anger, overall happiness, sleep patterns, and the sense of being loved. These areas align with established frameworks used to describe childhood stress perception (e.g., Byrne et al., 2011; Maldonado et al., 2008). To ensure inclusivity, we adapted references to "your parents" by broadening to "your parents or whoever takes care of you at home", acknowledging that not all children may be cared for by their parents.

Originally in English, the PSS-C questions were translated into Italian for children from Scampia and Pozzuoli by a bilingual speaker, with back-translation into English by another bilingual individual to ensure accuracy. The same procedure was followed for Roma children, with translation into Romanes and back-translation into English by bilingual speakers proficient in both languages.

Short-term Memory and Working Memory

STM is typically assessed through a "span task" which requires participants to recall items (e.g., digits, words, or figures) in the same order they were presented, a method utilised at least since Ebbinghaus (1885). The evaluation of WM normally couples recall with a concurrent activity, demanding not just retrieval but also the active manipulation of information.

To assess STM, we employed the Prove per la Misurazione della Memoria di Lavoro (PML-2, D'Amico & Lipari, 2020), a test battery aligned with the traditional Baddeley and Hitch's (1974) model. This battery, developed specifically for Italian children, was designed for easy administration across various contexts, ranging from schools to clinical settings. For verbal STM, we utilised Task 2 "rievocazione seriale di cifre" (serial recall of digits), in which participants are required to repeat a sequence of numbers between 1 and 9 in the order they were presented. A warm-up exercise introduced the task, in which two digits were presented orally for the child to repeat in the same order. This was used to assess children's task comprehension. If the child failed to recall the sequence correctly after the experimenter, they were given up to two further attempts. Failure to answer correctly in the third attempt resulted in discontinuation of the task, and these children's data were excluded from analyses.

To evaluate visuo-spatial STM, we used Task 6 "rievocazione di sequenze visuo-spaziali" (recall of visuo-spatial sequences) from the battery. The researcher sat beside the child and tapped a series of circles printed on a laminated paper sheet in a specific sequence, which the child was then required to replicate by tapping the circles in the same order. A comprehension check was performed as described above for the digit task.

For both tasks, stimuli were presented/indicated by the experimenter at a rate of one per second, beginning with two-item lists at the first iteration and extending up to eight-item lists. Each iteration consisted of two different lists, both administered. If the child correctly recalled at

least one list, they progressed to a longer one, incrementing by one item at a time. The task ended when both lists of a given length were recalled incorrectly. Correct recall required reproducing all elements in the same order as presented.

Each task generates two scores: the *span* score, which indicates the length of the longest correctly recalled list (e.g., if the child correctly recalled a five-item list and failed both six-item lists, their span score was five), and the *total* score, calculated as the sum of all correctly recalled lists (e.g., if the child recalled two two-item lists and one three-item list, their total score is 2 + 2 + 3 = 7). The span score was the primary variable of interest for the main analyses. The total score, reported in the SOM, enables a more fine-grained evaluation of variation among children who, with similar span measures, may have recalled more or longer lists.

To assess WM, we employed two tasks, one verbal and one visuo-spatial, that mirrored the STM tasks but differed in that they required items recall in reverse order. The backward span task necessitates greater cognitive effort to manipulate the sequence, and it is widely used as a measure of WM span (e.g., Alloway et al., 2006; Berry et al., 2018; St Clair-Thompson, 2010). The administration of the WM tasks followed the same procedure as the STM tasks described above, including the prior comprehension check.

3.1.2 Analyses

We ran four linear regression models, one for each of the dependent variables from the four tasks (i.e., verbal STM, visuo-spatial STM, verbal WM, visuo-spatial WM). The main predictor variable was participant environment, and we included participant age and sex as covariates. We used treatment contrasts on the environment variable, with Pozzuoli (lower-stress population) being the reference category. We also used linear regression models to test whether participants' PSS-C scores predicted the dependent variables. We did not exclude outlying

observations. Participant data were only excluded due to age or if they were unable to follow or complete the memory task (see SOM Tables S1-S2).

3.1.3 Results

Descriptive Statistics

Overall, task comprehension was high, although Roma children struggled slightly more with the backward tasks (see SOM Table S2). The scores on the memory tasks are reported below.

Table 2. Span scores for STM and WM tasks across the three populations.

Environment	Verbal STM		Verbal WM		Visuo-spatial STM		Visuo-spatial WM	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pozzuoli	4.36	0.95	2.88	0.83	4.30	1.05	3.70	1.19
Scampia	4.39	1.02	3.01	0.76	4.29	1.08	3.54	0.97
Roma	2.93	0.62	1.97	0.67	3.60	0.62	3.16	0.72

On the Perceived Stress Scale for Children (PSS-C), Roma children scored the lowest on average (M = 9.20, SD = 4.94), followed by Pozzuoli (M = 10.20, SD = 4.31), with Scampia showing the highest mean score (M = 11.00, SD = 4.80). An ANOVA revealed that these differences were statistically significant (F = 3.04, p = .049), and driven by the difference between the Roma and Scampia populations (*Mean difference* = 1.8, p = .054) (see SOM Tables S3-S4).

Effects of Environment on Memory Test Scores

Roma children scored significantly lower than the Pozzuoli control group in all four memory tasks: verbal STM (b = −1.58, SE = 0.142, t = −11.157, p < .001), verbal WM (b = −1.00, SE

= 0.126, $t = -7.986$, $p < .001$), visuo-spatial STM ($b = -0.799$, $SE = 0.159$, $t = -5.026$, $p < .001$), and visuo-spatial WM ($b = -0.641$, $SE = 0.166$, $t = -3.856$, $p < .001$). In contrast, the scores of Scampia children were not significantly different to the scores of Pozzuoli children across any of the tasks: verbal STM ($b = 0.046$, $SE = 0.092$, $t = 0.500$, $p = .618$), verbal WM ($b = 0.145$, $SE = 0.079$, $t = 1.842$, $p = .066$), visuo-spatial STM ($b = -0.024$, $SE = 0.103$, $t = -0.234$, $p = .815$), and visuo-spatial WM ($b = -0.167$, $SE = 0.106$, $t = -1.574$, $p = .116$). The effect of age was statistically significant and positive in all models, whereas the effect of sex was not statistically significant (see below). Full model results are reported in SOM Tables S5-S8, and results are plotted in Figure 3.

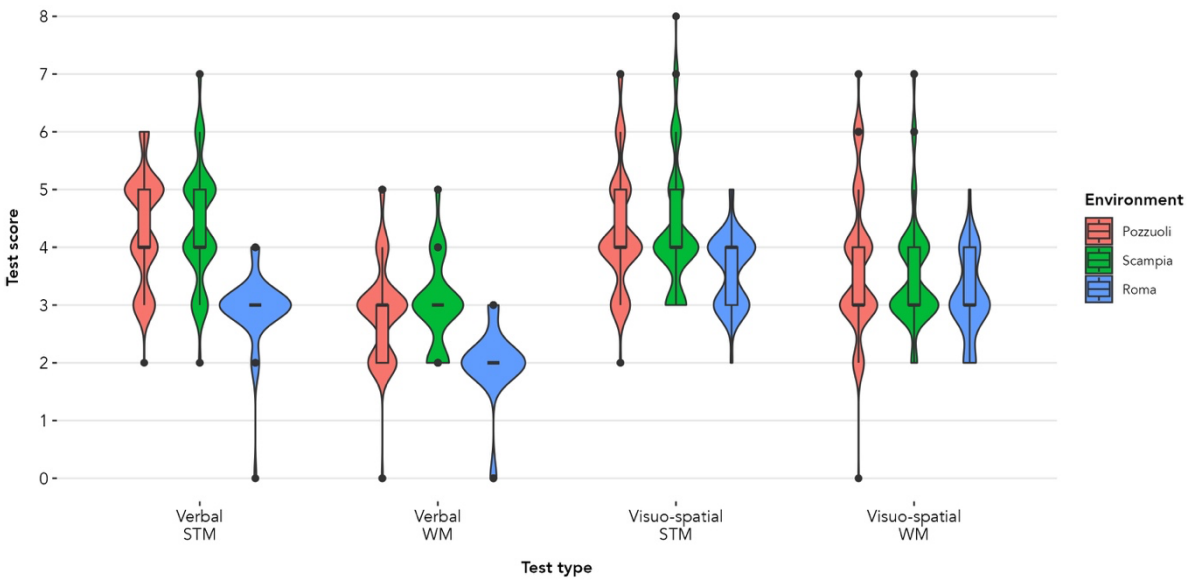


Figure 3. Participants' span scores by environment and test type.

Effect of Age and Sex on Memory Test Scores

Significant positive effects of age were found in all models, indicating that older children performed better on memory tasks. Specifically, age was positively related to verbal STM ($b = 0.310$, $SE = 0.031$, $t = 10.105$, $p < .001$), verbal WM ($b = 0.245$, $SE = 0.026$, $t = 9.346$, $p < .001$), visuo-spatial STM ($b = 0.275$, $SE = 0.034$, $t = 8.029$, $p < .001$), and visuo-spatial WM ($b = 0.307$, $SE = 0.035$, $t = 8.711$, $p < .001$). Sex was not a significant predictor of memory

performance in any task. A similar pattern for the age and sex covariates was observed when using the total score as the outcome variable (see SOM Tables S9-S12).

Effects of Perceived Stress on Memory Test Scores

Models revealed that there was no effect of the PSS-C on any of the four memory assessments (all *p*'s > .05; see SOM Tables S13-S16).

3.1.4 Discussion

This study aimed to explore STM and WM performance in children from high-stress environments, drawing samples from three populations in the Naples area (Italy): Scampia, a Roma camp, and a comparatively lower-stress setting, Pozzuoli. Both verbal and visuo-spatial components of STM and WM were assessed through four tasks.

Children from the Roma camp consistently scored significantly lower across all tasks. These results align with prior research indicating that individuals exposed to adversity often perform worse on conventional memory tests (e.g., Brooks-Gunn & Duncan, 1997; Calderón-Garcidueñas et al., 2015; Evans & Schamberg, 2009; Hackman et al., 2014; Mooney et al., 2021). This echoes the deficit model described earlier, which primarily draws from evidence on conventional cognitive assessments involving decontextualised or abstract tasks, and suggests that growing up in high-stress environments predisposes children to impaired development.

The absence of a "deficit" among children from Scampia, as evidenced by similar scores to those of Pozzuoli across all tasks, may be attributed to several factors. One possibility is that children are not exposed to significant stress; however, in light of our ethnographic work, we find this an unlikely explanation. More plausibly, supportive networks within the community, adaptive coping mechanisms, and resourcefulness acquired through navigating challenging

environments could contribute to resilience and buffer developmental stress, such that cognitive development has progressed similarly to children in the control environment. Further investigation into these factors could provide valuable insights into the mechanisms of resilience among children facing adversity.

The use of the Perceived Stress Scale for Children (PSS-C) aimed to gauge children's stress and anxiety with the expectation that these scores would predict memory tasks performance. Contrary to expectations, Roma children displayed the lowest stress/anxiety levels on average as measured by the PSS-C, followed by those from Pozzuoli and then Scampia. These differences were statistically significant, primarily driven by the disparity between the Roma and Scampia populations. The PSS-C scores did not predict memory task scores.

Based on our ethnographic research in the study populations, we suggest that the scale's questions did not fully align with the specific stressors these children face, contributing to poor face validity of the measure in these settings. The PSS-C focuses on general experiences in the past week, such as feeling nervous, sleep difficulties, or relationship with parents, but does not account for the chronic, context-specific challenges faced by children in these environments. For instance, children from the Roma camp endure extreme poverty, segregation, and lack of basic necessities, while children in Scampia are frequently exposed to criminal activity, such as drug trafficking. These severe, concrete challenges may not have been adequately captured by the milder questions of the PSS-C. This limitation may be attributed to ethical considerations that prevent direct questioning about sensitive topics (e.g., drugs, violence), which likely are significant sources of stress in the daily lives of these children. These findings also raise questions about how best to define and measure diverse environmental adversities and their actual impact on children's perception. Future research could aim to develop more contextually

sensitive measures to better capture the stressors and subjective experiences of stress in very harsh settings.

This study provides new insights into the cognitive abilities of children raised in adverse environments. While Roma children showed lower memory scores compared to their counterparts in the less stressful environment of Pozzuoli, Scampia's children scored comparably to their Pozzuoli's peers. This challenges the prevailing emphasis on impaired cognitive abilities in such circumstances. However, it is essential to acknowledge that this study employed solely conventional tools to assess STM and WM, and that memory for abstract stimuli may not be representative of children's memory capacities across other modalities. Previous research has indicated the existence of additional memory systems for processing different types of information, such as social and motor stimuli (e.g., Meyer et al., 2012; Smyrnis et al., 2014), while other research has suggested that adversity is associated with the development of enhanced social skills such as better incidental memory for faces (Dietze et al., 2022), increased accuracy in discerning trustworthiness among peers (Pitula et al., 2017), greater empathic accuracy (Kraus et al., 2010), or better memory for socioemotional stimuli (Rifkin-Graboi et al., 2018, 2021, 2023). Taken together, this underscores the pressing need for further research employing alternative and potentially more ecologically relevant stimuli to gain a more comprehensive understanding of memory development in children from high-stress environments and to explore additional memory modalities more thoroughly.

3.2 Study 2 – Social Memory

Building upon Study 1, which utilised conventional, abstract stimuli in assessing memory capacities, Study 2 was designed to explore the response to social stimuli in short-term and working memory in the same cohort of children.

3.2.1 Method

Participants

The same 404 children recruited for Study 1 also participated in Study 2. Recruitment procedures and exclusions criteria remained identical to those of Study 1. Children younger than five years old (n = 18), older than 11 years (n = 1) and those who did not understand the tasks (n = 7) were excluded from the analysis. The refined sample sizes are as follows (see SOM Table S17 for a full summary of exclusions by test).

Table 3. Demographic information of participants across tasks.

Environment	Task type	n	$n_{females}$ (%)	M_{age} (years)	SD_{age} (years)
Scampia	Social STM	157	83 (52.9)	8.35	1.41
	Social WM	156	83 (53.2)	8.35	1.42
Pozzuoli	Social STM	181	84 (46.41)	8.33	1.42
	Social WM	181	84 (46.41)	8.33	1.42
Roma	Social STM	45	13 (28.9)	8.76	1.38
	Social WM	45	11 (24.4)	8.75	1.38

Procedure

This study included two tasks assessing social STM and social WM, following the same procedure as Study 1.

Measures

To assess social STM and WM, we adapted the visuo-spatial memory task from Study 1, substituting conventional, abstract stimuli with social stimuli. These consisted of high-quality photos of children's faces, retrieved from a free online archive (www.pexels.com). The selection included 136 images of children balanced by sex and diverse in ethnic background.

The depicted children ranged in age from approximately 6 to 10 years old, aligning with the study participants' age group. The facial expressions varied from neutral to positive. All photos were cropped to a uniform dimension and printed on laminated A5 cards (14.8 cm x 21 cm).

In the social STM task, participants were required to point with their finger to the face cards in the same order as presented. Face cards were shown one at a time for one second each, positioned at the child's eye level at a distance of about 80 cm. After presentation, the cards were placed on the table partially following the pattern of the visuo-spatial task of Study 1 (See SOM 3). The comprehension check followed the same procedure as Study 1.

The task began with two different lists of two items, and both were administered. If the child correctly recalled at least one list, they progressed to longer ones (increased by one item per iteration). The task continued until the child correctly recalled at least one list, with correct recall requiring the reproduction of all elements in the presented order. To assess social WM, a similar task was used, but with children asked to recall the items in reverse order. As in Study 1, the tasks generate two scores: the *span* score indicates the length of the longest correctly recalled list, while a *total* score was calculated as the sum of all correctly recalled lists. Our main analyses focused on the span score, and analyses of total scores are reported in full in the SOM.

3.2.2 Analyses

We ran two linear regression models, one for each of the dependent variables (i.e., social STM and social WM). The main predictor variable was participant environment, and we included participant age and sex as covariates. Treatment contrasts were applied on the environment variable, using Pozzuoli (the lower-stress population) as the reference category. Additionally, we tested whether participants' PSS-C scores predicted the dependent variables using linear

models. We did not exclude outlying observations. Participant data were only excluded if they were unable to follow or complete the memory task (see SOM Table S17).

3.2.3 Results

Statistics

Task comprehension was high overall, but Roma children had slightly more difficulty with the backward tasks (see SOM Table S18). Tasks scores are reported in Table 4.

Table 4. Span scores for social STM and WM tasks across the three populations.

Environment	Social STM		Social WM	
	M	*SD*	*M*	*SD*
Pozzuoli	5.19	1.50	4.38	1.76
Scampia	6.03	1.42	4.84	1.64
Roma	4.87	1.06	3.21	0.842

The stress scale data from Study 1 were used to test effects of perceived stress on social memory performance.

Effects of Environment on Memory Test Scores

Scores from Roma children did not differ from the Pozzuoli control group in social STM (b = −0.318, SE = 0.208, t = −1.531, p = .127), but were significantly lower in social WM (b = −1.175, SE = 0.244, t = −4.617, p < .001). By contrast, Scampia children scored significantly higher than those from Pozzuoli in both social STM (b = 0.835, SE = 0.135, t = 6.186, p < .001) and social WM (b = 0.460, SE = 0.162, t = 2.836, p = .005). Full model results are reported in SOM Tables S19 and S20, and results are plotted in Figure 4 and 5.

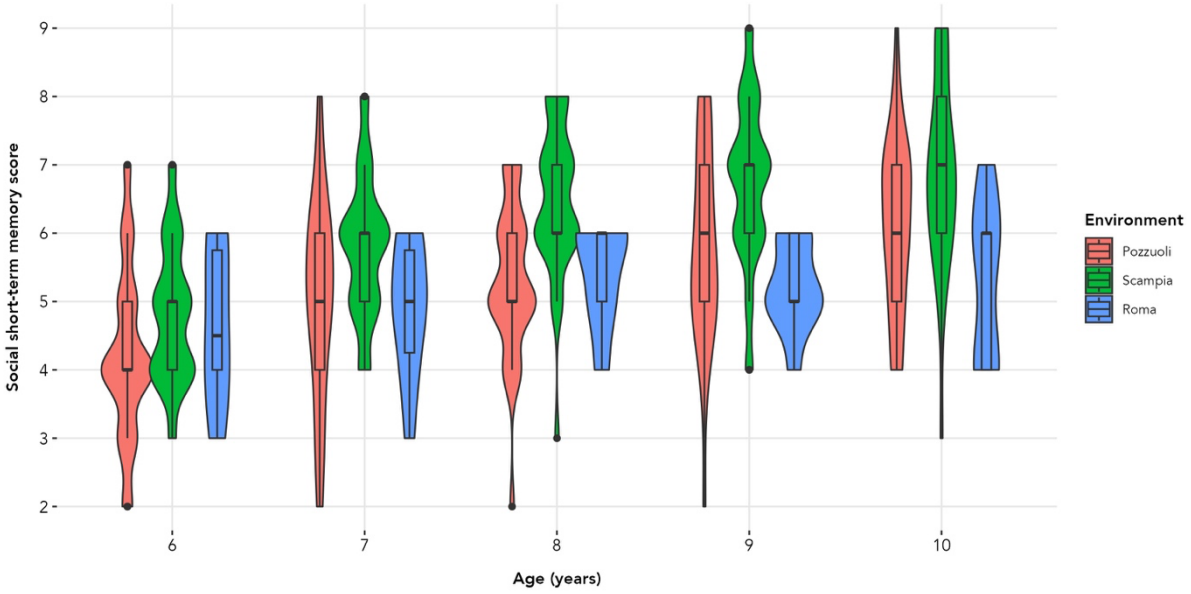


Figure 4. Participants' social STM span scores by environment and age.

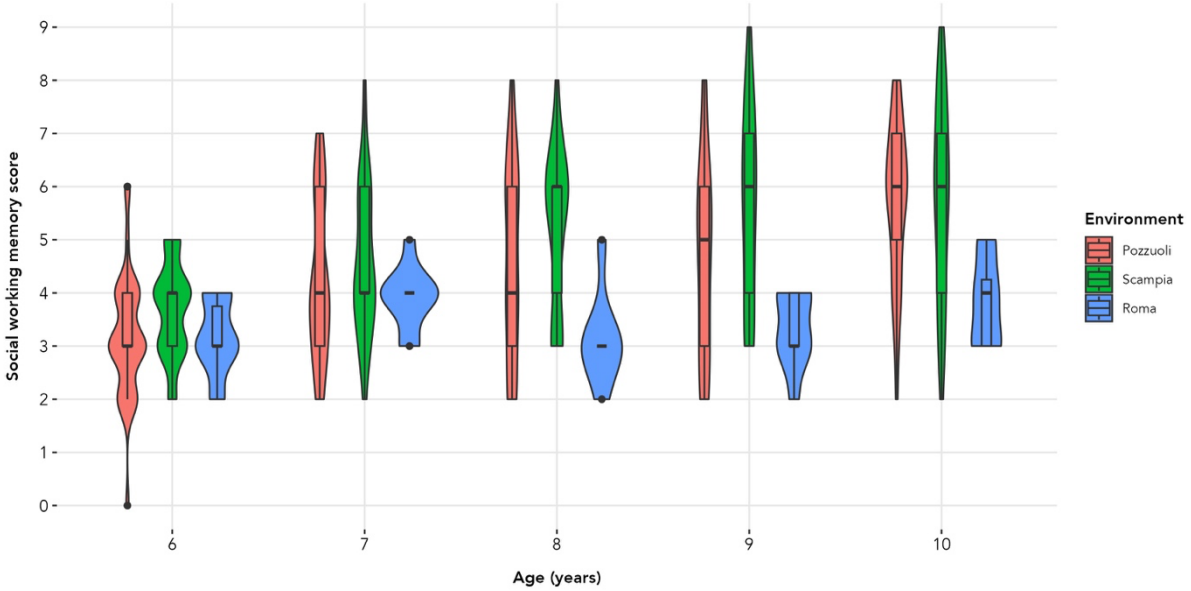


Figure 5. Participants' social WM span scores by environment and age.

When employing the total score as the outcome variable, the same pattern of results was observed (see SOM Tables S21 and S22).

Effect of Age and Sex on Memory Test Scores

Significant positive effects of age were found in all models, indicating that older children had better performance on memory tasks. Specifically, age was positively related to social STM (*b*

= 0.449, *SE* = 0.045, *t* = 10.004, *p* < .001) and social WM (*b* = 0.476, *SE* = 0.054, *t* = 8.814, *p* < .001).

Sex was not a significant predictor of memory performance on either social STM task (*b* = −0.055, *SE* = 0.128, *t* = −0.430, *p* = .667) or social WM task (*b* = 0.158, *SE* = 0.155, *t* = 1.025, *p* = .306).

Effects of Perceived Stress on Memory Test Scores

Results suggest no effect of the PSS-C on either assessment of memory (both *p*'s > .05; see SOM Tables S23 and S24).

3.2.4 Discussion

Study 2 aimed to investigate STM and WM using social stimuli with children from different environments in the Naples metropolitan area. Children from Scampia demonstrated significantly higher scores in both social STM and social WM compared to their peers from Pozzuoli. For example, the 7-year-olds from Scampia scored comparably to the 9-year-olds from Pozzuoli (see Figure 4-5). This suggests that children from more stressful environments may have more advanced memory abilities for socially relevant information earlier in development.

From an evolutionary-developmental perspective, natural selection has shaped developmental systems to adjust to environment demands (Bjorklund & Ellis, 2014), and memory can be considered an adaptive function that evolved to prioritise fitness-relevant information (see Nairne et al., 2009). For instance, previous research has demonstrated a propensity for children to acquire and remember information about potential threats, such as dangerous animals (Barrett & Broesch, 2012) or negative social actions (Baltazar et al., 2012). In Scampia, where social competition and criminal activity are relatively prevalent, threats primarily originate

from fellow humans. Navigating this environment requires residents to be constantly vigilant, detect potential threats, recognise individuals from different factions, distinguish law enforcement officers, and understand social hierarchies and appropriate behaviours. Our results suggest that children in Scampia have developed enhanced social memory as an adaptation to this challenging social landscape. This is consistent with previous research indicating that individuals from less affluent socioeconomic backgrounds have better incidental memory for faces (i.e., better spontaneous recall for faces they saw but were not instructed to learn; Dietze et al., 2022), likely due to the greater relevance of social information in their daily lives, where understanding and remembering social cues can have crucial consequences.

Contrary to our predictions, and in contrast to the children from Scampia, Roma children exhibited equivalent results to Pozzuoli children in social STM but achieved lower scores (relative to the Pozzuoli sample) in social WM tasks. Given the small Roma sample size, these results should be interpreted with caution. Nevertheless, the apparent difference might reflect Roma children's unfamiliarity with tasks of this kind. Unlike their peers from Scampia and Pozzuoli, who regularly attend school where they engage in didactic and dialogic question-answer interactions, Roma children have minimal experience of tasks that require them to follow instructions and attend to series of questions as prompts to right/wrong responses. Alternatively, the differences between Scampia and the Roma camp may reflect distinct profiles of harshness. While Scampia presents higher levels of social threats, which may drive the development of enhanced social memory, the Roma camp presents relatively greater marginalisation and deprivation. The camp's isolation may reduce children's exposure to threatening outsiders, potentially limiting the development of adaptive social memory skills. Furthermore, irregular school attendance among Roma communities may hinder the cognitive processes underlying WM development, as consistent attendance is known to positively influence WM (e.g., Davidson et al., 2023; Finch, 2019). Further research, ideally with a larger

sample and more fine-grained measures of the different types of adversity and threat to which children are exposed, is required to disentangle these interpretations and refine hypotheses about stress-adaptation in harsh environments.

As in Study 1, perceived stress levels, as measured by the PSS-C, did not correlate with performance on social memory tasks. This suggests that factors influencing memory performance in high-stress environments may be more complex than can be captured by self-reported stress measures alone (see earlier discussion). Taken together, our findings emphasise the need for more nuanced tools to assess the specific stressors that impact children's cognitive development across diverse contexts.

Overall, the results of Study 2 support the idea that harsh environments can cultivate adaptive cognitive skills in short-term and working memory. These findings also highlight the necessity of using ecologically relevant tasks when researching with children from diverse environments: the stronger performance of the Scampia sample overall would have remained "hidden" if only conventional memory tasks had been used, as in Study 1.

3.3 Comparison of Environment Effect Sizes by Test Type

To investigate how the differences in memory performance across environments vary by test type, we: 1) calculated and compared effect sizes for each test in both studies using Cohen's *d* with bootstrapped confidence intervals, and 2) used linear mixed-effects regression (LMER) models to test interactions between environments and test type on standardised memory test scores.

3.3.1 Cohen's *d* Analysis

Using bootstrap confidence intervals for Cohen's *d*, we compared the effect sizes of environment (Pozzuoli vs. Roma, Pozzuoli vs. Scampia) for each of the six test types across

Study 1 and Study 2. Confidence intervals were calculated using the `BootES` package in R (Kirby & Gerlanc, 2013), with each comparison based on 10,000 resamples. Results and summary statistics are shown in Figure 6.

Pozzuoli children scored significantly higher than Roma children in verbal STM (d = 1.599, 95% CI = [1.340, 1.862]) and verbal WM (d = 1.136, 95% CI = [0.804, 1.411]). Although smaller, significant differences in the same direction were also found for visuo-spatial STM (d = 0.717, 95% CI = [0.482, 0.952]) and visuo-spatial WM (d = 0.481, 95% CI = [0.240, 0.722]). In contrast, differences between Pozzuoli and Scampia children were not statistically significant for verbal STM, verbal WM, visuo-spatial STM, and visuo-spatial WM. However, in social STM (d = −0.596, 95% CI = [−0.809, −0.379]) and social WM (d = −0.272, 95% CI = [−0.480, −0.058]), Scampia children scored significantly higher than their Pozzuoli peers, indicating stronger performance in these tasks (see SOM Table S25 for full details).

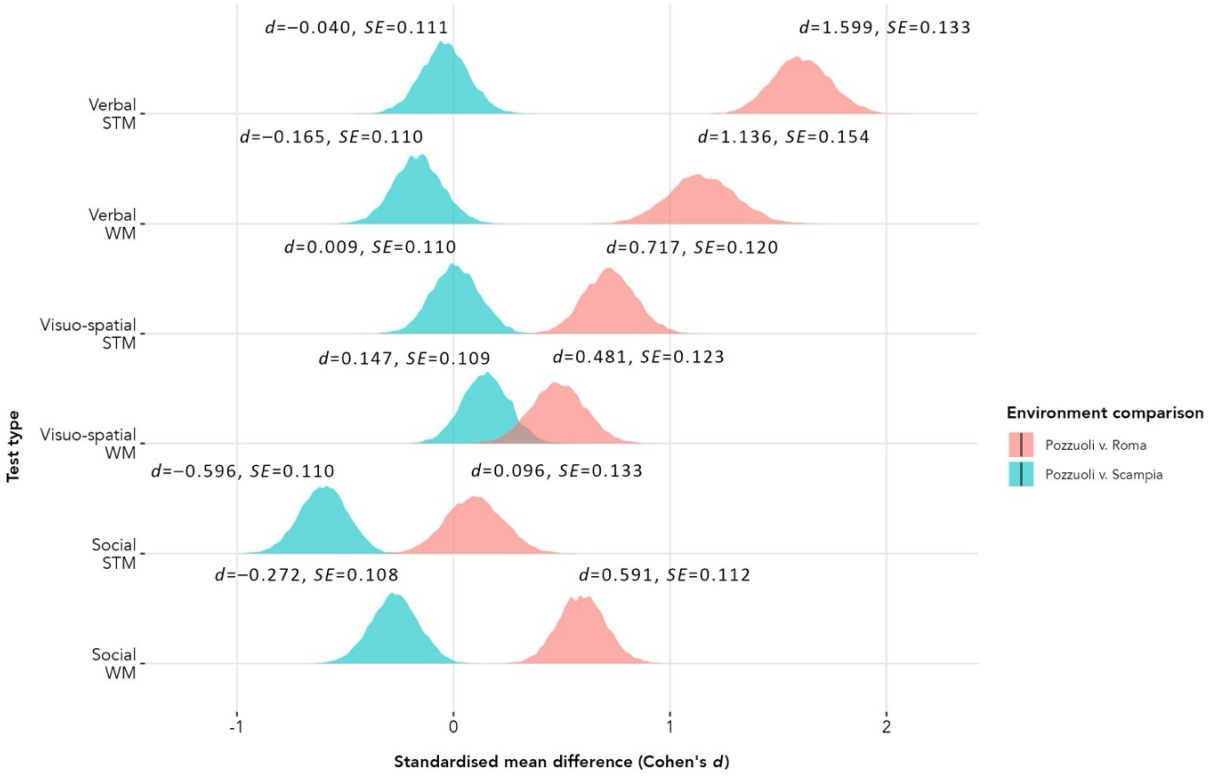


Figure 6. Effect sizes (Cohen's d) for environment comparisons across test types; effect sizes indicate the effect' of the Pozzuoli environment as compared to either the Roma or Scampia environment.

3.3.2 Environment × Test-Type Interaction

To further evaluate whether the effect of environment on memory scores differed across test types, we conducted linear mixed-effects models separately for STM and WM using the `lmer` package in R (Bates et al., 2014). For each model, environment, test type, and their interaction were included as fixed effects, with participant as a random effect to account for individual differences. Age and sex were included as covariates. Post-hoc analyses were performed using Tukey's Honest Significant Difference (HSD) test to examine the simple effects of environment on memory scores by test type (see SOM Figures S1-S2 for visualisations of standardised STM and WM scores by test type and environment).

Results revealed a significant interaction between environment and test type on standardised short-term memory scores. Specifically, the model revealed that the differences between Pozzuoli and Roma scores were significant for verbal STM and visuo-spatial STM ($b = 0.674$, $SE = 0.178$, $t = 3.789$, $p < .001$), and for verbal STM and social STM ($b = 1.253$, $SE = 0.178$, $t = 7.046$, $p < .001$). The differences between Pozzuoli and Scampia were not significantly different for verbal STM and visuo-spatial STM ($b = -0.055$, $SE = 0.117$, $t = -0.474$, $p = .636$), but were significantly different for verbal STM and social STM ($b = 0.545$, $SE = 0.116$, $t = 4.677$, $p < .001$). Post-hoc analyses of simple effects using Tukey's Honest Significant Difference (HSD) test for multiple comparisons are shown in Table 5. Results revealed that Roma children scored significantly lower than Pozzuoli children in verbal STM ($b = -1.344$, $SE = 0.158$, $t = -8.523$, $p < .001$) and visuo-spatial STM ($b = -0.670$, $SE = 0.158$, $t = -4.251$, $p < .001$), but not in social STM. Scampia children scored significantly higher than Pozzuoli children in social STM ($b = 0.586$, $SE = 0.103$, $t = 5.681$, $p < .001$), but not verbal STM or visuo-spatial STM.

Table 5. Simple effects for environment on standardised STM scores by test type, using Tukey's HSD test for multiple comparisons.

	Difference	*SE*	*df*	*t*	*p*
Verbal STM					
Roma − Pozzuoli	−1.344	0.158	901	−8.523	< .001
Scampia − Pozzuoli	0.042	0.103	901	0.401	.915
Scampia – Roma	1.385	0.160	900	8.659	< .001
Visuo-spatial STM					
Roma − Pozzuoli	–0.670	0.158	900	–4.251	< .001
Scampia − Pozzuoli	–0.014	0.103	902	–0.134	.990
Scampia – Roma	0.656	0.160	901	4.100	< .001
Social STM					
Roma − Pozzuoli	–0.091	0.158	900	–0.577	.832
Scampia − Pozzuoli	0.586	0.103	900	5.681	< .001
Scampia – Roma	0.677	0.160	900	4.233	< .001

These findings indicate that the magnitude and direction of environmental effects on STM performance vary by test type and domain. Roma children consistently showed lower performance than Pozzuoli children across all tests except in social STM, where they performed similarly. In contrast, Scampia children outperformed Pozzuoli children in social STM, while performing similarly in verbal and visuo-spatial STM tasks. Finally, the Roma children had lower scores than children from Scampia on every test type.

Results for working memory scores also revealed a significant interaction between environment and test type. Specifically, significant differences were found between Pozzuoli and Roma for verbal WM and visuo-spatial WM (b = 0.496, SE = 0.184, t = 2.701, p = .007), and for verbal WM and social WM (b = 0.439, SE = 0.184, t = 2.391, p = .017). Differences between Pozzuoli and Scampia were significant for verbal WM and visuo-spatial WM (b =

−0.339, *SE* = 0.116, *t* = −2.939, *p* = .004), but not for verbal WM and social WM (*b* = 0.079, *SE* = 0.115, *t* = 0.688, *p* = .492).

Post-hoc analyses of simple effects are shown in Table 6. These results show significant differences between Pozzuoli and Roma for all test types, while differences between Pozzuoli and Scampia were significant only for social WM.

Table 6. Simple effects for environment on standardised WM scores by test type, using Tukey's HSD test for multiple comparisons.

	Difference	***SE***	***df***	***t***	***p***
Verbal WM					
Roma − Pozzuoli	–1.017	0.169	897	–6.011	< .001
Scampia − Pozzuoli	0.195	0.107	852	1.822	.163
Scampia – Roma	1.212	0.171	891	7.091	< .001
Visuo-spatial WM					
Roma − Pozzuoli	–0.521	0.164	848	–3.186	.004
Scampia − Pozzuoli	–0.144	0.106	833	–1.365	.360
Scampia – Roma	0.377	0.166	847	2.270	.061
Social WM					
Roma − Pozzuoli	–0.578	0.163	847	–3.538	.001
Scampia − Pozzuoli	0.275	0.106	830	2.602	.026
Scampia – Roma	0.853	0.166	847	5.141	< .001

These findings indicate that the magnitude and direction of environmental effects on WM performance vary by test type and domain. Roma children consistently showed lower performance than Pozzuoli children across all tests. In contrast, Scampia children outperformed Pozzuoli children specifically in social WM, while performing similarly in verbal and visuo-spatial WM tasks. Finally, the Roma children had lower scores than children from Scampia on verbal and social WM, but similar scores on visuo-spatial WM.

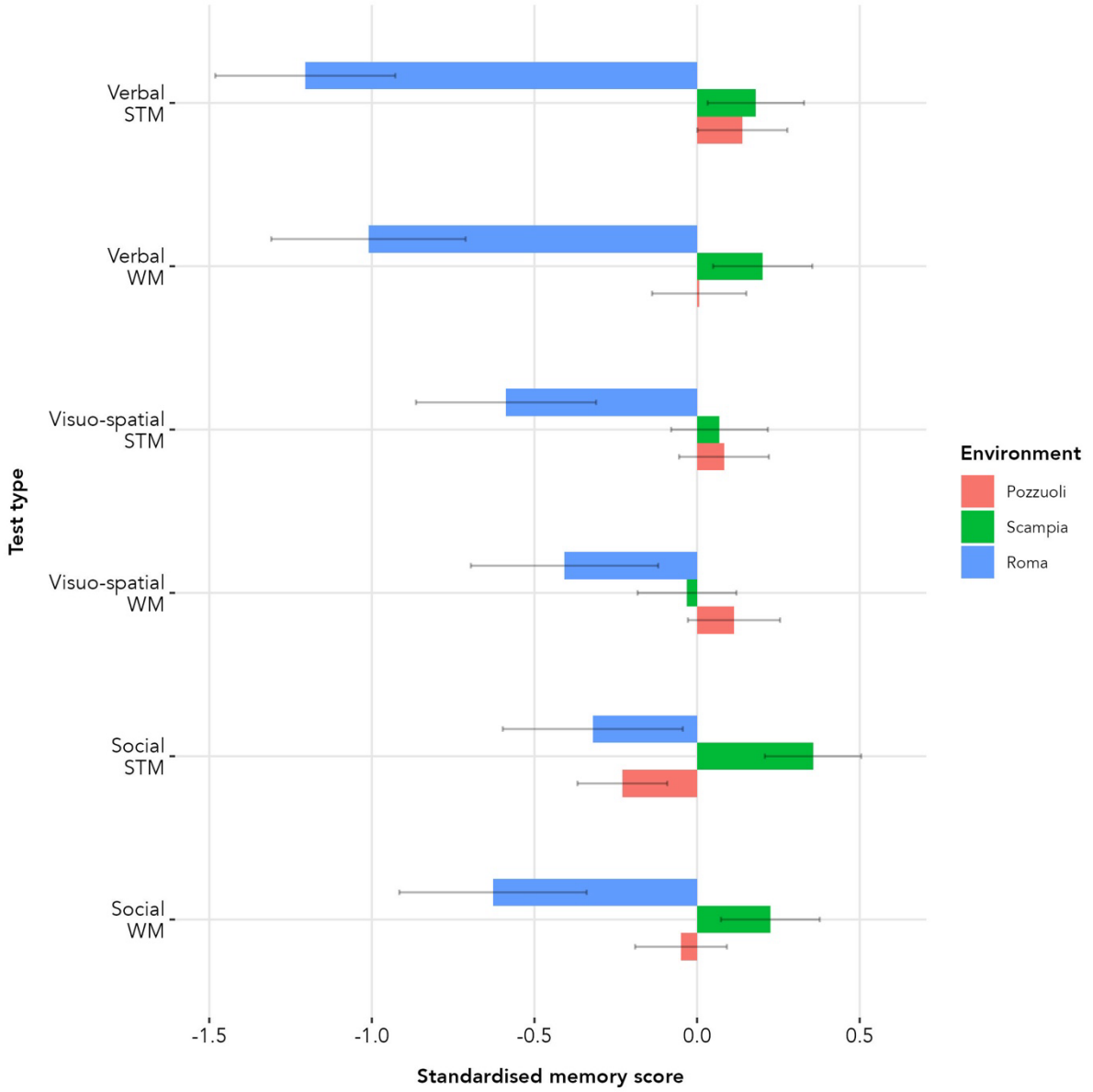


Figure 7. Simple effects for standardised memory test scores by test type and environment.

4. General Discussion

A substantial body of research indicates that growing up in adverse conditions can impair cognitive development in children (e.g., Brooks-Gunn & Duncan, 1997; Lupien et al., 2009; Pechtel & Pizzagalli, 2011). However, not all stress-exposed children exhibit cognitive deficits; some display resilience and achieve typical development "despite the odds" (e.g., Masten, 2001, 2014; Wright et al., 2013). Furthermore, research has suggested that children might

develop hidden talents—specific skills adapted to their environment (Ellis et al., 2017; Frankenhuis & de Weerth, 2013)—though empirical evidence for these remains limited.

This research contributes to an evolving understanding of how stressful environments shape cognitive development in children. Short-term memory and working memory, the cognitive domains examined here, are critical components of cognitive development. They not only support various cognitive functions such as learning and problem-solving, but are central to how individuals navigate and adapt to their surroundings (Cowan, 2014; Diamond, 2013). Our research provides new data on how children from high-stress environments perform in these key domains, challenging the exclusivity of traditional deficit models while revealing resilience and adaptive strengths that might otherwise remain hidden. In doing so, our results emphasise the complexity of cognitive development in children from diverse environmental backgrounds, and highlight the complementarity of the models discussed above.

In Study 1, the lower performance of Roma children in both STM and WM tasks aligns with a large body of prior research suggesting that high-stress environments often predict lower performance on conventional memory tasks (e.g., Brooks-Gunn & Duncan, 1997; Evans & Schamberg, 2009). This potentially supports the deficit model, which posits that exposure to adversity during development can impede cognitive development. However, the performance of children from Scampia, statistically similar to that of Pozzuoli children across all tasks, challenges this view. This outcome aligns with traditional resilience models, which suggest that not all children exposed to high-stress environments exhibit cognitive impairments (Goldstein & Brooks, 2013; Masten, 2001). Protective factors such as supportive community networks or adaptive coping mechanisms may contribute to cognitive resilience and account for these findings.

Study 2 expanded on this investigation by using social stimuli to assess STM and WM, revealing significant differences in memory performance between the groups. Scampia children outperformed their peers from Pozzuoli in both social STM and WM tasks, with some age groups scoring comparably to Pozzuoli children two years older. This suggests that children from high-stress environments may develop enhanced memory abilities for socially relevant information as an adaptive response to their surroundings. The high levels of social competition and criminal activity in Scampia necessitate acute social awareness and memory skills, which may drive the development of these abilities. These results are consistent with research indicating that individuals from less affluent socioeconomic backgrounds exhibit better social skills, such as enhanced incidental memory for faces (Dietze et al., 2022), accuracy in evaluating trustworthiness among peers (Pitula et al., 2017), empathic precision (Kraus et al., 2010), or memory for socioemotional information (Rifkin-Graboi et al., 2018, 2021, 2023). Moreover, these findings also support the specialization hypothesis of the Hidden Talents Model, which suggests that children in high-stress environments may develop specialised skills that are adaptive within their specific context (Frankenhuis & de Weerth, 2013). Furthermore, our results also resonate with theories suggesting that stressful environments may foster the development of cooperative strategies (e.g., Ember et al., 2018; Whitehouse et al., 2017). Developing superior memory for individual recognition could be particularly advantageous in resource-scarce environments, helping children identify who to trust, avoid, or cooperate with. This also connects with theories of tight-loose societies (e.g., Gelfand et al., 2006). In tighter environments, such as Scampia, where criminal networks operate under strict social norms, there are severe consequences for norm violations, and enhanced social memory could be particularly beneficial for monitoring others' behaviour, navigating social hierarchies, avoiding conflict, and forming strategic alliances.

A corollary of the specialization hypothesis within the hidden talents model is the *sensitisation hypothesis* (Ellis et al., 2017), which suggests that specialised, stress-adapted skills can find optimal expression in conditions resembling those in which they were originally acquired. In this view, it could be that an array of cognitive, physical, and behavioural skills, honed through adaptation to Scampia's high-stress environment, remain hidden in certain contexts but are readily observed in others, particularly those that mirror the demands of that environment. For example, (combat) sports require constant vigilance, rapid decision-making, and the ability to anticipate others' actions, skills that are highly adaptive in both sport and in daily life in Scampia, but may be less apparent in a school classroom setting. Notably, the Scampia neighbourhood has produced a remarkable number of elite judo athletes, including multiple European and world champions as well as an Olympic gold medallist. While there are likely many interacting factors contributing to this pattern, it could be speculated that this success reflects, in part, high-level skills acquired through adaptive development to this high-stress environment. Crucially, rather than prioritising convenience and convention in sampling and measures, developmental researchers may need to think more creatively about where to look for such "hidden talents".

Roma children performed similarly to Pozzuoli peers in social STM but worse in social WM tasks. This discrepancy can potentially be attributed to the close-knit nature of the Roma community, where frequent social interactions with different individuals support social STM development. However, irregular school attendance, limited formal education, and extreme marginalisation may affect the development of more complex cognitive processes required for WM (Davidson et al., 2023; Finch, 2019). Additionally, the relative isolation of Roma children from broader social structures might also reduce exposure to novel social threats, thereby limiting the necessity for adaptive social memory skills.

For a finer-grained analysis of how environmental context shapes memory performance, we compared effect sizes across different test types. Cohen's *d* analysis revealed that Roma children performed consistently worse than Pozzuoli children on conventional STM and WM tasks, particularly verbal STM and WM. However, the gap narrowed significantly in social memory tasks, especially for STM. This suggests that when tasks involve more ecologically valid stimuli, such as recognising human faces rather than abstract digits or geometrical figures, the performance gap between Roma and Pozzuoli children decreases—a pattern consistent with prior research showing that ecological stimuli can attenuate adversity-related performance gaps (Young et al., 2022). Conversely, Scampia children displayed negligible or reversed differences compared to Pozzuoli children for social STM and WM tasks, often outperforming them. This trend highlights how harsh environments with high levels of social competition and threat can foster the development of adaptive cognitive skills tailored to specific environmental demands, consistent with the hidden talents model.

Further support for this adaptive hypothesis was provided by the environment × test-type interaction analysis, which revealed that the effect of environment varied significantly across test types. Scampia children displayed a pronounced advantage in social memory tasks, where the contrast with conventional tasks was most evident. This finding reinforces the idea that the cognitive adaptations observed in Scampia children are domain-specific, likely shaped by the unique pressures and demands of their social environment.

Regarding the Roma children, Cohen's *d* analysis and interaction analysis revealed interesting nuances. While they performed comparably to Pozzuoli peers in social STM tasks, the deficits in social WM were smaller than those observed in the conventional tasks used in Study 1. We suggest that social memory tasks are more ecologically relevant to their experiences, and this

partly mitigates performance gaps observed in conventional (i.e., abstract) memory assessments.

It is important to recognise that environmental conditions may differentially affect STM and WM, and further research is needed into how specific environmental factors influence various aspects of memory development. Additional research is needed on STM and WM in diverse and underrepresented populations, and how these cognitive skills adapt to meet the survival demands of specific environments. The absence of a significant relationship between perceived stress levels as measured by the PSS-C and memory performance potentially reflects the complexity of defining and measuring exposure to stress. For ethical and other reasons, the PSS-C and similar tools likely do not adequately capture the types and severity of stressors faced by children in extremely harsh environments. Future research should aim to develop more ecologically valid measures and interventions that can accurately reflect the specific stressors and coping mechanisms relevant to children in these contexts.

5. Contributions and Limitations

This research holds several notable strengths. First, it uniquely concentrates on young children aged 6–10, diverging from most memory studies that primarily focus on adults. Second, to the best of our knowledge, this is the first research that investigates and compares social STM and WM in children from both harsh and relatively safer environments. Third, we collected data from a large sample exceeding 400 children across three distinct environments. Two of these, Scampia and the Roma camp, are relatively resource poor and high-stress, with the Roma camp also having little interaction with formal education, healthcare, and other essential public services. Our findings thus offer a valuable counterpoint to the predominantly W.E.I.R.D participants commonly found in existing research (Henrich et al., 2010). This inclusion advances the field by addressing the logistical challenges associated with studying children in

very high-stress settings. Furthermore, integrating cognitive and ethnographic research provides a comprehensive perspective on the investigated skills and the environments influencing their development. Also, this research combined conventional tests with novel tasks designed to be more ecologically relevant. Results could inform educational strategies tailored to the specific memory development profiles of the three groups studied, potentially leading to more effective educational approaches. Additionally, this research challenges stereotypes often associated with low socioeconomic status backgrounds, since individuals from such environments frequently face stigmatisation, which can significantly impact their social identity and opportunities (Cozzarelli et al., 2001; Spencer & Castano, 2007).

A limitation arises from employing a standard stress-scale to gauge children's exposure to environmental stressors. Allwood and colleagues (2017) revealed that a child's own perception of stress is affected by constraints deriving from their cognitive development. Furthermore, children may tend to select extreme responses in self-report questionnaires, or refer to a single experience (Varni et al., 2007). They may also exhibit reluctance to recall negative past experiences (Rotsika et al., 2011). Acquiring reliable questionnaire responses from parents is equally challenging, as they may withhold certain information, or misperceive their child's stress levels, potentially exaggerating difficulties (see Allwood et al., 2017; Rotsika et al., 2011). To mitigate these limitations, we complemented the PSS-C with environmental indices measuring social and material vulnerability, alongside ethnographic data.

Another consideration is the impact of the COVID-19 pandemic, which caused irregular school attendance in the two years preceding data collection and may have affected their performance. Several studies have demonstrated a correlation between schooling and outcomes on STM and WM tasks (e.g., Kosmidis et al., 2011; Roberts et al., 2015). Notably, most Roma children

participating in our research had never attended school before, and only participated in a short schooling program during the research period.

Furthermore, as a natural experiment, diverse environments inevitably pose challenges due to potential confounding factors. While stress adaptation may explain some variation, unaccounted factors and discrepancies in schooling attendance may also contribute to observed differences. Additionally, testing setting variations introduce potential bias, with unfamiliar environments potentially impacting performance, particularly for Roma children tested in a school in Scampia. While limitations such as irregular school attendance or the potential impact of COVID-19 exist, our findings remain valuable due to the use of complementary methodologies. Environmental indices offer measures of social and material conditions, ethnographic data provide in-depth contextual insights into children's lived experiences, and cognitive tests involving both conventional and ecologically relevant stimuli allow for a broader understanding of memory development across different contexts.

6. Conclusion

This research provides unique insights into the multifaceted nature of memory development in children raised in adverse environments. Rather than being fully explained by a single model, their memory performance varies depending on the stimuli being utilised and the sample being studied. While some tasks reveal deficits, others show equal or even superior performance compared to the control group, challenging the exclusivity of the predominant deficit model and highlighting the complex, context-dependent nature of memory development. Additionally, this research emphasises the importance of integrating diverse and complementary methodologies, such as environmental indices, ethnographic data, and cognitive testing, to ensure a more comprehensive understanding of how cognitive abilities emerge in response to environmental pressures.

In conclusion, our research reveals that children from high-stress environments can develop unique cognitive capacities, particularly in social memory, which may remain undetected by conventional assessments. Future studies should prioritise the development of more ecologically valid tools and approaches that account for the adaptive nature of cognitive development in diverse contexts. Recognising and supporting these capacities, or "hidden talents", is essential to creating educational and intervention strategies that better serve children growing up in challenging environments.

Data and code availability

The dataset and analysis code used in this study are available at the following link: https://osf.io/yuzcd/files/osfstorage?view_only=d661c694aec643b19feafa73460f70d8

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Authors' contribution

GP conceived of the study, designed and coordinated the study, collected data, analysed and visualised the data, and wrote the manuscript. **EC** provided supervision, participated in the design of the study, and commented on the manuscript. **AJD** analysed and visualised the data and commented on the manuscript.

4 Memory in Motion: Enhanced Motor Memory in Children from Harsh Environments

Submitted to *Developmental Science*

Memory in Motion: Enhanced Motor Memory in Children from Harsh Environments

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Abstract

Extensive research suggests that growing up in harsh or high-stress environments often negatively affects children's memory development. However, previous work on short-term (STM) and working memory (WM) indicates a more nuanced relationship, with effects varying by the type of stimuli used and the memory modality assessed. This study investigates memory for motor stimuli (i.e., memory for sequences of body movements) in 404 children from two high-stress environments in Naples, Italy—Scampia neighbourhood and a Roma camp—and from a lower-stress setting in the same region, Pozzuoli. Children from Scampia significantly outperformed those from Pozzuoli in both motor STM and motor WM tasks, while children from the Roma camp scored comparably to Pozzuoli's in motor STM and lower in motor WM. Importantly, cross-modal comparisons showed that motor tasks captured strengths that are typically overlooked by conventional assessments, and point to variation in the effects of higher/lower-stress environments across different memory domains. These results offer support for the view that children growing up in high-stress settings potentially develop stress-adapted cognitive skills, and that an expanded lens on development-as-adaptation can guide future research on the skills and strengths of children growing up in such settings.

Key words: Evolutionary Anthropology, Adaptation, Children, Memory, Hidden Talents Model, Harsh and Unpredictable Environments

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1. Introduction

Children growing up in harsh and unpredictable environments are often considered at risk of impaired development. While numerous studies have shown a negative correlation between early adversity and cognitive performance (e.g., Evans & Schamberg, 2009; Gustafsson et al., 2013; Pechtel & Pizzagalli, 2011), others have revealed a more complex relationship, with many children displaying *resilience*, defined as the ability to reach a typical development despite exposure to adversity (Masten, 2014). Recent research has further nuanced this picture by proposing that children can develop *hidden talents*, i.e. stress-adapted skills that may confer advantage in specific contexts (Ellis et al., 2017; Frankenhuis & de Weerth, 2013). These findings suggest that environmental stress does not universally hinder cognitive and behavioural development, but instead shapes it in context-dependent ways.

Despite growing interest in the complex relationship between environmental stress and development, several conceptual and methodological challenges persist (Ellis et al., 2017; Frankenhuis et al., 2020). For example, prevailing definitions of intelligence predominantly reflect Western standards (e.g., prioritising abstract thinking) and do not capture abilities shaped by diverse cultural contexts (Sternberg & Preiss, 2022). These standards have in turn influenced the design of most assessment tools and methodologies, limiting their cultural relevance to diverse populations. Research also disproportionately relies on Western, educated, industrialised, rich, and democratic (W.E.I.R.D.) samples, which limits cross-cultural generalisability (Henrich et al., 2010). Experimental manipulation of early-life stress in human populations is ethically unfeasible, and laboratory simulations rarely capture the complexity of real-world adversity (e.g., Dickerson & Kemeny, 2004). Consequently, much of the evidence relies on non-human animal models (e.g., Brust et al., 2014; Calandreau et al., 2011; Chaby et al., 2015). Also, conducting empirical research in adverse environments often entails

significant risks and logistical challenges. Together, these factors leave a substantial gap in our understanding of cognitive development under adversity.

The current study aimed to address this gap by examining whether short-term (STM) and working memory (WM) performance differs between children from higher and lower stress environments when assessed using motor stimuli (i.e., sequences of body movements). Participants were drawn from two high-stress contexts within the metropolitan area of Naples, Italy—Scampia neighbourhood and a Roma camp—and a control group from a relatively lower-stress environment within the same province—Pozzuoli (see research sites description below).

1.1 Why Focus on STM, WM, and Motor Memory?

STM is a specialised memory system involved in temporary storage and retrieval of information, while WM extends this function by also involving the active manipulation of such information (Alloway et al., 2004; Baddeley, 1992; Kolb & Whishaw, 2009). This operationalisation is widely used in developmental research and aligns with the structure of the tasks used in this study (though the distinction remains debated, see Aben et al., 2012).

This study focuses on these memory systems for three main reasons. First, they are foundational in children's cognitive development, underpinning essential skills such as reasoning, comprehension, and learning (Bull et al., 2008; Cowan, 2014; Gathercole & Alloway, 2008), and variations in STM and WM influence a wide array of developmental outcomes, positioning them as key targets for research and practical interventions (Alloway & Alloway, 2010; Dehn, 2011; Henry et al., 2022).

Second, like other executive functions, STM and WM are closely associated with the prefrontal cortex, a brain region that continues to mature well into adolescence and early adulthood (Best

& Miller, 2010; Tanaka et al., 2012). This extended developmental period potentially allows for considerable susceptibility to environmental factors (Farah et al., 2006). Indeed, extensive research has reported that both acute and chronic stress can negatively affect performance on STM and WM tasks (e.g., Brand et al., 2000; Bremner et al., 1993; Evans & Schamberg, 2009; Mika et al., 2012; Oei et al., 2006; Pechtel & Pizzagalli, 2011). However, emerging evidence points to a more complex relationship: individuals exposed to adversity may demonstrate enhanced WM (Nweze et al., 2020), or selective enhancements in certain aspects, such as rapid tracking or updating, but impairments in others, such as WM under distracting conditions (Young et al., 2018). These findings highlight the multifaceted and context-dependent nature of STM and WM across different developmental environments.

Third, STM and WM research has predominantly focused on verbal and visuo-spatial modalities, neglecting others such as memory for motor information—an area particularly relevant for children, whose daily lives and learning experiences rely heavily on physical action and sensorimotor engagement (Bushnell & Boudreau, 1993; Piaget, 1946; von Hofsten, 2004). In line with this relevance, recent evidence suggests the existence of a distinct memory system specialised in storing and manipulating patterned body movements, that is, those for which execution itself is the goal (e.g., performing an arabesque or crossing one's arms). These differ from positional movements, which are directed toward external targets (e.g., tapping an object) and rely primarily on the visuo-spatial sketchpad (Nicoladis & Gagnon, 2020; Rumiati & Tessari, 2002; Smyrnis et al., 2014; Smyth et al., 1988; Smyth & Pendleton, 1989, 1990; Wu & Coulson, 2014).

The ability to learn and perform action sequences is fundamental to human functioning, underpinning everyday motor behaviours such as walking, eating, or assembling objects (Seidler et al., 2012). Childhood is a critical period for acquiring and refining these motor skills,

which form the foundation for more complex cognitive and physical competencies later in life (Gallahue & Ozmun, 2012). Moreover, motor development drives cascading changes in perception, cognition, and social interaction, having therefore an important role in broader developmental processes (Adolph & Franchak, 2017). Importantly, the motor system exhibits considerable plasticity, enabling rapid behavioural adaptation to meet environmental demands (Yan et al., 2020), which emphasises the close relationship between motor development and the environments in which it occurs (Adolph & Hospodar, 2024).

Given that motor memory matures within children's everyday environments, it is crucial to understand how environmental stress and adversity may influence its development. Research suggests that children from low-SES backgrounds may have fewer opportunities for structured physical activity, potentially limiting certain forms of motor practice (e.g., Drenowatz et al., 2010; Krist et al., 2017; Yannakoulia et al., 2016). At the same time, in contexts of environmental adversity, children may engage more frequently in adaptive behaviours that rely on motor memory—such as navigating unpredictable terrain or responding quickly to threat cues—which could shape motor memory abilities differently than in more benign settings. While speculative, these considerations align with broader developmental frameworks suggesting that adverse environments may not only impair but also recalibrate cognitive systems toward context-relevant functions (Frankenhuis & de Weerth, 2013). However, to our knowledge, no prior studies have compared motor STM and WM in children across different environments using patterned body movements. In light of these considerations, we did not advance specific directional hypotheses; instead, we treated the study as an opportunity to explore whether environmental adversity interacts with memory systems in previously overlooked ways.

1.2 The Present Study

The primary objective of this study was to assess whether children from environments with differing levels of adversity in Naples, Italy, exhibit variation in motor memory tasks performance. We combined ethnographic fieldwork with natural experimental design to understand the environmental factors shaping children's cognitive development, while assessing motor memory skills and comparing performance across the three settings. Additionally, we employed the Perceived Stress Scale for Children (PSS-C, White, 2014) to gauge children's subjective perception of stress and explore potential correlations between perceived stress and memory performance.

Although previous studies have investigated how environmental adversity affects cognition, few have considered how the type of task—particularly conventional (abstract) versus motor-based assessments—may influence results. To address this gap, we conducted additional analyses comparing memory performance across modalities (motor, verbal, and visuo-spatial), using data collected from the same participant sample recruited as part of a broader research project (see Paone et al., 2025, *preprint* [Chapter 3]). This allowed us to examine whether the effects of environmental adversity on memory vary by modality, and whether motor-based tasks reveal patterns not detected with abstract and other (e.g., social) stimuli. This study was pre-registered on AsPredicted (https://aspredicted.org/f6bc-5ps4.pdf).

Below, we briefly describe the participants' environments (for a more comprehensive description, see Paone et al., 2025, *preprint* [Chapter 3]), present the study results, and report the analysis comparing effect sizes across memory modalities ("abstract" vs. "motor").

2. The Research Sites

Pozzuoli is a middle-class city on the west coast of the Gulf of Naples, with approximately 76,000 residents. The city has well-developed public services, including healthcare, educational facilities, and recreational amenities such as parks, theatres, and community centres. Recent policy initiatives have improved urban living standards further, earning Pozzuoli public recognition for fostering a safe, peaceful, and well-organised environment (see Comune di Pozzuoli, 2024; Olcesi, 2017).

According to the Italian National Institute of Statistics (Istat, 2011), Pozzuoli's Index of Social and Material Vulnerability (IVSM) is 104.1, indicating relatively lower vulnerability compared to the other sites in this study[4]. Ethnographic fieldwork supported this classification: children typically experience relatively structured and secure daily routines, attend well-resourced schools, and participate in extracurricular activities like music lessons, language courses, and organised sports. These have been broadly associated with positive effects on children's cognitive development, including improvements in short-term and working memory (e.g., Diamond & Lee, 2011; George & Coch, 2011; Sarsour et al., 2011), though effects may vary across populations and contexts. Trust in institutions appeared strong, with residents generally expressing satisfaction with public services—unlike in Scampia or the Roma camp, where institutional mistrust was more common.

Education and employment levels further underscore the city's stability: 47.5% of adults hold at least a high school diploma (Istat, 2011), and most parents work in relatively secure jobs. Although some families reported financial concerns—mirroring broader national trends

[4] The IVSM is a composite indicator that incorporates metrics such as education level, employment status, household composition, housing conditions, and access to services, to quantify social and material vulnerability across Italian municipalities.

(European Commission. Directorate-General for Economic and Financial Affairs, 2024)—interviews indicated that access to public services and stable employment help mitigate these issues. Parents' concerns tended to focus on their children's academic progress and future opportunities, rather than issues of safety or discrimination. Overall, Pozzuoli provides a relatively low-stress environment with strong structural support, educational opportunities, and social cohesion, setting it apart from the other two research sites.

Scampia is a densely populated northern suburb of Naples with severe socioeconomic challenges. Home to approximately 40,000 residents[5], it has long struggled with high crime rates, particularly due to the strong presence of Camorra—one of Italy's most powerful criminal organisations—which made it one of Europe's largest open-air drug markets (see Di Costanzo & Ravel, 2013; Saviano, 2006). A violent feud between rival factions in 2004 brought global attention to Scampia, with dozens of murders occurring in residential areas. Although the conflict officially ended in 2005, instability and violence persisted for years.

Beyond criminality, the neighbourhood suffers from poor infrastructure, incomplete housing projects, underdeveloped public services, and high unemployment, with many residents relying on informal or unregulated work for survival (see Orientale Caputo, 2012). Furthermore, it is located within the "Terra dei Fuochi" (Land of Fires), a region between the provinces of Napoli and Caserta plagued by decades of illegal toxic waste dumping by criminal organisations. This has led to the contamination of air, soil, and agricultural products, causing an increase in health-related problems including respiratory diseases, cancers, and congenital disorders (Di Gennaro & Fagnano, 2015; Greco, 2016).

[5] According to official statistics, although the actual number is likely higher due to informal housing occupations.

The neighbourhood IVSM score of 121.1 reflects severe socioeconomic and material vulnerability. Despite recent initiatives aimed at urban regeneration and social improvement, Scampia continues to present a high-stress environment where children are regularly exposed to crime, economic hardship, and environmental hazards that potentially significantly shape their developmental trajectories.

The **Roma Camp** is situated on the outskirts of Giugliano in Campania, and is home to around 420 individuals predominantly of Bosnian descent. Although the broader municipality has an IVSM score of 105.3, this does not reflect the extreme challenges faced within the camp, whose living conditions markedly diverge from municipal-level data. Residents of the camp live in severe poverty, housed in improvised shacks and caravans without reliable access to clean water, electricity, or sanitation. According to Arrevutammoce, the main NGO supporting the camp, most residents lack formal identification documents, which prevents access to public services such as healthcare, education, and legal employment.

Although formally enrolled in school as mandated by Italian law, children were not attending during the period of this research. Many face additional challenges such as malnutrition, chronic health problems, and regular exposure to criminal activities. Furthermore, power imbalances and violence frequently shape interpersonal dynamics within the camp, while blurred boundaries between adult and child spheres prematurely expose minors to alcohol, smoking, and sexual content (see Paone, forthcoming [Appendix B]).

The camp is also located within the "Land of Fires", further exacerbating health risks for residents. Beyond material hardship, the Roma community contends with persistent stigma and systemic discrimination: often portrayed as a social problem rather than a marginalised group in need of support, this perception has hindered effective policy responses and perpetuated cycles of poverty and exclusion (Sigona, 2005).

The conditions in both Scampia and the Roma camp, marked by economic hardships, limited access to formal services, exposure to criminality, and environmental hazards, create profoundly challenging developmental environments. Several studies have consistently linked such exposures with impaired short-term and working memory as assessed by conventional tasks (e.g., Bogliacino et al., 2017; Brand et al., 2000; Bremner et al., 1993; Evans & Fuller-Rowell, 2013; Evans & Schamberg, 2009; Klein & Boals, 2001).

In light of these contextual differences, the present study investigates whether children's motor memory performance varies across environments characterised by differing levels of adversity.

3. Methods

3.1 Participants

We recruited 404 children from the three populations (191 females, M_{age} = 8.33 years, SD_{age} = 1.49), covering the full age range of Italian primary school students, typically aged 6 to 10 years. The sample included 190 children from Pozzuoli (M_{age} = 8.29 years, SD_{age} = 1.47), 167 from Scampia (M_{age} = 8.28 years, SD_{age} = 1.51), and 47 from the Roma camp (M_{age} = 8.70 years, SD_{age} = 1.50). Sample sizes were determined through a priori power analysis, which indicated that a minimum of 75 participants would provide at least 85% power to detect mean group differences of 0.4 points in task scores between children from high-stress and lower-stress environments (see SOM 1). Due to the smaller population size and significant recruitment challenges—such as precarious living conditions and irregular school attendance—the Roma sample was smaller, which reduced statistical power for comparisons involving this group.

Although our primary focus was on children aged 6 to 10, 13 five-year-olds and one eleven-year-old participated to ensure inclusivity in the classroom setting, but their data were excluded

from analyses. Data from three additional participants were excluded as these children did not complete the preliminary trial (see Measures for task details, and SOM Table S1 for exclusion criteria by test). Final sample sizes following exclusions are reported in Table 1.

Table 7. Demographic information of participants.

Environment	Task type	N	n_{female} (%)	M_{age} (years)	SD_{age} (years)
Scampia	Motor STM	156	83 (53.2)	8.38	1.43
	Motor WM	156	83 (53.2)	8.38	1.43
Pozzuoli	Motor STM	186	86 (46.2)	8.33	1.44
	Motor WM	178	84 (47.1)	8.40	1.43
Roma	Motor STM	45	13 (28.9)	8.84	1.38
	Motor WM	37	11 (29.7)	8.84	1.40
Total	Motor STM	387	182 (47.0)	8.41	1.43
	Motor WM	371	178 (48.0)	8.43	1.43

Children from Scampia and Pozzuoli were recruited through their local primary schools. For the Roma children, recruitment was facilitated by an NGO supporting them, and study sessions held in a collaborating school in Scampia. Oral consent for the study was obtained from each participating institution and the teachers involved. Written consent was secured from the parents/guardians. In the Roma camp, where literacy levels vary, the participant information was read aloud, and the consent process was explained verbally to ensure full comprehension before obtaining written consent. Child assent was obtained prior to each session. As a token of appreciation, each child received stickers and a “Young Researcher” certificate for their participation. This study was approved by the Departmental Research Ethics Committee of the University of Oxford.

3.2 Procedure

Each session was conducted individually in a quiet room at the school during regular school hours. The study involved two tasks, one assessing motor STM and one assessing motor WM. For children from Pozzuoli and Scampia, the tasks were administered in Italian by the first author, a native Italian speaker. For the Roma children, tasks were conducted in Romanes, their primary language, with the assistance of a translator to ensure effective communication. Demographic details about the children (i.e., age, sex, and area of residence) were obtained from the school.

3.3 Measures

3.3.1 Stress Perception

To gauge children's general perceived stress levels, we administered the PSS-C (White, 2014). This tool screens for anxiety and stress-related disorders, and is designed to provide a reliable snapshot of a child's perceived stress. The scale is suitable for children aged 5 to 18 and covers domains such as time management, academic performance, friendships, relationships with caregivers, conflict, happiness, sleep quality, and feelings of being loved, in alignment with established frameworks on childhood stress (e.g., Byrne et al., 2011; Maldonado et al., 2008). References to "your parents" were modified to "parents or whoever takes care of you at home" to accommodate diverse caregiving situations and ensure inclusivity.

The original English PSS-C questions were translated into Italian for children from Pozzuoli and Scampia, and into Romanes for Roma children. Each translation was followed by a back-translation process by separate bilingual individuals to ensure linguistic accuracy and cultural sensitivity.

3.3.2 Motor Short-term Memory and Working Memory

STM evaluation typically involves tasks that require participants to recall a series of items in the order they were presented (i.e., digits or figures). This study employed a novel task specifically designed to assess memory for body movements in children. While it shares structural features with traditional span tasks—such as incremental sequence length, recall conditions, and span/total scoring (e.g., Kessels et al., 2000; Wechsler, 2014)—it departs from conventional paradigms by using patterned, symmetrical body movements as stimuli instead of rather abstract items like digits or geometrical figures.

For motor STM, children were asked to reproduce the sequence in the same order it was demonstrated by the researcher, beginning with two movements and increasing incrementally up to eight. To assess comprehension, the researcher first demonstrated a two-movement sequence during a warm-up trial, which the child was then asked to replicate. If the child was unable to perform the sequence correctly, they were given up to two additional attempts. Children who failed all three attempts did not complete the task, and their data were excluded from the analysis.

A set of 10 body movement combinations was developed for the task (see SOM 2). Movements were designed to be simple and unchallenging for the children to perform from a standing position (e.g., raising both arms upwards). The experimenter and participant stood facing each other, and the experimenter demonstrated the movements from a distance of 2.5 metres to ensure clear visibility while maintaining personal space. Each movement was symmetrical, involving both limbs in a way that allowed the child to mirror the movements without needing to distinguish left from right.

Each trial consisted of a sequence of movements presented at a steady pace of one movement per second. The task began with two-movement sequences and increased incrementally in

length. At each level, two different sequences of the same length were presented. Children were instructed to observe the entire sequence and then reproduce it after the experimenter finished the demonstration. The most recent movement in a sequence was maintained while subsequent movements were performed. For instance, if the first move involved raising the arms upwards, the arms were to remain raised until the next arm movement occurred, or the sequence ended. The task continued as long as the child could recall at least one of the two sequences at a given length. If both were recalled incorrectly at any level, the task was discontinued.

Movements were evaluated for morphological correctness (e.g., whether limbs were straight or bent, raised, or lowered) and direction (e.g., upward or frontward). Minor deviations, such as slight hesitation or open/closed hands, were not penalised as long as the essential movement pattern was replicated accurately. All movement responses were independently scored by the researcher and a research assistant. Any discrepancies in their evaluations were subsequently discussed until consensus was reached. The span score, used as the main outcome measure, represented the maximum sequence length recalled correctly (e.g., a child recalling a 3-item sequence but failing both 4-item ones would receive a span score of 3). The total score reflected the sum of all correctly recalled sequences (e.g., a child recalling two 2-item sequences and one 3-item sequence, would receive a total score of 2 + 2 + 3 = 7). The total score, presented in the SOM, enables a more detailed assessment of children who recalled more sequences or longer lists, despite having similar span scores.

Motor WM was assessed using the same procedure, with an added layer of complexity requiring participants to recall each movement sequence in reverse order. This heightened cognitive demand aligns with established WM assessments designed to measure the capacity for information manipulation (e.g., Alloway et al., 2006; Berry et al., 2018; St Clair-Thompson,

2010). The motor WM tasks included the same warm-up check to confirm comprehension before the main trials began.

3.4 Analyses

We conducted separate linear regression models for each outcome variable (motor STM and motor WM). The primary predictor was the child's environment, with age and sex included as covariates. We applied treatment contrast to the environment variable, using Pozzuoli—the lower-stress context—as the reference group. Additional models were run to test whether performance on the memory tasks was associated with children's scores on the Perceived Stress Scale for Children (PSS-C). No statistical outliers were excluded; participant data were only omitted if the child was unable to complete or understand the memory tasks (see SOM, Table 1).

4. Results

4.1 Descriptive Statistics

All tasks were well understood, though Roma children showed slightly more difficulty with the backward memory tasks (see SOM Table S2). Memory tasks span scores are reported below.

Table 8. Span scores for motor STM and WM tasks across the three populations.

Environment	**Motor STM**		**Motor WM**	
	M	*SD*	*M*	*SD*
Pozzuoli	3.11	0.67	2.60	0.65
Scampia	3.59	0.72	2.92	0.77
Roma	3.07	0.50	2.30	0.46

For perceived stress, measured by the PSS-C, Roma children reported the lowest average stress (M = 9.20, SD = 4.94), followed by children from Pozzuoli (M = 10.00, SD = 4.31), and those from Scampia (M = 10.90, SD = 4.72). An ANOVA confirmed that the variation in scores was statistically significant (F = 3.07, p = .048), and primarily driven by the difference between Roma and Scampia (*Mean difference* = 1.72, p = .067), and not between Roma and Pozzuoli (*Mean difference* = –0.84, p = .506), nor between Scampia and Pozzuoli (*Mean difference* = 0.88, p = .178) (see SOM Tables S3-S4).

4.2 Effects of Environment on Memory Test Scores

Analyses revealed that children from Scampia scored significantly higher than the Pozzuoli control group on both motor STM (b = 0.487, SE = 0.069, t = 7.050, p < .001) and motor WM (b = 0.319, SE = 0.074, t = 4.334, p < .001). Children from the Roma camp performed similarly to the Pozzuoli group in motor STM (b = −0.141, SE = 0.107, t = −1.321, p = .187), but scored significantly lower in motor WM (b = −0.336, SE = 0.122, t = −2.753, p = .006). Full model results are reported in SOM Tables S5-S6, and plotted in Figure 1-2.

This overall pattern of group differences—with Scampia children scoring significantly higher than Pozzuoli peers in both motor STM and WM, and Roma children performing similarly to Pozzuoli children in motor STM but lower in WM—remained consistent when analysing the total scores, with age emerging as a significant covariate, while sex did not show any significant effect (see SOM, Tables 7-8).

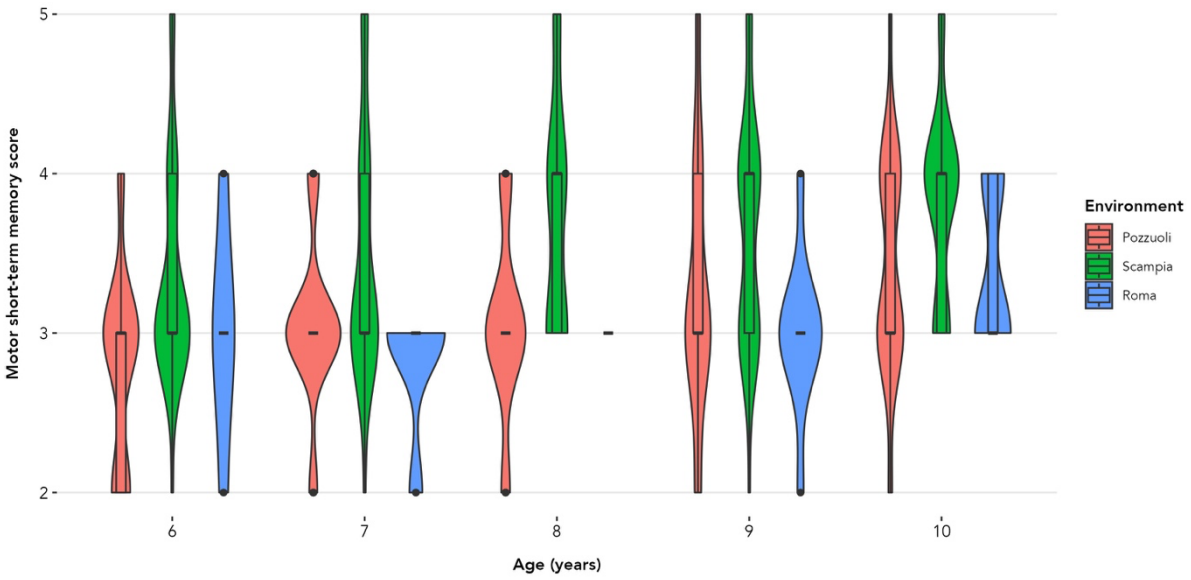


Figure 1. Participants' motor STM span scores by environment and age.

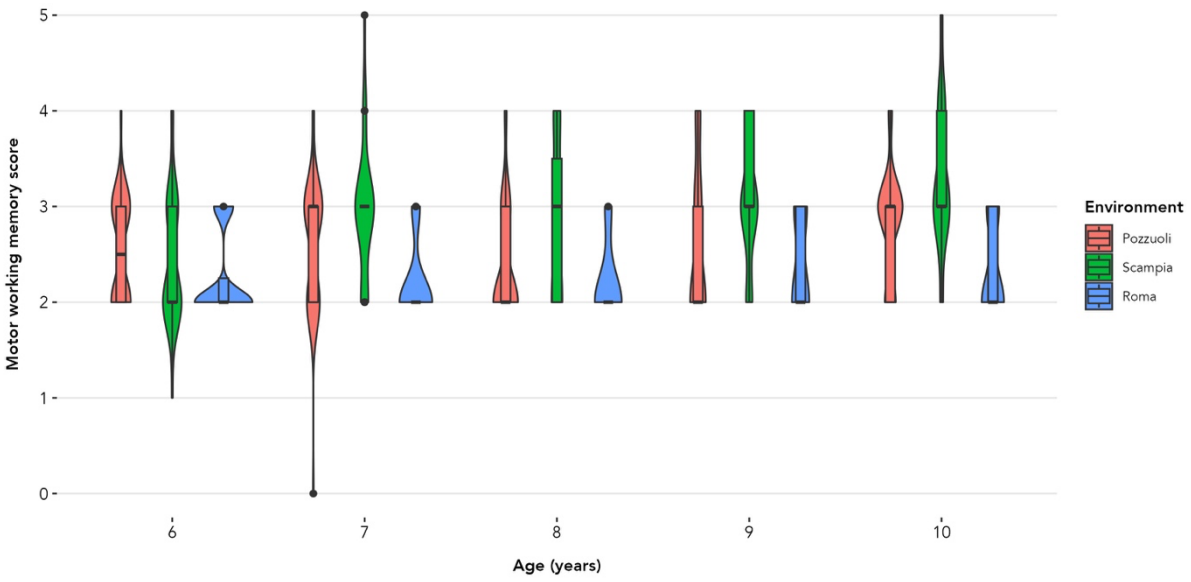


Figure 2. Participants' motor WM span scores by environment and age.

4.3 Effects of Covariates on Memory Test Scores

Age showed a significant positive effect across all models. Specifically, age was positively associated with motor STM (b = 0.140, SE = 0.023, t = 6.184, p < .001) and motor WM (b = 0.116, SE = 0.024, t = 4.764, p < .001), with older children outperforming younger ones on all

motor memory tasks. Similar effects were observed for the total scores, with age positively related to both motor STM total (b = 0.753, SE = 0.129, t = 5.850, p < .001) and motor WM total (b = 0.607, SE = 0.122, t = 4.974, p < .001).

Regarding sex differences, males scored higher than females on motor STM (b = 0.168, SE = 0.065, t = 2.574, p = .010), while no significant difference was found for motor WM (b = −0.079, SE = 0.070, t = −1.130, p = .259). A similar pattern appeared in the total scores: males scored higher than females on motor STM total (b = 0.771, SE = 0.372, t = 2.074, p = .039), with no significant difference for motor WM total (b = −0.580, SE = 0.351, t = −1.655, p = .099).

4.4 Effects of Perceived Stress on Memory Test Scores

There was no significant effect of the PSS-C on either of the memory assessments (all p's > .05; see SOM Tables 9-12).

5. Comparing Memory Modalities Across Diverse Environments

In this section, we examine whether group differences in children's memory performance depend on the type of stimuli used—verbal, visuo-spatial, or motor. Using tasks matched in structure and administered to the same sample as part of a broader research project (see Paone et al., 2025, *preprint* [Chapter 3]), we compared performance patterns across these three memory modalities. Verbal STM was assessed using a forward digit span task, and visuo-spatial STM was measured using a forward tapping sequence task, both taken from the Prove per la Misurazione della Memoria di Lavoro (PML-2, D'Amico & Lipari, 2020), a standardised Italian battery. WM for these modalities was measured using structurally identical tasks

requiring backward recall (Alloway et al., 2006; Berry et al., 2018; St Clair-Thompson, 2010). Our motor STM and WM tasks closely parallel these conventional assessments in format and scoring, enabling direct comparisons across memory domains within the same sample.

We conducted two complementary analyses to explore whether differences between children from Pozzuoli, Scampia, and the Roma camp varied depending on stimulus modality. First, we calculated Cohen's *d* effect sizes with bootstrapped confidence intervals to quantify and compare the magnitude of group differences separately for each memory task. This approach highlights where the largest and smallest differences between groups occurred.

Second, we tested whether these group differences significantly varied depending on memory modality (i.e., verbal, visuo-spatial, or motor) by employing linear mixed-effects regression (LMER) models. This inferential analysis examined whether the pattern and size of observed differences between environments changed systematically with task type.

Together, these analyses provide a valuable opportunity to evaluate whether using non-conventional (motor) stimuli reveals performance patterns that differ from those identified by conventional verbal or visuo-spatial assessments. Analyses included only participants who completed tasks in all three modalities (n = 353).

5.1 Cohen's *d* Analysis

Using bootstrap confidence intervals for Cohen's *d*, we compared the effect sizes of environment (Pozzuoli vs. Roma and Pozzuoli vs. Scampia) for each of the six test types across the three studies (verbal memory, visuo-spatial memory, and motor memory). Confidence intervals were calculated using the `BootES` package in R (Kirby & Gerlanc, 2013), with each comparison based on 10,000 resamples. Results are shown in Figure 3; effect sizes indicate the "effect" of the Pozzuoli environment as compared to either the Roma or Scampia environment.

The largest differences were observed between Pozzuoli and Roma children in verbal STM (d = 1.750, 95% CI = [1.460, 2.070]) and verbal WM (d = 1.070, 95% CI = [0.759, 1.400]), with Pozzuoli children scoring higher overall than Roma children. Pozzuoli children also scored significantly higher in visuo-spatial STM (d = 0.841, 95% CI = [0.603, 1.090]) and visuo-spatial WM (d = 0.567, 95% CI = [0.316, 0.815]). However, there were no significant differences in motor STM scores between Pozzuoli and Roma children (d = 0.009, 95% CI = [–0.301, 0.318]).

In contrast, Pozzuoli children scored lower than their Scampia peers in both motor STM (d = –0.678, 95% CI = [–0.451, –0.901]) and motor WM (d = –0.425, 95% CI = [–0.651, –0.205]). There were no statistically significant differences in scores for Pozzuoli and Scampia children in verbal STM (d = 0.024, 95% CI = [–0.201, 0.244]), verbal WM (d = –0.168, 95% CI = [–0.385, 0.051]), visuo-spatial STM (d = 0.065, 95% CI = [–0.155, 0.285]), and visuo-spatial WM (d = 0.220, 95% CI = [–0.001, 0.443]) (see SOM Table S13 for full details).

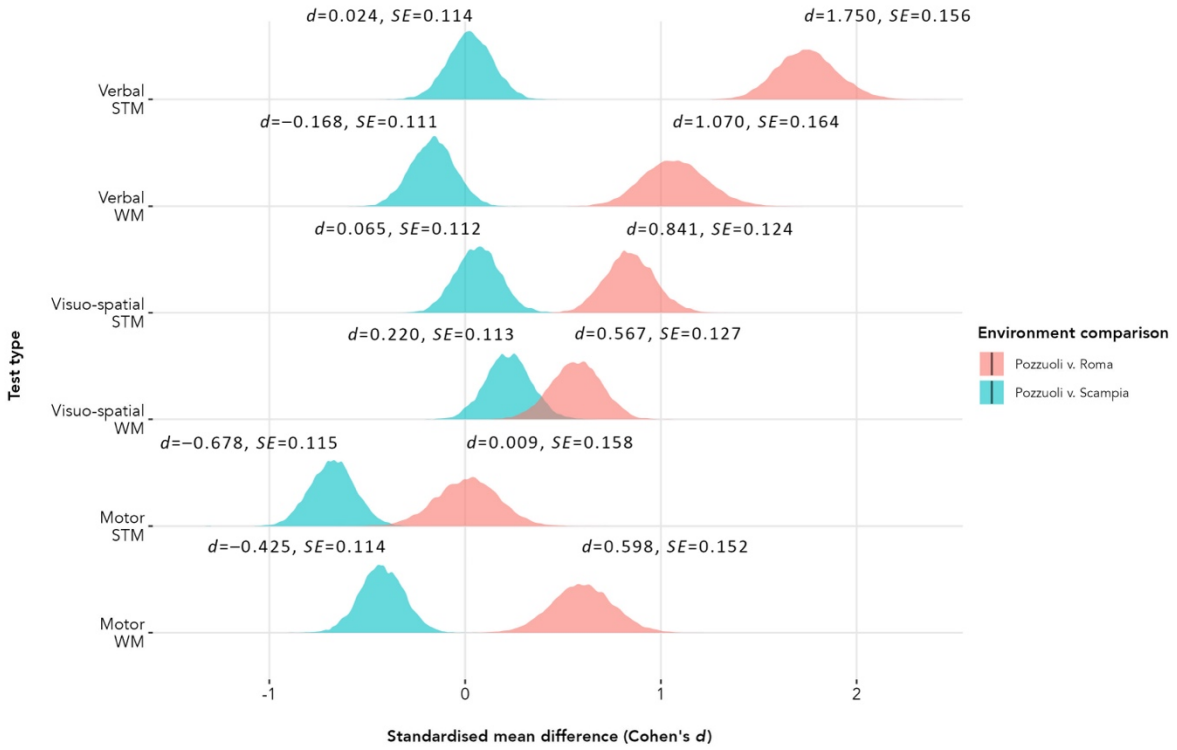


Figure 3. Effect sizes (Cohen's d) for environment comparisons across test types; effect sizes indicate the effect of the Pozzuoli environment as compared to either the Roma or Scampia environment.

5.2 Environment × Test-Type Interaction

To further evaluate whether the effect of environment on memory scores differed across test types, we conducted linear mixed-effects models separately for STM and WM using the `lmer` package in R (Bates et al., 2014). For each model, environment, test type, and their interaction were included as fixed effects, with participant as a random effect to account for individual differences. Age and sex were included as covariates (see SOM Figures S1-S2 for visualisations of standardised STM and WM scores by test type and environment). Post-hoc analyses were performed using Tukey's Honest Significant Difference (HSD) test to examine the simple effects (differences in estimated marginal means) of environment on memory scores

by test type. Simple effects for standardised memory test scores by test type and environment are shown in Figure 4.

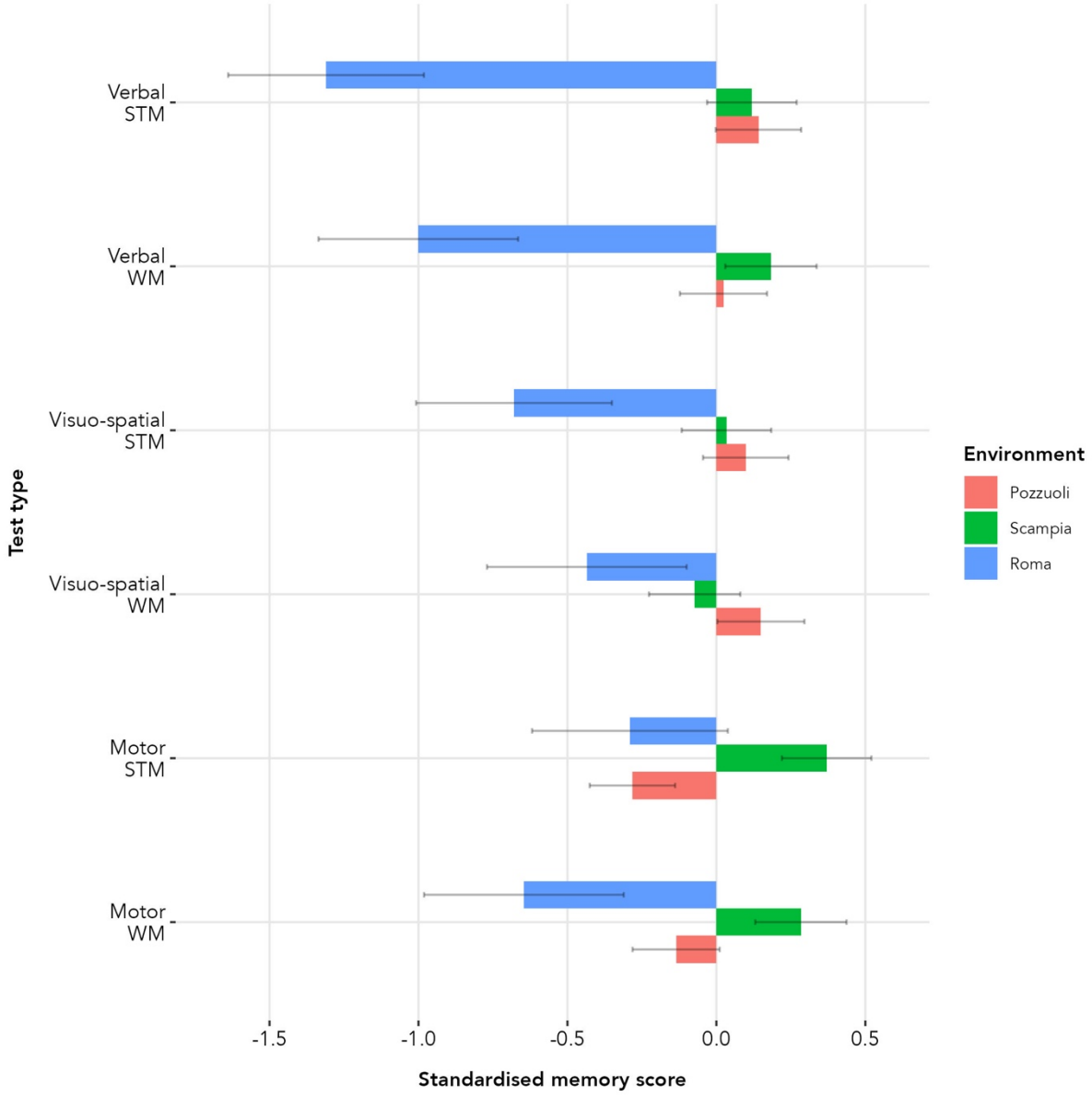


Figure 4. Simple effects for standardised memory test scores by test type and environment.

Results revealed significant interactions between environment and test type on standardised short-term memory scores. Specifically, the model and simple effects estimates revealed that the differences between Pozzuoli and Roma scores were significantly different for verbal STM

and visuo-spatial STM (b = 0.673, SE = 0.229, t = 2.946, p = .003), and for verbal STM and motor STM (b = 1.443, SE = 2.229, t = 6.314, p < .001).

The differences between Pozzuoli and Scampia were not significantly different for verbal STM and visuo-spatial STM (b = −0.043, SE = 0.132, t = −0.324, p =.746), but were significantly different for verbal STM and motor STM (b = 0.673, SE = 0.132, t = 5.090, p < .001). Post-hoc analyses of simple effects using Tukey's Honest Significant Difference (HSD) test for multiple comparisons are shown in Table 3.

Table 9. Simple effects for environment on standardised STM scores by test type, using Tukey's HSD test for multiple comparisons.

	Difference	***SE***	***df***	***t***	***p***
Verbal STM					
Roma − Pozzuoli	–1.451	0.183	959	–7.944	< .001
Scampia − Pozzuoli	–0.022	0.106	959	–0.208	.976
Scampia – Roma	1.429	0.184	959	7.763	< .001
Visuo-spatial STM					
Roma − Pozzuoli	–0.778	0.183	959	–4.259	< .001
Scampia − Pozzuoli	–0.065	0.106	959	–0.613	.813
Scampia – Roma	0.713	0.184	959	3.873	< .001
Motor STM					
Roma − Pozzuoli	–0.008	0.183	959	–0.046	.999
Scampia − Pozzuoli	0.652	0.106	959	6.158	< .001
Scampia – Roma	0.660	0.184	959	3.586	.001

These findings indicate that the magnitude and direction of environmental effects on STM performance vary by test type. Roma children consistently showed lower performance than Pozzuoli children across all tests, with the largest difference observed in the verbal domain. However, no significant difference emerged in motor STM, where they performed similarly.

In contrast, Scampia children outperformed Pozzuoli children in motor STM, while showing comparable performance in verbal and visuo-spatial STM tasks. Finally, Roma children had lower scores than Scampia children on every test type.

Results for working memory scores also revealed a significant interaction between environment and test type. Specifically, the model revealed that the differences between Pozzuoli and Roma scores were not significantly different for verbal WM and visuo-spatial WM (b = 0.440, SE = 0.228, t = 1.932, p = .054). However, differences between Pozzuoli and Roma scores were significantly different for verbal WM and motor WM (b = 0.513, SE = 0.228, t = 2.253, p = .025). Differences between Pozzuoli and Scampia were significantly different for verbal WM and visuo-spatial WM (b = –0.382, SE = 0.132, t = –2.890, p = .004), and for verbal WM and motor WM (b = 0.260, SE = 0.132, t = 1.966, p = .050).

Post-hoc analyses of simple effects are shown in Table 4. These results show significant differences between Pozzuoli and Roma for all test types, while differences between Pozzuoli and Scampia were significant only for motor WM.

Table 10. Simple effects for environment on standardised WM scores by test type, using Tukey's HSD test for multiple comparisons.

	Difference	***SE***	***df***	***t***	***p***
Verbal WM					
Roma − Pozzuoli	–1.024	0.186	932	–5.499	< .001
Scampia − Pozzuoli	0.159	0.108	932	1.476	.303
Scampia – Roma	1.184	0.188	932	6.305	< .001
Visuo-spatial WM					
Roma − Pozzuoli	–0.584	0.186	932	–3.135	.005
Scampia − Pozzuoli	–0.222	0.108	932	–2.059	.099
Scampia – Roma	0.362	0.188	932	1.927	.132

Motor WM					
Roma − Pozzuoli	–0.511	0.186	932	–2.743	.017
Scampia − Pozzuoli	0.419	0.108	932	3.880	< .001
Scampia – Roma	0.930	0.188	932	4.952	< .001

The strongest difference in WM was again found in the verbal domain between Roma and Pozzuoli children, indicating notably lower performance in Roma children. A significant gap also emerged in motor WM, with Roma children underperforming compared to both Pozzuoli and Scampia children. Meanwhile, Scampia children outperformed Pozzuoli in motor WM. Differences in visuo-spatial WM were more modest and not statistically significant across all group comparisons.

6. Discussion

This study examined motor STM and WM performance among children living in three distinct environments in Naples with varying levels of adversity. Children from Scampia consistently outperformed those from Pozzuoli in both motor STM and WM, while children from the Roma camp performed comparably to Pozzuoli peers in motor STM, but scored significantly lower in WM. These findings suggest that environmental conditions play a significant role in shaping motor memory development in different ways.

Although this study did not investigate divergent developmental trajectories, and relevant theory or evidence is lacking generally on the possible contribution of adversity to the pattern of results identified, ethnographic observations offer some speculative insights on these preliminary findings. Scampia's urban environment presents children with unique challenges that possibly contribute to their superior motor memory performance. The neighbourhood's high-density housing, incomplete infrastructure, and high rates of criminality require children

to regularly navigate complex and unpredictable spaces. Activities such as running while overcoming physical obstacles or finding and remembering routes in and out of complex buildings are integral to daily life, and may promote heightened motor memory abilities. These circumstances may also foster enhanced situational awareness and rapid decision-making, which are closely tied to motor cognition. In contrast, the relative safety and predictability of Pozzuoli may limit the environmental pressures that drive the refinement of these abilities.

The superior motor memory performance of Scampia's children may also help to contextualise the neighbourhood's prominence in elite judo, a discipline that relies heavily on the encoding, retention, and execution of complex motor sequences. This possibility aligns with the *sensitisation hypothesis* (Ellis et al., 2017), which proposes that adaptations emerging under early-life adversity are most evident in contexts that mirror the high-demand, unpredictable conditions in which they developed—as may be the case for a combat sport such as judo. Future research could examine this connection more systematically, exploring whether stress-adapted motor skills contribute to athletic achievement.

Another possible explanation for the differences observed may lie in the potential link between adverse environments and capacities for learning. Animal studies, such as those in rodents and birds, have found that individuals reared in unpredictable environments often exhibit superior learning abilities relative to those from safer, more predictable conditions (e.g., Bagot et al., 2009; Farine et al., 2015). However, while learning effects may have contributed to the observed differences, they cannot fully account for the pattern observed here, as Scampia children did not outperform peers across all tasks in our broader research, suggesting a more nuanced interplay of environmental and cognitive influences.

An alternative account is that differences in motor memory reflect variation in children's everyday motor experience across sites. If this were the case, one might expect Scampia

children to be the most physically active, given their higher test scores, and Roma children the least active, given their lower scores. Ethnographic data, however, indicate the opposite pattern: Roma children were the most physically active, spending much of their day outdoors in play or work; Pozzuoli children had greater access to organised sports and a wider variety of activities; and Scampia children engaged in activity levels broadly comparable to those in Pozzuoli, though with fewer formal options and less variety. This mismatch between physical activity patterns and task performance observed in our samples suggests that motor memory differences cannot be explained by activity levels alone, but instead likely arise from the combined influence of environmental adversity and other developmental factors. However, more systematic measurement and investigation of possible alternative factors contributing to the differences observed is warranted.

The performance of Roma children—comparable to Pozzuoli peers in motor STM but lower in motor WM—possibly illustrates a nuanced environmental influence. The similarity in motor STM scores suggests that basic motor memory functions may be relatively resilient to adverse conditions, possibly because they rely less on enriched cognitive or environmental input. These results are consistent with traditional resilience research (see Masten, 2014). Motor STM, which primarily involves the recall of sequences without significant cognitive manipulation, appears less affected by the challenging conditions faced by Roma children. Everyday activities within the camp, such as navigating their confined environment or assisting in routine tasks, may provide sufficient opportunities to support motor STM development.

In contrast, the lower motor WM performance may reflect a lack of opportunities for higher-order motor planning and sequence manipulation. WM requires not only recalling information but also manipulating it, which necessitates greater cognitive engagement (Alloway et al., 2004). Limited access to formal schooling, structured play and sports clubs, and different

cognitively stimulating activities likely reduces opportunities for planning, problem-solving, and integrating motor sequences—skills potentially relevant for motor WM development. Future research could investigate whether the lower motor WM performance by Roma children reflects a lack of exposure to specific types of motor-cognitive challenges or broader neurocognitive impacts of chronic adversity.

An alternative explanation is that the tasks used in this study, though designed to be broadly applicable, may not fully reflect the motor activities Roma children encounter in their daily lives. For example, a task involving movements related to scavenging or recycling various materials—common activities in the camp—might yield different results (see Paone, forthcoming [Appendix B]). Future research could explore ecologically valid tasks tailored to the specific motor experiences of children in such environments, providing deeper insights into the adaptability of motor memory under extreme adversity.

Beyond motor memory assessment, we examined how the environment-related differences observed in motor memory compared with those in conventional verbal and visuo-spatial tasks, all administered to the same samples of participants. These cross-modal analyses revealed that motor tasks yielded smaller and less consistent differences across groups than conventional verbal tasks, particularly in STM. For example, the largest performance gaps were observed in verbal WM and STM, where Roma children scored substantially lower than Pozzuoli peers. In contrast, motor STM showed no difference between Roma and Pozzuoli children, and Scampia children outperformed Pozzuoli peers only on motor but not verbal or visuo-spatial memory tasks.

These preliminary findings lend support to the Hidden Talents Model, which emphasises that strengths developed under adversity may only become visible when performance is compared across domains or task conditions, rather than solely across groups (Frankenhuis et al., 2020).

In line with this perspective, our results suggest that conventional assessments relying exclusively on verbal or visuo-spatial stimuli may provide an incomplete picture of cognitive development, disproportionately highlighting deficits while overlooking adaptive skills—such as those emerging in motor domains. Incorporating diverse and ecologically relevant stimulus modalities can provide a more comprehensive and balanced understanding of cognitive development across different environments. We suggest that the exploratory evidence reported here can provide a firmer empirical foundation on which to develop and refine theoretical accounts of the specific contribution of environmental adversity to children's developing motor memory abilities, and to test proposals against competing hypotheses.

7. Contributions and Limitations

This study offers several important contributions to the understanding of motor memory development in children from diverse and high-stress environments. First, to the best of our knowledge, it is the first to examine motor STM and WM in children using sequences of body movements. Second, it focuses on children between 6 and 10 years old, addressing an underrepresented population in cognitive research that has traditionally prioritised adult samples. Third, the study involved over 400 children across three distinct environments, including high-stress and/or non-W.E.I.R.D. contexts. This approach helps to redress the imbalance in cognitive science research, which disproportionately examines Western, educated, industrialised, rich, and democratic populations (Henrich et al., 2010). Furthermore, by combining cognitive assessments with ethnographic fieldwork, this study offers a multidimensional perspective on how environmental adversity may shape motor memory. Additionally, the use of tasks designed to evaluate memory for movements—rather than abstract or decontextualised stimuli—represents a significant step forward in aligning cognitive assessments with the daily experiences of children from diverse backgrounds. While research

exploring the influence of physical activity on cognitive ability is abundant (e.g., Brisswalter et al., 2002; Mualem et al., 2018; Thomas, 2012), the question of how cognitive processes influence motor performance in everyday physical activities remains relatively underexplored. This study contributes to addressing this gap, emphasising the importance of understanding bidirectional relationships between cognition and motor abilities, particularly under high-stress developmental conditions.

These insights have also practical implications for education and intervention. They highlight the importance of recognising the distinct memory profiles that may emerge in children from harsh and unpredictable environments, which could inform more inclusive and context-sensitive pedagogical approaches. Importantly, our results challenge the exclusivity of deficit-oriented perspectives by demonstrating that cognitive impairment is not inevitable among these children, but that they may instead develop adaptive cognitive skills suited to their circumstances. In doing so, they contribute to countering negative stereotypes often associated with low socioeconomic status, which can perpetuate stigma and limit opportunities for individuals from such environments (Cozzarelli et al., 2001; Spencer & Castano, 2007).

There are limitations that warrant consideration. While the Perceived Stress Scale for Children (PSS-C) was employed to assess children's self-reported stress, self-report measures in younger populations can be influenced by developmental factors, such as difficulty conceptualising stress or a tendency to select extreme responses (Allwood et al., 2017; Varni et al., 2007). Children may also underreport negative experiences, while parental reports—had they been collected—could be prone to minimisation or exaggeration (Rotsika et al., 2011). To mitigate these issues, we complemented the PSS-C with environmental indices of social and material vulnerability and ethnographic data to provide a broader understanding of stress exposure.

Finally, while the naturalistic design enhances ecological validity, there are factors not controlled for that could confound results and may not directly relate to environmental adversity. For example, Roma children were tested in an unfamiliar school environment, which might have affected their comfort and performance. Future research should aim to disentangle these factors and control for potential confounds by incorporating longitudinal designs and more precise measures of potential environmental influences.

8. Conclusion

This research contributes to our understanding of how motor STM and WM is shaped by childhood environments, particularly in high-stress contexts. By examining motor memory across diverse settings, it highlights the interplay between environmental challenges and cognitive development. In particular, it underscores the importance of considering ecological validity in cognitive assessments and demonstrates that children raised in harsh environments may not be exclusively cognitively impaired, but instead develop skills tailored to their unique circumstances.

The findings provide a foundation for developing educational policies and interventions that leverage these adaptive skills. Tailoring educational practices to reflect the specific cognitive strengths of children from high-stress environments could help maximise their potential while addressing areas of need. Furthermore, this study contributes to moving beyond deficit-based narratives by showing that cognitive development in adversity is multifaceted and not uniformly impaired.

Future research should explore how specific environmental factors, such as unstructured play, peer interactions, and exposure to complex physical challenges, contribute to the observed differences in motor memory. Additionally, investigating the role of task relevance—designing

tasks that align more closely with everyday motor experiences—could shed light on the adaptability of memory systems under adversity.

Data and code availability

The dataset and analysis code used in this study are available at the following link: https://osf.io/pzb56/files/osfstorage?view_only=b4fedc0fc24649beb4dee236e247947c

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Authors' contribution

GP conceived of the study, designed and coordinated the study, collected data, analysed and visualised the data, and wrote the manuscript. **EC** provided supervision, participated in the design of the study, and commented on the manuscript. **AJD** analysed and visualised the data and commented on the manuscript.

5 Social Memory in Children from Urban and Rural Mozambique: A Pre-Registered Replication Study

Submitted to *Cognitive Development*

Social Memory in Children from Urban and Rural Mozambique: A Pre-Registered Replication Study

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Abstract

This Short Article reports a replication of prior research suggesting that children from high-stress environments may exhibit enhanced memory for social stimuli. We tested children from two Mozambican communities (n = 124): Nhandar, a rural area historically marked by poverty and paramilitary control, and Gorongosa, a comparatively lower-stress town. Using the same short-term and working memory tasks as the original study in Italy, we found that Nhandar children outperformed their peers in both tasks. These findings provide cross-cultural support for the idea that adversity may shape memory development in context-sensitive, adaptive ways.

Key words: Evolutionary Anthropology, Adaptation, Children, Memory, Hidden Talents Model, Harsh and Unpredictable Environments

Statements and Declarations

Data Availability Statement: The data supporting the findings of this research will be accessible upon publication.

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Highlights*

- Children growing up in adversity may develop enhanced social memory skills
- Cross-cultural evidence required to test this idea is lacking
- This study replicates prior research from Italy in a new cultural context (Mozambique)
- Children from a higher stress rural environment outperformed urban peers on social short-term and working memory tasks
- Socially relevant tasks can reveal strengths hidden by conventional assessments
- Results add further support to the Hidden Talents Model of cognitive development

***** *This chapter includes a "Highlights" section, as required by the journal.*

1. Introduction

Dominant deficit models have extensively documented the negative effects of early stress on development (e.g., Heim & Nemeroff, 1999; McLaughlin et al., 2019; Teicher & Samson, 2016). However, resilience research has shown that such effects are not inevitable among stress-exposed children (e.g., Cicchetti & Rogosch, 2012; Masten, 2001; Masten & Cicchetti, 2016). The recently developed Hidden Talents Model, grounded in evolutionary theory, proposes that adversity may foster specialised skills adapted to environmental demands (Ellis et al., 2023; Frankenhuis & de Weerth, 2013).

Despite its wide generalisability and promise for far-reaching impact, research in this area is limited by ethical constraints on stress manipulation with humans, logistical barriers of working in high-stress environments, and theoretical and methodological challenges (see Frankenhuis et al., 2020). Therefore, most evidence comes from non-human animal models (see Ellis et al., 2017), or a few adult Western, Educated, Industrialized, Rich, and Democratic (W.E.I.R.D.) human samples (see Henrich et al., 2010).

To address this gap, our previous study in Naples (Italy) examined memory for social information in children from high-stress environments marked by poverty, crime, and social exclusion (Paone et al., 2025, *preprint* [Chapter 3]). Here, rapidly interpreting social cues—e.g., identifying and remembering who is trustworthy or threatening—can be critical for navigating complex social dynamics. Based on the existing literature, we anticipated that these pressures could heighten sensitivity to socially relevant information—a response that may be less necessary in more stable, predictable environments (Ellis et al., 2017). Supporting this idea, we found that children from a high-stress neighbourhood outperformed peers from a lower-stress area on memory tasks involving social stimuli.

The current study replicates this research in Mozambique to examine whether similar patterns emerge in a culturally and ecologically distinct setting. We compared children from Nhandar, a rural community marked by poverty and a history of paramilitary control, to children from Gorongosa, a relatively safer and resource-stable town within the same district. Based on the results of our original study in Naples, we hypothesised that Nhandar children would outperform their urban peers in social STM and WM tasks.

STM refers to the transient retention and retrieval of information, while WM also involves active manipulation of information (Baddeley, 1992; Cowan, 2008; Kolb & Whishaw, 2009). These functions are central to cognitive development and rely on the prefrontal cortex (Curtis & D'Esposito, 2003; Diamond, 2013), a brain region with a prolonged developmental trajectory (Giedd et al., 1999; Tanaka et al., 2012), and particularly sensitive to environmental influences (Farah et al., 2006). Although adversity exposure is often linked to STM and WM deficits (e.g., Brand et al., 2000; Mizoguchi et al., 2000; Morgan et al., 2006), recent findings present a more nuanced picture, with evidence of stress-related cognitive enhancements (e.g., Nweze et al., 2020). Moreover, neuroscientific research indicates that STM and WM involve

also subsystems specialised for processing social information (Meyer et al., 2012, 2015), yet conventional assessments typically rely on abstract, decontextualised stimuli such as digit strings or geometric patterns. Emerging evidence shows that stress-exposed children may excel in social-cognitive tasks, such as face memory (Dietze et al., 2022), peer trustworthiness evaluation (Pitula et al., 2017), or empathic accuracy (Kraus et al., 2010), suggesting that socially meaningful assessments may reveal abilities hidden by conventional testing, as demonstrated in the Naples study.

To assess the robustness of the original effects, we investigated whether children in a relatively higher-stress rural environment in Mozambique show enhanced performance on social STM and WM tasks compared to peers from a lower-stress area, using the same protocol as the Naples study. Age and sex, though not central to our hypotheses, were included as covariates to account for developmental variation and maintain consistency with the original study.

2. The Research Sites

Mozambique, a coastal nation in Southeast Africa, known for its rich ecosystems and cultural diversity, ranks among the world's poorest countries (International Monetary Fund, 2024), with a Human Development Index of 0.461 (United Nations Development Programme, 2024) high child mortality (Central Intelligence Agency, 2024), widespread illiteracy, and youth unemployment (Institute for Peace & Security Studies [IPSS], 2020). The country has experienced prolonged political instability, beginning with its struggle for independence from Portugal in the 1960s and finally obtained in 1975 (Funada-Classen, 2013), followed by a devastating civil war between the ruling FRELIMO party and the Mozambican National Resistance (RENAMO). The war continued until 1992 (Campbell, 1984; Manning, 1998) and left a lasting impact on the nation's development trajectory (IPSS, 2020). Tensions reignited in 2013, triggering an insurgency mainly in central and northern provinces like Sofala (Vines,

2013; Wiegink, 2020). Despite a 2019 peace agreement, violence has continued to disrupt services and stability in several rural communities (Sambo, 2024). Political violence remains frequent, particularly around elections, and elements of authoritarianism continue to shape key sectors of society (de Abreu Coutinho & Svartman, 2024).

This study was conducted in two sites within Sofala Province: Gorongosa and Nhandar. Town- or community-level socio-economic data are not publicly available; statistics exist at the district level, which includes both Gorongosa and Nhandar, and thus do not permit comparisons between the two sites. Accordingly, our descriptions draw on a combination of ethnographic observations, interviews conducted during fieldwork, and the limited literature available on the region.

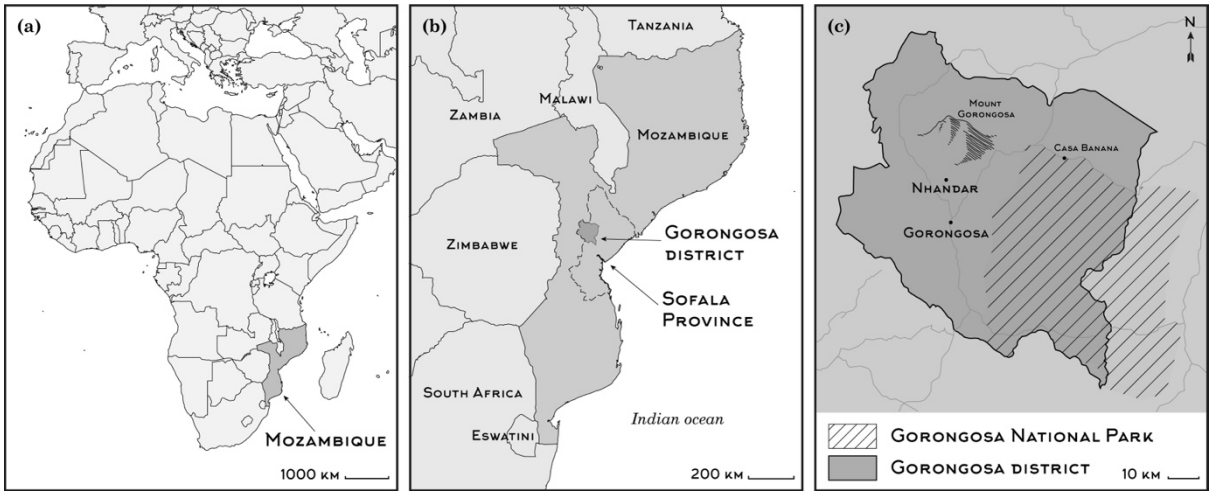


Figure 1. Location of Gorongosa District and key sites in Mozambique. From left to right: (a) Mozambique within the African continent; (b) Gorongosa District within Sofala province and Mozambique; (c) Gorongosa District with key locations labelled.

2.1 Gorongosa

Gorongosa town is the administrative capital of the Gorongosa District, located in central Mozambique (see Fig. 1). The region's rich biodiversity has contributed to the establishment

of Gorongosa National Park, situated just east of the town, now considered a leading African conservation, rewilding, and community development initiative (see Huntley, 2023; Stalmans et al., 2019). Its presence has generated employment in ecotourism, conservation, education, and local infrastructure, providing opportunities for many local families. Compared to surrounding rural areas, the town has stronger institutional presence and access to basic services. Interviews suggest that children experience more consistent access to education, healthcare, and adult supervision, contributing to a more structured and predictable daily life. Social skills undoubtedly remain important, but children face relatively fewer immediate pressures to monitor others for cues related to safety or survival. We therefore selected this context to serve as a comparison setting for the more unpredictable, higher-stress environment of Nhandar.

2.2 Nhandar

Nhandar is a rural community in the *zona tampao* (buffer zone) of Gorongosa National Park, at the foot of Mount Gorongosa. Residents report that "Gorongosa" means "place of danger" in the local language, reflecting traditional perceptions of the mountain and its surroundings.

Families face multiple structural and logistical challenges. Most households depend on subsistence agriculture, which contributes to food insecurity and school absenteeism, particularly during planting and harvest seasons. Although a new primary school was recently built through international cooperation (Parque Nacional da Gorongosa, 2023), late enrolment and high dropout rates remain common. Gender expectations also shape developmental trajectories: early marriage is common, and many girls leave school early. Domestic violence (both physical and verbal) is reported as widespread, with some caregivers viewing it as a form of proactive discipline. Alcohol use is also reported as a common coping mechanism among adults, particularly in the absence of structured mental health or social support services.

The region is also marked by the legacy of Mozambique's civil war. Nearby Casa Banana was RENAMO's wartime headquarter (Minter & Researcher, 1989), and the surrounding zone remained a stronghold long after the war. Nhandar area has been deeply affected by the legacy of the conflict, both through its historical ties with RENAMO and the lack of sustained post-conflict recovery support (Igreja, 2008). Authorities avoided entering the area until recent years, and this lingering tension is consistent with previous research documenting high levels of post-conflict symptoms and the need for intervention in rural Gorongosa (Igreja et al., 1999). The allegedly last RENAMO rifle was only officially surrendered in June 2023 (Sebastião, 2023), just before data collection for this study, in July and August.

These conditions create a complex and volatile social environment that demands heightened social vigilance. Compared to the relatively benign setting of Gorongosa, children's safety critically depends on sensitivity to and memory of social cues, such as recognising trustworthy individuals and anticipating potential threats, opportunities, and alliances. Nhandar thus provides a valuable context for exploring how adversity and unpredictability shape cognitive development, particularly in the domains of STM and WM.

While prior research typically reports lower performance among stress-exposed populations on conventional STM and WM tasks (e.g., Evans, 2016; Mani et al., 2013; Tine, 2014), our previous findings suggested this gap could narrow—or even reverse—when memory is tested using social stimuli. Based on this, we hypothesised that Nhandar children would outperform their Gorongosa peers on two social STM and WM tasks. This hypothesis, study design, and analysis plan, were pre-registered on AsPredicted (https://aspredicted.org/pp9s-b5dj.pdf).

This research was conducted within the broader Gorongosa Restoration Project, one of Africa's most comprehensive conservation and community development programs (https://gorongosa.org/). The park's interdisciplinary network includes experts in

anthropology, primatology, biology, conservation, and education, and collaborates with Mozambican authorities and international institutions to promote ecological restoration, human development, and scientific research. This interdisciplinary infrastructure enabled us to conduct ethically grounded, context-sensitive developmental studies in collaboration with local communities and institutions.

3. Methods

3.1 Participants

We collected data from 124 children (62 females, M_{age} = 7.94 years, SD_{age} = 1.37 years): 59 from Gorongosa (29 females, M_{age} = 7.92 years, SD_{age} = 1.38 years), and 65 from Nhandar (33 females, M_{age} = 7.95 years, SD_{age} = 1.37 years).

A power analysis indicated that a minimum of 25 participants per group would provide 81% power to detect a 0.841-point difference in social STM span scores, and 80% power to detect a 0.75-point difference in social WM span scores, at α = .05. These thresholds were based on effect sizes observed in the original study. Final sample sizes exceeded this minimum to ensure that no children felt excluded. Full power analysis details are available here: https://osf.io/g6rhu/files/osfstorage?view_only=c472a406bb104ab4a3139ae0fa363de0.

Participants who failed a comprehension check assessing ability to follow task instructions were excluded from analyses (see Measures, and SOM Table S1). All remaining participants completed two tasks, described below. Final sample sizes after exclusions are presented in Table 1.

Table 11. Participants demographic information across tasks.

Environment	Task type	*n*	n_{female} (%)	M_{age} (years)	SD_{age} (years)
Gorongosa	Social STM	59	29 (49.15)	7.92	1.38
	Social WM	56	27 (48.21)	8	1.36
Nhandar	Social STM	63	33 (52.38)	7.97	1.39
	Social WM	63	33 (52.38)	7.97	1.39

Participants were recruited through their schools, in collaboration with Gorongosa National Park's education programme. Written permission for the study was provided by the Park's education office, which oversees educational activities in the participating schools. Oral consent was obtained from the teachers, who informed families about the research and obtained their consent, and assent was obtained from all children prior to participation. As a token of appreciation, children received stickers after the session. The study was approved by the relevant Departmental Research Ethics Committee of the University of Oxford, and by the Comité de Bioética do Ministério da Saúde in Mozambique.

3.2 Procedure

Sessions were conducted individually in a quiet room at each school during regular hours. Each child completed two tasks assessing STM and WM. To facilitate engagement and reduce fatigue, children first completed the less cognitively demanding STM task, followed by the more demanding WM task (St Clair-Thompson, 2010).

In Gorongosa, tasks were administered in Portuguese by the first author. In Nhandar, where Sena is the primary language, tasks were administered in Sena with support from an interpreter (a teacher or park staff). Task instructions were translated and back-translated by bilingual

speakers to ensure accuracy and cultural relevance. Demographic information (i.e., age, sex, and place of origin) was obtained from the school.

3.3 Measures

We employed the same task as the original study, adapted from the visuo-spatial sequences recall task in the PML-2 battery (D'Amico & Lipari, 2020). Instead of abstract geometrical shapes, we used 136 high-quality photographs of children aged approximately 6 to 10 years, retrieved from a free-access online archive (www.pexels.com). The images were of ethnically diverse children, balanced by sex, and displaying neutral to positive expressions. All were cropped to a uniform size and printed on laminated A5 cards (14.8 × 21 cm).

In the STM task, the participant was shown a sequence of face cards, one at a time for one second each, held at eye level about 80 cm in front of them. After each sequence, the cards were placed face-up on the table in a pre-determined layout (see SOM 2), and the child was asked to point to the faces in the same order as presented. In the WM task, they were asked to reproduce the sequence in reverse order, an approach commonly used to assess WM (see Alloway et al., 2006; Berry et al., 2018; St Clair-Thompson, 2010).

To ensure task comprehension, a warm-up trial was administered using a two-item sequence. Children had up to three attempts to reproduce the sequence correctly. Those who failed all three were excluded from the final analyses.

The task began with two 2-item sequences and progressed by one item per level, contingent on correct performance. Testing ended when both trials at a given length were failed. Recall was considered correct only if the full sequence was reproduced in the correct order.

Each task produced two scores: a *span* score, representing the length of the longest sequence correctly recalled (e.g., a participant recalling a 4-item sequence but failing both 5-item ones

would receive a span score of 4), and a *total* score, reflecting the sum of all correctly recalled sequences (e.g., if a participant correctly recalled two 2-item sequences and one 3-item sequence, their total score would be 2 + 2 + 3 = 7). Our primary analyses focused on the span score, and analyses of total scores are reported in full in the SOM.

3.4 Analyses

We conducted two separate linear regression analyses, one for each outcome variable: social STM and social WM performance. The primary independent variable was the child's environment, coded using treatment contrasts with Gorongosa as the reference group. Age and sex were included as covariates. No data points were excluded as statistical outliers. Only participants who were unable to understand or complete the task were excluded from the final analyses (see SOM Table S1).

4. Results

4.1 Descriptive Statistics

Overall, task comprehension was high across participants (see SOM Table S2). Descriptive statistics for performance on the STM and WM tasks are presented in Table 2.

Table 12. Span scores on social STM and WM tasks across the two groups.

Environment	**Social STM**		**Social WM**	
	M	*SD*	*M*	*SD*
Gorongosa	4.39	1.51	3.16	1.33
Nhandar	5.02	1.72	4.10	1.20

4.2 Effects of Environment on Memory Test Scores

Environment significantly predicted memory performance on both tasks. In the STM task, Nhandar children outperformed those from Gorongosa *(b* = 0.605, *SE* = 0.267, *t* = 2.266, *p* = .025). A stronger effect in the same direction was observed for the WM task (*b* = 0.958, *SE* = 0.227, *t* = 4.219, *p* < .001), indicating a robust advantage for children from Nhandar. Full model results are reported in SOM Tables S3-S4, and plotted in Figures 2-3. Analyses using total scores repeated this pattern, confirming the Nhandar children's better performance across both memory tasks (See SOM Tables S5-S6).

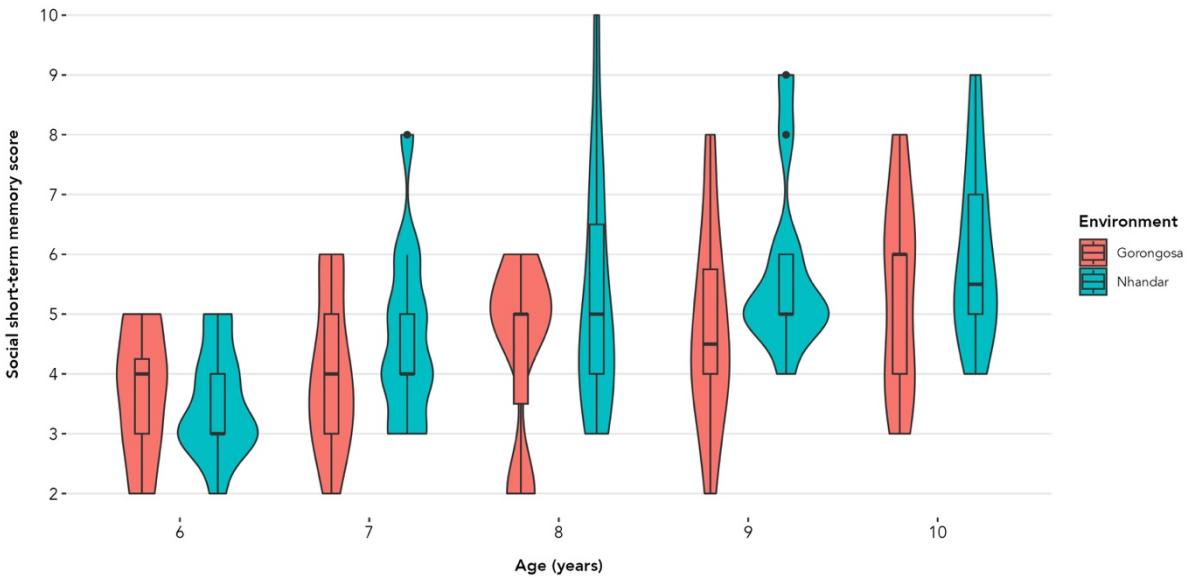


Figure 2. Participants' STM span scores by environment and age.

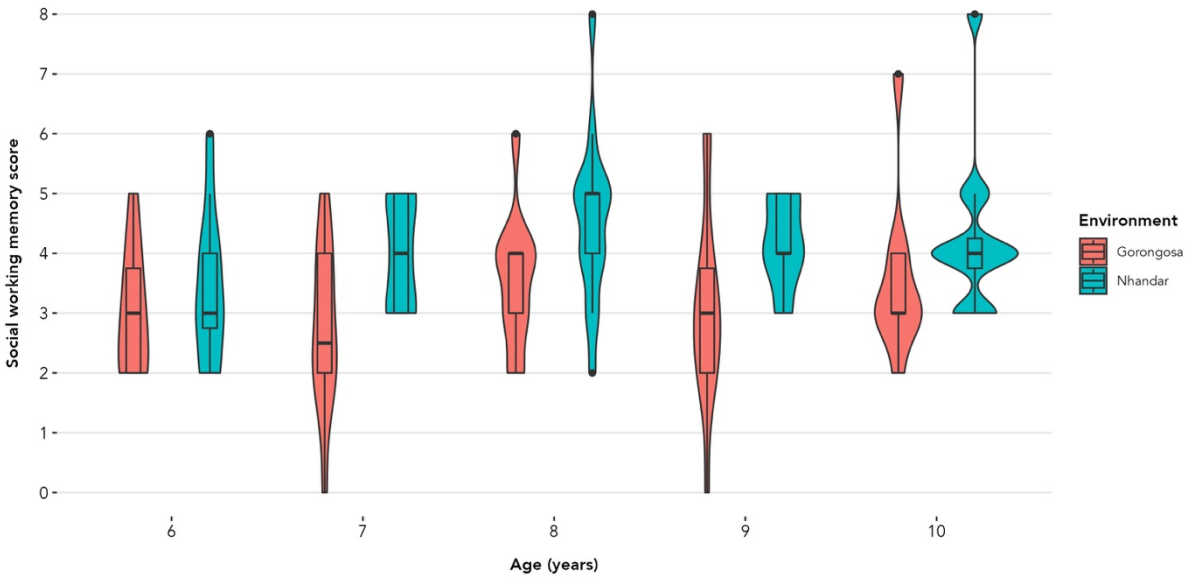


Figure 3. Participants' WM span scores by environment and age.

4.3 Effects of Age and Sex on Memory Test Scores

Age was positively associated with performance on both tasks. For social STM, the effect was strong ($b = 0.501$, $SE = 0.097$, $t = 5.158$, $p < .001$), and a marginal effect was observed for WM span ($b = 0.157$, $SE = 0.083$, $t = 1.896$, $p = .061$), indicating that older children tended to perform better.

Sex was not a significant predictor in the STM model. However, a marginal effect emerged in the WM model ($b = 0.438$, $SE = 0.227$, $t = 1.933$, $p = .056$), with boys performing slightly better. Analyses based on total scores showed broadly similar patterns (see SOM Tables S5–S6).

5. Discussion

This study aimed to replicate and extend previous research in a new cultural setting by examining whether children in a relatively high-stress environment in Mozambique would exhibit enhanced performance in social short-term and working memory compared to peers

from a lower-stress area in the same province. As hypothesised, Nhandar children outperformed those from Gorongosa on both tasks, with particularly robust effects in WM. These findings extend prior results to a culturally and ecologically distinct setting, and provide further support for the Hidden Talents Model, which proposes that children in high-stress environments may develop adaptations suited to their surroundings (Ellis et al., 2023; Frankenhuis & de Weerth, 2013).

Our findings also align with recent evidence that individuals in adverse contexts may develop enhanced social-cognitive abilities. Previous studies have shown, for example, that those from lower-SES backgrounds exhibit better memory for faces (Dietze et al., 2022), improved accuracy in evaluating others' trustworthiness (Pitula et al., 2017), and heightened empathic precision (Kraus et al., 2010). In environments where the ability to rapidly interpret social information can aid in navigating uncertain or potentially dangerous social dynamics, such skills may offer concrete adaptive advantages.

These results also reinforce the importance of task design in cognitive assessments. Studies reporting STM and WM deficits among stress-exposed children have typically relied on abstract and decontextualised stimuli. In contrast, both the current and Naples studies used more socially relevant stimuli (i.e. human faces) to assess memory. This may explain why the typical performance gap appears to narrow or reverse when tasks align more closely with the demands of children's lived environments. Memory for social information may be a domain in which children in high-stress environments can not only keep pace with, but exceed, peers from more affluent settings.

While the Naples study reported a weaker effect in WM relative to STM, the Mozambican sample showed a particularly robust WM advantage. These differences may reflect distinct adversity profiles: the Scampia urban environment—with high criminality, high social

demands, and rapid exposure to varied faces and interactions—appears to enhance STM, enabling fast encoding and recall of immediate social information. In contrast, the Nhandar rural context—with fewer but more sustained relationships and less changeable social stimuli—appears to strengthen WM, supporting the maintenance and manipulation of social information over longer durations. Although speculative, this account offers a hypothesis for future research on how environmental contexts may differentially shape social STM and WM. Alternatively, these differences may reflect sampling variability or unmeasured variables (e.g., differences in school exposure, task familiarity).

In sum, our findings offer a more nuanced understanding of cognitive development under adversity. Rather than portraying children solely through a deficit lens, this research suggests some may show enhancements in ecologically relevant cognitive domains, under specific conditions. This underscores the importance of considering not only which skills we investigate, but also how, highlighting the need for culturally and contextually sensitive tools that can reveal hidden strengths. Future research should investigate the mechanisms underlying these adaptations, their long-term developmental implications, and how they might be leveraged in educational and policy interventions aimed at supporting children growing up in diverse environments.

6. Contributions and Limitations

This research makes several contributions to developmental cognitive science. First, it focuses on children, diverging from most memory studies that predominantly examine adults. Second, it provides rare empirical data from non-W.E.I.R.D. contexts, addressing calls for greater global diversity in developmental research (see Henrich et al., 2010). Third, it shows that the cognitive advantages in high-stress contexts are not confined to Euro-American urban settings, but may generalise across cultural and ecological boundaries, including rural environments.

Furthermore, it reinforces the value of using ecologically relevant tasks to uncover skills that remain hidden with conventional assessments. The research also demonstrates a viable and ethical model for field-based collaboration in low-resource settings, involving partnerships with local educators and the Gorongosa National Park.

Nevertheless, the study also has limitations. As with most naturalistic experiments, various uncontrolled factors—such as differences in educational resources, exposure to formal testing environments, or family support—may have influenced the observed effects. While age and sex were included as covariates, other factors such as nutrition, home language, or potential trauma were not systematically assessed.

We also opted not to administer the Perceived Stress Scale for Children (PSS-C, White, 2014), which in the Naples research did not appear to capture key forms of adversity, such as community violence or institutional instability. Instead, we relied on ethnographic observations and interviews to contextualise the findings. While less standardised, this approach offers rich and relevant insight into the lived experiences of participants and helped guide our understanding of the settings and interpretation of the quantitative data.

7. Conclusion

This study adds to an emerging body of evidence demonstrating that children growing up in harsh or high-stress environments can exhibit not only deficits or resilience, but domain-specific cognitive advantages. Our findings confirm and extend previous research suggesting that memory for social information can be enhanced in individuals from such environments (e.g., Dietze et al., 2022). These strengths may remain undetected in standard testing paradigms, which typically rely on theoretical frameworks developed in Western settings, abstract or decontextualised tasks, and participant samples unrepresentative of global diversity. By replicating earlier findings in a distinct cultural and ecological context, this research

provides cross-cultural support for the Hidden Talents Model and reinforces the value of rethinking how, where, and what we assess when studying cognitive development in adversity-exposed populations (Ellis et al., 2023). Recognising these talents—and moving beyond a solely deficit and risk-based view—has the potential to inform educational practices, interventions, and policies that are equitable, contextually appropriate, and supportive for millions of children worldwide.

Data and code availability

The dataset and analysis code used in this study are available at the following link: https://osf.io/g6rhu/files/osfstorage?view_only=c472a406bb104ab4a3139ae0fa363de0

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Authors' contribution

GP conceived of the study, designed and coordinated the study, collected data, analysed and visualised the data, and wrote the manuscript. **EC** provided supervision, participated in the design of the study, and commented on the manuscript. **AJD** analysed and visualised the data and commented on the manuscript.

6 Discussion

This thesis was motivated by a central and still unresolved tension in developmental science: can strengths emerge from adversity—and if so, under what conditions, in which cognitive domains, and for whom? Traditional deficit models have long dominated research and interventions, providing evidence that early-life adversity risks to impair brain development and behavioural functioning, often resulting in poorer outcomes across domains such as memory, attention, academic performance, and emotion regulation (McEwen, 1998; Pechtel & Pizzagalli, 2011; Shonkoff et al., 2012). From this perspective, children exposed to poverty, violence, displacement, or environmental instability are "at risk", and interventions aim primarily to avoid or remediate developmental harm.

While useful in identifying and trying to prevent vulnerabilities, this framework has also shown its limitations. Rather than viewing all outcomes under adversity as inevitably negative, the traditional resilience model highlighted that many children "beat the odds", developing competently despite significant challenges (Goldstein & Brooks, 2013; Masten, 2001; Werner & Smith, 1992). This work emphasises protective factors such as supportive caregivers, school engagement, or individual traits like optimism that help buffer against stress. Although the traditional resilience model expanded our understanding of possible developmental outcomes, it still largely assumed that the gold standard of development is defined by low-risk, resource-rich, stable and predictable environments. In other words, resilience meant approximating normative developmental benchmarks *despite* adversity—not developing different strengths *because of* it.

A third perspective, grounded in evolutionary-developmental theory, has begun to question this assumption. Adversity does not simply challenge development—it actively shapes it. Evolutionary models suggest that human cognitive systems are highly plastic, calibrated by

early environmental cues to optimise function within expected future conditions (Bjorklund & Ellis, 2014; Del Giudice et al., 2011). Human childhood is thought to have evolved under ecologically unstable conditions, supporting a developmental architecture that is especially plastic and responsive to environmental variation (Frankenhuis & Amir, 2022). If adversity has long been part of the expected conditions of human development, then understanding its effects requires moving beyond a framework of impairment to consider how it may also give rise to contextually beneficial cognitive and behavioural strategies. Within this broader framework, the Hidden Talents Model formalises this view, proposing that children growing up under harsh and unpredictable environments may develop specialised cognitive skills that are finely tuned to the demands of their context (Ellis et al., 2017; Frankenhuis & de Weerth, 2013). Despite the model's theoretical appeal and growing interest, empirical studies remain limited, largely due to the considerable ethical, theoretical, and methodological challenges of studying real-life adversity (see section 2.1.3).

This thesis aimed to help bridge this gap by combining experimental and ethnographic methods to investigate whether and how exposure to adversity shapes children's short-term and working memory across multiple modalities: abstract (verbal, visuo-spatial), social, and motor. These domains were chosen not only for their relevance to core developmental outcomes, but also because they are particularly sensitive to environmental influences, given their reliance on brain regions with protracted developmental timelines. Additionally, social and motor modalities are underexplored within memory systems research (see section 2.2). By comparing children from relatively low- and high-stress environments in both European and sub-Saharan African contexts, this thesis provides rare empirical evidence that while adversity is often associated with impairments in conventional STM and WM tasks, children in high-stress environments may display equal or even enhanced performance in ecologically relevant memory modalities, particularly those involving social or motor information. These findings

support aspects of the Hidden Talents Model, while also echoing predictions from the deficit model (e.g., Roma children's lower performance on conventional tasks) and the traditional resilience model (e.g., Scampia children's equal performance on conventional tasks). Together, they challenge the exclusivity of any single explanatory framework and point towards a more differentiated understanding of memory development under adversity. They also raise a critical question: when children perform relatively poorly, are they truly impaired—or, at least in some situations, are we simply measuring the wrong things?

6.1 Synthesis of Findings Across Studies

The four empirical studies presented in this thesis examined how children from diverse environments—from relatively stable, low-stress settings to highly adverse and unpredictable ones—perform on STM and WM tasks across three modalities: abstract, social, and motor. Taken together, the results offer a nuanced picture of memory development under adversity, one that neither confirms nor rejects any single theoretical model outright, but instead reveals a complex and patterned interplay between environmental demands, cognitive systems, and developmental outcomes.

6.1.1 Study 1 – Conventional Memory Tasks Support for Deficit and Resilience Models

Study 1 examined verbal and visuo-spatial STM and WM using conventional abstract tasks in three groups of children from Naples: Pozzuoli (low-stress), Scampia (high-stress), and the Roma camp (high-stress). As predicted by the deficit model, Roma children performed significantly worse than their Pozzuoli peers across all tasks. These results are consistent with a large body of research on the negative impact of early-life stress on executive function and memory (Evans & Schamberg, 2009; Mika et al., 2012; Noble et al., 2015).

However, children from Scampia—a high-stress but more structured environment—performed comparably to the Pozzuoli group on conventional STM and WM tasks. This suggests a form of resilience as defined by the traditional resilience frameworks: the preservation of cognitive performance despite exposure to adversity (see section 2.1.2), aligning with normative benchmarks in tasks commonly used in developmental research.

Thus, the findings support both the deficit model (in the case of Roma children) and the resilience framework (in the case of Scampia children), demonstrating that development under adversity is not uniformly impaired.

6.1.2 Study 2 – Social Memory: Evidence for Context-Specific Enhancement

Study 2 assessed memory for social stimuli (i.e., faces of unfamiliar individuals), a domain shown to rely on different brain circuits than those used for conventional stimuli (see section 2.2.5), and hypothesised by the HTM to be particularly relevant for children growing up in volatile or threatening environments. Here children from Scampia outperformed their Pozzuoli peers on both STM and WM tasks. Roma children performed comparably in STM, consistent with the resilience framework, and lower in WM, in line with the deficit model.

Scampia findings align with the Hidden Talents Model, suggesting that children in high-stress environments may develop enhanced memory for socially salient information—skills essential for navigating complex and often risky social environments. Importantly, these results do not contradict the deficit model, but rather complement it: while certain cognitive systems may be compromised under stress, others may be sharpened when ecologically relevant. This pattern exemplifies the core HTM claim that the impact of adversity is not globally negative or

positive, but can lead to selectively stress-adapted skills, depending on what kind of information is most relevant to the child's everyday survival and functioning.

6.1.3 Study 3 – Motor Memory: A Third Modality of Adaptive Strength

Study 3 extended the investigation to a third modality—motor memory—using a novel task involving the reproduction of patterned body movements. Again, children from Scampia outperformed those from Pozzuoli in both STM and WM tasks, consistent with the Hidden Talents Model; Roma children performed comparably in STM, aligning more closely with the resilience framework, but scored lower in WM, as predicted by the deficit model.

These results, taken together, align with the broader assumptions of the HTM, which does not exclude the presence of deficits or equivalences. Rather, it proposes that under conditions of adversity, developmental outcomes may diverge across domains—some showing impairment, others preservation, and others still specialised enhancement—depending on the ecological demands of the environment. In contexts where physical movement is central to daily survival—whether through navigating unsafe neighbourhoods, helping with labour, or engaging in informal economies—motor memory may be not only more stimulated but also confer an adaptive advantage. This also aligns with broader claims from cultural and ecological psychology that intelligence is not a general trait, but it is situated and shaped by the demands and routines of everyday life (Greenfield, 2009; Sternberg, 2014).

6.1.4 Study 4 – Cross-Cultural Replication of Social Memory Enhancement

Study 4 replicated the social memory task in rural Mozambique, comparing children from Nhandar (high stress) with those from Gorongosa (lower stress). As in the Italian Scampia sample, children from the more adverse environment outperformed their peers on both social STM and WM tasks.

This cross-cultural replication strengthens the claim that enhanced memory for social information is not culturally idiosyncratic, but may represent a broader adaptive pattern. Especially in settings characterised by instability and threat, the ability to read and accurately remember social cues may be critical for social functioning and survival.

These findings also challenge assumptions of developmental universality, particularly when normative standards are based on W.E.I.R.D. populations (Henrich et al., 2010). In this context, adversity may foster specialised strengths rather than global deficits.

6.2 Theoretical Integration and Implications

The findings of this thesis lend support to multiple theoretical models, while also highlighting their limitations when considered in isolation. Rather than confirming a single account of cognitive development under adversity, the results point towards a pluralistic and domain-sensitive perspective—one that acknowledges variability in both developmental mechanisms and outcomes. This section examines how the data refine or challenge the deficit model, the resilience model, and the Hidden Talents Model, and considers their implications for future research and theory-building.

6.2.1 Beyond the Deficit Model: Recognising Variation and Context

The deficit model has dominated much of the literature on childhood stress, with good reason: decades of research have linked early adversity to impaired cognitive and behavioural development, academic underachievement, and increased risk for mental and physical health problems (see section 2.1.1). In this thesis, the lower performance of Roma children on conventional STM and WM tasks could be interpreted in line with this model, which predicts impairments in these memory systems under adverse conditions.

However, one of the central claims of this thesis is that children growing up in such environments are not necessarily impaired. Lower scores on conventional tasks may reflect limitations in specific cognitive domains, or may arise from the use of decontextualised assessment tools, like digit span tasks, that fail to capture skills developed through everyday experience. Impairment, in this view, may not be an inherent trait but an artefact of what is measured and how. This cautions against overinterpreting low performance as evidence of cognitive deficit, particularly in the absence of contextually grounded assessments.

Findings from the Scampia sample—and to some extent the Nhandar group—suggest that not all stress-exposed children follow this trajectory. Conventional tasks alone do not capture the full range of cognitive functioning across different environments. If we rely exclusively on abstract, decontextualised assessments, we risk reinforcing a narrow and possibly ethnocentric view of what counts as “memory”, “intelligence”, or “typical” development. Thus, while the deficit model remains valuable for identifying vulnerabilities, it does not fully explain how children actively adapt to their environments, nor does it account for domain-specific strengths.

6.2.2 Resilience as Stability in the Face of Adversity

Resilience theory offers an important complement to the deficit model by showing that children exposed to adversity do not always exhibit impairments. In this thesis, resilience is evident in the comparable performance of Scampia children on conventional tasks, despite living in a high-stress context. These children are not outperforming their peers, but they are keeping pace with them—a meaningful achievement given the environmental constraints they face.

However, resilience theory often frames such outcomes in relation to external normative standards—often derived from W.E.I.R.D. populations—without interrogating whether they are universally appropriate. Moreover, it rarely accounts for the possibility that children might develop *alternative* strengths, not merely retain expected ones. A child may allocate cognitive resources towards skills that are more immediately useful in their environment—a potential trade-off that might appear as a deficit in one domain but reflect adaptation in another.

6.2.3 Refining the Hidden Talents Model: A Domain-Specific View

The strongest support in this thesis is for the Hidden Talents Model, particularly in its claim that children growing up under adversity may develop enhanced cognitive performance in specific, ecologically relevant domains. The superior performance of Scampia children on social and motor memory tasks aligns with HTM claims that adaptation to harsh and unpredictable environments can result in heightened sensitivity to relevant cues. Similarly, children from Nhandar showed enhanced social memory performance. These are not general-purpose enhancements, but niche-specific adaptations shaped by everyday challenges.

At the same time, the findings help refine the HTM by clarifying its boundaries. Not all stress-exposed groups show enhancement: for example, Roma children performed worse or similarly across all modalities, including those where adaptation was expected. This suggests that

enhancement may depend on the interaction between environmental adversity and developmental affordances—such as opportunities to practice relevant skills, cultural coherence, and experiences of inclusion or exclusion. In short, the type of adversity, the structure of the environment, and the cognitive demands of everyday life all matter.

Moreover, the results support a multidimensional view of development: strengths, resilience, and deficits may coexist within the same individual. A child may excel, for example, in motor WM but struggle in verbal WM. This pattern reinforces the HTM's emphasis on specificity, and underscores the need for a pluralistic, trade-off-sensitive view of adaptation.

6.3 Methodological Contributions and Innovations

Beyond its theoretical contributions, this thesis makes several methodological advances that address persistent limitations in the study of childhood adversity and cognition. Much of the existing literature relies on narrow operationalisations of both stress and cognitive performance, often using abstract, decontextualised tasks with limited ecological validity (see Chapter 2). The research reported here implements a multimodal, cross-cultural, and integrative design that offers new tools and strategies for uncovering how adversity shapes development in domain-specific ways.

A key methodological innovation lies in the modality-sensitive design. Whereas most research on memory and stress focuses exclusively on abstract tasks—such as the digit span for verbal STM and WM—this thesis systematically assessed memory across modalities. This enabled the identification of patterns that would have remained hidden in a single-domain approach. For example, while Roma children underperformed on abstract tasks, Scampia children showed enhanced performance in both social and motor memory, and Nhandar children showed specific advantages in social memory. These results illustrate that memory under adversity is

not a monolithic construct, and that different modalities may be differentially shaped by environmental demands. This design directly operationalises the specialization hypothesis (Frankenhuis & de Weerth, 2013), and allows for the detection of stress-adapted skills that conventional tests typically overlook.

The tasks employed in this thesis were explicitly designed to be more ecologically relevant to children's lived experiences. The social memory task used unfamiliar human faces—stimuli central to everyday navigation in socially unpredictable environments—while the motor memory task involved patterned body sequences that were physically grounded and potentially more aligned with the kinds of action-based learning common in everyday life, especially in contexts where physical interaction with the environment is necessary for survival. These choices align with broader movements in cognitive-developmental research advocating for context-sensitive assessments (Sternberg, 2014) and with calls from the HTM literature to design tasks that reveal hidden talents rather than merely confirm expected deficits (Ellis et al., 2017; Frankenhuis et al., 2020).

Another key contribution is the inclusion of five distinct populations across varying cultural, socio-economic, and ecological contexts (i.e., Pozzuoli, Scampia, Roma camp, Gorongosa, and Nhandar). While the research did not isolate specific stressor types, it offers preliminary evidence that contextual variation—such as urban poverty, social exclusion, or rural infrastructural neglect—leads to differences in memory performance across modalities. This framework also allows for rare cross-cultural replication of the social memory study, strengthening the external validity of the findings and underscoring the importance of environment in shaping cognitive development.

A further methodological contribution is the integration of cognitive testing with ethnographic fieldwork. While the memory tasks were designed to be ecologically meaningful across diverse

settings, ethnographic research was instrumental in interpreting performance patterns and evaluating the salience of each memory modality within children's everyday lives. This combination ensured that findings were not only statistically robust, but also situated within the lived realities of the participating communities. The approach reflects a broader movement in developmental science towards culturally sensitive, field-based cognition research—a necessary correction to overreliance on abstract, context-free assessments (e.g., Arnett, 2008; Broesch et al., 2023; Causadias, 2013).

Finally, the use of the Perceived Stress Scale for Children (PSS-C, White, 2014) revealed important limitations that could inspire future refinements. Although included to assess individual differences in perceived stress, the PSS-C scores did not reflect the environmental realities observed ethnographically and were not significantly associated with memory performance in any task. For example, Roma children reported the lowest stress levels despite facing the most severe social and material deprivation among the groups involved in the research. While this study does not aim to validate or invalidate the tool, it raises questions about how well standardised self-report tools like the PSS-C capture the kinds of chronic, context-specific stressors—such as social exclusion, infrastructural neglect, or violence—that may be more salient in certain environments. This highlights the value of combining psychometric tools with composite indicators like the IVSM (see Chapter 3) and ethnographic research to better understand developmental risk and adaptation.

6.4 Implications and Future Directions

The findings of this thesis have important implications for theory, research, and practice. By demonstrating that memory development under adversity does not follow a singular trajectory of impairment—and may instead reflect differentiated, context-specific adaptations—this work contributes to a broader rethinking of how the effects of adversity on development are

conceptualised and measured. It also offers concrete guidance for improving research design, assessment practices, and educational interventions in ways that better reflect the realities of diverse environments.

6.4.1 Rethinking Cognitive Assessment in High-Stress Contexts

One of the clearest implications of this research is the need to reconsider the tools and assumptions used to assess cognition in children exposed to adversity. Conventional tasks, while valuable for comparison, may misrepresent the abilities of children whose environments emphasise different kinds of learning, memory, and attention. This thesis showed that children who scored lower on conventional abstract tasks could perform equally well—or even better—on memory tasks with social or motor content. Such findings underscore the importance of designing assessments that are not only psychometrically valid but also ecologically meaningful.

To avoid pathologising children from harsh and unpredictable environments, research must move beyond one-size-fits-all tools and instead adopt a domain-sensitive approach that reflects the ecological demands and learning opportunities present in children's everyday lives. This is especially critical in cross-cultural research, where “norms” are often drawn from W.E.I.R.D. populations and used to evaluate development in radically different contexts.

6.4.2 Educational and Policy Implications

These findings also have direct relevance for educational practice and social policy. In systems driven by conventional definition of intelligence and standardised testing, children from high-stress environments are often labelled as underachieving or cognitively deficient. This thesis suggests that such judgements may be based more on the misalignment between assessment and ability rather than on any universal cognitive deficit. If children in Scampia or Nhandar

can demonstrate strong memory for social stimuli or motor sequences, educational strategies might consider incorporating more interactive, embodied, or socially embedded learning tasks, which could provide more equitable opportunities for engagement and success.

From a policy perspective, these results suggest that interventions targeting children in adversity should not only aim to "remediate" presumed deficits, but also identify and cultivate existing strengths. Rather than compensating for what children are assumed to lack, programmes can support what they are already good at and help bridge those abilities into academic or vocational success. A clear example comes from applied work with Roma children, who demonstrated remarkable adaptive intelligence for different materials—a skill honed through daily involvement with informal economies and exposure to hazardous environments (see Appendix B). This ability was successfully leveraged in a school-based programme designed around their experiential knowledge and practical reasoning. Such an approach illustrates how contextually developed skills, often dismissed, can become powerful entry points for educational inclusion and engagement—not only for Roma children, but potentially across a range of high-adversity contexts. This strength-based model aligns with a growing movement in developmental science that sees children not solely as at-risk, but as adaptively attuned to their environments (e.g., Gauvain, 2001; Grigorenko et al., 2004; Sternberg et al., 2001).

6.4.3 New Directions for Theory and Research

While this thesis supports a shift towards adaptation-sensitive models, it also highlights several questions that remain open for future research.

First, this thesis adds support for the specialization hypothesis (Frankenhuis & de Weerth, 2013)—with certain groups showing enhanced memory performance in domains such as social or motor memory—while raising the question of whether these adaptations involve cognitive

trade-offs. Future studies should explicitly test whether enhancements in one cognitive domain (e.g., social memory) come at the cost of lower performance in others (e.g., sustained focus) within the same individuals. Longitudinal designs will be especially valuable for determining if such trade-offs exist, how stable they are over developmental time, and whether they change with evolving environmental conditions or educational exposure.

Second, future research should investigate whether and how stress-adapted skills confer advantages in contexts beyond those in which they emerged. The sensitisation hypothesis suggests that certain skills shaped by adversity may become particularly evident or advantageous under conditions of current stress or uncertainty, rather than in neutral or benign contexts (Ellis et al., 2017). For instance, the superior motor memory performance observed among children from Scampia might contribute to the remarkable success of young judokas from this neighbourhood—many of whom have become international champions, including an Olympic gold medallist. This hypothesis invites further investigation into how specific cognitive adaptations translate into tangible advantages in educational, athletic, vocational, or even informal contexts of daily life, providing a deeper understanding of the broader value and applicability of stress-adapted skills.

Third, this thesis points to the importance of more precisely characterising different profiles of adversity. Although direct testing of environmental specificity was beyond the scope of this research, the observed task scores differences between Scampia, the Roma camp, and Nhandar suggest that diverse forms of adversity—like social exclusion, chronic violence, or infrastructural neglect—may lead to distinctive developmental adaptations. Future studies should compare these dimensions and further refine models of how different types and combinations of adversity interact with cognitive development over time.

Finally, this research demonstrates both the value and the difficulty of studying populations often excluded from developmental science. The ethical, logistical, and methodological challenges of conducting research in Scampia, Roma camp, and Nhandar are real—but so too is the cost of ignoring these populations. Future research should continue to invest in community-engaged, flexible, and contextually grounded approaches that prioritise inclusion without compromising rigour.

7 Conclusion

This thesis was motivated by a central question: can adversity produce strengths, and if so, under what circumstances, in which domains, and for whom? By investigating short-term and working memory across multiple modalities in children living in diverse environments, this research provides nuanced answers. The findings clearly illustrate that the cognitive effects of childhood stress are neither uniform nor universally detrimental. Rather, cognitive development under adversity is characterised by complexity, specificity, and adaptability, shaped by both ecological demands and the nature of the cognitive domains assessed.

The conventional deficit model remains partially supported: certain groups, such as the Roma children in Naples, did exhibit lower performance on standard, abstract memory tasks. Yet these children were not simply cognitively impaired; rather, their performance was sensitive to the types of stimuli and tasks employed. When assessments moved beyond conventional formats to include social or motor memory—domains more relevant to their daily life—different patterns emerged. Roma children showed similar performance than Pozzuoli on social STM task, children from Scampia showed not only resilience on conventional tasks, but also clear advantages in social and motor memory, while Mozambican children from Nhandar similarly demonstrated enhanced social memory performance. These patterns support both the

resilience framework, which highlights the capacity for stable development under adversity, and the Hidden Talents Model, which argues for contextually adaptive specialisations.

Methodologically, this thesis also made significant advances by using ecologically grounded cognitive assessments, integrating experimental and ethnographic research, and conducting cross-cultural replication with underrepresented populations. These contributions underscore the importance of moving beyond standardised, undifferentiated cognitive assessments towards approaches that meaningfully reflect children's lived experiences and environments.

When translated beyond theory, the findings suggest that educational and social interventions targeting children in adversity should shift from only remediation of presumed deficits to recognition and cultivation of existing strengths. The example of the adaptive knowledge that Roma children showed with materials illustrates how identifying and leveraging context-specific abilities can lead to meaningful educational inclusion and social engagement.

Looking ahead, this thesis opens promising pathways for future research. Longitudinal studies exploring how cognitive adaptations evolve over time, investigations into potential cross-context advantages as predicted by the sensitisation hypothesis, and systematic comparisons of different adversity profiles will all contribute to refining our understanding of developmental trajectories under stress. More broadly, there is an urgent need to expand the scope of developmental science to include culturally and contextually diverse populations, embracing the full spectrum of human developmental experiences.

Ultimately, this thesis contributes to a more balanced and integrative view of child development under adversity. Rather than necessarily linking stress-adaptation with impairment, the findings prompt us to consider how cognitive skills developed in response to challenging environments could represent valuable strengths. By recognising and understanding these stress-adapted skills, we can move beyond simplistic deficit-focused

models towards approaches that recognise, validate, and build upon the strengths children have already developed, helping children from all backgrounds reach their full potential.

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Appendices

Appendix A: Terminological Clarifications

This research centres on four core concepts—stress, adaptation, skill, and child—each of which is widely used but inconsistently defined across academic and non-academic contexts. Clarifying and standardising their usage is essential for the coherence and analytical precision of this thesis.

Stress

This thesis adopts McEwen's (2000) broad definition of *stress* as "…a real or interpreted threat to the physiological or psychological integrity of an individual that results in physiological and/or behavioural responses…" (p. 508). This definition offers a useful starting point, as it spans both biological and psychological processes, and allows for the integration of subjective experience with physiological activation.

Nonetheless, scholarly consensus on what stress *is* remains elusive. The term has acquired multiple meanings across disciplines, often referring interchangeably to environmental triggers, internal perceptions, physiological responses, or long-term outcomes (Le Moal, 2007; Levine, 2005). In physiological research, stress typically refers to the activation of the hypothalamic-pituitary-adrenal (HPA) axis in response to environmental demands, leading to the release of glucocorticoids such as cortisol and adrenocorticotropic hormone (ACTH) (Carrasco & Van de Kar, 2003). In psychology, stress is more commonly defined in terms of perceived threat, emotional dysregulation, and coping difficulty (Fink, 2016). The Diagnostic and Statistical Manual of Mental Disorders (DSM-5, *Diagnostic and Statistical Manual of Mental Disorders: DSM-5*, 2013) adopts a broad approach, describing stressors as "any emotional, physical, social, economic, or other factor" that disrupts behavioural or psychological equilibrium.

Historical definitions reflect this ambiguity. Selye's (1936) foundational concept of stress as the "nonspecific response of the body to any demand" (p. 32) laid the groundwork for a generalised stress response, but was so broad that it included both minor and life-threatening events. Selye (1973) himself later remarked, "everyone knows what stress is, but nobody really knows". More recently, Peters et al. (2017) argued that uncertainty itself may be the defining feature of stress, pointing to the difficulty of establishing a stable definition for a phenomenon that is inherently dynamic and context-sensitive.

In light of this, some researchers have proposed conceptual frameworks rather than fixed definitions. Levine and Ursin (1991) for instance, suggest that stress is best understood as a three-part process involving (i) an input or environmental challenge, (ii) a cognitive-affective appraisal system, and (iii) an output in the form of physiological or behavioural responses. Still, in practice, the term "stress" is often used to refer to all three components simultaneously, leading to further conceptual conflation.

Rather than attempting to resolve this definitional impasse, this thesis aligns with a growing body of evolutionary-developmental research that shifts the focus from what stress is to what stress does in developmental terms. From this perspective, stress is treated not as a singular biological process or pathology, but as a class of environmental inputs that influence developmental trajectories. Specifically, it is seen as a calibrating force: one that can influence developmental trajectories in ways that may entail significant costs in some contexts, while also potentially supporting functional or advantageous adaptations in others (Ellis et al., 2017; Frankenhuis & de Weerth, 2013).

This reconceptualisation challenges traditional deficit-oriented views, which treat stress as a disruption to an otherwise optimal developmental path. Instead, stress is understood as a developmental condition under which specific capacities may be shaped, prioritised, or trade

off against others. For example, while chronic or overwhelming stress may impair attention regulation in classroom settings, it may enhance threat detection, memory for social hierarchies, or the ability to shift attention rapidly—skills that may be adaptive in volatile or resource-scarce environments (see Ellis et al., 2017; 2023).

Accordingly, this thesis adopts a functional, context-dependent definition of stress: exposure to environmental pressures that may alter physiological, cognitive, or behavioural development, with effects that may be impairing or adaptive, depending on the ecological niche and the assessment methods used. This approach enables a more nuanced investigation into how children's developmental systems respond not only to risk but also to opportunity, and how what may appear as deficit in one setting may in fact represent adaptation in another (Ellis et al., 2017).

Throughout this thesis, the terms stress and adversity are used largely interchangeably to refer to environmental conditions that pose challenges to a child's physiological, psychological, or social development. While stress often refers to the individual's internal response and adversity to the external event or context, this distinction is not always maintained in empirical literature. In line with the functional-developmental perspective adopted here, both terms are used to denote experiences that may impose risk but also shape adaptive outcomes, depending on context, timing, and intensity.

Adaptation

Adaptation is a foundational concept in both evolutionary biology and developmental science. In this thesis, adaptation refers to how children adjust—physiologically, cognitively, and behaviourally—to the specific demands of their environments. Consistent with the Hidden Talents Model, which underpins the theoretical framework of this research (see Section 2.1.3), adaptation is viewed not only as a response to immediate challenges but as a potential pathway

toward the development of context-sensitive skills. More specifically, this study draws on the concept of *conditional adaptations*, defined as "evolved psychobiological mechanisms that monitor specific features of childhood environments as a basis for calibrating the development of stress response systems to adaptively match those environments" (Boyce & Ellis, 2005, p. 271). Such mechanisms allow developmental systems to flexibly adjust to varying levels of harshness, unpredictability, or resource availability, yielding behavioural and cognitive traits that are often well-suited to local conditions.

Anthropological and biological traditions have long recognised the role of adaptation in shaping human diversity. Although anthropology as a formal discipline emerged in the 19th century, attention to cultural variation has deep roots. As early as the 5th century BCE, Herodotus suggested that differences among human groups stemmed from their ability to adapt to different contexts. In contemporary science, this intuition has been elaborated through a range of evolutionary frameworks that describe how organisms—including humans—adjust their morphology, physiology, and behaviour to maximise survival and reproduction in ecologically variable environments (e.g., Bennett, 2017; Frisancho, 1993; Gould, 1983; Laland & Brown, 2011; Pritchard et al., 2010).

Within evolutionary biology, adaptation is typically understood in relation to fitness—that is, an organism's capacity to survive and reproduce in its environment (Laland & Brown, 2011). Given the diversity of physical and social ecologies in which humans live, no single developmental strategy can be considered universally optimal (Brandon, 2014; Schmidt-Nielsen, 1997). Instead, human development is characterised by phenotypic plasticity—the capacity of a single genotype to produce different phenotypes in response to environmental conditions (Pigliucci, 2001; Schlichting, 1986). This plasticity supports the emergence of a variety of developmental adaptations, which can be broadly categorised into three types:

- *Ontogenetic adaptations* are traits that arise during specific life stages to solve particular developmental problems, then fade when no longer needed. Biological examples include the placenta or umbilical cord (Blasi, 2018).
- *Deferred adaptations* emerge in childhood to serve immediate functions while also preparing the individual for likely future conditions. For example, play can enhance motor, social, and problem-solving skills that are critical in adulthood (Blasi & Bjorklund, 2003; Pellegrini et al., 2007).
- *Conditional adaptations* are developmental strategies tailored to environmental cues during early life, particularly those indicating harshness, danger, or unpredictability. These adaptations may calibrate attention, learning, or social reasoning in ways that enhance fit with the local ecology (Boyce & Ellis, 2005).

This thesis is primarily concerned with conditional adaptations as they relate to cognitive development under conditions of adversity. From this perspective, children's skills—such as memory, attention, or social reasoning—are not simply developed or impaired, but dynamically shaped in relation to the environments in which they grow. This reconceptualisation moves beyond universal benchmarks of "typical development" and instead foregrounds the adaptive logic of variation.

Skill

In this thesis, *skills* are understood as measurable cognitive or social abilities that emerge through development and can be evaluated against objective criteria such as accuracy, speed, or success in competitions (e.g., athletic, Ellis et al., 2017, 2023). This criterion-referenced approach to skill assessment distinguishes the Hidden Talents Model from other models that emphasise physiological responses (e.g., early puberty), behavioural dispositions (e.g.,

insecure attachment), or attitudes (e.g., hostile attribution bias) as indicators of developmental adaptation to stress (Ellis et al., 2023).

Stress-adapted skills, as used in this thesis, can be regarded as a form of successful intelligence (Sternberg, 2014) that works “toward the attainment of one’s goals in life, within one’s cultural context" (p. 209). For example, the ability to rapidly interpret subtle social cues may be especially adaptive in unstable or high-risk environments, even if it is less emphasised in traditional academic assessments.

Child

In this thesis, the term *child* is used in accordance with the United Nations Convention on the Rights of the Child (UNCRC), to refer to any individual under the age of 18 (UNICEF, 1989), a principle commonly known as “straight eighteen”. This legal definition provides a clear and internationally recognised boundary for inclusion in childhood research. However, it is equally important to acknowledge that the concept of childhood is neither fixed nor universal, but rather a category shaped by historical and cultural contexts.

In Western societies, contemporary notions of childhood emphasise innocence, dependency, and vulnerability. Yet this view is relatively recent. Up to the Middle Ages, children in much of Europe were considered miniature adults and expected to work and participate in society with minimal protection (Ariès, 1962, but see Wilson, 1980). It was only with the gradual decline of child labour and the rise of formal schooling during the late Middle Ages and Renaissance that a distinct and protected notion of childhood began to emerge. This shift reflected broader transformations in economic systems, social norms, and institutional investment in child development, and the perception of the child as an innocent, delicate, and vulnerable began to solidify (Özerdem & Podder, 2011). In this respect, Musgrove (1964 p. 84) famously asserted that "adolescence was invented at the same time as the steam engine".

Over the years, social anthropologists have produced a wealth of ethnographies that document how childhood is experienced and conceptualised across different human societies (e.g., Cohen, 1964; Lancy, 2015; LeVine & New, 2008; Van Gennep, 1909). Nonetheless, the Western conception of childhood, like many other Western cultural constructs, has been exported and imposed on non-European contexts (Boyden, 1997), becoming dominant in psychological and humanitarian discussions.

This thesis recognises these complexities. While it adopts the legal definition of childhood for methodological clarity, it also critically acknowledges the fluid and culturally contingent nature of childhood. The children involved in this study—whether living in Roma camps, urban Naples, or rural Mozambique—occupy social realities that can differ markedly from the environments typically assumed in mainstream developmental science. Their experiences, challenges, and competencies must therefore be understood within their local ecological and cultural contexts, an approach that has guided the analysis presented here.

Appendix B: Forged in Fires: Notes on Adaptive Intelligence among Roma Children in the "Terra dei Fuochi"

This photo essay has been accepted for publication in *BioSocieties*

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1. Children standing on frames in the car graveyard behind the camp, September 2022. Photo by Simone Strozzi.

"Karkuma, look how red it is!" Valerio[1] exclaims, his eyes gleaming with excitement as he explains how to extract copper from electrical cables while we walk by the car graveyard. Valerio is a well-built boy, and I am surprised to learn that he is only 10 years old. *"And you sell it for 7 Euro per kilo!"* he adds energetically. *Karkuma*, copper, is the first word I learn in Romanes, followed by *szástri*, iron, and *kash*, wood.



2. A child extracts copper from an electronical device by burning the plastic surrounding the metal. Photo by Simone Strozzi.

Valerio lives with about 200 other children in the Roma camp of Via Carrafiello, located outside of Giugliano in Campania, in the northern outskirts of Naples. I had been visiting the camp for a few months as part of a research project aimed at uncovering the hidden talents of children growing up in harsh environments. And Valerio's camp is undoubtedly one of them.

The camp is located near the Asse Mediano, a highway that stretches from Acerra to Lago Patria. Exiting at Giugliano/Borgo Riccio, there are only a few commercial activities, and in the warm season, tall wheat fields recesses have been chosen as workplaces by some prostitutes. Turning right onto Via Carrafiello, the view suddenly opens to the largest Roma camp of the four in the Giugliano area, which houses around 70 families totalling 420 people. Originally Bosnian migrants who arrived in Italy 30 years ago, they occupied an abandoned paint factory in 2019 after several evictions from previous locations. The site covers 12,000 m^2, with additional dwellings added around over time.

The Roma people live in disastrous conditions in caravans or shacks built with salvaged materials. With no running water or electricity, they resort to illicit taps, dragging pipes and cables for tens of metres to the nearest usable point. Just last January, a 6-year-old girl was fatally electrocuted by an exposed live wire on the ground. I vividly recall her laughter as she played. She had so much fun getting into a shopping bag, one of those big, thick plastic ones, which I would lift and carry around while running through the camp amidst the laughter of the other kids...it's one of the most beautiful memories I have of these children.



3. Children collecting water from a pipe, June 2022. Photo by Gabriele Paone.

The money for survival comes from scavenging and reselling metal, especially copper, their red gold obtained from items found in the rubbish. However, metal is also acquired from public electrical cables, gutters, or other sources. Other informal activities include car thefts, ATM robberies, and minor thefts, which often also involve minors. Numerous women, accompanied by their children, resort to begging in nearby shopping centres. According to Arrevutammoce, the NGO that has been assisting the camp residents for years, 95% of adult residents have criminal records, with over 30 individuals incarcerated at the time of the research.

For cooking and warmth, they use open fires or old stoves where they burn wood, plastic, and whatever else they find. Extended families huddle together in shacks or caravans, and children spend most of their time outdoors amidst heaps of rubbish and a notable rat population.



4. Playing outdoors with the children, August 2022. Photo by Max d'Amato

Additionally, the camp is located in the so-called *Terra dei Fuochi* (Land of Fires), which encompasses several cities including Giugliano, an area severely polluted from decades of illegal waste disposal by organised crime. The toxic landscape is made of industrial waste, particularly from the steel industry, thermal power plants, or incinerators. And petrochemical waste, tannery sludge, shredded money, printer toners, as well as hospital waste and cemetery remains (Saviano, 2006). All that can be thrown away can be found here. This waste comes

from both large national and foreign companies, and from small local producers looking to cut waste disposal costs. And finally, there are also individuals, including the camp residents, who dump their rubbish where there is already a mountain, anyway. The waste is frequently burned—hence the name "Terra dei Fuochi"—releasing toxic smoke into the air. And often, the blame for these fires is attributed to the Roma who live nearby.



5 and 6. The stark reality of fire's aftermath, with mountains of burned rubbish still smoking on the background, August 2022. Photos by Gabriele Paone.

All of this has inflicted severe pollution upon the soil, groundwater, and air. Research has found high concentrations of toxic elements in the area, such as dioxins or heavy metals including barium, cadmium, chromium, lead, and mercury (e.g., Maresca et al., 2020). Pollutants are then transmitted to organisms living in this environment: toxic elements have been detected in animal products (e.g., Esposito et al., 2009; Lambiase et al., 2017) and in humans (e.g., Forte et al., 2020; Giovannini et al., 2014). Consequently, the area faced a surge in health concerns,

including cancers, cardiovascular ailments, diabetes, leukaemia, asthma, and a higher prevalence of preterm births and neonatal congenital myasthenic syndromes compared to national and regional averages (Beccaloni et al., 2020; Buonaugurio, 2019; Forte et al., 2020; Greco, 2016; Rocco et al., 2016; Senior & Mazza, 2004).

Adding to the direct exposure to a toxic environment, children in this community face inadequate nutrition and engage in risky behaviours such as consuming alcohol or smoking. Furthermore, many suffer from skin diseases like scabies, parasites such as lice and crabs, and display signs of malnutrition. These observations have been corroborated by voluntary visits from a paediatrician due to the lack of regular medical check-ups.

In addition to environmental toxicity, the camp residents also grapple with *social toxicity* (Garbarino, 1995), including poverty, disruption of family ties (e.g., due to the incarceration), stigma, and marginalisation in relation to the wider population.

This brings to mind Marc Augé's concept of *non-places* (1992), which refers to transitional spaces lacking the cultural significance to be considered "places" in the anthropological sense. Similarly, many camp residents survive in a state of *non-personhood* (Cefisi, 2011), no longer Bosnian, yet not quite Italian citizens. They straddle a unique existence, with Italy being their only homeland, yet 80% of the camp residents lack regular IDs. They are legal phantoms. They speak Romanes and Italian, but often not the languages of their familial origins, and they stand as Italy's sole minority devoid of linguistic recognition as per constitutional mandates (Cefisi, 2011). This legal vacuum deprives them of vital social services and employment prospects, with none appearing to hold formal employment contracts. In addition to this, the Roma and Sinti communities, long subjected to racism and marginalisation (see Armillei, 2018), are the most despised minority in Italy, facing widespread antipathy among youth and adults, and increasingly targeted by rising intolerance (Cefisi, 2011). I have often been asked *"What good are you doing helping them?"* when discussing my volunteer work with the Roma in Giugliano. For example, during a schooling initiative spearheaded by the NGO Arrevutammoce, we managed to take about fifty children to a summer school program. However, this was contingent upon us attending at different times from the "Italian" children to prevent complaints from their parents.

There is thin physical divide between the camp and the city, just a few minutes by car, but there is an enormous social gap between Roma people and *Gadje*—the rest of society which seems

distant in its comforts, and unattainable. Many Roma—especially the younger ones—appropriate the most immediate symbols of that society, perhaps unconsciously seeking to participate in it. Faded haircuts on the sides and thick beards in vogue today. Clothes, likely counterfeit, bearing oversized brand names. An extreme desire for belonging that even leads several children to permanently imprint some symbols of the consumer society on their own skin. A multitude of tattoos depicting the Rolex, Louis Vuitton, Playboy logos—sometimes tattooed backwards or without knowing exactly what they represent. *"Priboi"*, Peppe tells me when I ask him if he knows the meaning of the symbol that appeared on his hand one day. But it doesn't matter what they really mean, they remain emblems of a world they can merely observe from afar, of a status they can only possess in a reflected form, on their own skin, where no one can take them away from them. The practice of naming children after celebrities perhaps reflects similar motivations for participation: there were children named "Shakira", "Elvis", "Cavani", as well as children with Italian politicians' surnames used as first names, like "Salvini", "Renzi", or "Napolitano".



7-10. Children proudly display their tattoos, August 2022. Photos by Gabriele Paone.

The mainstream idea in social and psychological sciences is that early-age exposure to adversity such as environmental toxicity, poverty, social insecurity, or malnutrition can impair children's cognitive and behavioural development (Anne Lown et al., 2011; Felitti et al., 1998; Kim et al., 2013). Although these studies have the merit of recognising and trying to alleviate the potential damages caused by adversity on development, they offer only a partial picture

since they focus solely on the negative outcomes (Ellis et al., 2017; Frankenhuis & Nettle, 2020).

In all the places I visited where children live in challenging conditions, from the favelas of Rio de Janeiro controlled by narcotraffickers to rural communities in Mozambique, it was always apparent that there was a lot more beyond the potential traumas and impairments well described in the literature—there were evident strengths, too. And with the Roma children, the epiphany dawned on me one late summer afternoon.

I had gone to the camp to deliver some documents and after distributing them, I joined in with the children's games. In addition to the usual games of cops and robbers—where no one ever wants to be the cop—we played chase, with the children trying to catch me. Once caught, I said *"Let's catch Cesare"*, who swiftly dashed away among tires and other remnants of dismantled cars. As soon as he was touched, all the little big eyes full of energy turned to me, awaiting the name of the next prey. *"Touch...Damiano!",* and before I even finished pronouncing the name, the designated seven-year-old was already off like a shot. We played like this indefinitely, in a carefree reverie that often accompanies playing with children when, having finished the names of my list, at the umpteenth inquisitive glance from these little predators I said *"Touch...wood!"*, and they leaped onto the panels forming the surrounding shacks, and onto some boards scattered on the ground.



11. Children tapping wooden shack walls upon hearing "touch wood!", August 2022. Photo by Gabriele Paone.

Touch...iron!", came next. I expected them to touch generic metal objects, but instead, Smeralda grabbed a hammer, Mario seized an iron rod, and Martin picked up a rusty horseshoe.

"Touch...plastic!", and the children darted towards old dashboards and a buttered bumper on the ground.

"Touch...steel!". Paki and his brothers ran their hands over a dismantled car frame. Peppe touched a bicycle fender laying nearby, but Giulio immediately corrected him, *"No, that's aluminium, can't you feel it's light?"*.

And then... *"Touch...karkuma!"*. Giovanni lifted an old square black transformer, one of those that came with electronic devices from the '90s. Mario pointed at the cable of a broken fan, Rocky showed a power strip, and the others touched pieces of copper collected in a bucket.

"Touch...gold!" and after a quick dash among the shacks, Elvis and Barabba returned with a catalytic converter, while Tony went to touch a tooth of an old lady sitting on the doorstep of her shack, who shooed him away with curses in Romanes, amidst the laughter of the other children.

I recall some time earlier when, walking through the car graveyard behind the camp, Valerio unfolded the secrets of the trade, revealing the hidden treasures amidst the wreckage. *"You can extract gold from a muffler"* he explained, his eyes gleaming like the metal he spoke of. *"Gold? How?"* I queried, intrigued. *"You heat it...and you could pocket as much as 500 Euro"*. And I gladly listened to another lesson on metals from my young mentor. *"Gold is 30, 40, 50 Euro per gram, depending on gold and where you sell"*. Indeed, a catalytic converter contains several grams of gold, as well as palladium, rhodium, and platinum, which fetch 700, 70, and 30 Euro per gram respectively. The math adds up.

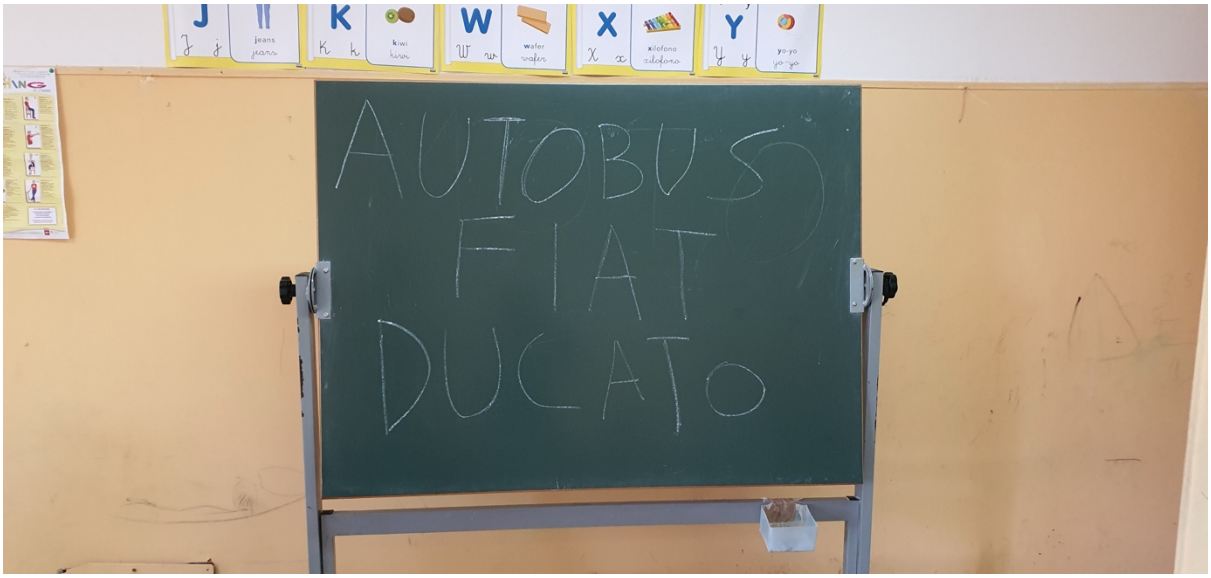
My mind goes immediately to the children in a rural village in Kenya, who exhibited extensive knowledge of the medicinal properties of several local plants, which correlated negatively with measures of academic intelligence (Sternberg et al., 2001). Similarly, Yup'ik children from Southwest Alaska outperformed urban children in knowledge of herb gathering, preparation, fishing, hunting, and weather patterns, but showed reverse results on conventional intelligence tests (Grigorenko et al., 2004). Or the *catadores*—waste pickers in Rio de Janeiro's dumps — who can identify different materials simply by squeezing a trash bag, without even opening it (Millar, 2018). These represent manifestations of *practical* or *adaptive intelligence*, skills honed through environmental adaptation that can enable individuals to survive and thrive in their surroundings (Sternberg, 2014, 2019), much like the Roma children, who possess a vast knowledge enabling them to distinguish between various materials, especially metals, understand where to find them, how to extract them, and where and for how much to sell them. In their challenging environment, this knowledge is essential for their survival. Yet, these skills are often overlooked by conventional intelligence tests or Western education programmes, despite their immense potential if identified and nurtured.

I witnessed this potential during a summer schooling program initiated to bring the Roma camp children to school. Most had never attended it, despite the legal obligation, and the program, organised by Arrevutammoce at an institute in Scampia neighbourhood, faced immediate hurdles. Accustomed to outdoor freedom, the confines of the classroom proved stifling to the children, and their practical-oriented and oral-centric culture left them adrift amidst the sea of abstract words and digits, and textbooks. For days, attempts to teach conventional lessons like copying letters and basic math were chaotic, with children unmotivated and distracted.

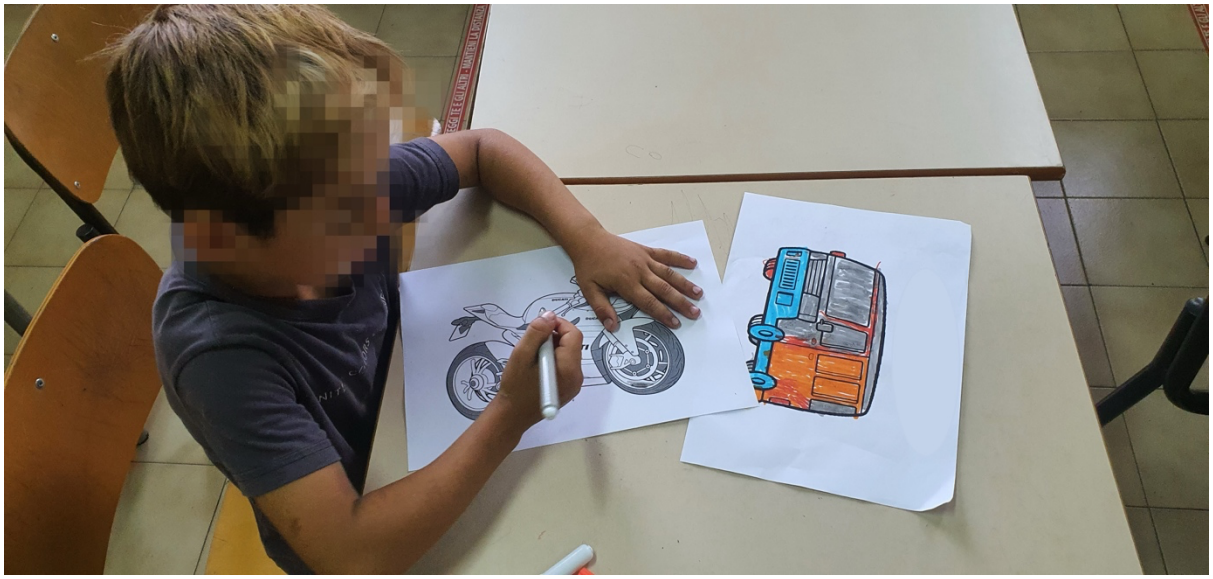


12. Implementing conventional teaching methods proved challenging, September 2022. Photo by Gabriele Paone.

In my small class, I tried a different approach, leveraging their interest in vehicles. I provided the younger ones with pictures of cars to colour, aiming to have them familiarise with holding a pencil. When it came to teaching letters, I utilised automotive words such as *autobus* or *Fiat Ducato*. These were not just familiar to them but more importantly, they captured their attention. All the children asked how to write car names and proudly showed me when they had written *Mercedes*, *Audi*, or *BMW*.



13. Whiteboard displaying automotive words used creatively for teaching children reading and writing, September 2022. Photo by Gabriele Paone.



14. The same child who was hanging on the whiteboard, colours images of a motorbike and a bus, demonstrating engagement with subjects more relevant to them, September 2022. Photo by Gabriele Paone.

But it was during our mathematics lessons that I was even more impressed. I had attempted to teach them simple operations in the conventional manner, with minimal success. Then, one morning, I framed a problem around something familiar to them: gathering copper. *"We collect 1 kilo, and then another 2 kilos. How much do we have in total?"* I inquired. *"3 kilos"*, replied Luca, Valerio's brother, who had been excluded from all the other classes for his behaviour.

"Good...and how much does a kilo of copper sell for?".

"7 Euro!" Gianco chimed in, *"but it has to be clean, just copper, without plastic around"*.
"Well done. And if you have 3 kilos, how much...".
"21 Euro" he confidently answered, even before I finished the question.

This practical approach, akin to the principles of street mathematics (see Banerjee et al., 2017; Carraher et al., 1985), marked the beginning of a rewarding journey, during which these children began to learn reading, writing, and mathematics, but, most importantly, they discovered the school in a different light—an environment previously unfamiliar to many of them, and hostile to those who had been there.

The observations I made with the Roma children are, of course, ethnographic and would require systematic study to move beyond anecdotal evidence of adaptive intelligence. Yet, even this preliminary evidence suggests that the deficit idea regarding children growing up in adversity is, at the very least, incomplete. Humans, especially children, have a remarkable capacity to adapt to their environments, including challenging ones (Frankenhuis & Amir, 2022; Frankenhuis & de Weerth, 2013). These adaptations can take as many forms as there are environments humans live in, manifesting in skills like plant knowledge, climate reading, spatial navigation, or material identification. For Roma children, the ability to distinguish between various materials, particularly metals, knowing where to find them, how to extract them, and where and for how much to sell them, are vital skills for their survival. Therefore, the cognitive and behavioural traits of individuals from challenging environments should not solely be viewed as deficient or maladaptive. Instead, these individuals may develop unique adaptations to solve problems specific to their environment. It is important to note, however, that these skills may deviate from standard Western norms, potentially remaining "hidden" if not recognised or valued by the wider society (Ellis et al., 2017). However, although this perspective holds promise for theory-driven research and evidence-based interventions, knowledge in this area is still in its infancy due to a dearth of empirical studies.

The overarching goal of the research project to which this study belongs has been to uncover abilities that children develop growing up in challenging circumstances. But beyond scientific value, recognising and nurturing such forms of adaptive intelligence can be leveraged for education and later employment, and can show that the Roma children of Giugliano—as well as millions of their peers growing up in challenging environments—may possess hidden talents beneath the ashes of their harsh realities.

Notes

1. All names have been changed to protect the identities of individuals.

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Appendix C: Supplementary Material for Chapter 3

1. Indice di Vulnerabilità Sociale e Materiale (IVSM, Istat, 2011)

This IVSM index relies on data obtained from a national census conducted every decade. The last census occurred in 2011, and the subsequent one, originally planned for 2021, was postponed due to the COVID-19 pandemic. The index is built using seven indicators regarding adult education, family size, single-parent demographics, caregiving needs, overcrowded housing, youth inactivity, and economic hardship.

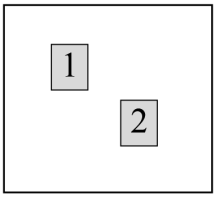
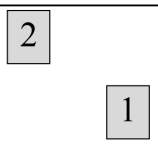
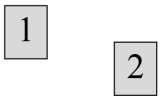
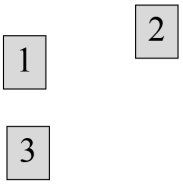
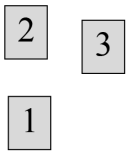
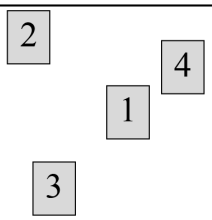
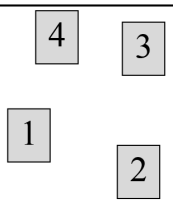
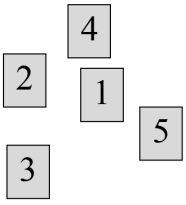
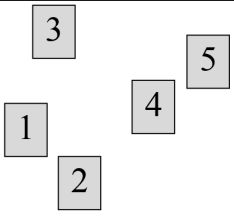
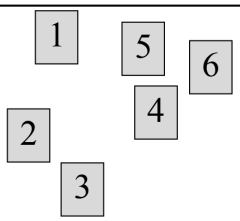
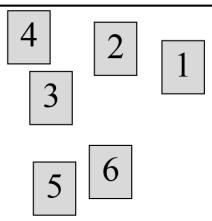
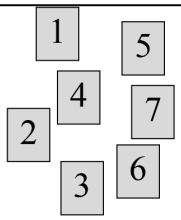
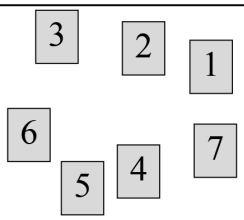
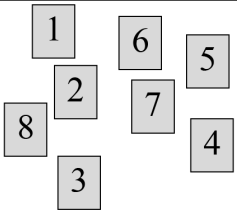
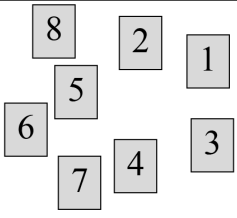
2. Power Analyses

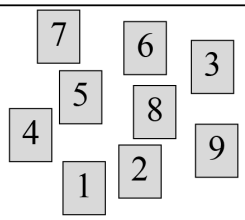
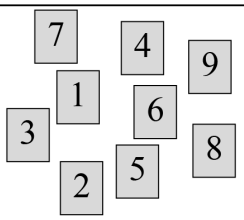
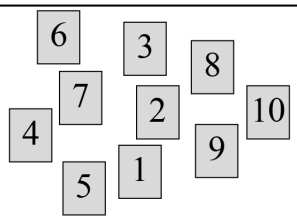
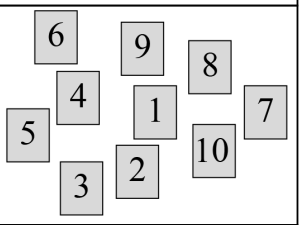
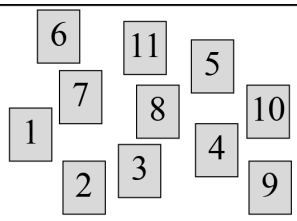
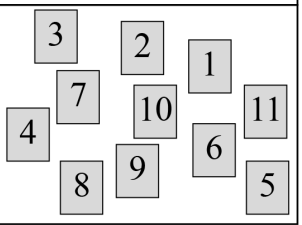
For Study 1, sample sizes were determined by a power analysis, which assumed a power of 0.8, and that children from high-stress environments would have verbal memory test span scores on average 0.5 lower than children from Pozzuoli and visuo-spatial memory test span scores on average 0.3 lower than children from Pozzuoli. The power analyses suggested a sample size of 125 participants per environment to give a power of at least 0.8 to detect all effect sizes. The full power analysis can be found here: https://github.com/Social-Body-Lab/stress_adaptation_and_memory/tree/main/power_analysis_faux.

For Study 2, sample sizes were determined by a power analysis that was based on piloting and data from conventional working memory tests. The power analysis showed that 125 participants per environment would be needed to have a power of 0.84 to detect a 0.4-point difference in visuo-spatial social memory test span scores between the higher-stress environments of the Roma camp and Scampia and the lower-stress environment of Pozzuoli (i.e., a positive effect of higher-stress environment on visuo-spatial social memory test span scores). The power analysis used an alpha (significance) level of 0.05 for its hypothesis testing.

The full power analysis can be found here https://github.com/Social-Body-Lab/stress_adaptation_and_social_memory/tree/main/Napoli/power_analysis.

3. Face cards order

Example:			
2A		2B	
3A		3B	
4A		4B	
5A		5B	
6A		6B	
7A		7B	
8A		8B	

9A		9B	
10A		10B	
11A		11B	

4. Tables

Study 1

Table S1. Participants excluded from analysis; reason for exclusion by environment.

Test	< 5 years old	≥ 11 years old	Did not understand	Total
Verbal STM	18	1	3 (S: 1, P: 2)	22
Verbal WM	18	1	23 (S: 4, P: 13, R: 6)	42
Visuo-spatial STM	18	1	3 (S: 2, P: 1)	22
Visuo-spatial WM	18	1	7 (S: 2, P: 3, R: 2)	26

Table S2. Children's tasks understanding.

Sample	Verbal STM	Verbal WM	Visuo-spatial STM	Visuo-spatial WM
Scampia	99.37%	97.40%	100%	98.72%
Pozzuoli	100%	92.31%	100%	98.32%
Roma	95.56%	84.62%	100%	95.35%

Table S3. One-Way ANOVA Results for Perceived Stress Scale for Children (PSS-C) Scores by Environment.

Source	*df*	Sum of Squares	Mean Square	*F*	*p*
Environment	2	127.90	63.95	3.04	.049 *
Residual	381	8023.14	21.06		

Table S4. Tukey HSD Post-hoc Comparisons for PSS-C Scores by Environment.

Comparison	Mean Difference	95% CI Lower	95% CI Upper	*p*-adj
Roma – Pozzuoli (R–P)	−1.01	−2.81	0.79	.385
Scampia – Pozzuoli (S–P)	0.79	−0.38	1.97	.254
Scampia – Roma (S–R)	1.80	−0.03	3.63	.054

Table S5. Regression model for effect of environment on span scores for verbal STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.046	0.092	0.500	.618
Environment (Roma camp)	−1.580	0.142	−11.157	< .001
Sex (Male)	0.154	0.087	1.762	.079
Age	0.310	0.031	10.105	< .001

Multiple R^2 = 0.370, Adjusted R-squared = 0.364

Table S6. Regression model for effect of environment on span scores for verbal WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.145	0.079	1.842	.066
Environment (Roma camp)	−1.005	0.126	7.986	< .001
Sex (Male)	0.096	0.075	1.287	.199
Age	0.245	0.026	9.346	< .001
Multiple R^2 = 0.306, Adjusted R-squared = 0.299				

Table S7. Regression model for effect of environment on span scores for visuo-spatial STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	−0.024	0.103	−0.234	.815
Environment (Roma camp)	−0.799	0.159	−5.026	< .001
Sex (Male)	−0.114	0.098	−1.164	.245
Age	0.275	0.034	8.029	< .001
Multiple R^2 = 0.188, Adjusted R-squared = 0.179				

Table S8. Regression model for effect of environment on span scores for visuo-spatial WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	−0.167	0.106	−1.574	.116
Environment (Roma camp)	−0.641	0.166	−3.856	< .001
Sex (Male)	−0.045	0.101	−0.441	.660
Age	0.307	0.035	8.711	< .001
Multiple R^2 = 0.189, Adjusted R-squared = 0.180				

Table S9. Regression model for effect of environment on total scores for verbal STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.468	0.733	0.639	.523
Environment (Roma camp)	−12.217	1.127	−10.839	< .001
Sex (Male)	0.650	0.694	0.937	.349
Age	2.857	0.244	11.717	< .001
Multiple R^2 = 0.397, Adjusted R-squared = 0.390				

Table S10. Regression model for effect of environment on total scores for verbal WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.429	0.406	1.057	.291
Environment (Roma camp)	−4.910	0.651	−7.547	< .001
Sex (Male)	0.357	0.387	0.924	.356
Age	1.476	0.136	10.843	< .001
Multiple R^2 = 0.326, Adjusted R-squared = 0.319				

Table S11. Regression model for effect of environment on total scores for visuo-spatial STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	−0.127	0.766	−0.166	.868
Environment (Roma camp)	−6.345	1.177	−5.389	< .001
Sex (Male)	−0.764	0.725	−1.054	.293
Age	2.289	0.254	9.007	< .001
Multiple R^2 = 0.220, Adjusted R-squared = 0.212				

Table S12. Regression model for effect of environment on total scores for visuo-spatial WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	−0.848	0.684	−1.240	.216
Environment (Roma camp)	−5.142	1.070	−4.805	< .001
Sex (Male)	0.180	0.651	0.277	.782
Age	2.150	0.227	9.467	< .001
Multiple R^2 = 0.222, Adjusted R-squared = 0.214				

Table S13. Regression model for effect of PSS on span scores for verbal STM.

Variable	***b***	***SE***	***t***	***p***
Intercept	1.902	0.318	5.988	< .001
PSS	−0.003	0.011	−0.232	.817
Sex (Male)	0.016	0.100	0.161	.872
Age	0.276	0.036	7.689	< .001
Multiple R^2 = 0.136, Adjusted R-squared = 0.130				

Table S14. Regression model for effect of PSS on span scores for verbal WM.

Variable	*b*	*SE*	*t*	*p*
Intercept	0.850	0.259	3.279	.001
PSS	0.010	0.009	1.125	.261
Sex (Male)	0.011	0.082	0.138	.890
Age	0.223	0.029	7.610	< .001
Multiple R^2 = 0.149, Adjusted R-squared = 0.142				

Table S15. Regression model for effect of PSS on span scores for visuo-spatial STM.

Variable	***b***	***SE***	***t***	***p***
Intercept	2.025	0.313	6.462	< .001
PSS	0.016	0.011	1.446	.149
Sex (Male)	−0.179	0.100	−1.790	.074
Age	0.252	0.035	7.121	< .001
Multiple R^2 = 0.135, Adjusted R-squared = 0.128				

Table S16. Regression model for effect of PSS on span scores for visuo-spatial WM.

Variable	***b***	***SE***	***t***	***p***
Intercept	1.111	0.318	3.488	< .001
PSS	0.002	0.011	0.212	.832
Sex (Male)	−0.090	0.102	−0.881	.379
Age	0.296	0.036	8.207	< .001
Multiple R^2 = 0.156, Adjusted R-squared = 0.150				

Study 2

Table S17. Participants excluded from analysis (reason for exclusion and total).

Test	< 5 years old	≥ 11 years old	Did not understand	Total
Social STM	18	1	2 (S: 1, P: 1)	21
Social WM	18	1	5 (S: 2, R: 2, P: 1)	24

Table S18. Children's tasks understanding.

Sample	Social STM	Social WM
Scampia	100%	98.73%
Pozzuoli	100%	99.40%
Roma	100%	95.56%

Table S19. Regression model for effect of environment on span scores for social STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.835	0.135	6.186	< .001
Environment (Roma camp)	−0.318	0.208	−1.531	.127
Sex (Male)	−0.055	0.128	−0.430	.667
Age	0.449	0.045	10.004	< .001
Multiple R^2 = 0.280, Adjusted R-squared = 0.273				

Table S20. Regression model for effect of environment on span scores for social WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.460	0.162	2.836	.005
Environment (Roma camp)	−1.175	0.255	−4.617	< .001
Sex (Male)	0.158	0.155	1.025	.306
Age	0.476	0.054	8.814	< .001
Multiple R^2 = 0.227, Adjusted R-squared = 0.219				

Table S21. Regression model for effect of environment on total scores for social STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	6.911	1.242	5.566	< .001
Environment (Roma camp)	−8.614	1.912	−4.504	< .001
Sex (Male)	−0.097	1.176	−0.083	.934
Age	4.711	0.413	11.415	< .001
Multiple R^2 = 0.337, Adjusted R-squared = 0.330				

Table S22. Regression model for effect of environment on total scores for social WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	3.758	1.326	2.833	.005
Environment (Roma camp)	−10.317	2.080	−4.959	< .001
Sex (Male)	1.357	1.263	1.075	.283
Age	4.096	0.441	9.284	< .001
Multiple R^2 = 0.245, Adjusted R-squared = 0.237				

Table S23. Regression model for effect of PSS on span scores for social STM.

Variable	*b*	*SE*	*t*	*p*
Intercept	2.103	0.423	4.976	< .001
PSS	−0.011	0.015	−0.737	.462
Sex (Male)	−0.162	0.134	−1.206	.229
Age	0.440	0.048	9.213	< .001
Multiple R^2 = 0.186, Adjusted R-squared = 0.179				

Table S24. Regression model for effect of PSS on span scores for social WM.

Variable	*b*	*SE*	*t*	*p*
Intercept	0.732	0.503	1.455	.147
PSS	0.008	0.018	0.451	.653
Sex (Male)	−0.001	0.160	−0.006	.995
Age	0.446	0.057	7.854	< .001
Multiple R^2 = 0.145, Adjusted R-squared = 0.138				

Table S25. Cohen's *d* effect size by test type.

Task	Pozzuoli v. Roma	Pozzuoli v. Scampia
Verbal STM	d = 1.599, SE = 0.133, 95% CI = [1.340, 1.862]	d = −0.040, SE = 0.111, 95% CI = [−0.249, 0.182]
Verbal WM	d = 1.136, SE = 0.154, 95% CI = [0.804, 1.411]	d = −0.165, SE = 0.110, 95% CI = [−0.381, 0.054]
Visuo-spatial STM	d = 0.717, SE = 0.120, 95% CI = [0.477, 0.945]	d = 0.009, SE = 0.110, 95% CI = [−0.209, 0.225]
Visuo-spatial WM	d = 0.481, SE = 0.123, 95% CI = [0.230, 0.714]	d = 0.147, SE = 0.109, 95% CI = [−0.070, 0.362]
Social STM	d = 0.096, SE = 0.133, 95% CI = [−0.165, 0.354]	d = −0.596, SE = 0.110, 95% CI = [−0.809, −0.379]
Social WM	d = 0.591, SE = 0.112, 95% CI = [0.368, 0.806]	d = −0.272, SE = 0.108, 95% CI = [−0.480, −0.058]

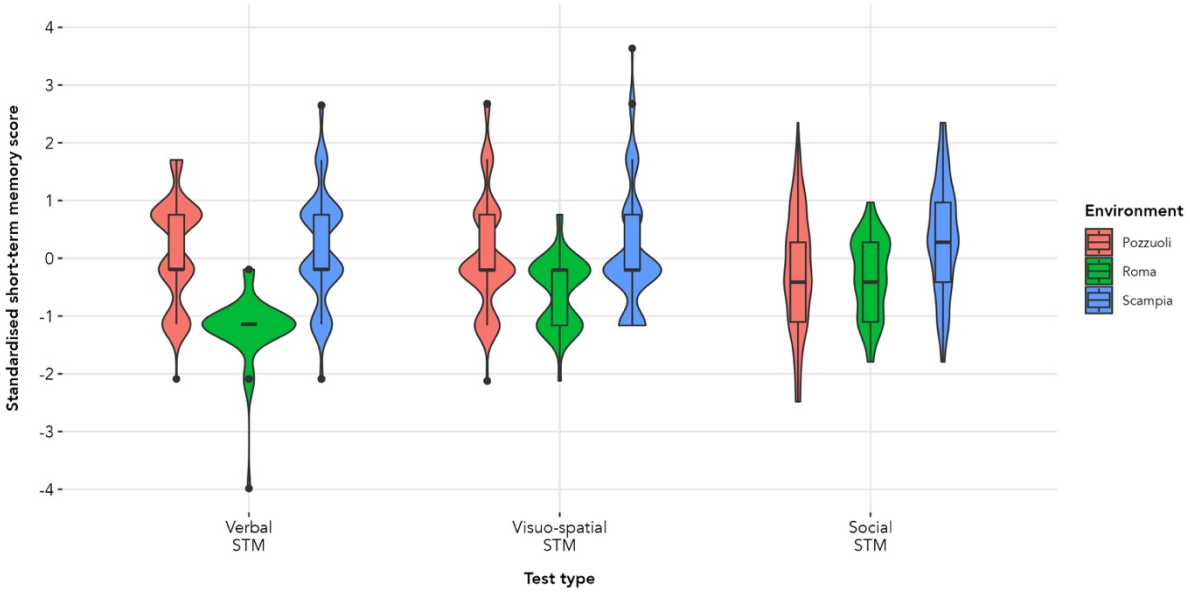


Figure S1. Standardised STM scores by test type and environment.

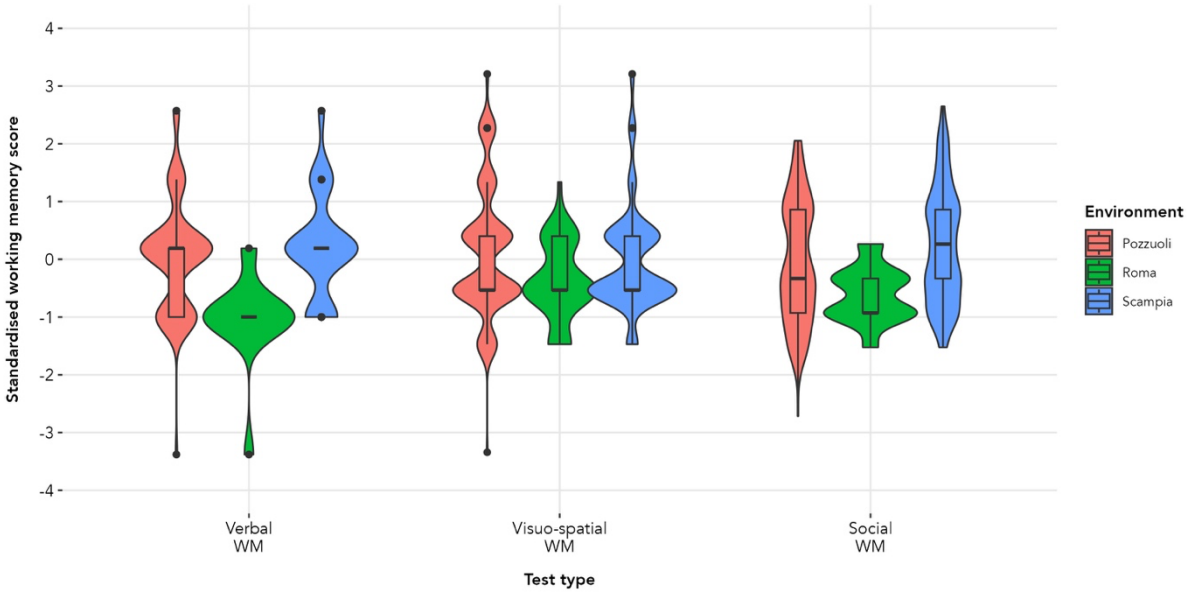


Figure S2. Standardised WM scores by test type and environment.

Appendix D: Supplementary Material for Chapter 4

1. Power Analysis

These sample sizes were determined by a power analysis based on data from conventional working memory tasks. The power analysis showed that our model would have a power of 0.85 to detect mean differences of 0.4 points on test span scores between the higher-stress environments and Pozzuoli (with the higher-stress environments scoring 0.4 points lower, on average).

Power analyses for the models testing whether any of the populations perform relatively better on the short-term and working memory tests for motor tasks than they do on conventional visuo-spatial and verbal short-term and working memory tests suggested that a sample size of at least 75 participants (with participants having scores for each test) is needed to detect a difference of 0.75 in standardised scores between the two test types with a power of 0.87. The full power analysis can be found here: https://github.com/Social-Body-Lab/stress_adaptation_and_motor_memory/blob/b413a10d64dd0abb4104fec6ac198541479ec7c9/power_analysis/summary/power_analysis.pdf.

2. Movements

Single Movements:

1. Lift arms above head
2. Jump forward
3. Open arms sideways
4. Open legs sideways
5. Stretch arms forward
6. Cross arms on chest
7. Bent knees
8. Jump backwards

Combinations:

Example: 3, 4	
2A: 1, 2	2B: 5, 7
3A: 3, 4, 5	3B: 6, 7, 3
4A: 6, 7, 5, 8	4B: 1, 8, 5, 4
5A: 5, 8, 3, 4, 1	5B: 5, 4, 3, 2, 1
6A: 1, 7, 6, 4, 5, 8	6B: 6, 4, 3, 8, 5, 7

3. Tables

Table S1. Participants excluded from analysis (reason for exclusion and total).

Test	< 5 years old	≥ 11 years old	Did not understand	Unable to participate	Total
Motor STM	13	1	0	3 (S:2; P:1)	17
Motor WM	13	1	16 (P:8; R:8)	3 (S:2; P:1)	33

Table S2. Children's tasks understanding.

Sample	Motor STM	Motor WM
Scampia	100%	100%
Pozzuoli	100%	95.70%
Roma	100%	82.22%

Table S3. One-Way ANOVA Results for Perceived Stress Scale for Children (PSS-C) Scores by Environment.

Source	*df*	Sum of Squares	Mean Square	*F*	*p*
Environment	2	127	63.95	3.07	.048 *
Residual	384	7966	20.74		

Table S4. Tukey HSD Post-hoc Comparisons for PSS-C Scores by Environment.

Comparison	Mean Difference	95% CI Lower	95% CI Upper	*p*-adj
Roma – Pozzuoli (R–P)	–0.84	–2.62	0.94	.506
Scampia – Pozzuoli (S–P)	0.88	–0.28	2.04	.178
Scampia – Roma (S–R)	1.72	–0.09	3.54	.067

Table S5. Regression model for effect of environment on span scores for motor STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.487	0.069	7.050	< .001
Environment (Roma camp)	–0.141	0.107	–1.321	.187
Sex (Male)	0.168	0.065	2.574	.010
Age	0.140	0.023	6.184	< .001
Multiple R^2 = 0.208, Adjusted R-squared = 0.200				

Table S6. Regression model for effect of environment on span scores for motor WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	0.319	0.074	4.334	< .001
Environment (Roma camp)	–0.336	0.122	–2.753	.006
Sex (Male)	–0.079	0.070	–1.130	.259
Age	0.116	0.024	4.764	< .001
Multiple R^2 = 0.137, Adjusted R-squared = 0.127				

Table S7. Regression model for effect of environment on total scores for motor STM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	2.960	0.393	7.535	< .001
Environment (Roma camp)	–0.975	0.607	–1.608	.109
Sex (Male)	0.771	0.372	2.074	.039
Age	0.753	0.129	5.850	< .001
Multiple R^2 = 0.215, Adjusted R-squared = 0.207				

Table S8. Regression model for effect of environment on total scores for motor WM.

Variable	*b*	*SE*	*t*	*p*
Environment (Scampia)	2.013	0.367	5.481	< .001
Environment (Roma camp)	–1.412	0.609	–2.317	.021
Sex (Male)	–0.580	0.351	–1.655	.099
Age	0.607	0.122	4.974	< .001
Multiple R^2 = 0.165, Adjusted R-squared = 0.156				

Table S9. Regression model for effect of PSS on span scores for motor STM.

Variable	coefficient	*SE*	*t*	*p*
Intercept	2.149	0.216	9.965	< .001
PSS	–0.005	0.008	–0.704	.482
Sex (Male)	0.108	0.070	1.547	.123
Age	0.136	0.024	5.576	< .001
Multiple R^2 = 0.081, Adjusted R-squared = 0.074				

Table S10. Regression model for effect of PSS on total scores for motor STM.

Variable	coefficient	*SE*	*t*	*p*
Intercept	3.871	1.240	3.122	.002
PSS	–0.013	0.044	–0.301	.763
Sex (Male)	0.394	0.401	0.983	.326
Age	0.719	0.141	5.114	< .001
Multiple R^2 = 0.067, Adjusted R-squared = 0.060				

Table S11. Regression model for effect of PSS on span scores for motor WM.

Variable	coefficient	*SE*	*t*	*p*
Intercept	1.879	0.226	8.304	< .001
PSS	–0.001	0.008	–0.182	.856
Sex (Male)	–0.131	0.073	–1.801	.073
Age	0.107	0.026	4.178	< .001
Multiple R^2 = 0.053, Adjusted R-squared = 0.045				

Table S12. Regression model for effect of PSS on total scores for motor WM.

Variable	coefficient	*SE*	*t*	*p*
Intercept	2.373	1.145	2.072	.039
PSS	–0.003	0.041	–0.065	.948
Sex (Male)	–0.856	0.368	–2.326	.021
Age	0.560	0.130	4.313	< .001
Multiple R^2 = 0.061, Adjusted R-squared = 0.053				

Table S13. Cohen's *d* effect size by test type.

Task	Pozzuoli v. Roma	Pozzuoli v. Scampia
Verbal STM	*d* = 1.750, *SE* = 0.156, 95% CI = [1.460, 2.070]	*d* = 0.024, *SE* = 0.113, 95% CI = [–0.201, 0.244]
Verbal WM	*d* = 1.070, *SE* = 0.164, 95% CI = [0.759, 1.400]	*d* = –0.168, *SE* = 0.111, 95% CI = [–0.385, 0.051]
Visuo-spatial STM	*d* = 0.841, *SE* = 0.124, 95% CI = [0.603, 1.090]	*d* = 0.065, *SE* = 0.113, 95% CI = [–0.155, 0.285]
Visuo-spatial WM	*d* = 0.567, *SE* = 0.127, 95% CI = [0.316, 0.815]	*d* = 0.220, *SE* = 0.113, 95% CI = [–0.001, 0.443]
Motor STM	*d* = 0.009, *SE* = 0.158, 95% CI = [–0.301, 0.318]	*d* = –0.678, *SE* = 0.115, 95% CI = [–0.901, –0.451]
Motor WM	*d* = 0.598, *SE* = 0.153, 95% CI = [0.296, 0.893]	*d* = –0.425, *SE* = 0.114, 95% CI = [–0.651, –0.205]

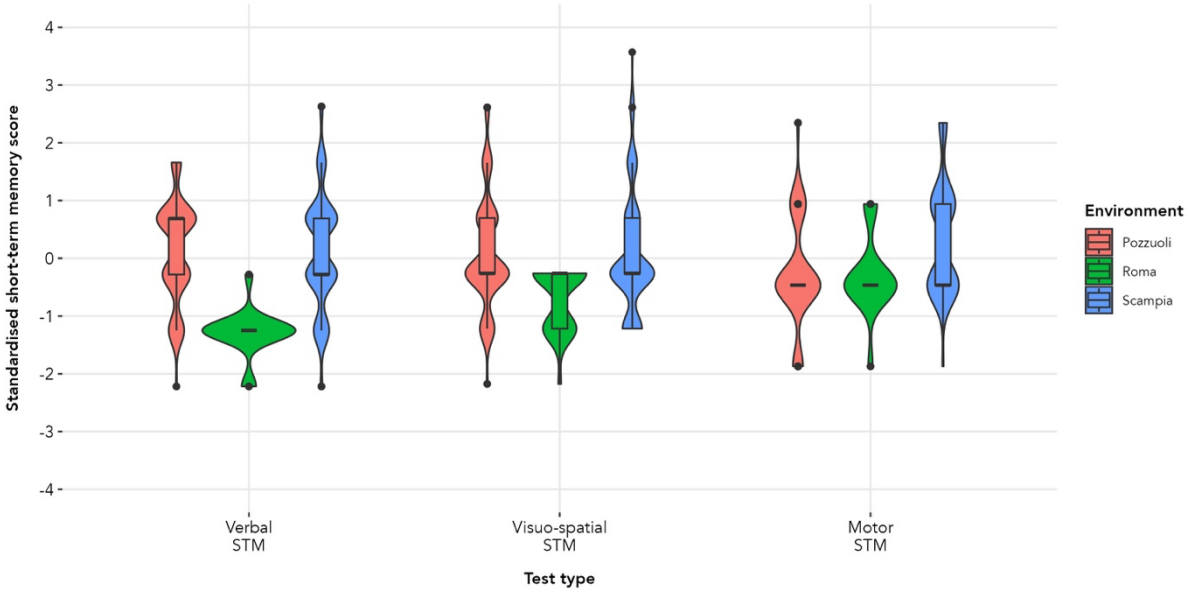


Figure S9. Standardised STM scores by test type and environment.

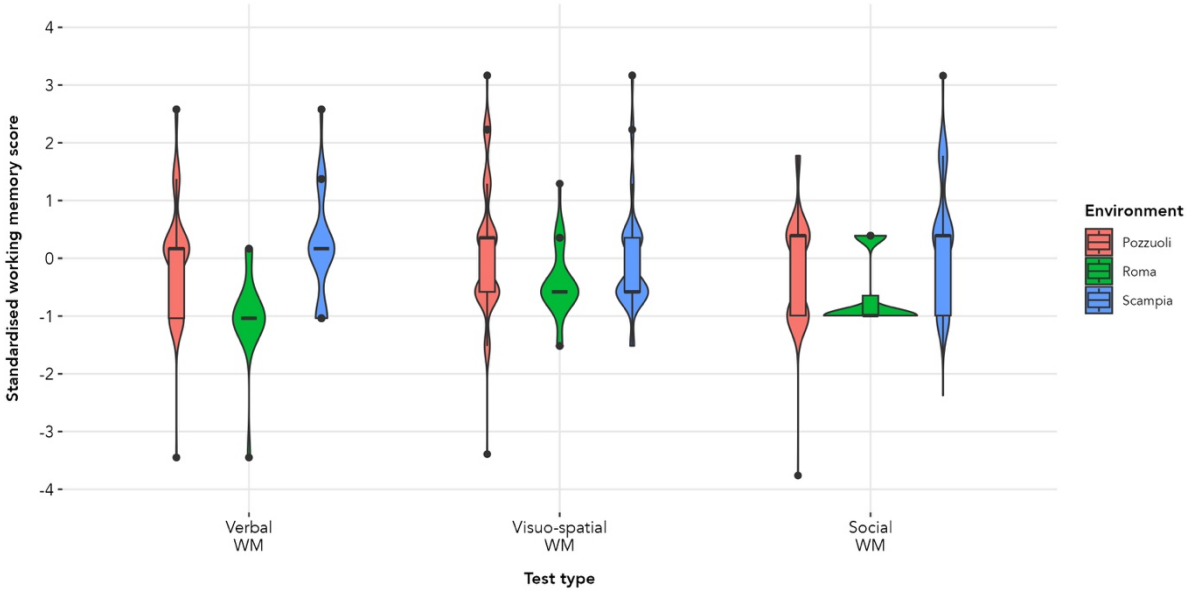


Figure S10. Standardised WM scores by test type and environment.

Appendix E: Supplementary Material for Chapter 5

1. Tables

Table S1. Participants excluded from analysis by task; reason for exclusion.

Test	Did not understand
Social STM	2 (VG: 0, N: 2)
Social WM	5 (VG: 3, N: 2)

Table S2. Children's tasks understanding.

Sample	Social STM	Social WM
Villa Gorongosa	100%	94.92%
Nhandar	96.92%	96.92%
Total	98.39%	95.97%

Table S3. Regression model for effect of environment on span scores for social STM.

Variable	***b***	***SE***	***t***	***p***
Environment (Nhandar)	0.605	0.267	2.266	.025
Sex (Male)	0.167	0.267	0.625	.534
Age	0.501	0.097	5.158	< .001
Multiple R^2 = 0.218, Adjusted R-squared = 0.198				

Table S4. Regression model for effect of environment on span scores for social WM.

Variable	***b***	***SE***	***t***	***p***
Environment (Nhandar)	0.958	0.227	4.219	< .001
Sex (Male)	0.438	0.227	1.933	.056
Age	0.157	0.083	1.896	.061
Multiple R^2 = 0.176, Adjusted R-squared = 0.155				

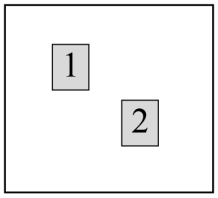
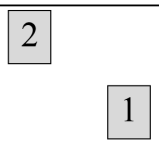
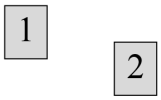
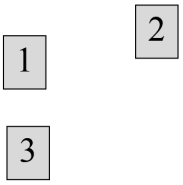
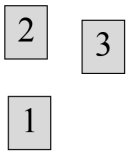
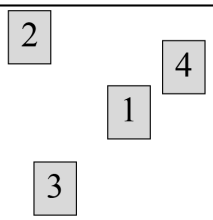
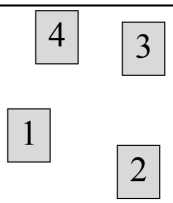
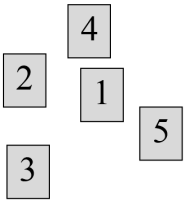
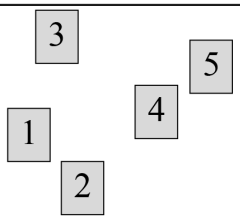
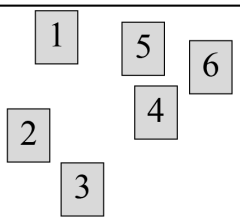
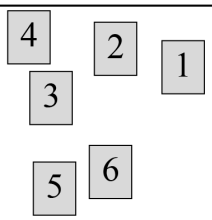
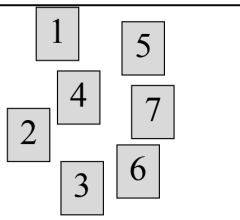
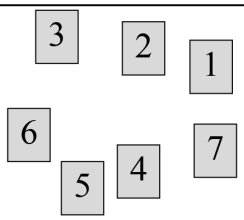
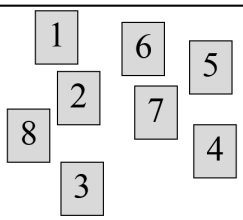
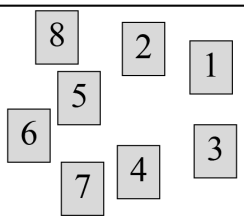
Table S5. Regression model for effect of environment on total scores for social STM.

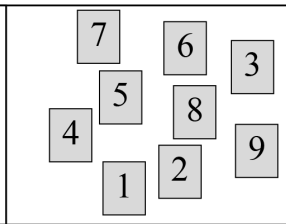
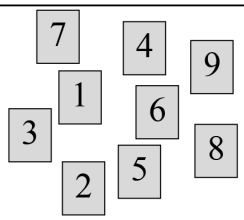
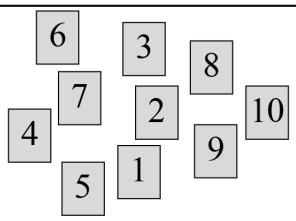
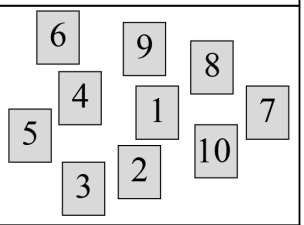
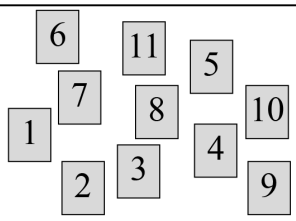
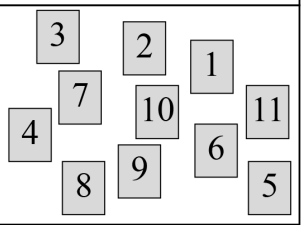
Variable	*b*	*SE*	*t*	*p*
Environment (Nhandar)	4.379	2.269	1.930	.014
Sex (Male)	1.749	2.270	0.770	.443
Age	4.387	0.825	5.318	< .001
Multiple R^2 = 0.220, Adjusted R-squared = 0.200				

Table S6. Regression model for effect of environment on total scores for social WM.

Variable	***b***	***SE***	***t***	***p***
Environment (Nhandar)	5.440	1.464	3.717	< .001
Sex (Male)	3.184	1.462	2.178	.031
Age	1.236	0.535	2.311	.023
Multiple R^2 = 0.169, Adjusted R-squared = 0.148				

2. Face cards order

Example: 			
2A		2B	
3A		3B	
4A		4B	
5A		5B	
6A		6B	
7A		7B	
8A		8B	

9A		9B	
10A		10B	
11A		11B	

Publication Note

Parts of this thesis have subsequently been published as:

Paone, G., Davis, A. J., & Cohen, E. (2026). Modality matters: Intact and enhanced memory skills in children from high-stress environments. *Cognitive Science*, *50*(4), e70214. https://doi.org/10.1111/cogs.70214

Paone, G.**,** Davis, A. J., & Cohen, E. (2026). Memory in motion: Enhanced motor memory in children from harsh environments. *OSF Preprints.* https://doi.org/10.31234/osf.io/ukt9a_v1

Paone, G., Davis, A. J., & Cohen, E. (2026). Social memory in children from urban and rural Mozambique: A pre-registered replication study. *Cognitive Development*, *78*, 101690. https://doi.org/10.1016/j.cogdev.2026.101690

Paone, G**.** (2025). Forged in fires: Notes on adaptive intelligence among Roma children in the "Terra dei Fuochi". *BioSocieties*, *20*(4), 645–659. https://doi.org/10.1057/s41292-025-00375-0