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Critical considerations about the use of poverty measures in the study of cognitive development

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Developmental psychology and developmental cognitive neuroscience generated evidence at different levels of analysis about the influences of poverty on neurocognitive development (i.e., molecular, neural activation, cognition, behaviour). In addition, different individual and environmental factors were identified as mediators of such influences. Such a complexity is also illustrated through the many poverty conceptual and operational definitions generated by social, human and health sciences. However, to establish the causal relationships between the different factors of poverty and neurocognitive outcomes is still an issue under construction. Most studies of this area apply classic unidimensional poverty indicators such as income and maternal education. Nonetheless, this approach does not take into adequate consideration the variability of neurocognitive outcomes depending on the type of poverty measures, and the dynamic nature of changes during development. This creates a virtual underestimation of the complexity imposed by the involved mediating mechanisms. The scientific and policy implications of this underestimation include the risk of not adequately addressing children rights and developmental opportunities. This article proposes to explore such scenario, which is necessary for the reconsideration of the criteria used to analyse the influences of poverty on child development in general and neurocognitive development in particular.

Keywords: Childhood poverty; Cognitive development; Poverty measures.

INFLUENCES OF POVERTY ON NEUROCOGNITIVE DEVELOPMENT

The scientific study of the influences of poverty on cognitive development is an area with more than 9 decades of history, mostly approached by education and developmental psychology[1] (Bradley & Corwyn, 2002; Yoshikawa, Aber, & Beardslee, 2012). Until the 1980, most studies focused their efforts on the study of the developmental impacts of material and symbolic deprivations. Accumulating evidence indicates that during the first two decades of life, low socioeconomic status (SES) –a composite of income and parental education and occupation – is associated with declining scores on motor, emotional, cognitive and language development. In addition, studies found higher incidence of learning disorders, and decreased number of completed years of schooling (Bradley & Corwyn, 2002). Regarding the progression of these findings at later stages of development, some studies showed a reduction of the negative impact of poverty on IQ in adolescents. However, the same trend is not verified by analysing other measures of cognitive functioning, such as performance in mathematics and reading standardised tests, or attentional processing tasks (D'Angiulli & Lipina, 2012).

Since the mid-1990s different researchers began to apply neurocognitive behavioural paradigms to compare the performance of children with disparate SES. Then, technological advances in neuroimaging and behavioural-genetics allowed the incorporation of neural network, epigenetic and stress-regulation analyses. The main questions currently included in this neuroscientific agenda, focus on some topics already analysed in the fields of developmental psychology, cognitive psychology and health sciences. In particular, the focus is aimed at identifying effects and mechanisms of mediation of poverty at the behavioural level of analysis. Nonetheless, the intrinsically innovative aspect of the neuroscientific

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[1] In the context of this work, the term "poverty" refers in general to any form of material and symbolic deprivation. When necessary, each conceptual and operational definition of poverty is mentioned to address its specificity.

research efforts is that neuroscience allowed the beginning of these explorations in terms of elemental components considering different levels of analysis (i.e., molecular, neural networks, cognition and behaviour). Several studies verified the modulation of SES on attentional, inhibitory control, working memory, flexibility, planning, phonological awareness, self-regulatory, decision making, and theory of mind processing in infants, preschoolers, and school- and middle school-age children (for recent reviews on this topic see Lipina, 2014; Pavlakis, Noble, Pavlakis, Ali, & Frank, 2015; Urasche & Noble, 2016). In some of these studies, researchers have reported that the modulation of SES on performance is neither similar in all the administered measures, nor uniform at all ages. Conceptually, this implies that poverty would not necessarily generate homogeneous and continuous changes in neurocognitive processing.

A summary of the MRI evidence indicates that: (a) *parental nurturance* is associated with volumetric changes in hippocampus (a structure related to memory and learning processes) between ages 4 and 8 years, (b) *income* and *maternal education* are related to changes in brain growth and volumetric changes in frontal and parietal areas in children from 1 month to 4 years, and to volumetric changes in hippocampus and amygdala (a structure involved in emotional processing) between ages 4 and 22 years, and (c) *parental education* is related to changes in cortical thickness and volume in different cortical areas (i.e., prefrontal, parietal, occipital) between ages 4 and 18 years (Avants et al., 2015; Hair, Hanson, Wolfe, & Pollak, 2015; Noble et al., 2015; Pavlakis et al., 2015). This evidence also indicates that some of the changes in cortical thickness and volume of areas involved in cognitive control, language and learning processing were correlated with an income-cognitive and -academic achievement gap (e.g., Hair et al., 2015; Noble et al., 2015). In turn, evidence from fMRI studies shows (a) *SES* variability in the activation of the left occipito-temporal cortex during discrimination of rhymes and combination of sounds to form words tasks, and in the activation of prefrontal cortex during associative learning tasks in children with ages between 4 and 8 years; and (b) greater amygdala reactivity to threatening faces in orphans and adults who lived in low-*SES* homes as children (Pavlakis et al., 2015). Finally, EEG evidence shows (a) *SES* modulation of topographic maps of resting state in infants aged 6- to 9-months, and (b) the control of irrelevant information in tasks demanding inhibitory control and auditive attention processing in children and adolescents from 3-to 14-years old (Pavlakis et al., 2015).

MECHANISMS OF MEDIATION

Poverty is a multidimensional, relational and dynamic phenomenon, clearly illustrated through the many conceptual and operational definitions that disciplines such as economy, sociology, political science, epidemiology and anthropology have generated during the last 200 years. For example, in the second edition of the International Glossary of Poverty (Spicker, Álvarez Leguizamón, & Gordon, 2006), there are 194 terms referring to different aspects of poverty. Conceptually, these definitions could be grouped in a discrete number of semantic families or dimensions with specific components. For example, in the social sciences researchers proposed the following dimensions and components of poverty: (a) as a *material condition* in which needs, pattern of deprivations, and limited access to resources are the main components; (b) as an *economic circumstance*, in which standard of living, inequality, and the economic position are the main components; and (c) as a *social circumstance*, in which lack of basic security, lack of entitlement, exclusion, dependency and social class are the most referred components.

In general, the unidimensional approaches, attempt to identify how many people live in some type of poverty in terms of one indicator, or a set of indicators, that relate to an income or a non-income criterion. Examples of this type of indicators are (a) the *income measures* of absolute and relative thresholds, income-to-needs ratio, enrolment in poverty programs, basic family budgets, and socioeconomic status, and (b) the *non-income measures* of economic pressure, hunger, food insecurity, collective poverty, time dynamics, school poverty, social exclusion and basic rights violations (Minujin, Delamonica, Davidziuk, & González, 2006; Roosa, Deng, Nair, & Lockhart Burrell, 2005). In turn, multidimensional approaches simultaneously consider several indicators of basic needs and rights such as (a) *health* (i.e., nutrition, infant mortality), (b) *education* (i.e., years of education, school enrollment), and (c) *standard of living* (i.e., cooking fuel, sanitation, water, electricity, floor and goods) (UNDP, 2010).

The incidence of poverty using unidimensional or multidimensional measures could be significantly different. For example, the comparison between the World Bank income threshold for extreme poverty (i.e., USD 1,25 per day) and the Multidimensional Poverty Index (MPI) used by the UNDP results in significant and different incidences. In 2010, Ethiopia had an MPI of 90% and an extreme poverty of 39%; or India 55% and 42%, respectively. In both cases, lack of good health, education and standard of living were more insidious than income. But in the case of China (i.e., 12% vs. 16%) or Uzbekistan (i.e., 2% vs. 46%) the profile of needs and access to resources were the opposite of the previous examples. These findings highlight the need to design different types of interventions and policies for people living in income or MPI poor conditions (UNDP, 2010). Thus, different poverty measures identify different amount of poor people and needs.

The findings about the influences of poverty on neurocognitive development were identified applying three types of classic unidimensional measures: income, parental education and occupation. All of them refer to poverty in terms of the material and economic conditions of parents and the home. Importantly, unidimensional and multidimensional poverty measures do not explain the mechanisms through which poverty generates its influences on cognitive development. The experience of poverty involves a set of potential mediators that shapes a virtual ecology of protective and risk factors of cognitive development, involving multiple individual and environmental mediating factors at different levels of analysis (Beddington et al., 2008) (Figure 1). This set of factors can influence cognitive development in a positive (protective) or negative (risk) way. The contemporary literature on development psychology and cognitive neuroscience of poverty postulates the following as the most important protective/risk factors: (a) prenatal maternal health (i.e., nutrition, exposure to environmental toxic agents and drugs, environmental stressors), (b) perinatal health (e.g., prematurity, birth weight), (c) quality of early attachment; (d) environmental stressors at home and schools; (e) parenting and care styles; (f) early cognitive and learning stimulation at home, care centres and schools; (g) parental and teachers mental health; (h) developmental disorders; (i) family financial stress; (j) access to social security and health systems; community resources; (k) lack of social mobility; (l) social, political and financial crisis; (m) family, social and cultural expectations about child development (e.g., discrimination, stigmatisation, exclusion); and (n) natural disasters (Lipina, 2014; Bradley & Corwyn, 2002; Urasche & Noble, 2016; Yoshikawa et al., 2012). In addition, the evidence suggests that the influences of poverty on cognitive development are a function of the accumulation of risk factors, the individual susceptibility to environment and the duration of the exposure to deprivations (NICHD & Early Child Care Research Network, 2005; Wagmiller, 2015).

In particular, the evidence on mediation mechanisms indicates that both cognitive and language development are the two aspects that are highly vulnerable to the impact of poverty during the first two decades of life (Lipina & Colombo, 2009; Lipina, 2014; Urasche & Noble, 2016). The quality of language exposure and the presence of stressors in developmental contexts, would be two of the main mechanisms involved in the mediation of the influences of poverty on cognitive and language development (NICHD, 2015; Hackman, Gallop, Evans, & Farah, 2015). Moreover, the chronicity of adversities related to the experience of poverty can increase the allostatic load associated with the regulatory response to stress, which in turn increase the probability of premature cardiovascular and immune disorders in adulthood (Gianaros & Wager, 2015). In addition, because of the individual differences in susceptibility to the environment, developmental cognitive and self-regulatory trajectories could vary among distinct groups of children. Together, this evidence addresses the importance of specifying what aspects of the experience of poverty are associated with different factors that influence cognitive development (e.g., Lipina & Colombo, 2009; Lipina, 2014; Hackman et al., 2015).

Underestimating the use of appropriate definitions of childhood poverty in a developmental context of analysis, also implies dismissing the efforts and progress that economists have made during the last decade regarding the generation and use of alternative childhood poverty measures (e.g., Gordon, Nandy, Pantazis, Pemberton, & Townsend, 2003; Minujin et al., 2006; Roosa et al., 2005). For example, Minujin et al. (2006) proposed the following dimensions to approach the study of childhood poverty: (a) *deprivation*, related to the access to adequate basic social services and the satisfaction of the material conditions for a worthy life; (b) *exclusion*, related to any type of religious, ideological, class, gender or age discrimination; and (c) *vulnerability*, related to the lack of social capacity to cope with the threats and deprivations related to poverty (e.g., disasters, financial crises, wars). The measures of poverty used in the studies of neurocognitive development, are mainly focused in the *deprivation* approaches represented by the classic unidimensional measures. Approaches like those proposed by Gordon and Minujin, allow the exploration of other type of childhood poverty measures. This kind of efforts could contribute to the understanding of how different aspects of deprivation, exclusion and vulnerability are associated with the distinct forms of neurocognitive development.

Two multidimensional approaches that illustrate the importance of such efforts were developed. The first one was made by Gordon et al. at the University of Bristol, and proposes different levels of deprivation (i.e., absent, mild, moderate, severe and extreme) aggretated in eight dimensions (i.e., food, safe drinking water, sanitation facilities, health, shelter, education, information, basic social services) (Gordon et al., 2003). These researchers applied this framework to estimate the incidence of childhood poverty in Latin America. The same kind of approach was made by Adamson in European countries and the Pacific Islands (Adamson, 2012). The novelty of these approaches consists in applying conventional indicators of deprivation and rights to child populations. This implies the recognition that the deprivations that children face are not necessarily in the same dimensions that are relevant for adults (Lipina & Colombo, 2009). In addition, this approach contributes to promote the creation of new indicators as *access to information*, and new forms of aggregation of classic ones, but referred specifically to how children experience poverty.

The second approach was developed in the context of the Young Lives project at the University of Oxford. Its

aim is to study the influence of poverty on the development of a cohort of 12,000 children during their first two decades of life in India, Ethiopia, Vietnam and Peru. This project proposes three components of evaluation. The first one is quantitative and involves the administration of questionnaires and standardised tests to children, caregivers and members of the community. This approach is aimed at obtaining information on parental education and occupation, access to goods and services, changes in the family economy, daily activities of children, their cognitive functioning and general health, and the adult expectations of child development. The second component is qualitative and administers interviews and runs focus groups with children, caregivers and teachers. It is aimed at obtaining information of child well-being, exposure to risk and protective factors, and the experience of transitions between different stages of development. A third component is aimed at providing quantitative and qualitative information about child development to policymakers. It specifically proposes a virtual village that users can visit to learn about the everyday experience of children in their developmental contexts of socialisation and learning (e.g., personal stories, use of the time to play or study) (Barnett et al., 2012). The Young Lives project is innovative regarding how to implement combined measures based on diverse disciplinary theoretical frameworks, which accounts for how children experience poverty in different cultural contexts through the first two decades of development.

The approaches implemented by the researchers from the University of Bristol and the Young Lives projects, are an exception within the field of study of the impact of poverty on children's development. In this context, the inertia of using unidimensional criteria, based on income and basic needs of households and adults, persists. Thus, the indicators most commonly used do not consider the experience of poverty by itself, or the magnitude of the change in time of the ways in which children and adolescents experience the shortcomings and difficulties (Najman et al., 2009; NICHD & Early Child Care Research Network, 2005; Lipina, Simonds & Segretin, 2011). These approaches do not include the contemporary advances in developmental psychology and cognitive neuroscience regarding neural and cognitive plasticity, and the variability of temperament and susceptibility to the environment. Thus, despite the significant advances in many disciplines in the field of childhood poverty and cognitive development, it still needs more multidisciplinary integration to focus on the mediating mechanisms. The importance of the elucidation of these types of mechanisms resides in the possibility of identifying what neural networks are influenced by different type of poverty experiences. Consequently, this information has the implication of potentiality contribute to the design of interventions aimed at optimising cognitive and language development of families suffering poverty (Lipina & Segretin, 2015).

DEPENDENCE OF NEUROCOGNITIVE OUTCOMES ON POVERTY MEASURES

As mentioned, identifying factors of childhood poverty associated with specific effects on cognitive development is an area that continues to receive little attention, beyond its large theoretical and applied interest in improving our understanding of causal relations. Among the reasons that could explain this, are different theoretical, methodological and logistical difficulties associated with obtaining information on specific aspects of the daily lives of children and families; and barriers for financing interdisciplinary efforts. Currently, it is possible to identify two lines of research in this area. The first deals with the analysis of how the cognitive outcomes vary depending on the method used for poverty measurement (e.g., Duncan & Magnusson, 2012). The second analyses how the cognitive outcomes vary depending on the temporal dynamic of childhood poverty (e.g., Najman et al., 2009; NICHD & Early Child Care Research Network, 2005; Wagmiller, 2015). In addition, both approaches of research highlight the importance of identifying mediators, randomising the independent variables involved in the complex phenomenon of poverty (e.g., Duncan & Magnusson, 2012; Hackman et al., 2015), and generating information at different levels of analysis (Lipina, 2014; Lipina & Segretin, 2015).

As mentioned, studies on how the adversity involved in childhood poverty affects cognitive development mainly use measures based on the criteria of income, parental education and occupation. The Hollingstead scale, the need-to-income ratio and indicators of structural deprivation (e.g., unsatisfied basic needs) are typical examples of such approaches. The first measure is a scale that assesses household income along with levels of parental education and occupation. The second measure refers to household income that in general is determined by a national threshold, either absolute or relative. Finally, indicators of basic needs refer to parental educational and occupational backgrounds, safety of dwelling, overcrowding, sanitation, availability of drinking water and assistance of children to school, among others. These indicators are still useful in studies of childhood poverty and cognitive development, as they help discriminate differences at the level of cognitive performance and neural activation – as was illustrated in the first section.

However, cognitive outcomes associated with one or a combination of a set of poverty indicators are not necessarily the same, nor do they consider the temporal variations in the experience of childhood poverty. Cognitive development is the result of the interaction and integration of multiple biological and environmental

factors. Consequently, the causal relationships between SES components and cognitive development are complex and require adequate research designs that can transcend the level of correlation (Duncan & Magnusson, 2012). In the contemporary neuroscientific study of childhood poverty, these limitations have not yet been solved, given that correlational models based on income, parental education and occupation are still prevailing (Lipina & Segretin, 2015).

With respect to the variability of cognitive outcomes depending on diverse poverty measures, Duncan and Magnusson (2012) argue for the importance of considering the differential influence of the components of the SES construct, because each one represents a different resource that could influence cognitive development in distinct ways. However, researchers tend to underestimate the fact that income, education and occupational components of SES are based on different conceptual frameworks associated with cognitive outcomes. Furthermore, these components are highly correlated, and are assumed as stable across the first two decades of life and in their influences on child development. Finally, the causal role of each one of these components on cognitive development is not clear enough. In their paper of SES components, Duncan and Magnusson (2012) first address the conceptual diversity of the economic component, in which economic resources, income and mean wealth vary in their explanatory capacity to define the adversity that poor families face. For example, *family income* could be volatile across a family's life cycle, due to changes in parental employment or family structure, which implies that different children could have distinct income levels during their development. Additionally, the use of money to satisfy the nutritional and educational children´s needs is not necessarily homogeneous among and within poor families (Minujin et al., 2006). Regarding the specific impact of changes in family income on cognitive development, few studies have been able to implement appropriate designs that allowed for the manipulation of indicators as independent variables. One of the first studies in this area showed that the increase in household income in the experimental group was associated with improved academic performances (Maynard & Murnane, 1979). Other studies conducted more recently showed that improved parental employment and family income, was also associated with improvements in the academic performance of preschoolers and elementary school children (Duncan, Morris, & Rodrigues, 2011).

Higher parental *education* and *occupation* have been related to more nurturing parenting practices that in turn have been associated with better children's cognitive and academic outcomes during the first two decades of life (Bradley & Corwyn, 2002; Yoshikawa et al., 2012). However, the correlation between the level of parental education and children´s cognitive and school achievement could also be the result of the combination of parental individual characteristics, and children's individual differences in temperament and susceptibility to the environment (e.g., Lipina, 2014; Lipina & Colombo, 2009). In turn, parental *occupation* could be affected by dynamic transitions during the life cycle of children and families. In turn, this could affect in different ways parental skills and lifestyles, including parenting practices aimed at fostering children's learning and cognitive skills. Many studies have found correlations between parents completing years of schooling, parenting styles, home learning environments and children's cognitive and academic achievement (Duncan & Magnusson, 2012). However, the causal relationships of these associations remain unclear. As in the case of income, parental education and occupation are multifactorial constructs that involve many individual and environmental factors that have not been explored enough in terms of disentangling the potential causal mechanisms of each one.

Recently, Noble et al. (2015) examined the associations between different socioeconomic factors, brain morphometry and cognitive performance controlling for aspects of individual ancestral genetic variation in a sample of 1099 individuals between 3 and 20 years old. The results of their cross-sectional study indicated that parental education and family income separately accounted for individual variation in independent characteristics of brain areas considered critical for language, memory and cognitive development. Researchers found that family income was logarithmically associated with the brain surface area, in a way that small differences in income of the poorest individuals were associated with relatively large differences in surface areas. At the same time, in children from high-income families, similar income increments were associated with smaller differences in surface areas. Thus, income was more strongly related to brain structure in children from low-income families. Interestingly, parental education was linearly associated with brain surface areas so increments in the number of school years completed were associated with increments in surface areas. Beyond the design limitations to support causal relationships, the importance of these findings resides in the fact that different aspects of SES seem to be related in different ways to brain structural and functional development. Also recently, Hair et al. (2015) found similar associations between parental SES and children's structural brain development. In their longitudinal study, SES influences on brain structure were also concentrated among those children from the poorest backgrounds. Importantly, these researchers used mediation analysis to test whether the brain anatomical differences may contribute to explain the influences of poverty on academic achievement. They found that developmental differences in the frontal and temporal lobes explained between 15 and 20% of poor children's academic achievement. These findings

support the hypothesis of differences in specific brain regions rather than differences at the overall brain, and address the importance of support the efforts aimed at disentangling specific causal mechanisms.

TEMPORAL DYNAMICS OF POVERTY AND COGNITIVE DEVELOPMENT

As mentioned, income, education, occupation and many other aspects of family functioning and parenting are characterised by the overlapping of different dynamics of temporal change. The design of this type of research approaches, calls the need to use specific analytical methods aimed at allowing the consideration of simultaneous changes of events at different levels of analysis. In the last 10 years, different researchers have begun to contribute to such an effort. For instance, in 2005 the NICHD and the Human Development Early Child Care Research Network published a study in which they analysed the relationships of duration and developmental timing of poverty in a cohort of children from birth to 9 years of age. This study compared four income groups: never poor, poor only during infancy (birth-to-3 years of age), poor only after infancy (4-to-9 years of age) and always poor. Their findings showed that the condition of chronic poverty (i.e., always poor) was associated with lower quality of home environments and lower language and cognitive performance. Regarding the other groups, the study found more externalising and internalising behaviours than the chronic condition. In addition, authors observed that transitory experiences of poverty (i.e., birth-to-3, and 4-to-9 years of age) were related to adequate levels of maternal sensitivity independently of income limitations. In addition, mediation analyses indicated that poverty was partially associated with language and cognitive development through less positive parenting.

In 2009, Najman et al. published a study in which they analysed if family income between pregnancy and adolescence predicted changes in cognitive development in adolescence. After implementing a longitudinal design with a cohort of 7223 dyads, they observed that poverty experienced at any stage of development was associated with reduced outcomes. However, as in the NICHD study (2005), the chronic condition was more detrimental in cognitive outcomes than the other conditions of exposure to poverty. The same trend of results was verified even in a similar sociocultural context regarding behavioural problems. In this sense, Zachrisson and Dearing (2015) verified that in a population-based sample of 75,296 families from Norway, within-family changes in income predicted changes in externalising and internalising behaviours in children from 18-to-36 months of age.

Also recently, Hackman et al. (2015) have analysed the temporal dynamics of SES and the potential mediation influences of different components on cognitive development. These researchers explored 1009 individuals from the NICHD Study of Early Childcare, and found that family income and maternal education predicted planning performance in first graders, and that income predicted working memory performance in preschoolers. They also observed that the effects of poverty on cognition remained consistent through middle childhood, as was observed in the NICHD study (2005). In addition, the results of the mediation analyses support the importance and contribution of home nurturing skills on cognition (i.e., working memory and planning), and maternal sensitivity on the association between maternal education and planning performance.

In summary, these studies support the notion that the impact of childhood poverty on cognitive development depends on the timing, sequence and duration of exposure to deprivations. Mostly, this evidence was built applying poverty income-based indicators. Because different poverty indicators could be related to distinct aspects of the experience of poverty, the study of the temporal dynamics of the influences of poverty must involve other poverty measures or SES components in future studies. In such a sense, Wagmiller (2015) argues that the traditional indicator-based approach to analyse the temporal dynamics of childhood poverty is not adequate, because it does not consider simultaneously how the duration, timing and sequencing of economic deprivation during childhood influences outcomes in later stages of development. Instead of the indicator-based approach, this author proposes to explore a latent-class one, which would allow testing in a more adequate way the theories that emphasise the importance of the temporal dynamics of deprivation (e.g., if the duration of exposure to poverty is more significant than timing or sequencing).

DISCUSSION

Scientific knowledge on the impact of childhood poverty on cognitive development is a complex process that involves many conceptual and methodological issues. In this context of complexity, establishing how poverty influences child development has been an academic goal for many decades in the agendas of human, social and health sciences. However, (a) the concerns for identifying what aspect of cognitive development is more likely to be affected by what kind of experiences of poverty, and (b) how the timing of poverty during the first two decades of life might differentially influence cognitive development, are just an emerging issue in some the studies of childhood poverty.

In this area of study, the majority of approaches tend to apply unidimensional measures to identify vulnerable groups, without manipulating the different components of SES as independent variables. To stay in this area

of methodological comfort is becoming less possible, because contemporary developmental disciplines have begun to generate evidence at different levels of analysis. What this evidence suggests is that different types of adverse experiences generate distinct influences on cognitive development at least at molecular, neural activation and behavioural levels. This means that progress in the understanding of such influences, is also necessary to improve our comprehension of childhood poverty as a multidimensional phenomenon in terms of the experiences for children. An excessively reductionist representation of childhood experiences, could also implicitly raise the lack of adequate consideration of rights to identity, health and education (Adamson & Brennan, 2014).

Specific research needs

The influence that poverty has on the multiplicity of events and temporal dynamics that characterise the cognitive development, requires approaches that could integrate theoretical and experimental efforts from different disciplines. It is important to advance in the understanding of such influence in specific ways. For example, both cognition and SES change during the lifetime, so both should be studied together to understand the mediational pathways and temporal dynamics by which each component of SES is embedded at molecular, neural and cognitive levels, and how it influences children's learning skills (Lipina & Segretin, 2015). In this sense, economical approaches have begun to consider how early investments on cognitive and non-cognitive building capacities are related to adult health and labour outcomes (e.g., Campbell et al., 2014). Current studies of epigenetics and cognitive training, also begun to generate information suggesting that environmental changes can produce modifications in methylation markers even with intervention experiences of low and moderate intensity (Voelker, Sheese, Rothbart, & Posner, submitted). Another example is the analysis of temporal patterns and trends in family transitions and instabilities in terms of how they are related to cognitive development (Brown, 2012). Historiographic and anthropological approaches regarding representations of childhood and parenting processes, could also be of help to deepen the understanding of how different components of SES influence cognitive development.

In the contemporary neuroscientific study of childhood poverty, many of the mentioned limitations have not been solved yet, because most studies use correlational designs based on classic unidimensional measures. Innovation in this field requires the generation of research designs that could involve more diverse measures, and the exploration of their specific contributions. In addition, the next advances in the understanding of the links between childhood family economic resources and achievement will most likely come from improvements in our ability to measure and assess the consequences of family income instability for individuals (Wagmiller, 2015).

Inspiring academic experiences

With respect to the kind of efforts that these challenges impose, there are recent academic experiences that illustrate what opportunities and obstacles are necessary to consider the generation of efficient interdisciplinary collaborations. One of such examples is the experience of the National Scientific Council on the Developing Child. For the past decade, this effort has brought together an interdisciplinary group of researchers who have worked to translate complex research on early brain development into useful, accurate, credible and understandable language to nonscientists and policy makers (Center on the Developing Child at Harvard University, 2014). One of the projects that emerged from this effort was a systematic empirical collaboration among neuroscientists, developmental psychologists, paediatricians, economists, anthropologists, linguists and communications researchers. This interdisciplinary team was engaged in the iterative building of a core story of development by using metaphors (e.g., toxic stress) to explain complex scientific concepts (Shonkoff & Bales, 2011). The MacArthur Network on Socioeconomic Status and Health made a similar effort (Adler & Stewart, 2010).

In such interdisciplinary efforts, among the most significant determinants of success, were (a) the commitment of the researchers towards a collective effort that transcended the personal interests, (b) the practice of framing with patience and flexibility, (c) the adequate estimation of infrastructure needs to develop basic and applied interdisciplinary research, and (d) the conscience of being just a contributing piece of a larger landscape. It is important to consider that these types of collaborations, which require significant financial support to gather human and technical resources, are less usual to find in the periphery of industrialised countries (e.g., Africa, South Asia, and Latin America). Consequently, it should be ethically necessary to allow the inclusion of those countries and regions of the world in which childhood poverty is more prevalent, and to avoid consider them as a test bench.

There are other examples of genuine and productive interdisciplinary efforts. The Young Lives Project built integrated and combined quantitative and qualitative approaches considering different developmental contexts (Barnett et al., 2012). In 2014, the UNDP made a report on the role of the private sector on inclusive development, based on the work of researchers from different disciplines studying human poverty. This effort consisted

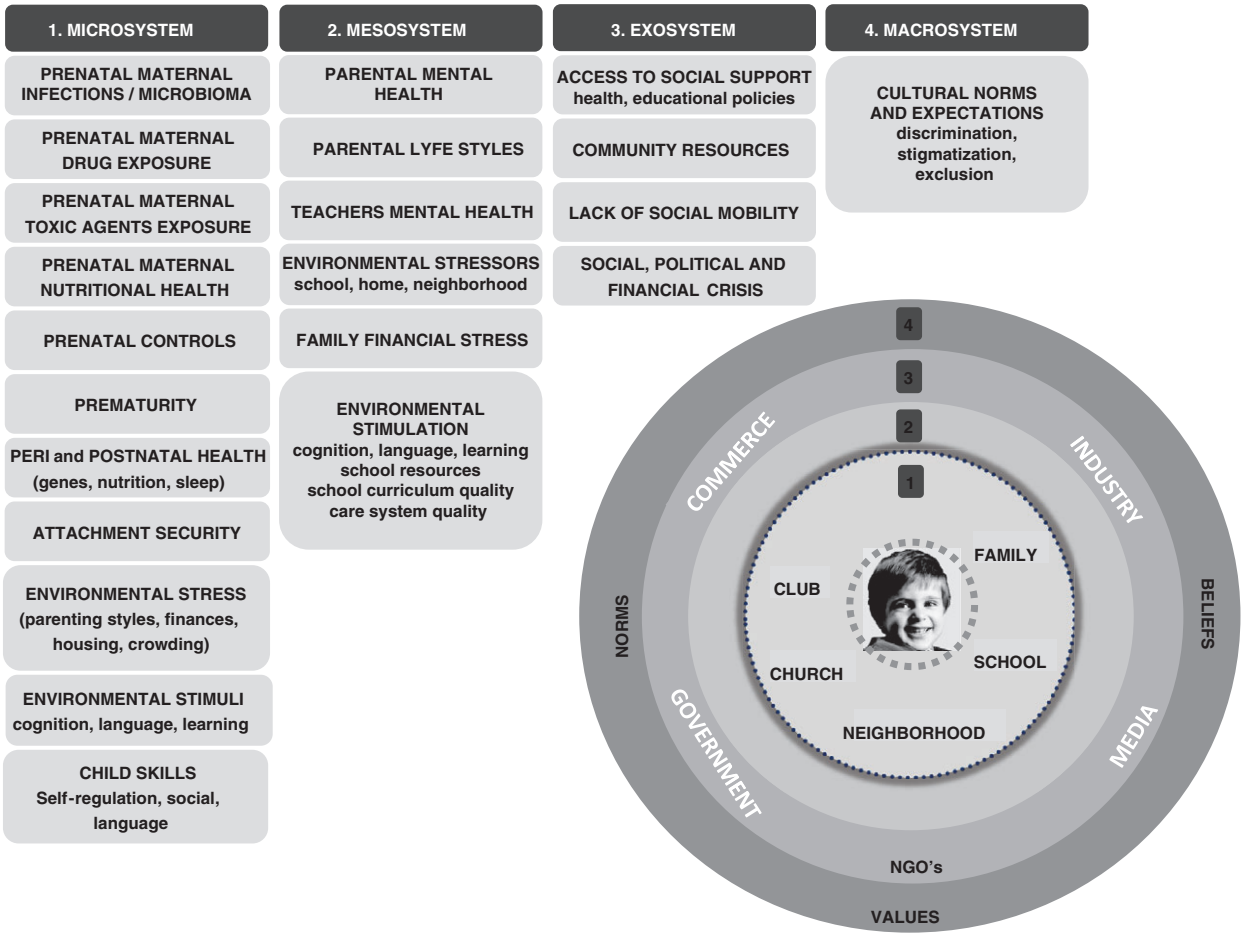

Figure 1. Diagram illustrating different sets of risk and protective factors that influence the neurocognitive development, classified by Bronfenbrenner's categories of developmental contexts. Embedding these factors in an ecological framework contribute with the identification of potential targets of interventions aimed at optimizing the neurocognitive development of vulnerable children.

of disaggregating several poverty components in terms of how they influence people's lives from childhood to retirement. Finally, the international Ethical Research Involving Children (ERIC) project, assists the world research community to understand, plan, and conduct ethical research involving children in any geographical, social, cultural and methodological context (Graham, Powell, Taylor, Anderson, & Fitzgerald, 2013).

Future directions

In summary, the challenge of improving our understanding about what aspects of childhood poverty influence the different attributes of cognitive development, requires the building of an interdisciplinary agenda that could progressively involve conceptual, methodological and technical innovations. In this respect, ecological and transactional considerations on child development and determinants should contribute to build a research agenda considering the following issues.

(1) Identifying protective and risk factors at different levels of analysis (e.g., molecular, neural activation, cognitive, behaviour), and in distinct developmental contexts (i.e., home, school, community, culture).
(2) Analysing the associations between different childhood poverty measures, their experiential implications, and the complex set of real and hypothetical mediators on neurocognitive development.
(3) Guiding the design of interventions and policies in terms of different systems and dimensions involved in the components and processes that characterise cognitive development. In this sense, it would be of interest to think in terms of building an *ecology of interventions*, what means the design, implementation and evaluation of actions aimed at influencing the different mediating mechanisms present in all the developmental contexts (Figure 1).
(4) Promoting financial priorities for government agencies and philanthropic foundations that support both basic and applied interdisciplinary research in child development.

(5) Establishing programs for professional training focused on child development as a complex phenomenon, to allow those interdisciplinary efforts aimed at progressively eliminating myths, prejudices, and conceptual dogmatisms.
(6) Influencing the public opinion, through the media, to promote collaborations between researchers and journalists, based on the consideration of child development as a complex and systemic phenomenon.

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