How and to what extent resilience relates to the neurobiology of individual differences and how this relationship can inform curriculum decisions: a heuristic analysis

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The present study aims at investigating how and to what extent resilience relates to the neurobiology of individual differences and how this relationship can inform curriculum decisions. To that end, a working definition of basic terms is necessary.

For the purposes of this study, resilience translates into bouncing back from stressful situations (Luthar, Cicchetti & Becker, 2000; Wright, Masten & Narayan, 2013) and lies at the interaction between potentiality and different scenarios. It plays a pivotal role in our adaption to life but does not constitute a permanent trait or ability (Karatsoreos & McEwen, 2013). Neurobiology of individual differences can be taken as the ontological aspects related to the development of the neural systems and mechanisms that shape individual trajectories throughout life (Martinez & Kesner, 1998; Thompson, 1986). Curriculum decisions are those taken by educational professionals, namely, teachers, coordinators, and directors, within the boundaries of their possibility and discretion that directly impact children's academic trajectory (Glatthorn, 1967).

Taken at face value, the guiding question seems to bring a fallacy of relevance (Copi, 1917), i.e., that which contains a complex question which covers up the assumption of a premise. In this case the premise would be that resilience is related to the neurobiology of learning differences. In fact, there is no fallacy here. It indeed is and the case that I will lay out below is also intent on demonstrating it. Inasmuch as this is assumed ad hoc for the purposes of education, I have taken the 'intelligent procedure' suggested by Copi (1917) and analyzed this premise from various standpoints. These are relative to the components of the premise and, to the extent of this research, will provide the input for the biological measures that will be taken from the population under study.

Previous body of research has shown that resilience and neurobiology of learning differences converge in respect to: neurobiological sensitivity to environmental conditions; differential effects in situations of support and/or adversity; conditional adaptation; (re-)activity to stress; and emotional regulation (Cicchetti & Curtis, 2007; Masten & Obradović, 2006) .

The interaction of the aspects above is reflected in different mechanisms that together operate in a feedback circle. It starts with the interaction between an individual's neurobiology and their environment. This interaction shapes the mechanisms that modulate an individual's response to stress. Such response generates effects over adaptive or maladaptive behavior that is in tandem with one's emotional processing. That processing is in turn mediated by executive functions (EF). How this individual develops such functions confers their degree of susceptibility to stressors or adverse effects, both internal and external, that will determine the array of learning differences seen in schools (Cicchetti et al, 2000; Curtis & Cicchetti, 2003; Ellis & Boyce, 2008; Ellis *et al.*, 2010; Obradović & Boyce, 2009; Obradović *et al.*, 2010; Seidman et al, 2001).

In this respect, I take that my ***demarcation criteria****, a critical point both for Lakatos (1980) and Popper (1972), states a clear set of observable and previously identified propositions (the empirical basis). In that way, the theory I have laid, in trying to weave together these strands of thoughts and propositions, can be questioned and scrutinized to inform the field further.*

To Lakatos (1980), the finite sample does not disprove a universal probabilistic theory. But as I see it, I am not attempting at disproving any of the points made so far. It is rather an attempt to improve the area by engendering ways of producing novel knowledge. However, if the points of contact - either supportive or suggestive as stated by Polya (1954) - or factual propositions, as Lakatos (1970) pose them, at the bottom are dislodged, I am aware that the whole construct that I have proposed here will need to be revised.

If I must analyse this approach under the light of sophisticated falsificationism, I believe that I am treading new routes with honesty. This is due to trying to look at the different aspects of this triangulation that I have set (resilience, neurobiology, schooling) from a different point of view; one that puts forward a new theoretical basis for the understanding of learning differences and that anticipates future problems in learning trajectory for students.

Thus, a successful learning performance is highly dependent on EFs as they impact children's social environments bidirectionally, i.e., they feed into and are, in turn, fed by them (Carlson, 2005). EFs are herein taken to mean ideas we can mentally deal with, such as thinking before acting; tackling new and unforeseen challenges; resisting temptations; and staying focused (Diamond, 2013). Taken together, they allow for the integration of thought and action (Shallice & Burgess, 1996).

The main EFs examined herein are inhibitory control, working memory and cognitive flexibility, which reflect the model for EFs mostly used in research (Miyake *et al.*, 2000). In this model, the three interrelated yet distinguishable cognitive functions can be described as: (i) *updating*, relative to the manipulation of information stored in working memory, (ii) *inhibition*, relative to the restraint from performing prepotent responses and to the resistance of distraction. i.e., inhibitory control; and (iii) *shifting*, relative to the reallocation of one's attention between different task sets, i.e., cognitive flexibility.

Such functions are in development from the age of eight to twelve months (Diamond, 2006) in a domain-general path that gets more specific and diverse in relation to components as a function of development (Davidson et al, 2006; Diamond, 2013), specially during preschool (Garon, Bryson, & Smith, 2008). They peak at around the second decade of life and tend to stabilize till erosion by normal aging and cognitive decline around the age of 65 (Brennan, Welsh, & Fisher, 1997; Espy, 1997; Kempton *et al.*, 1999; Klingberg, Vaidya, Gabrieli, Moseley, & Hedehus, 1999; Parkin, 1997; van der Molen & Ridderinkhof, 1997; Sowell & Jernigan, 1998; Stuss, 1992). Relevant to this study is the fact that EFs soar between ages four to six, which are within the scope of participants of the present study.

In developing their EFs to an optimal pace, children are able to mediate the effects of stressors and to adapt to the adverse conditions that they may face within the different environments they live by upgrading their resilience skills (Levitt & Eagleson, 2018). Such adverse conditions, which signal the activation of the stress mechanism, might be better known and acknowledged if biomarkers are in place, such as concentrations of cortisol.

Cortisol, is the final product of the hypothalamus-pituitary-adrenal (HPA) axis, a steroid hormone of the glucocorticoid class, which can be measured through concentrations of Adrenocorticotropic Hormone (ACTH) and Corticotropin-releasing Hormone (CRH) in the blood (Heim *et al.* , 2000). However, such measures are obtained in invasive ways (blood samples) and unreliable for children (Gunnar & Talge, 2008).

Another form of measurement would be by salivary collection which, due to its instability, has not been considered robust for an investigation of the effects of stress during longer time intervals (Short *et al.*, 2016). Among children - whose developmental phase, with specific implications on age, sleep/wake cycle and social context acquire high relevance - hair cortisol can provide a more interesting avenue of investigation into the neurobiology of coping mechanisms over time (Meyer & Novak., 2012; Sugaya *et al.*, 2020; Vanaelst *et al.*, 2012).

In fact, the measurement of cortisol by hair samples has recently acquired greater adherence. Such move in the investigation of stress levels happens via hair cortisol concentration (HCC), measured in picograms of hair strands (da Silva & Enumo, 2014). HCC reveals a picture of monthly cortisol sedimentation per centimeter of hair strand (Gray *et al.*, 2018; Groeneweld *et al.*, 2013; 2020). This framework allows for more robust and longer-term research - as during a school semester - on HPA axis activity (Hennesey *et al.*, 2020; Stadler *et al.*, 2017) especially for those in the early stages of development (Fuchs *et al.*, 2018).

Measuring HCC in the transition to formal schooling (from pre- to elementary school) could signal to educators how to best help those children most prone to suffering from a highly reactive profile in face of stressors that may adversely impact their academic trajectory. In the current study, we will measure HCC alterations in young children at two distinct point in their transition to formal schooling. When they first enter preschool, at around age four, and when they are about to leave preschool, at around age six.

At this point I figure that Popper's supreme heuristic rule is applied, i.e., I have employed a conjecture which has more empirical content than what has previously been done. In this respect, the positive heuristics of harnessing auxiliary hypotheses to sophisticate the initial proposition is in place. This 'protective belt' is set forth below.

Based on prior studies of cortisol in relation to this transition period (Bruce *et al.*, 2000; Groeneveld *et al.*, 2013; 2020), but finely tuned to the environment conditions of the present pandemic, we have proposed two different hypothesis. First, we hypothesized that children's HCCs at around age four are lower after school entry than before school entry (first measure). Also, we expect that these will be moderated by sex, socioeconomic status (SSE) and COVID-19. And we have formulated this hypothesis based on the social function of a school: one that can moderate the adverse effects of stressors in the environment and can positively influence children's optimal development.

For the second measure, i.e., at around age six, we formulated a second hypothesis: that children's HCCs will be higher before entering elementary school as a transition is usually a time for much anxiety among children and their families. This hypothesis will also be moderated by sex, SSE and the lingering effects of a year-long pandemic.

Besides the HCCs, there will be another means of measurement and analysis. This aims at providing a better understanding of how resilience may come into action after we have identified the cortisol response in children. Such measure maps out an EF component, inhibitory control, via action withholding.

A go/no-go task, measured in response time (RT), provides a lens into the development of this cornerstone ability – inhibitory control - in children. This development paves the way for some resilient mechanisms that individuals may differentially use during early schooling. These responses may be understood inferentially by EF tasks which are directly related to the success in learning throughout life (Biederman *et al.*, 2004; Morgan *et al.*, 2019).

In relation to the present study, the component of inhibitory control, more specifically of its subcomponent of motor withholding, will be the variable under scrutiny. That because it was shown to be a strong correlate of early math and reading skills for preschoolers (Blair & Razza, 2007; Bull & Scerif, 2001; Cartwright, 2012).

The choice for this component has also taken into consideration the fact that content, practice, performance and assessment of math and reading will be the focus of many curriculum decisions throughout one's scholastic life. Therefore, understanding how children react to early difficulties and manage stressors relative to these learning difficulties might show how they are applying their skills at a very early stage. This application might, in turn, signal to professionals how the school – in implementing changes to curriculum – may contribute to setting the course that these children may take for (un-)successful learning trajectories.

Among the population under study (four- to six-year olds), motor processes that have taken an earlier, protracted developmental pathway are under intense, exponential maturation (Diamond, 2000). Investigating the extent of their action withholding ability – a motor response so necessary for school related tasks and behaviors - seems to be adequate for the focus of this investigation (Piek *et al.*, 2008; Roebers *et al.*, 2014; Schachar *et al.*, 2007). This action withholding ability can be assessed through a go/no-go task. During such tasks, no-go-stimuli is presented at a less frequent rate that go-stimuli, thus requiring inhibition of a prepotent response tendency.

The hypothesis under study for this assessment is that there will be a positive association between RT and school adaptation (a proxy for a resilient response). The more consistent the RT in relation to inhibiting the prepotent motor response in the go/no-go task, the more adaptive is the child's response. This signals a neurobiological profile that is less prone to changes/stressors in the environment. Also, RTs will be cross analyzed in relation to possible modulation according to : (i) child's age (birthdays in the initial or final months); (ii) presence or absence of adverse psychosocial factors from family; and (iii) school's moderating effect as post-COVID-19 stress stabilization.

In this second round at examining the same conjecture under a different set of lens, I have delineated the hypothesis in such a way that falsifiability is not reduced but rather enhanced. According to Popper (1972), the proposition of auxiliary hypotheses *(under i, ii and ii above) in this case should be aimed at elevating the degree of falsifiability instead of reducing it. I believe that by framing the hypotheses (the testable part) in view of the different modulations it can be subjected to, I have compiled a set of criteria against which intersubjectivity can be trialed.*

Polya (1954) stated that in Science, as opposed to personal life, an inductive attitude is needed. This implies adapting one's beliefs to experience and that requires intellectual courage, honesty, and wise restraint. My research program is ambitious; I have attempted at bridging gaps that have for decades hampered the understanding of how human beings operate biologically as if cognition could be torn apart from morphological and/or psychological aspects along one's scholastic life.

I do not believe that this program will change things, but I do believe that it can add to the budding effort in the scientific community to build bridges with Education. For a long time, education professionals seemed to have adhered to the simplistic paradigm that a curriculum should always pave the way for any learning endeavor. As Kuhn (1972) points out, a paradigm is time-bound, i.e., it should serve the purposes of linking problems to solutions in models for as long as the scientific basis upon which they have been forged remains stable.

However, science is constantly changing, and humans are also evolving in the kind of learning they develop due to the environment. Educators seemed to have forgone of the fact that behaviors are rooted in our neurobiology and its interdependence on internal and external stimuli. Also, that learning, which is ultimately a behavior, needs to be resilient. This is a complex phenomenon which cannot be taken at face value. Perhaps a novel way of looking at neurobiological mechanisms that are intrinsically unique to each learner may better inform decisions that seem to be made on a couch of Procustes, i.e., without tailoring the curriculum to the needs of each learner.

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