1.1 Introduction

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This introductory section outlines why we utilize the D-score:

- reviewing key discussions about the first 1000 days in a child's life (1.1.1)
- highlighting the relevance of early childhood development for later life (1.1.2)
- discussing the use of stunting as a proxy for development (1.1.3)
- pointing to existing instruments to quantify neurocognitive development (1.1.4)
- explaining why we have written this chapter (1.1.5)
- delineating the intended audience (1.1.6)

1.1.1 FIRST 1000 DAYS

The *first 1000 days* refers to the time needed for a child to grow from conception to the second birthday. It is a time of rapid change. During this period the architecture of the developing brain is very open to the influence of relationships and experiences (Shonkhoff *et al.*, 2016). Early experiences affect the nature and quality of the brain's developing architecture by reinforcing some synapses and pruning others through lack of use. The first 1000 days shape the brain's architecture, but higher-order brain functions continue to develop into adolescence and early adulthood (Kolb *et al.*, 2017).

The classic *nature versus nurture debate* contrasts the viewpoints that variation in development is primarily due to either genetic or environmental differences. The current scientific consensus is that both genetic predisposition and ecological differences influence all traits (Rutter, 2007). The environment in which a child develops (before and soon after birth) provides experiences that can modify gene activity (Caspi *et al.*, 2010). Negative influences, such as exposure to stressful life circumstances or environmental toxins may leave a *chemical signature* on the genes, thereby influencing how genes work in that individual.

During the first 1000 days, infants are highly dependent on their caregivers to protect them from adversities and to help them regulate their physiology and

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behavior. As Figure 1.1.1 illustrates, caregivers can do this through responsive care, including routines for sleeping and feeding. To reach their developmental potential, children require nutrition, responsive caregiving, opportunities to explore and learn, and protection from environmental threats (Black *et al.*, 2017). Gradually, children build self-regulatory skills that enable them to manage stress as they interact with the world around them (Johnson *et al.*, 2013).

1.1.2 RELEVANCE OF CHILD DEVELOPMENT

The first 1000 days is a time of rapid change. Early experiences affect brain development and influence lifelong learning and health (Shonkhoff *et al.*, 2016). Healthy development is associated with future school achievement, well-being, and success in life (Bellman *et al.*, 2013).

Professionals and parents consider it important to monitor children's development. Tracking child development enables professionals to identify children with signs of potential delay. Timely identification can help children and their parents to benefit from early intervention. In a normal population, developmental delay affects about 1–3% of children. A delay in development may indicate underlying disorders. About 1% of children have an autism spectrum disorder (Baird *et al.*, 2006), 1–2% a mild learning disability, and 5–10% have a specific learning disability in a single domain (Horridge, 2011).

Children develop at different rates, and it is vital to distinguish those who are within the "normal" range from those who are following a more pathological

FIGURE 1.1.1 Serve and return interactions shape brain architecture.

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course (Bellman *et al.*, 2013). There is good evidence that early identification and early intervention improve the outcomes of children (Britto *et al.*, 2017). Early intervention is crucial for children with developmental disabilities because barriers to healthy development early in life impede progress at each subsequent stage.

Monitoring child development provides caregivers and parents with reliable information about the child and an opportunity to intervene at an early age. Understanding the developmental health of populations of children allows organizations and policymakers to make informed decisions about programmes that support children's greatest needs (Bellman *et al.*, 2013).

1.1.3 STUNTING AS PROXY FOR CHILD DEVELOPMENT

Stunting is the impaired physical growth and development that children experience from poor nutrition, repeated infection, and inadequate psychosocial stimulation. Linear growth in children is commonly expressed as length-for-age or height-for-age in comparison to normative growth standards (Wit *et al.*, 2017). According to the World Health Organization (WHO), children are stunted if their height-for-age is more than two standard deviations below the Child Growth Standards median. Stunting caused by chronic nutritional deprivation in early childhood is as an indicator of child development (Perkins *et al.*, 2017).

There is consistent evidence for an association between stunting and poor child development, despite heterogeneity in the estimation of its magnitude (Miller *et al.*, 2016; Sudfeld *et al.*, 2015). Considering impaired linear growth as a proxy measure for child development is easy to do, and quite common. Yet, using impaired height growth as a measure for child development is not without limitations:

- The relation between height and child development is weak after adjustment for age;
- Height is a physical indicator that does not take into account a direct evaluation of a child's cognitive or mental performance;
- There is considerable heterogeneity in heights of children all over the world;
- Height is not sensitive to rapid changes in child development.

1.1.4 MEASURING NEUROCOGNITIVE DEVELOPMENT

Assessment of early neurocognitive development in children is challenging for many reasons (Ellingsen, 2016). During the first years of life, developmental change occurs rapidly, and the manifestation of different skills and abilities varies considerably across children. Moreover, a child's performance on a cognitive task is very susceptible to measurement setting, timing and the health of the child that day.

Recently, a toolkit was published that reviews 147 assessment tools developed for children ages 0–8 years in low- and middle-income countries (Fernald *et al.*, 2017). Some of the most widely used tools include the Ages & Stages Questionnaires (ASQ), Achenbach Child Behavior Checklist (CBCL), Bayley Scales of Infant Development (BSID), Denver Developmental Screening Test (DEN), Griffiths Scales of Child Development (GRF), Mullen Scale of Early Learning (MSEL), Strengths and Difficulties Questionnaire (SDQ), Wechsler Intelligence Scale for Children (WISC), and its younger age counterpart Wechsler Preschool and Primary Scale of Intelligence (WPPSI).

Each of these tools has its strengths and limitations. For example, the ASQ and DEN are screeners for general child development. The CBCL and SDQ are screeners for behavioral and mental health, not cognition or general development. DEN is relatively easy and quick to administer, but not very precise. It is out of production, not being sold or re-normed. The BSID, MSEL, and GRF provide a clinical assessment at the individual level and requires a skilled professional to administer. Some instruments collect observations through the caregiver (ASQ), whereas others emphasize traits and behavior over performance (SDQ, CBCL). Also, the age ranges to which the instruments are sensitive vary. Furthermore, they may cover different domains of development.

The ideal child development assessment would be easy to administer and has high reliability, validity, and cross-cultural appropriateness. It should also show appropriate sensitivity in scores at different ages and ability levels. It is no surprise that no test can meet all of these criteria. Many tests are too long, difficult to administer, lack cross-cultural validity, or have low reliability. Also, many instruments are proprietary and costly to use.

1.1.5 WHY THIS CHAPTER?

We believe that **there cannot be one instrument** for measuring child development that is suitable for all situations. In general, the tool needs tailoring to the setting. For example, to find a delayed child, we need an instrument that is precise for that individual child, and that is sensitive to different domains of delay. In contrast, if we want to estimate the proportion of children that is *developmentally on track* in a region, we need one culturally unbiased, relatively imprecise low-cost measurement made on many children across many ages. The optimal instrument will look quite different in both cases.

We also believe that **there can be one scale** for measuring child development and that this scale is useful for many applications. Such a scale is similar to well-known measures for body height, body weight or body temperature. These measurements have a clearly defined unit (i.e., centimetre, kilogram, degree Celsius), which moreover is assumed to be constant across all scale locations. We express measurements as the number of scale units (e.g. 92 cm). Note that there may be multiple instruments for measuring a child height (e.g. ruler, laser distance meter, echolocation, ability to reach the door handle,

and so on). Still, their result translates into scale units (cm here). The opposite is also true, and perhaps more familiar. We may have one instrument and express the result in multiple units (e.g. cm, inches, light-years).

Instruments and scales are different things. Currently, instruments for measuring child development define their own scales, which renders the measurements made by distinct tools incomparable. No measurement unit for child development yet exists. It would undoubtedly be an advance if we could tailor the measurement instrument to the setting while retaining the advantage of a scale with a clearly defined unit across different tools. We can then compare the data collected by distinct devices. This chapter explores the theory and practice for making that happen.

1.1.6 INTENDED AUDIENCE

We aim for three broad audiences:

- Professionals in the field of child growth and development;
- Policymakers in international settings;
- Statisticians, methodologists, and data scientists.

Professionals in child development will become familiar with a new approach to measuring child development in early childhood. We plan to separate the measurement instrument from the scale used to express the result. This formulation allows the user **to select the instrument most suited for a particular setting**. Since instruments differ widely in age coverage, length, administration mode, and domain coverage (Boggs *et al.*, 2019), the ability to choose the instrument, while not giving up comparability, represents a significant advance over routines that marry the scale to the instrument.

Policymakers in international settings wish to know the effect of different interventions on child development. Gaining insight into such effects is not so easy since different studies use different instruments. The ability to place measurements made by different instruments onto the same scale will allow for a **more accurate understanding of policy effects**. It also enables the setting of priorities and actions that are less dependent on the way the data were collected.

Statisticians and data scientists generally prefer numeric values with an unambiguous unit (e.g., centimeters, kilograms) over a vector of dichotomous data points. This chapter shows how to convert a series of PASS/FAIL scores to a numeric value with interval scale properties. The existence of such a scale opens the way for the **application of precise analytic techniques**, similar to those applied to child height and body weight. The techniques have a solid psychometric backing, and also apply to other types of problems.