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Developmental Origins of Chronic Physical Aggression: An International Perspective on
using Singletons, Twins and Epigenetics.

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Abstract

This chapter takes an international and historical perspective to discuss the present state of knowledge on the developmental origins of physical aggression and its implications for the prevention of chronic physical aggression. An increasing number of longitudinal studies of singleton and twins initiated at birth or during the first few years of life are showing that physical aggressions are more frequent in early childhood than at any other time during the life-span. Because chronic physical aggression generally starts in early childhood, preventive interventions during this period are much more likely to be effective and substantially decrease the costs of criminal behavior during adolescence and early adulthood. Unfortunately, most criminological studies on physical aggression development and prevention target the adolescent and adulthood periods and do not take into account gene-environment contributions. Early childhood studies are needed to identify early bio-psycho-social mechanisms that put individuals on a chronic trajectory of physical aggression from early childhood to adulthood. These studies can also help identify the preventive interventions that are most effective in preventing a life-course of crime and misery. Developmental criminology needs to take a bio-psycho-social intergenerational and life-span perspective as well as focus more systematically on females as the key target for intergenerational prevention of chronic physical aggression.

Keywords: Early childhood, children, adolescents, adults, life-span, physical aggression, crime, delinquents, criminals, prevention, bio-psycho-social mechanisms, genetics, environment, epigenetics, development, trajectories.

Introduction

From a historical perspective, the clearest and most influential statement of the social learning of antisocial behavior hypothesis was probably made by the famous citizen of the Republic of Geneva, Jean-Jacques Rousseau, in the first sentence of his book on education: “Everything is good as it leaves the hands of the Author of things; everything degenerates in the hands of man” (Rousseau, 1762/1979). Two centuries later, a laboratory observation of American children imitating an adult hitting a large inflated doll (Bandura, Ross, & Ross, 1961) had a similar influential impact on our understanding of the origins of human aggressive behavior. The study gave *experimental* evidence of children learning to aggress through observation of adult aggression. Two decades later the US Academy of Science Panel on Understanding Violent Behavior confirmed the popularity of this hypothesis by concluding that “Modern psychological perspectives emphasize that aggressive and violent behaviors are learned responses to frustration, that they can also be learned as instruments for achieving goals, and that the learning occurs by observing models of such behavior. Such models may be observed in the family, among peers, elsewhere in the neighborhood, through the mass media...” (Reiss & Roth, 1993). The social learning hypothesis was reinforced again 10 years later by the World Health Organisation in its report on worldwide violence with a very specific statement: “The majority of young people who become violent are adolescent-limited offenders who, in fact, show little or no evidence of high levels of aggression or other problem behaviors during their childhood” (Krug, Dahlberg, Mercy, Zwi, & Lozano, 2002).

This paper summarizes results from recent longitudinal studies on the development of physical aggression which question this widely accepted social learning

of aggression hypothesis, it highlights the importance of studying the very early development of human behavior and of replicating findings in as many cultures as possible, as well as at different historical periods to help establish external validity. These studies also highlight the importance of using an intergenerational bio-psycho-social perspective to take into account the role of the environment, of genes and of the biological interactions between environment and genes from conception onwards.

Development of Physical Aggression from Kindergarten to Adolescence

Longitudinal studies initiated in the 1970s and 1980s in different parts of the United States and Canada showed that the mean frequency of physical aggression declined during the elementary school years and adolescence (Cairns & Cairns, 1994; Loeber & Stouthamer-Loeber, 1998; Nagin & Tremblay, 1999). However, it was strangely assumed that, although most children decrease their level of physical aggression during the elementary school years, the violent offenders were initiating their frequent physical aggression during adolescence (Krug et al., 2002).

Canadian data on the development of physical aggression from a longitudinal study of elementary school boys in poor areas, initiated in the early 1980s, helped question this idea. A developmental trajectories analyses of physical aggression with teacher assessments of physical aggression yearly from age 6 years to 15 years (Nagin & Tremblay, 1999) confirmed that the frequency of physical aggression was generally decreasing from school entry to mid-adolescence, but also that the most physically aggressive adolescents were the most physically aggressive during their kindergarten year. The data analysis with a semi-parametric developmental trajectory approach did not

identify any significant group of children that increased their frequency of physical aggressions from 6 to 15 years, although, according to the social learning approach, one would have expected to identify such a trajectory with a longitudinal study based on a large sample (N = 1037) of males from 53 schools in low socioeconomic areas of Montreal.

In order to test the external validity of these findings, which came from a relatively homogenous gene pool¹ in a relatively small isolated culture within North America, we looked for similar data sets in other countries. We identified two studies from different cities in New Zealand and two studies from different areas of the United States. We also had access to data from a representative sample of female and male kindergarten children in the Canadian province of Québec. The resulting analyses compared six large samples of males and five large samples of females (all singletons) in different regions of three different countries. Results (Broidy et al., 2003) replicated the main finding of the Montreal study of boys from low socioeconomic families: there was no evidence of a significant group of children that showed low levels of physical aggression at school entry and significantly increased such levels during the elementary school years. Similar results were reached also later in Italy (Di Giunta et al., 2010).

Development of Physical Aggression from Infancy to School Entry

Once it was clear that the frequency of physical aggression decreases from kindergarten to adolescence, the following developmental question was obviously “when

¹ To control for cultural effects, the boys were included in the longitudinal study only if both their biological parents had low levels of education, were born in Canada and their parents' mother tongue was French. Thus a homogeneous White, French-speaking low SES sample was created (Nagin & Tremblay, 1999: 1183).

do children learn to aggress if they are already at their peak in frequency during kindergarten?” To answer that question data became available from studies of singleton social behavior development, including physical aggression, with large birth cohorts during the 1990s in different countries including Canada, Great Britain, Norway and the United States. The results were similar across nations, and they clearly showed that humans start to use physical aggression towards the end of the first year after birth when they have acquired the motor coordination to push, pull, hit, kick, etc. (Alink et al., 2006; Côté, Vaillancourt, LeBlanc, Nagin, & Tremblay, 2006; Hay et al., 2011; Naerde, Ogden, Janson, & Zachrisson, 2014; NICHD Early Child Care Research Network, 2004; Tremblay et al., 1999; Tremblay et al., 2004). Furthermore, in an intensive US observational study of children’s response to the delay of gratification (getting a reward) in a laboratory situation from 18 to 48 months, it was observed that with age children reduced the frequency of their angry responses to the delay of gratification while they increased the frequency of calm responses (Cole et al., 2011).

An analysis of philosophical writings over the past two and a half millennium clearly shows that Rousseau’s success with his social learning of evil hypothesis is probably due to the fact that he broke rank with a long tradition of philosophers who had understood that the human child learns to control his aggressive instincts and that those who do not learn to control themselves become adults who behave like children (see Hobbes, 1647/1998). For example, in his brief article *On Education*, the great Dutch humanist Erasmus wrote in 1529: “We should be especially careful with our children during their first years. For at this stage their behaviour is guided by instinct more than by reason, so that they are inclined equally to good and evil –more to the latter perhaps – and

it is always easier to forget good habits than to unlearn bad ones. This truth was already known to pagan philosophers and caused them great perplexity”. One thousand years earlier, the North African Saint-Augustine had indeed use physically aggressive behaviour of infants as an example of the “original sin” (St. Augustine, 401/1960)². Augustine was in fact following the footsteps of Aristotle, a thousand years earlier, who wrote in his book on Politics (Aristotle, 1943): “as the body is prior in order of growth to the soul, so the irrational is prior to the rational. The proof is that the anger and will and desire are implanted in a child from their very birth, but reason and understanding develop as they grow older.”

Conclusions from the Studies on the Developmental Trajectories of Physical Aggression from Infancy to Adolescence

From the available international data on the development of physical aggression during childhood and adolescence summarized in the previous two sections, we can conclude that: (i) the vast majority of preschool children use physical aggression; (ii) the vast majority also learn with age to use other means of solving problems; (iii) some need more time than others to learn; (iv) girls learn more quickly than boys; (v) most of the cases of chronic physical aggression during adolescence were chronic cases since early childhood; (vi) attempting to use retrospective information to determine “age of onset” of physical aggression is futile because recall of a specific age is unreliable and in all cases, it will have been in early childhood.

² “Thus it is not the infant’s will that is harmless, but the weakness of infant limbs... These things are easily put up with; not because they are of little or no account, but because they will disappear with increase in age. This you can prove from the fact that the same things cannot be borne with patience when detected in an older person” (St. Augustine, 401/1960: pp. 49-50).

Early Bio-Psycho-Social Mechanisms for the Development of Chronic Physical Aggression

Research on the development of chronic physical aggression during early childhood using singletons has helped identify early environmental risk factors for trajectories of chronic physical aggression (Tremblay, 2010). Most of these risk factors can be identified prior to or at the start of pregnancy: mothers' behavior problems during adolescence, mothers' poor education, mothers' first pregnancy at a young age, mothers' depression, mothers' smoking during pregnancy, dysfunctional relations between mother and father, and low family income.

There is also good evidence from twin studies (quantitative genetics) conducted in the UK and Canada (e.g., Arseneault et al., 2003; Dionne, Tremblay, Boivin, Laplante, & Pérusse, 2003; Lacourse et al., 2014), as well as molecular genetic studies in the US and New Zealand (Enoch, Steer, Newman, Gibson, & Goldman, 2010; Fergusson, Boden, Horwood, Miller, & Kennedy, 2011), that genetic factors are strongly implicated in differences of antisocial behavior observed during early childhood. For example, genetic factors accounted for 80% of the variance in the frequency of aggression by Canadian twins at 18 months of age (Dionne et al., 2003). These Canadian twin studies and molecular studies with singletons also indicate that the genetic effects on aggression change over time (Pingault et al., 2013; Lacourse et al., 2014) ().

New evidence from gene expression studies (epigenetics) suggest that the numerous environmental risk factors related to the mother may start to have their impact on the child's developing brain and eventual self-control problems during fetal life, and

soon after, through their impact on gene expression. The first study to point in that direction was done with rats a decade ago in a Canadian laboratory (Weaver et al., 2004). We now have good evidence that the quality of the prenatal environment impacts the expression of genes that are essential for the normal development of our brain (Meaney, 2010). Offspring of women who have a history of behavior problems, who smoke, drink alcohol, and are exposed to abuse, are at high risk of gene expression modifications during the prenatal period that can lead to brain development problems that will affect the ability of the child to gain control over his emotional reactions.

Recent longitudinal studies of males and females from low socioeconomic environments in Canada show that those with chronic physical aggression problems during childhood have different gene expression profiles and different brain functioning profiles when compared to individuals from the same deprived economic background who did not have aggression problems (Guillemin et al., 2014; Provençal et al., 2013; Wang et al., 2012). In another recent study in Canada (Checknita et al., 2015) results on epigenetic differences between male prisoners with a diagnosis of “Antisocial Personality Disorder” (ASPD) and matched males without a criminal history showed that DNA hypermethylation of the MAOA (Monoamine Oxydase A) gene promoter contributes to the downregulation of the MAOA gene expression and correlates with elevated whole-blood serotonin levels in offenders with ASPD. This mechanism could explain the simple MAOA gene-environment statistical interaction effect on antisocial behaviour that was found a decade ago in a New Zealand sample (Caspi et al., 2002). From this perspective it may not be the gene sequence itself that is at fault, but the effect of the environment on the expression of that gene. These two different interpretation lead to different

perspectives on the prevention mechanisms needed to be put in place as well as their timing. Other studies have shown that children from low socioeconomic environments present a greater risk of brain development problems, but only if the family environment has serious deficits (Nelson, 2013). For example, Luby et al. (2013) showed, with a longitudinal study that American children growing up in poverty, that they had reduced volumes of their hippocampus mainly if they were living in a family environment that lacked support and was hostile, while a Canadian study (Lupien et al., 2011) and a Romanian study (Mehta et al., 2009) showed that poor maternal care in early childhood leads to an enlarged amygdala volume in children.

Implications for the Prevention of Chronic Physical Aggression

Epigenetic and brain development mechanisms are especially important for effective prevention of chronic physical aggression because they provide a powerful explanation for early maternal and family effects on brain and behaviour development from early childhood onwards. Furthermore, DNA methylation changes over time can be used as markers of environmental effects during development, including assessment of preventive and corrective intervention effects.

The above discussion of early risk factors has shown that trajectories of chronic physical aggression are specifically related to maternal characteristics: maternal age at first pregnancy, history of behaviour problems, education, smoking, depression, coercive parenting, etc. This can easily be understood from the traditional environmental perspective: a poor early environment has an impact on the developing foetus and infant. Mother characteristics turn out to be more important risk factors than father

characteristics because the former carry the child in their womb during foetal life and are more involved in care giving during early childhood. However, the exact bio-psycho-social mechanisms linking poor quality environment to disorganized behaviour remain unclear, to say the least.

The epigenetic story provides a basic mechanism that has the advantage of being parsimonious, testable, and promising for prevention. The most fascinating aspect of this mechanism is that it provides an environmentally based explanation of intergenerational transmission for physical, mental and social disorders, which involves genes but is not genetically transmitted. These mechanisms are still far from being clearly understood, but they provide a challenging alternative perspective to the traditional gene vs. environment and gene by environment statistical interaction hypotheses. For example, a recent study in Singapore of 237 new born and their parents showed that their DNA methylation profile could differentiate their ethnic origin and was correlated with a number of prenatal environmental characteristics such as maternal smoking and depression that have been associated with the development of antisocial behaviour problems (Teh et al., 2014).

Conclusions

From the studies presented above we come to the same conclusion that was reached 65 years ago by Lucien Bovet (1951), the Swiss child psychiatrist, in his WHO report on juvenile delinquency, based on his review of American and European studies: the prevention of antisocial behavior should start by supporting girls who have behaviour problems and will become the mothers of the next generation of delinquent boys.

Bovet reached that conclusion from the available research at the time which showed the intergenerational patterns of juvenile delinquency (e.g., Glueck & Glueck, 1950; Healy & Bronner, 1926). The research reported above simply describes mechanisms by which the intergenerational problems may be transmitted. There are clearly genetic effects involved in these mechanisms, but the life style of the parents, especially the mothers during pregnancy has a biological impact on gene expression which in turn has an impact on brain development, the main instrument a child has to learn to use alternatives to physical aggression. If his brain is handicapped by the environmental effects on gene expression (epigenetic effects) during pregnancy, and if his parents also lack self-control, it is easy to understand that the child will have serious difficulties in gaining the self-control that is needed to learn to use alternatives to physical aggression.

We thus conclude that developmental trajectories of physical aggression from early childhood to adulthood are the consequence of the biological interactions between genetic and environmental endowment. The early environment is created by the parents' own developmental history and has a major impact on physical aggression development through its impact on gene expression and brain development. Mothers are likely to have the greatest impact on early gene expression because her life style during pregnancy has direct biological impacts on his development. As children grow older their peers also have an impact on learning to control physical aggression. Most of these risk factors can be identified prior to or at the start of pregnancy: mother's behavior problems during adolescence, poor education, first pregnancy at a young age, depression, smoking, dysfunctional relations with the father, and poverty.

Although sex of the child, a genetic characteristic, is by far the most robust predictor, we need to completely revisit our thinking about prevention of chronic antisocial behavior: males are much more affected, but females should be our prime target to prevent a new generation of males and females with chronic antisocial behavior. It is clear that the perinatal bio-psycho-social environment that impacts gene expression is very largely related to pregnant women's health status and lifestyle. This epigenetic perspective suggests that successful prevention of antisocial behavior may be easier to achieve by ameliorating the early environment rather than chasing bad genes (Bernet, Vnencak-Jones, Farahany, & Montgomery, 2007; Gluckman, Hanson, Cooper, & Thornburg, 2008). It is important to emphasize that mothers, fathers and children should not be blamed for the genes and the environment they inherit at conception. The main argument here is that we need to give intensive support to at-risk parents from conception, at the latest, to help children achieve better control over their behavior and prevent other generations of victims from the intergenerational transmission of behavior problems.

Afterthoughts on the Recent Twin-Epigenetic Controversy in Criminology

At the first American Society of Criminology meeting I went too in 1987, I heard the late David Rowe courageously trying to convince skeptical criminologist that they needed to take into account biological variables, and that the twin and sibling study methodology was an important asset to achieve this aim. Soon after, David and I were invited to participate in a MacArthur foundation study group to plan coordinated large longitudinal studies on criminal behaviour, which would start at birth and collect bio-

psycho-social data. A series of papers and a book were published highlighting new methodological approaches, including the study of twins and siblings to understand environmental and genetic contributions to the development of antisocial behavior (Tonry et al., 1991). The project was eventually implemented in Chicago (Project on Human Development in Chicago Neighborhoods, see Bingenheimer, Brennan, & Earls, 2005; Sharkey & Sampson, 2010). Although the aims of the study were to examine “the development of delinquency, criminal behavior, and substance abuse from birth to young adulthood” it focussed largely on the assessment of neighborhoods and essentially excluded the collection of biological data to avoid public reactions to the association of biology, crime and minorities. Furthermore, the developmental origins part of the study was limited to the assessment of less than 500 children a few months after birth, at 3 years and finally at 7 years. The twin and sibling design was not implemented.

The Chicago project on Human Development is probably the best example of the enormous historical resistance of the social sciences, and criminology in particular, to take an integrated bio-psycho-social approach to the study of criminal propensity. Although the project was very generously funded and the planning stage included the best experts on the association between early childhood, biological determinants and later criminal behavior, it ended up putting most of the resources and focus on the neighborhood determinants of juvenile and adult antisocial behavior.

Over the past twenty years the study of developmental origins of physical and mental health problems has made huge progress by integrating the advances in genetic and epigenetic research. Longitudinal studies of singleton and twins from birth to adulthood have made important contributions to numerous fields of research, and will

continue to do so by integrating epigenetic studies. As an example, we first used singletons followed from birth to adulthood to study the association of chronic physical aggression with DNA methylation and brain development (Guillemin et al., 2014; Provençal et al., 2014) (Wang et al., 2013). We are now using Australian, Canadian and Irish identical twins to study the impact of prenatal and postnatal environmental adversity on the development of gene expression and brain development (e.g., Lévesque et al., 2014). Identical twins are indeed a natural experiment to study the effects of the environment while controlling for genetic effects. The ultimate experimental design to study preventive and corrective interventions with regards to antisocial behavior from early childhood to adulthood is to randomly allocate identical twins to different treatment conditions while monitoring gene expression as well as brain and behavior development (Tremblay, 2013).

From my perspective there are two important reasons why the prevention and treatment of antisocial behavior has not progressed as much as the prevention of physical and mental health over the past half century: First, because there is strong resistance to new methodologies, especially if they involve taking into account biological factors; second, methodologies are often adopted as ideologies. Using different methodologies to address a given problem should be more productive than long and aggressive debates on “which method is Criminology’s Holy Grail?”

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