Designing Multidisciplinary Longitudinal Studies of Human Development : Analyzing Past Research to Inform Methodology

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Designing Multidisciplinary Longitudinal Studies of Human Development

Analyzing Past Research to Inform Methodology

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This review identifies key issues associated with the design of future longitudinal studies of human development. Sixteen international studies were compared for initial response and retention rate, sample size, type of data collected, and sampling frames. The studies had little information about the influences of fathers, extended family members, childcare, and educational institutions; the effects of peers; children's use of time; the needs of disabled children; urban versus rural environments; or the influence of genetic factors. A contemporary longitudinal study should include measures of physical and mental health, cognitive capacity, educational attainment, social adjustment, conduct and behavior, resiliency, and risk-taking behaviors. It needs to address genetic and intergenerational factors, cultural identity, and the influences of neighborhood, community, and wider social and political environments and to encompass outcomes at all life stages to systematically determine the role each factor plays in individuals' lives, including interactions within and across variables.

Keywords: *newborn; infant; child; child development; preschool; humans; longitudinal studies; cohort studies; New Zealand*

Over the past 50 years, numerous longitudinal studies have followed cohorts of children from birth through to later stages in their lives with the aim of increasing understanding of human life-course development.

The development of an individual human from the moment of conception through to fully functioning adulthood is an extraordinarily complex process (Nicholson & Rempel, 2004). Longitudinal studies offer a robust way to acquire in-depth understanding of the complexity of child development by following a large number of children from birth, or preferably from prior to birth, through to adulthood (Zollinger, 2002). By studying the processes of development of children across time, in the context of their families and wider environments of influence, it is possible to identify not only normative developmental trends and indicators of causal relationships but also individual differences in development. Internationally, such longitudinal data are recognized to be of unparalleled value both to researchers studying human development and to policy makers across the whole of government (Joshi, 2006).

Human development is the result of the continuous interaction of individual characteristics within the family context and the wider physical, cultural, social, and political environments (Zeanah, Boris, & Larrieu, 1997). Any developmental outcome, whether social, physical, behavioral, or psychological, represents a snapshot during the evolution of complex trajectories that run throughout an individual's own life from birth to adulthood. These are, in turn, influenced by continuities in biological and social conditions across generations and by an individual's development prior to birth. To properly predict the impact of any policy measures that are intended to alter these pathways, either for individuals or the population as a whole, it is necessary to take a holistic view of child development and understand more about the complex way in which developmental trajectories across different domains are determined and interrelated. This involves consideration of initial set points for different developmental trajectories, when these occur, and the identification of periods along the pathway or components of the family or wider environment that may be amenable to change to enhance an individual's development from fetal to adult life.

Existing longitudinal studies have made significant contributions to our understanding of the complexity of human development and have been influential in their impact on policy and practice. For example, researchers have identified relationships between health and social circumstances over time, such as the long-term impact of exposures during pregnancy (Fogelman & Manor, 1988; Power & Jefferis, 2002) and the importance of

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social position in early life (Power & Moynihan, 1988) as well as examining childhood risk factors that are the best predictors of adult health conditions (Viner & Hotopf, 2004). Other notable findings include those that have leveraged the detailed environmental histories of birth cohorts in combination with collection of genetic information to demonstrate how genetic makeup can moderate a person's susceptibility to adverse environmental conditions (Caspi et al., 2002, 2003).

Recognizing the value of longitudinal studies, our aims were to review characteristics of these studies such as sampling frame, size, and attrition rate to determine the optimum study design for participant retention and to identify areas of child development that had either not been previously addressed or had not been addressed within a single study. The purpose was to inform the design of future multidisciplinary longitudinal studies of human development, given both the recent renewal of investment in such studies by governments worldwide and the increasing international utilization of findings to inform the development of health, education, and social policy.

Method

A literature search was conducted using the academic databases Medline (1966 to 2005), EMBASE (1980 to 2005), PsycINFO (1806 to 2005), and the Education Resources Information Center (1965 to 2005). Additional searches were undertaken on the Internet for relevant Web sites, particularly that of the Centre for Longitudinal Studies at the Institute for Education in London (http://www.cls.ioe.ac.uk) and Keeping Track, of the Institute for Social and Economic Research (http://www.iser.essex.ac.uk/ulsc/keeptrack/index.php). Relevant papers were accessed and reference lists checked for additional studies. The search terms used in the literature search were "longitudinal and study," "birth cohort," and "child development." Inclusion criteria were all studies involving a single human birth cohort that continued for at least 12 years and were published in the English language in the past 50 years. Studies using multiple cohorts were excluded, unless they provided sufficient data on the cohort that followed children aged less than 1 year onward. Studies that followed participants for less than 12 years were excluded because that span could not cover all stages of development from birth to (early) adolescence.

A detailed review was undertaken of 16 major longitudinal studies from eight different countries that began after 1950. The earliest was the 1958 British National Child Development Study (Jefferis, Power, & Hertzman,

2002). The review also considered studies in their initial stages of planning or implementation, including those in Ireland (Department of Social and Family Affairs, 2004), Australia (Sanson et al., 2002), and Norway (Norwegian Institute of Public Health, 2004). A description and comparison of sample sizes, sampling methods, and data collected was prepared, together with bivariate analyses of any association between these characteristics and the success of the recruitment and retention of participants. Existing gaps in these studies to date were also identified.

Results

Twenty-seven international longitudinal studies were identified (see Table 1). The majority of these studies still follow the participants, some of whom are now in their fourth or fifth decades. Sixteen of these studies met the inclusion criteria for comparative review (Table 2).

Sample Size and Attrition

A review of the relationship of the sample size and initial response rate (Figure 1) and initial response rate by year of inception (Figure 2) was conducted for 16 major studies. Data for attrition rates were available for 10 of the studies (Figure 3).

Measuring the relationship between the sample size and the response rate is important for the design of longitudinal studies. The smaller the response rate, the greater the vulnerability for selection biases. This is crucial particularly because of the decline in responses over time and the risk that attrition is not randomly spread across the sample (Thomas, Frankenberg, & Smith, 2001). The relationship between the response rate and the year of inception is also of interest, for a very different reason. The sense of obligation to participate in such a study appears to have declined over time. Furthermore, studies commenced in recent years tend to cover more aspects of participants' lives and often include more intrusive information than earlier studies. Taken together, these factors may affect response rates.

The findings revealed that sample sizes varied from 686 participants in the Australian Aboriginal Birth Cohort (Mackerras et al., 2003) to 22,831 in the National Longitudinal Survey of Youth (Statistics Canada, 1999). Initial recorded response rates (recruitment) also varied considerably, ranging from 55% in the Australian Aboriginal Birth Cohort (Mackerras et al., 2003; Sayers et al., 2003) to 97% in the Christchurch Health and Development Study (Fergusson, 1998). Initial response rate was related to sample size,

Table 1
Longitudinal Cohort Studies Identified by Search Strategy

Year of Onset	Name of Study	Country	Included/Excluded
1946	National Survey of Health and Development	United Kingdom	Excluded: data collection started at 8 weeks of age
1947	Newcastle Thousand Families Cohort	United Kingdom	Excluded: methodology not robust[a]
1955	Kauai Longitudinal Study	Hawaii	Excluded: methodology not robust[b]
1958	National Child Development Study	United Kingdom	Included
1959	Copenhagen Perinatal Cohort	Denmark	Excluded: data were unavailable in English
1966	Northern Finland Birth Cohort Study	Finland	Included
1968	Panel Study of Income Dynamics and the Child Development Supplement	United States	Excluded: study of families, not birth cohort
1970	British Cohort Study 1970	United Kingdom	Included
1972	Dunedin Multidisciplinary Health and Development Study	New Zealand	Included
1977	Christchurch Health and Development Study	New Zealand	Included
1979	Children and Young Adults of the National Longitudinal Survey of Youth	United States	Included
1982	Australian Temperament Project	Australia	Excluded: not birth cohort
1983	Cebu Longitudinal Health and Nutrition Survey	Philippines	Included
1987	Aboriginal Birth Cohort	Australia	Included
1990	Birth to Ten, Birth to Twenty Study	South Africa	Included
1990	Avon Longitudinal Study of Parents and Children ("Children of the 1990s")	United Kingdom	Included
1990	European Longitudinal Study of Pregnancy and Childhood	Eight European countries	Excluded: multiple nations, onset in different years

(continued)

Table 1 (contined)

Year of Onset	Name of Study	Country	Included/Excluded
1994	National Longitudinal Survey of Children and Youth	Canada	Included
1995	Project on Human Development in Chicago Neighborhoods	United States	Included
1995	Fragile Families and Child Wellbeing Study (Survey of New Parents)	United States	Included
1997	Children and Young Adults of the National Longitudinal Survey of Youth	United States	Included
1998	Quebec Longitudinal Study of Child Development	Canada	Included
1999	Norwegian Mother and Child Cohort Study	Norway	Excluded: data unavailable in English
2000	Millennium Cohort Study	United Kingdom	Included
2001	Early Childhood Longitudinal Study Birth Cohort	United States	Excluded: two overlapping cohorts
2004	Growing up in Australia: Longitudinal Study of Australian Children	Australia	Excluded: too soon for data
2006	Footprints in Time: Longitudinal Study of Indigenous Children	Australia	Excluded: too soon for data
2007	National Children's Study of the Effect of Environment on Health	United States	Excluded: under development

a. Follow-up was confined to children who continued living in the city of Newcastle. By age 15, 28% of the children were excluded solely because of departure from the city. Thus, the follow-up was severely influenced by family mobility, which is related to sociodemographic factors.
b. Participants were assessed at birth and at ages 1, 2, 10, 18, and 32, which does not provide enough information for trends.

such that larger absolute sample sizes tended to be associated with proportionately higher initial response rates (see Figure 1). There was, however, a downward trend in initial response rates over the 50-year period, but no association between the age of infants or children at recruitment and the initial response rate (Figure 2).

An analysis of retention rates for each study (response rates over time) indicated that maintaining a response rate over the long term of about 80%

Table 2
Comparative Details of Longitudinal Cohort Studies

Year Commenced	Study	Sample Size	Initial Response Rate	Child Recruitment Age (years)	Country	Description of Cohort	Current Status of Study
1958	National Child Development Study (Makepeace & Dolton, 2001)	17,000	98%	0.0	United Kingdom		Last data collection at age 42, 2000
1966	Northern Finland Birth Cohort Study (Tammelin, 2003)	12,231	96%	–0.3	Finland	Children born in northern Finland (Lapland and province of Oulu)	Last follow-up at age 31, 1997
1970	British Cohort Study 1970 (Signle-Ruston, 2004)	16,135	98%	0.0	United Kingdom	Children born in United Kingdom, April 5 to 11	Last data collection age 30, 2000
1972	Dunedin Multidisciplinary Health and Development Study (Silva & Stanton, 1996)	1,037			New Zealand	Children born in Dunedin in 1972 and 1973	Last follow-up at age 32, 2004
1977	Christchurch Health and Development Study (Fergusson, 1998)	1,266	97%	0.0	New Zealand	Children born in Christchurch in 1977	Last data collection at age 25, 2002
1979	National Longitudinal Survey of Children and Youth (NLSY; Statistics Canada, 1999) (NLSY79 and NLSY97)	22,831	94%	0.0	Canada	Random national sample of children aged 0 to 11 years plus special samples of children from sparsely populated of Yukon Territory and Northwest Territories	Last wave of data collection 2003 (all ages)
1982	Cebu Longitudinal Health & Nutrition Survey (Office of Population Studies, University of San Carlos, Carolina	3,289	94%	0.0	Philippines	Children of pregnant women selected randomly in 33 randomly selected communities in Metro Cebu	Last data collection at age 16, 1999

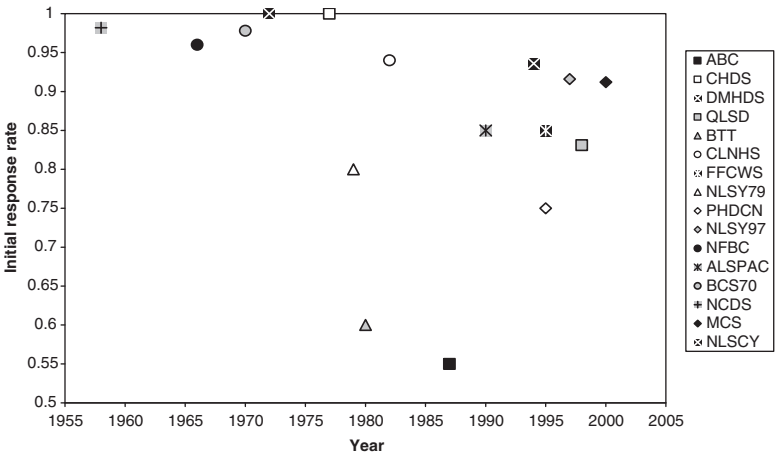
(continued)

Table 2 (continued)

Year Commenced	Study	Sample Size	Initial Response Rate	Child Recruitment Age (years)	Country	Description of Cohort	Current Status of Study
	Population Center, The University of North Carolina at Chapel Hill, & Nutrition Center of the Philippines,1989)				(17 urban and 16 rural)		
1987	Aboriginal Birth Cohort (Mackerras et al., 2003; Sayers et al., 2003)	686	55%		Australia	Aboriginal children born at Royal Darwin Hospital January 1987 to March 1990	Last data collection at age 14, 2001
1990	Birth to Ten, Birth to Twenty Study (Yach et al., 1991)	3,274	60%	0.0	South Africa	Children born in metropolitan area of Johannesburg-Soweto in 7 weeks between March and June	Last follow-up at age 13, 2003
1990	Avon Longitudinal Study of Parents and Children (Golding, 1990; Golding, Pembrey, Jones, & the ALSPAC Study Team, 2001)	14,000	85%	–0.3	United Kingdom	Children born to mothers whose expected dates of delivery were between April 1, 1991, and December 31, 1992, resident within the three Bristol-based health districts of Avon	Last data collection 2001
1995	Project on Human Development in Chicago Neighborhoods (Earls, 2002)	6,234	75%	–0.3	United States	Children aged 6 months ($n = 413$) and older children and adolescents randomly selected in Chicago area using 1990 census records	Last data collection 2001

1995 (pilot), 1998 (full)	Fragile Families and Child Wellbeing Study (McLanahan et al., 2003)	4,898	85%	0.0	United States	Representative sample of nonmarital births in 20 cities with populations >200,000	Last data collection at age 3, 2001 onward
1998	Quebec Longitudinal Study of Child Development (Jetté & DesGroseillers, 2000)	2,809	83%	0.2	Canada	Children aged 0 to 12 months (around 5 months) in Quebec	Last data collection at age 45 to 56 months, 2002
2000	Millennium Cohort Study (Dex & Joshi, 2004; Joshi et al., 2002)	18,819	91%	0.8	United Kingdom	Children born in all four countries constituting the United Kingdom; probability methods of selection were combined with stratification and clustering methods	Last data collection 2004

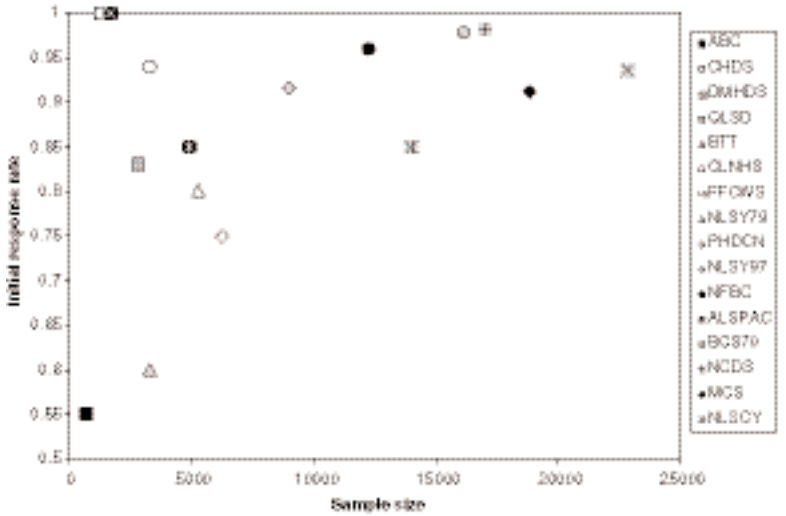
Figure 1
Initial Response Rate by Year of Inception



Note: Sixteen studies were included ($r = –.33$, $p = .22$). Note that the r value may not accurately represent the association between the variables in Figures 1 and 2, because the association was not linear. Thus, it is important to present the figures, not only the r values. It is also noted that 16 is a very small sample size, so achieving a high level of significance was unlikely. ABC = Australian Aboriginal Birth Cohort; ALSPAC = Avon Longitudinal Study of Parents and Children; BCS70 = British Cohort Study 1970; BTT = Birth to Ten, Birth to Twenty Study; CHDS = Christchurch Health and Development Study; CLHNS = Cebu Longitudinal Health and Nutrition Survey; DMHDS = Dunedin Multidisciplinary Health and Development Study; FFCWS = Fragile Families and Child Wellbeing Study; MCS = Millennium Cohort Study; NCDS = National Child Development Study; NFBC = Northern Finland Birth Cohort Study; NLSY79 = National Longitudinal Survey of Youth 1979; NLSY97 = National Longitudinal Survey of Youth 1997; NLSCY = National Longitudinal Survey of Children and Youth; PHDCN = Project on Human Development in Chicago Neighborhoods; QLSCD = Quebec Longitudinal Study of Child Development.

of the initial population is achievable, although studies that have included relatively large numbers of indigenous peoples have tended to have higher attrition rates (Figure 3). Similarly, cohort studies conducted in developing countries with limited resources tend to have higher attrition rates. For example, in the South African Birth to Twenty study, 70% of the 3,275 children recruited were followed up for more than 12 years, with an average attrition rate of less than 3% per year, but most attrition occurred in the first 2 years of the study. Attrition was primarily due to participants' moving out of the study area, although reestablished contacts indicate considerable circular

Figure 2
Relationship of Sample Size and Initial Response Rate



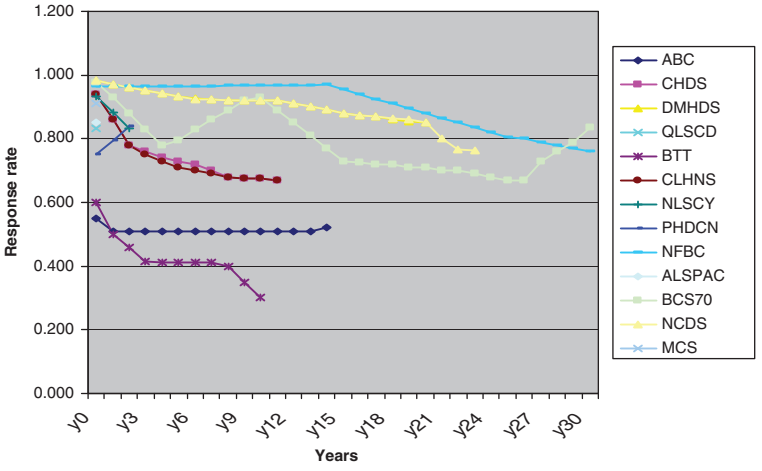
Note: Sixteen studies were included ($r = .40$, $p = .12$). Note that the r value may not accurately represent the association between the variables in Figures 1 and 2, because the association was not linear. Thus, it is important to present the figures, not only the r values. It is also noted that 16 is a very small sample size, so achieving a high level of significance was unlikely. ABC = Australian Aboriginal Birth Cohort; ALSPAC = Avon Longitudinal Study of Parents and Children; BCS70 = British Cohort Study 1970; BTT = Birth to Ten, Birth to Twenty Study; CHDS = Christchurch Health and Development Study; CLHNS = Cebu Longitudinal Health and Nutrition Survey; DMHDS = Dunedin Multidisciplinary Health and Development Study; FFCWS = Fragile Families and Child Wellbeing Study; MCS = Millennium Cohort Study; NCDS = National Child Development Study; NFBC = Northern Finland Birth Cohort Study; NLSY79 = National Longitudinal Survey of Youth 1979; NLSY97 = National Longitudinal Survey of Youth 1997; NLSCY = National Longitudinal Survey of Children and Youth; PHDCN = Project on Human Development in Chicago Neighborhoods; QLSCD = Quebec Longitudinal Study of Child Development.

migration of women and young children between urban and rural areas, as well as urban residential mobility (Richter, Norris, & De Wet, 2004).

Sampling Methods

A range of sampling methods was used in these longitudinal studies, with variation in the prevailing method over time. Studies that commenced prior to 1990 tended to use sampling frames aimed at recruiting all children born

Figure 3
Attrition Rates of Longitudinal Studies



Note: Starting points for 13 studies; attrition over time for 10 studies. ABC = Australian Aboriginal Birth Cohort; ALSPAC = Avon Longitudinal Study of Parents and Children; BCS70 = British Cohort Study 1970; BTT = Birth to Ten, Birth to Twenty Study; CHDS = Christchurch Health and Development Study; CLHNS = Cebu Longitudinal Health and Nutrition Survey; DMHDS = Dunedin Multidisciplinary Health and Development Study; MCS = Millennium Cohort Study; NCDS = National Child Development Study; NFBC = Northern Finland Birth Cohort Study; NLSY79 = National Longitudinal Survey of Youth 1979; PHDCN = Project on Human Development in Chicago Neighborhoods; QLSCD = Quebec Longitudinal Study of Child Development.

in specified areas and/or on particular dates, whereas more recent studies have tended to use representative sampling methods (random selection, stratified or cluster sampling). However, as Figure 2 shows, the initial response rates for more recent studies that have tended to use the latter sampling approach have been lower than those obtained by earlier studies that predominantly recruited birth cohorts, and retention has been more difficult.

On average, studies that sampled all births within a defined date range yielded an initial response rate of 98% in comparison with 81% in other studies ($p = .013$). Similarly, studies that sampled all births in a defined area achieved 96% initial response rate in comparison with 82% in other studies ($p = .066$). It is noted that studies that sampled all births in a defined area

or defined date range had commenced much earlier (mean commencing years 1971 and 1975, respectively) than studies that adopted different sampling methods (mean commencing years 1994 and 1992, respectively) ($p < .001$). Cluster sampling and representative sampling for defined populations yielded higher initial response rates (94% and 90%, respectively) than studies undertaking other sampling methods (84% and 86%), but these differences were not statistically significant.

Data Collected

The nature of the data collected in longitudinal studies has undergone broad changes that have tended to reflect the preoccupation of the research community at the time the studies began. Studies prior to 1980 tended not to collect extensive data on the social and physical environments of children (such as neighborhood and schools), whereas studies developed after 2000 generally included these measures. Between 1950 and 1980 there was an emphasis on collecting data on cognition and antisocial behavior including criminal activity. These domains appear to be absent from studies beginning in the 1990s but are reappearing in some data collection waves in more recent studies.

Data on ethnicity, migration status, socioeconomic status, financial income, work skills, parents' education and age, and pregnancy outcomes were collected in most of the studies, whereas data on schools, neighborhoods, cultural beliefs and practices, social capital, religiosity, home environment, mothers' IQs and knowledge of health behaviors, parental practices and parent-child relationships, peer relationships, family history, and sudden infant death were collected infrequently (only three of the studies covered any of these aspects). There was also a lack of focus on beforebirth and intergenerational factors.

In addition to our summary of the international literature, it is important to note that a recent comprehensive review of longitudinal studies in Australia and New Zealand found that overall, although most areas of child development have been addressed independently in longitudinal studies, no single study in Australasia has addressed the interplay between the multiple domains that influence child development (Nicholson & Rempel, 2004). Particular areas identified where there is a paucity of information were "genetic factors; the influence of fathers, extended family, peers, child-care, school and rural environments; children's time use; and the needs of children with disabilities" (p. 94).

Discussion

The various longitudinal studies included in this comparative review have made important contributions to our understanding of the complexity of human development and helped inform social policy. However, many of these studies were initiated three to four decades ago. Since then, there has been increasing acknowledgement of the complex interactions between different domains of societal, family, psychological, and biological exposures. We have improved our knowledge of human development, in particular the importance of intergenerational factors (including at the biological level), the importance of the antenatal and perinatal periods of life-course development (including maternal nutritional, psychological, physical, and social status before and during pregnancy), and an acknowledgement of the enduring influence of the socioeconomic environment on all aspects of health and development.

In contrast, many of the existing longitudinal studies have tended to be fragmented by discipline or have drawn a false dichotomy between influences considered social or environmental and those considered biological, rather than recognizing the mutual influence that exists across domains (Nicholson & Rempel, 2004). There has also been a tendency to consider the trajectory of development of the individual in isolation from the environment in which he or she grows (Green, Hoogstra, Ingels, Greene, & Marnell, 1997; West, Hauser, & Scanlan, 1998). Efforts to incorporate that trajectory have been limited to considering development over a time frame that does not allow for influences over the entire life course from before birth through early life to adulthood, including cross-generational influences. Often, consideration of the temporal dimension is constrained by statistical techniques that favor proximal factors (such as adult obesity being associated with increased risk for Type 2 diabetes) as key determinants of any outcome and disregard the more distal factors (such as childhood nutrition and activity) in multivariate analyses because proximal factors tend to be so highly associated with the outcome being considered (in this example, diabetes). This relegates more distal factors (whether in time or context) to nonsignificant status (Stanley, 2001).

For example, McMichael (1999) highlighted the case of modern epidemiology being trapped by a preoccupation with proximal determinants in seeking causal theories and identified a number of different types of proximal constraints on research. These include a focus on individual-level risk factors at the expense of population-level influences on health (e.g., focusing on individual drinking behavior as the proximate cause of liver cirrhosis

and ignoring population factors such as alcohol production and advertising and socioeconomic influences on consumption) and adherence to a static as opposed to dynamic account of disease risk. This fails to acknowledge that changes in risk status evolve gradually over the life course of an individual and that early-life experiences play a significant role for a range of adult diseases, including cardiovascular and respiratory diseases and immune disorders (McMichael, 1999).

Failure to give due consideration to such distal factors means that underlying determinants of the proximal factors, and the causal pathways that have led to them, are often overlooked, and in particular that early-life influences and the rapidly changing sociocultural environment in which these factors have emerged are not taken into account. Ignoring these "upstream" influences is of little concern when the purpose of the analysis is to understand the associations between cross-sectional factors and developmental outcomes. However, it becomes problematic when the intent is to apply policy initiatives designed to modify those outcomes. A failure to acknowledge more distal factors in that case may lead to interventions that are of little value at best, and ineffectual or damaging at worst, because they fail to address the underlying and often complex multidomain causal factors, and the fact that the individual and the environments to which they are exposed (from the family to the wider society) are interdependent (Collins, 1991). Likewise, Stanley (2001) highlighted the limitations of "late-in-pathway responses" to societal problems and pointed to the potential advantages in terms of both cost and efficacy that could be realized by reorienting the focus of policy interventions to upstream causal influences, such as early interventions to combat criminal offending and targeting factors in a population that contribute to prematurity in newborns.

Moreover, there is an increasing acknowledgement among researchers of the need to shift our focus from a consideration of adverse or poor outcomes and recognize the need to understand the determinants of resilience in terms of factors that can counter the effects of an adverse environment and indeed to understand better the influences across the full range of normal early development (Rutter, 2005).

To ensure that a new longitudinal study can effectively inform future policy, it therefore needs to examine the development of children within their families across the life course and across generations, integrating the extensive knowledge that now exists in various disciplines and inspecting the layers of influence on a child in the wider physical and social environment. It should also incorporate the concept that a particular developmental milestone at one time point is both an outcome in its own right as well

as a potential mediating factor in the pathway between that time and an outcome at a later stage of development. In addition, it needs to focus on the range of normal development and identify mediating factors associated with resilience.

Concerning the nature of the data collected, it is proposed that a new longitudinal study of human development should include intergenerational factors (genes, environment, and epigenetic markers of their mutual influence). Emerging evidence suggests that understanding genetic potential alone without an acknowledgement of how that potential might be modified by environment factors in a dynamic two-way process limits understanding of differences in outcomes throughout life (Caspi et al., 2005). This indicates that any new study must include information to allow the nature of gene-environment interactions to be investigated further. Specifically, this calls for a disentanglement, or at least a better recognition of, what is familial continuity of behavior and environment across generations and what is inherited through a shared genetic makeup.

Moreover, it is now possible to consider gene-environment interactions for populations at a reasonable cost. Although the nature and timing of biological sampling need to take account of both financial cost and cost to the ongoing viability of the study in terms of possible attrition, advances in the collection of biological samples such as those recently trialled in the Millennium Cohort Study in the United Kingdom attest to the feasibility and cost-effectiveness of incorporating these analyses for a population of young children in any new longitudinal study (Bartington, 2006).

In addition to the inclusion of intergenerational factors, a new longitudinal study should also gather data during the antenatal period, collect sufficient developmental data to allow the investigation of the association between early-life factors and later-life status, and additionally collect data about the domains of influence, especially the family and the wider physical and social environments. It must consider children in the context of their environments, acknowledging the mutual interaction and influence that occurs between them. In particular, the way in which the family and extended kinships shape a child's development needs to be considered, together with the effects of the physical environment, socialization, friendships, and peer groups; social networks, neighborhood, and community; education; the socioeconomic environment; the cultural environment; prevailing social values; mass media communications and new technologies; and the broader political environment and policy (Barker, Forsen, Uutela, Osmond, & Eriksson 2001; Black, 2001; Jefferis et al., 2002; Richards, Hardy, Kuh, & Wadsworth, 2001).

Regarding the conceptual foundations of a new longitudinal study, a number of comprehensive models of human development have been proposed (Bronfenbrenner, 1979; Lerner & Castellino, 2002; Lynch, 2000). Although these models are composed of similar factors, such as the characteristics of individuals, the immediate family environment, and the broader social and economic environments, they have tended to draw different conclusions in terms of the relationships between these factors and how they influence developmental outcomes. In addition, these models portray development as a sequence of events in individuals' lives that start at birth and terminate at death and usually do not consider effects that may extend across generations. Given that these conceptual models usually determine the practical frameworks for conducting longitudinal studies, it is suggested that these need to be broadened to allow a longitudinal study to extend the period of interest beyond a single generation.

Furthermore, by exploring a range of conceptual frameworks within the analyses of any longitudinal study, testing a range of possible pathways, cause-effect relationships, and interactions, investigators may reduce the impact of their own biases. In addition, a theoretical model should have sufficient explanatory power to consider trajectories of development within different ethnic groups within a country as well as between them.

One disadvantage of longitudinal studies that needs to be mitigated is the "cohort effect." This is the phenomenon whereby individuals who are born during one period in time will experience similar macro-environmental effects (e.g., environmental, political, or societal phenomena), which means that it is difficult to establish the effect that these factors have at an individual level (Willett, Singer, & Martin, 1998). One way to overcome this cohort effect is to recruit cohorts from more than one age group. However, the disadvantage of this approach is that it may lead to a dilution in study power, unless numbers are maintained within (and effectively doubled across) each age group. There is also the issue that a cohort that is recruited some years after birth will lack crucial early-life data, so that it may also be difficult to establish how important the individual early-life factors are for this group. Another way to potentially overcome the cohort effect is to apply an accelerated longitudinal design (Miyazaki & Raudenbush, 2000), which incorporates a number of consecutive cohorts, so that over a number of years, the sample includes different cohorts that all began data collection at the same time in an individual's life course, but groups of individuals' data were initiated at several different time points. However, this method has the disadvantage of requiring a large total sample size, but it nevertheless provides a robust methodology to disentangle historic effects.

Finally, with the development and accessibility of software packages that allow the statistical testing of more complex models of development, it is now possible to answer more complex questions that test the "mediators" of developmental outcomes or "why" or "how" a particular outcome is related to earlier development and the "moderators" of developmental outcomes or "when" or "for whom" a developmental outcome is likely to occur. This type of information has the greatest potential to be useful for formulating policy that relates to interventions aimed at optimizing development.

In summary, we have increasing understanding of the complexity of child development through the convergence of information from a broad range of disciplines, including biology, genetics, developmental psychology, psychopathology, education, epidemiology, anthropology, and sociology. Furthermore, increasing numbers of links have been established between varying aspects of a child's early environment and later health, social, and psychological outcomes in adulthood. Although a wide variety of approaches have been used, longitudinal studies provide one of the most powerful methods of exploring stability and change in the health, behavior, and development of individuals over time.

Differences identified in this review between the types of data collected by earlier longitudinal studies compared with more recent studies not only reflect an inevitable "science period effect" but may also provide some insights for the design of future studies. For example, the inclusion of information on neighborhoods and communities in more recent birth cohort studies indicates a greater awareness of the importance of the broader social and physical environments for a range of health and development outcomes. Likewise, being cognizant of the interrelationships between developmental outcomes across different domains and recognizing that outcomes often share common developmental trajectories suggests that a longitudinal study starting in the 21st century should encompass the full range of domains of functioning across development. These include physical and mental health, cognitive capacity, educational attainment, social and cultural adjustment, conduct, and behavior. Other aspects that should be measured include children's capacity for resiliency in response to harsh life events and later engagement in risk-taking behaviors, such as substance use and abuse, sexual behavior, crime, and threats to personal safety. Studies should encompass a range of outcomes at every stage of children's lives and consider such things as the impact of risk and protective factors on life outcomes. They should systematically deal with each factor to determine the role it plays in a child's and, later, adult's life and any interactions within and across these variables.

Overall, children's development is subject to myriad influences from multiple sources, some of which, at best, are as yet only partially understood. Some influences are internal to children (e.g., the genetic endowment inherited from parents, children's innate temperaments); others are external, namely, the multiple environmental contexts to which children are exposed, which become progressively wider as their experiences of the world expand. A new longitudinal study should capture the uniqueness of the culture and the social characteristics of its country of origin while connecting with important, robust, international longitudinal studies. This will enable us to better understand which factors that affect children's lives are unique to specific contexts and which are universal. In this way, a longitudinal study can provide a robust platform for improving the prospects of future generations by informing current and future public policy.

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