NEUROSCIENTIFIC STUDIES OF POVERTY
Inputs for the science of learning

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GLOBAL CONVERGENCE ON THE SCIENCE OF LEARNING
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DEFINITIONS, INDICATORS AND EXPERIENCE OF POVERTY

More than **200 definitions and indicators** of poverty (3% childhood)
DEFINITIONS, INDICATORS AND EXPERIENCE OF POVERTY

More than 200 definitions and indicators of poverty

The experience of poverty **differs among cultures**

**SOURCE:** Duncan et al., 2017; Gutierrez, 1972; Lipina, 2016; Narayan et al., 2000; Spicker et al., 2009.
DEFINITIONS, INDICATORS AND EXPERIENCE OF POVERTY

More than 200 definitions and indicators of poverty

The experience of poverty differs among cultures

**All poverty definitions refer to some kind of **loss of skills and rights**
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**Different measures could be associated with distinct outcomes**

*SOURCE:* Duncan et al., 2017; Gutierrez, 1972; Lipina, 2016; Narayan et al., 2000; Spicker et al., 2009.
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Different measures could be associated with distinct outcomes

The psychological experience of poverty is associated with stress, pain, and sometimes with impairments in the consciousness of being a person

SOURCE: Duncan et al., 2017; Gutierrez, 1972; Lipina, 2016; Narayan et al., 2000; Spicker et al., 2009.
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All poverty definitions refer to some kind of loss of skills and rights

Different measures could be associated with distinct outcomes

The psychological experience of poverty is associated with stress, pain, and sometimes with impairments in the consciousness of being a person

The experience of childhood poverty is not necessarily well represented in the classic indicators of income and SES

SOURCE: Duncan et al., 2017; Gutierrez, 1972; Lipina, 2016; Narayan et al., 2000; Spicker et al., 2009.
CO-OCCURRENCE OF ADVERSITIES

- High deprivation
- Low deprivation
- Threatening environments
- Deprived environments
- Normative environments
- Poverty
- Negligence
- Institutionalization
- Community violence
- Domestic violence
- Abuse

Different forms of stressful adversities affect the brain differently.

MULTIPLE DETERMINANTS OF SELF-REGULATORY DEVELOPMENT

- Positive influences
- Negative influences

**Source:** Beddington et al., 2008; Lipina, 2016.
MULTIPLE DETERMINANTS OF SELF-REGULATORY DEVELOPMENT

- Positive influences
- Negative influences

Prenatal

- Fetal programming
- Toxins
- Poor diet

Infancy

- Nurturing parenting
- Early development
- Stress

Childhood

- Learning stimulation
- Learning motivation
- Stigma
- Social exclusion

Adolescence

- Positive social relationships

Self-regulatory development

SOURCE: Beddington et al., 2008; Lipina, 2016.
MULTIPLE DETERMINANTS OF SELF-REGULATORY DEVELOPMENT

IMPACT OF POVERTY ON DEVELOPMENT

- Accumulation of risks
- Individual susceptibility
- Co-occurrence of adversities
- Exposure time to deprivations

SOURCE: Beddington et al., 2008; Lipina, 2016.
OVERVIEW

What is the evidence of the associations between poverty and NS?
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What are the hypothetical mechanisms that underlie these associations?
OVERVIEW

What is the evidence of the associations between poverty and NS?

What are the hypothetical mechanisms that underlie these associations?

What is the degree of change of these associations (interventions)?
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Future directions
NEUROSCIENTIFIC STUDIES OF POVERTY

PUBLISHED EMPIRICAL ARTICLES USING NEURAL TECHNOLOGY (N=85)

NEUROSCIENTIFIC STUDIES OF POVERTY

PUBLISHED EMPIRICAL ARTICLES USING NEURAL TECHNOLOGY (N=85)

80%

NEUROSCIENTIFIC STUDIES OF POVERTY

PUBLISHED EMPIRICAL ARTICLES USING NEURAL TECHNOLOGY (N=85)

NEUROSCIENTIFIC STUDIES OF POVERTY

PUBLISHED EMPirical ARTICLES USING NEURAL TECHNOLOGY (N=81)

Designs: 77% cross-sectional
Levels: 51% structural (MRI)
          (functional: fMRI, EEG/ERP, NIRS)
Learning: <5%
Countries: USA (82%)

BEHAVIOURAL LEVEL

FAMILY INCOME, MATERNAL EDUCATION, UBN

LOWER PERFORMANCE

Executive functions, metacognition, phonological awareness, and episodic memory - from infancy to adolescence

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MODULATION OF ASSOCIATIONS
Age, health, cognitive paradigm, length and type of poverty experience

Changes in growth rates and volumes of frontal and parietal cortices (1 mo to 4 yo)
STRUCTURAL LEVEL: GRAY AND WHITE MATTER

FAMILY INCOME, MATERNAL EDUCATION, QUALITY OF PARENTING

Changes in growth rates and volumes of frontal and parietal cortices (1 mo to 4 yo)

Volumetric changes in hippocampus and amygdala (4 to 22 yo)

SOURCE: Avants et al., 2015; Betancourt et al., 2015; Hair et al., 2015; Johnson et al., 2016; Mackey et al., 2015; Noble et al., 2015.
Changes in growth rates and volumes of frontal and parietal cortices (1 mo to 4 yo)

Volumetric changes in hippocampus and amygdala (4 to 22 yo)

Volumetric changes and thickness of prefrontal, parietal, and occipital cortices (4 to 18 yo)

SOURCE: Avants et al., 2015; Betancourt et al., 2015; Hair et al., 2015; Johnson et al., 2016; Mackey et al., 2015; Noble et al., 2015.
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Changes in fronto-temporal fiber integrity (FA) (12 to 24 yo)

**SOURCE:** Avants et al., 2015; Betancourt et al., 2015; Hair et al., 2015; Johnson et al., 2016; Mackey et al., 2015; Noble et al., 2015.
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Different patterns of corticostriatal connectivity depending on household or community SES (6 to 17 yo)

SOURCE: Avants et al., 2015; Betancourt et al., 2015; Hair et al., 2015; Johnson et al., 2016; Mackey et al., 2015; Marshall et al., 2018; Noble et al., 2015.
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Different patterns of corticostriatal connectivity depending on household or community SES (6 to 17 yo)

**Structural changes were associated with performance on executive functions, language and learning tasks**

**SOURCE:** Avants et al., 2015; Betancourt et al., 2015; Hair et al., 2015; Johnson et al., 2016; Mackey et al., 2015; Marshall et al., 2018; Noble et al., 2015.
FUNCTIONAL LEVEL: EEG/ERP

MATERNAL EDUCATION, PARENTAL OCCUPATION

Changes in topographic maps of different frequencies in resting state (6 to 9 mo)

SOURCE: Tomalski et al., 2013.
FUNCTIONAL LEVEL: EEG/ERP

FAMILY INCOME, MATERNAL EDUCATION

Changes in topographic maps of different frequencies in resting state (6 to 9 mo)

ERP changes during tasks of selective attention and inhibitory control (3 to 8 yo)

SOURCE: Stevens et al., 2014.
FUNCTIONAL LEVEL: EEG/ERP

MATERNAL EDUCATION

Changes in topographic maps of different frequencies in resting state (6 to 9 mo)
ERP changes during tasks of selective attention and inhibitory control (3 to 8 yo)
Changes in auditory brainstem responses to the speech stimulus (14 to 15 yo)

SOURCE: Skoe et al., 2014.
FUNCTIONAL LEVEL: fMRI

FAMILY INCOME, MATERNAL EDUCATION, PARENTAL OCCUPATION

Changes in the activation of occipito-temporal networks in task demanding phonological processing (5 to 6 yo)

SOURCE: Noble et al., 2006.
Changes in the activation of occipito-temporal networks in task demanding phonological processing (5 to 6 yo)

Changes in the asymmetry of inferior frontal gyrus in tasks demanding discrimination of rhymes between monosyllabic words and non-words (5 yo)
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Changes in the activation of prefrontal networks in a task of associative learning (8 to 12 yo)

SOURCE: Sheridan et al., 2012.
FUNCTIONAL LEVEL: fMRI

FAMILY INCOME, MATERNAL EDUCATION, PARENTAL OCCUPATION

Changes in the activation of occipito-temporal networks in task demanding phonological processesing (5 to 6 yo)

Changes in the assymetry of inferior frontal gyrus in tasks demanding discrimination of rhymes between monosyllabic words and non-words (5 yo)

Changes in the activation of prefrontal networks in a task of associative learning (8 to 12 yo)

Changes in the activation of prefrontal, parietal and other region in a working memory task in correlation with mathematics scores (14 yo)

SOURCE: Finn et al., 2016.
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Changes in the activation of prefrontal, parietal and other region in a working memory task in correlation with mathematics scores (14 yo)

History of childhood poverty (9 yo) was associated in adulthood to: (a) increments in amygdala and prefrontal reactivity, and (b) less connectivity between these networks to threatening faces

SOURCE: Javanbakht et al., 2015.
SUMMARY OF EVIDENCE

Poverty and SES are associated to a diverse set of NS structural and functional outcomes both in quantity and quality terms.
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The most sensitive systems seem to be those related to executive functions, language, learning and stress regulation.
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Partly, the psychological meaning of this evidence must still be elucidated.
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The evidence is mostly associative.

Partly, the psychological meaning of this evidence must still be elucidated.

It is also necessary to elucidate the global value of this evidence (cultural variability).
OVERVIEW

What is the evidence of the associations between poverty and NS?

What are the hypothetical mechanisms that underlie these associations?
MULTIPLE POTENTIAL MEDIATORS AND MODERATORS

DIFFICULTIES
- ADHD
- SLI
- Deafness
- Autism
- Sibling with SLI
- MAOA genotype
- SES
- Mother’s education
- Care style
- Sibling aggression
- Age

COGNITION
- Language
- Social Cognition
- Auditory processing skills
- Inhibitory Control
- Attentional Flexibility
- Working Memory
- Metacognition
- Self-esteem
- Self-efficacy
- Emotional Regulation
- Cognitive Regulation
- Action Regulation

FAMILY
- Oral arts storytelling
- Sociodramatic pretend play
- Music, Arts

SCHOOLS
- School Exclusion
- Parent Knowledge
- Stigmatizing
- School Resources
- Academic Achievement
- Teacher Training
- Teacher Style

EXECUTIVE FUNCTION

MULTIPLE POTENTIAL MEDIATORS AND MODERATORS

DIFFICULTIES
- ASB/CD
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- Sibling with SLI
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EXECUTIVE FUNCTION

Curriculum
- Oral arts storytelling
- Sociodramatic pretend play
- Music, Arts

MODERATION/MEDIATION: NEUROSCIENTIFIC PERSPECTIVE

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MODERATOR

Socioeconomic Status

Brain structure and function

Life outcomes
cognitive ability, emotional health, occupational success, etc.

MEDIATOR

Brain structure and function

MEDIATOR

Proximal factors
stress, linguistic and cognitive stimulation, parenting practices, prenatal care, toxins, nutrition, etc.

MEDIATOR

Socioeconomic Status

Life outcomes
cognitive ability, emotional health, occupational success, etc.

Socioeconomic Status

Brain structure and function

Mediators and moderators involve several individual and contextual factors at different levels of organization

- Early linguistic environment and stressors
- Structural and epigenetic changes
OVERVIEW

What is the evidence of the associations between poverty and NS?

What are the hypothetical mechanisms that underlie these associations?

What is the degree of change of these associations (interventions)?
### INTERVENTIONS INVOLVING NEURAL MEASURES

<table>
<thead>
<tr>
<th>Design</th>
<th>Controlled randomized</th>
</tr>
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<tbody>
<tr>
<td><strong>Sample</strong></td>
<td>n=141</td>
</tr>
<tr>
<td></td>
<td>Low-SES</td>
</tr>
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<td></td>
<td>3-5 yo</td>
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<td><strong>Intervention</strong></td>
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**SOURCE:** Neville et al., 2013.
INTERVENTIONS INVOLVING NEURAL MEASURES

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Cognitive and behavioral gains + Attentional ERP effect

SOURCE: Neville et al., 2013.
# Interventions Involving Neural Measures

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<td>6-9 yo</td>
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<td><strong>Intervention</strong></td>
<td>Reading training</td>
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*Source: Romeo et al., 2017.*
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**Reading gains**  
+ Increase thickening in OT/TP  
(low-SES + RD)

*SOURCE: Romeo et al., 2017.*
It is possible to modify the neural resources of children from low-SES homes through different intervention strategies. Changes are not the same for all participants (individual variability).
SUMMARY OF DEGREE OF MODIFICATION

It is possible to modify the neural resources of children from low-SES homes through different intervention strategies.

Changes are not the same for all participants (individual variability).

These changes have been verified at different ages during the first decade of life.
SUMMARY OF DEGREE OF MODIFICATION

It is possible to modify the neural resources of children from low-SES homes through different intervention strategies.

Changes are not the same for all participants (individual variability).

These changes have been verified at different ages during the first decade of life.

This potentiality of change questions the attribution of immutability of the impact of poverty on brain structures associated with self-regulation, reading and learning skills.
FUTURE DIRECTIONS

Neuroscientific evidence is of value and still preliminary to inform policy

Psychological meanings of findings
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Neuroscientific evidence is of value and still preliminary to inform policy

Psychological meanings of findings

Need to specify neuroscientific contributions

Mechanisms, timing of interventions, specificity of different adversities
FUTURE DIRECTIONS

**Neuroscientific evidence is of value and still preliminary to inform policy**

Psychological meanings of findings

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  - Mechanisms, timing of interventions, specificity of different adversities

Transcend the «inform policy» mindset
  - Participation of scientists: design, implementation, evaluation
  - Ethical and stereotypes issues
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Design of experiments: *among* disciplines (transdisciplinary mindset)

Ecology of learning
ECOLOGY OF HYPOTHETICAL MEDIATORS AND MODERATORS
SCIENCE OF LEARNING PERSPECTIVE

MULTIPLE MEDIATORS AND MODERATORS
SCIENCE OF LEARNING PERSPECTIVE

MULTIPLE MEDIATORS AND MODERATORS: SCIENCE OF LEARNING PERSPECTIVE

Future learning
- Open teaching – learning communities
  - Teacher training and professional development
- Developing the theoretical basis for new:
  - Tools – technologies
  - Techniques and processes
  - Environments
- Reflective practitioners:
  - Designing and testing new approaches
  - Researching, experimenting, innovating
  - Sharing ideas

Learning environment
- Education managers
  - Autonomy
  - Knowledge and skills
  - Affective and behavioural
  - Empowerment
- Teachers
  - Mentors
  - Caregivers
- Learners
  - Early school experiences
  - Early home experiences
  - Parental involvement

Individual learning
- Responsibility
- Flexibility
- Remote/informal learning
- Negotiate ever-changing demands

Learner identity
- Subjective opportunity structure
  - Attitudes
  - Aspirations
  - Autonomy
  - Motivation
  - Curiosity
  - Beliefs
  - Values

Home/family environment
- Social gradient
  - Income
  - Genes
  - Occupation
  - Status
  - Family size
  - Ethnicity
  - Migration and demographic change
  - Cultural dynamics and diversity

FUTURE DIRECTIONS

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Ecology of learning

Multiple learning theories
MULTIPLICATION OF LEARNING THEORIES

FUTURE DIRECTIONS

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Design of experiments: among disciplines (transdisciplinary mindset)

Ecology of learning

Multiple learning theories
  Application of common integrative conceptual frameworks
### FUTURE DIRECTIONS: Integrative frameworks

<table>
<thead>
<tr>
<th>Layer</th>
<th>Developmental phase</th>
<th>Layer name</th>
<th>Relevant discipline</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>Populations</td>
<td>Sociocultural</td>
<td>Education, social sciences</td>
<td>Individuals interact with other organisms, in ecological, sociocultural contexts in which information is processed and transmitted. This communication leads to group wide behavioural patterns, cultural norms and larger societal value sets (e.g. what should be included in curriculum?)</td>
</tr>
<tr>
<td>V</td>
<td>Organisms</td>
<td>Individual</td>
<td>Cognitive &amp; behavioural psychology</td>
<td>The complete complement of biological, psychological and emotional systems embodied in an individual person. Communication between individuals generates larger sets of behaviour which are typically measurable and conscious.</td>
</tr>
<tr>
<td>III</td>
<td>Organs</td>
<td>Cerebral</td>
<td>Systems, cognitive and behavioural neurosciences</td>
<td>Groups of neurons form connections with other neurons and non-neuronal cells to form larger networks. Patterns of network activity and excitability allow for the transmission and processing of information within and between specific organs in the body. This communication leads to specialised, occasionally unmeasurable and largely subconscious proto-behavioural patterns.</td>
</tr>
<tr>
<td>I</td>
<td>Cells</td>
<td>Cellular</td>
<td>Biology/pure neuroscience</td>
<td>Unspecialised cells can individually store, encode, process and transmit information by use of proto-neurotransmitters which float freely in the cytoplasm. Specialised neurons capable of storing, processing and transmitting information.</td>
</tr>
<tr>
<td>I</td>
<td>Matter</td>
<td>Physical</td>
<td>Physics</td>
<td>Information obtained from the external environment can be encoded, stored in, and occasionally transmitted between atoms, particles and complex molecules. Examples include machine learning (supervised and unsupervised) in computing devices.</td>
</tr>
</tbody>
</table>

**SOURCE**: Donoghue and Harvath, 2016.
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    Ethical and stereotypes issues

Design of experiments: *among* disciplines (transdisciplinary mindset)
  Ecology of learning
  Multiple learning theories
    Application of common integrative conceptual frameworks
    Networking
FUTURE DIRECTIONS: Networking

Neuroscience: brain circuits rewire with children’s cognitive development

Children’s brains rewire as their cognitive skills improve.

Perspective  | 14 December 2017  | OPEN
Towards AI-powered personalization in MOOC learning
Han Yu, Chunyan Miao [...] Timothy John White

Announcement
November 2017 research round-up
Read all about the latest science of learning research from around the world on our Community.

Article  | 04 December 2017  | OPEN
Dynamic, continuous multitasking training leads to task-specific improvements but does not transfer across action selection tasks
Angela D. Bender, Hannah L. Filmer [...] Paul E. Dux
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**Design of experiments: among disciplines (transdisciplinary mindset)**

Ecology of learning
Multiple learning theories
  Application of common integrative conceptual frameworks
  Networking

Innovation
FUTURE DIRECTIONS: Infrastructure for ecological approaches

Science of Learning Research Classroom, University of Melbourne

Child Development Center, Oregon State University
FUTURE DIRECTIONS: Validation of EEG portable methods

SOURCE: Pietto et al., in preparation.
FUTURE DIRECTIONS: Validation of EEG portable methods

SOURCE: Pietto et al., in preparation.
FUTURE DIRECTIONS: Individuality in the design of interventions

Case VS Trial

Sorted by amount of correct trials

SOURCE: Giovannetti et al., in preparation.
FUTURE DIRECTIONS: Algorithms for policy decision making

FUTURE DIRECTIONS: Algorithms for policy decision making

FUTURE DIRECTIONS: Algorithms for policy decision making (individuality)

“We have learned that the boundaries between academic disciplines offer important opportunities for progress”

Michael I. Posner, 2016