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Sex Differences in Physical and Indirect Aggression: A Developmental Perspective

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Abstract Males generally use aggression more often than females. However, the magnitude of difference between the sexes varies widely according to the type of aggression that is considered, and according to the developmental period studied. Taking a developmental perspective, this paper reviews research that compares the progression of physical aggression (predominantly used by males) with indirect aggression (predominantly used by females) among males and females. Existing empirical evidence indicates that most children cease to use physical aggression during the course of childhood, but that a minority fails to do so. This group is comprised of children with high, stable levels of PA and is mostly male. Overall, most children use low levels of IA, but there is one group that uses this type of aggression with increasing frequency. This group is mostly female. Importantly, the differences between the sexes are not stable over time. Rather, while the gap between males and females is present during preschool years, it widens considerably during childhood and preadolescence. A review of hypotheses based on evolution, biology and social learning provides critical insight into the origins and development of sex differences in aggression over the life course. We conclude by arguing that violence in males may be effectively reduced through early, sustained intervention with high-risk mothers.

Keywords Sex differences · Physical aggression · Indirect aggression · Development · Antisocial behaviors

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Sexual dimorphism is one of the most robust findings in studies on aggression. Men generally use aggression more than females, when direct forms of aggression (e.g., physical or verbal) are considered. Conversely, females generally use aggression more often than males, when indirect forms of aggression are considered (e.g., psychological, social) (Archer 2000). However, both sexes use both direct and indirect forms of aggression. What then, are we referring to when we discuss "sex differences in aggression"?

In their broadest expression, sex differences range from being nearly *absolute* to being simply *statistical*. *Absolute* or sex-dichotomous differences refer to aspects of development which are distinctly characteristic of one sex. Differences may be readily identifiable at a physiological level, the most obvious examples being sex-specific genital organs (e.g., the uterus or penis). Height and muscle mass differences constitute *statistical* differences: on average, males are taller and have greater muscle mass.

Sex differences in acts of aggression are often a matter of degree. But for some specific types of aggression, sex differences are dramatic. For instance, among primates, infanticide is a type of homicide almost exclusively committed by females (Hrdy 1999). It may also be said that important sex differences exist in the contexts and motives associated with acts of aggression. For instance, women are as likely as men to use physical aggression in the context of intimate relationships (Archer 2000; Moffitt et al. 2001). Males, however, are much more likely than women to use physical aggression with strangers (Archer 2000). Nonetheless, there is a great deal of overlap between the sexes in the distribution of aggressive behaviours. In this paper, we review evidence that measures the magnitude of sex differences between two common forms of aggression: physical aggression and indirect aggression. We take a developmental perspective to examine a major variable in the magnitude of the sex differences during the life-course: the age at which sex differences are measured. In the second section of the paper, we present possible explanations for sex differences in the development of aggression and conscience. The roles of evolution, biology and social learning are considered. The paper concludes with a discussion of possible implications for preventive and corrective interventions.

The term *physical aggression* (PA) is used in this paper to refer to physical acts that are directed at another person and that may cause bodily harm (e.g., kicking, pushing, hitting; e.g., Cairns et al. 1989; Straus and Gelles 1990; Tremblay 2000). We use the term *indirect aggression* (IA) to refer to social manipulations (such as spreading rumours, excluding peers, betraying trust or divulging secrets) that are circuitous in nature and that can be socially harmful (Crick 1995; Crick and Grotpeter 1995; Lagerspetz et al. 1988). It may be noted that our use of the term IA (e.g., Björkqvist et al. 1992a) is synonymous with both the term *social aggression* (e.g., Cairns et al. 1989; Galen and Underwood 1997) and the term *relational* aggression (Crick and Grotpeter 1995).

PA: Sex Differences in the Development of Physical Aggression

Owing to a paucity of relevant longitudinal studies, information on the comparative development of human and non-human, male and female physical aggression is limited. Longitudinal studies with data on PA during the first years of life-the period at which PA is most prevalent-are all the more scarce. However, over the past decade, data from longitudinal studies initiated during preschool years and comprising assessments of PA have started to become available.

Several studies have demonstrated that boys and men use PA more frequently than do girls and women after school entry (Broidy et al. 2003; Cairns et al. 1989; Tremblay et al. 1996).

It has been less clear, however, whether boys are more physically aggressive in their preschool years. In their often-cited review of the literature, Keenan and Shaw (1997) posited that girls and boys exhibit similar levels of aggression during toddlerhood and that the rate of externalising behaviours starts to diverge around 4–5 years of age (Keenan and Shaw 1997). Indeed, some studies reported no sex differences in externalizing behaviours (Hay et al. 2000) or in conduct problems (Keenan and Wakschlag 2000) among preschoolers. By middle childhood, evidence of higher levels of physical aggression and conduct problems among males has been well established (Maccoby 1998; APA 1994). But recent studies also provide evidence that boys are already more physically aggressive than girls during their preschool years (Baillargeon et al. 2007; Côté et al. 2007, 2006; National Institute for Child Health Development -[NICHD]- Early Childhood Care Research Network [ECCRN] 2004; Tremblay et al. 1996, 2004).

For instance, Baillargeon et al. (2007) noted that sex differences had already emerged by 17 months, according to reports from mothers regarding specific acts of PA. In their study, boys were found to be twice as likely as girls to hit another child frequently. Alink et al. (2006) found boys to be slightly more physically aggressive than girls at the age of 12 months, although the effect size was small and the sex difference was not significant (d=0.18). However, significant sex differences were observed among older infants. More specifically, the sex differences among infant groups between 24 and 36 months of age ranged between 0.30 and 0.37. This study suggests a gradual increase in the magnitude of the sex differences in PA over the course of early childhood. Observational studies also showed substantial sex differences by 3 years of age (Hay et al. 2000; Sears et al. 1965; McGrew 1972). Thus, these studies suggest that, as previously proposed by Keenan and Shaw (1997), there appears to be a gradual emergence of sex differences in PA during preschool years. However, sex differentiation appears to begin earlier than what was originally proposed: i.e., during infancy (12 months) as opposed to near the end of preschool years (around 4–5 years of age).

Is the next developmental period, from school entry to pre-adolescence, also characterized by a continued increase in the divergence of male-female PA levels? The results from Archer's meta-analysis (2000) suggest that this is the case, at least when self-report data are considered. According to a summary of cross-sectional studies of self-reported PA, the mean effect size of the sex differences increased from d=0.26 (95%CI=0.20–0.31) during middle childhood (6–11 years) to d=0.35 (95%CI=0.28–0.41) at 11–13 years.

In sum, the evidence reviewed suggests that the PA sex gap gradually widens during childhood. However, this hypothesis does not provide any insight into the direction of changes. For instance, is the increasing sex gap attributable to a faster increase in PA among boys? Or is it related to a faster decrease in PA among girls? For a more precise evaluation of these possibilities, let us turn our attention to longitudinal studies that offer repeated assessments of PA and data on both sexes.

Recently, two longitudinal studies provided information on the developmental patterns of PA and the magnitude of sex differences from toddlerhood to middle-childhood (NICHD-ECCRN 2004) or pre-adolescence (Côté et al. 2006). These studies provided information on the changes in the magnitude of the PA sex gap, but they also distinguished between atypically elevated PA and normative levels of PA by modeling the development of PA with group-based developmental trajectories.

First, in our work with the National Longitudinal Survey of Children and Youth [NLSCY] we, Côté et al. (2006) modelled the development of PA among a large (n=10,658) nationally representative sample (in Canada), using data on males and females, from ages 2 to 11. Using a group-based trajectory methodology, we found that at the earliest assessment, in toddlerhood (age 2), PA was already part of most children's behavioural repertoire.

Typical developmental trajectories then declined in the frequency of PA (see Fig. 1). More specifically, the moderate-desister group represented 52.2% of the sample group children, who used PA occasionally in toddlerhood and desisted to infrequent use by age 11. The low-level desister group represented 31.1% of the sample, who used PA infrequently in toddlerhood and virtually not at all by age 11. A third group of children, representing 16.6% of the sample, was also identified, showing high, stable levels of PA when compared with their peers. This particular developmental pattern was atypical in the sense that it was distinct from the general declining and lower levels of PA exhibited by the rest of the sample.

The overall pattern of the results from this Canadian study was similar to that found in the US-based NICHD-ECCRN (2004) study, in which most children were also found to exhibit low-to-moderate levels of PA, with declining trajectories between toddlerhood and middle childhood. Similarly, the NICHD-ECCRN study results showed that a proportion of children exhibiting higher levels of PA during toddlerhood maintained relatively high trajectories throughout childhood. These two studies replicate earlier analyses of PA trajectories during the elementary school years and high school in Canada, New Zealand and the US (Brame et al. 2001; Broidy et al. 2003; Nagin and Tremblay 1999), but show that the same phenomenon is found in preschool years.

In the NLSCY, comparisons between boys and girls indicated that boys were 1.67 times more likely to follow a high and stable PA trajectory. Thus, between 2 and 11 years of age, boys tended to be more physically aggressive than girls. Similar sex differences were found among the participants in the NICHD-ECCRN 2004 study. More specifically, boys were more likely to follow a moderate (the second-highest Odds Ratio (OR): 1.68) or a high (OR: 2.89) PA trajectory, when compared with the (two) lowest trajectories. Together, these results suggest that the PA sex gap is already substantial in toddlerhood, since girls are more likely to follow low, desisting PA trajectories and boys are more likely to follow high,

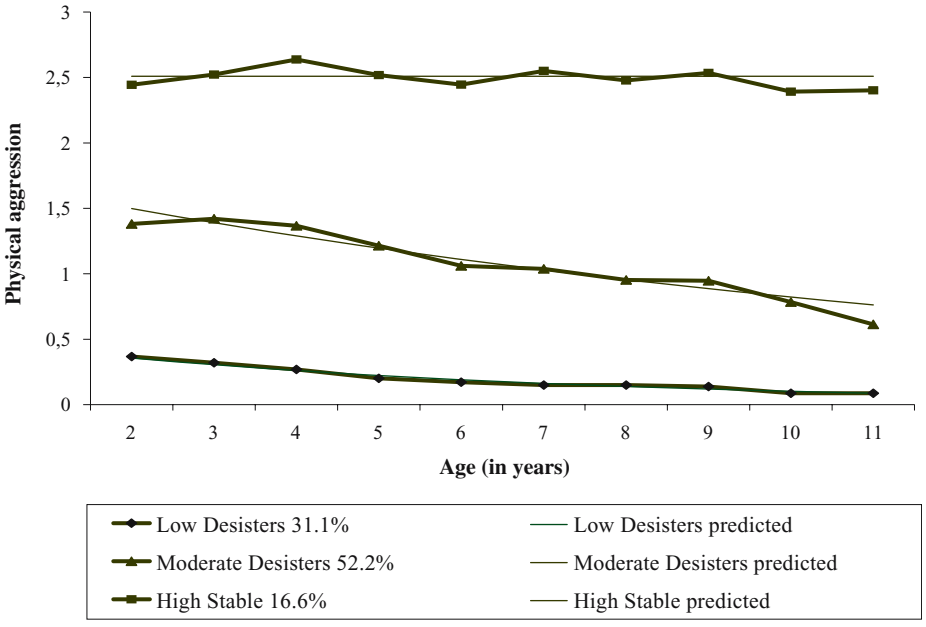

Fig. 1 Developmental trajectories of physical aggression. From Côté et al. (2006)

stable PA trajectories. Overall, the male-female dichotomy found in this study was consistent with previous studies on sex difference in various forms of social behaviour (Archer and Côté 2005; Kochanska et al. 2000; Maccoby 1998; Tremblay et al. 2004), and with other studies which show that a much larger proportion of males than females follow a chronic trajectory of PA or a persistent life course trajectory of antisocial behaviours from an early age (Moffitt et al. 2001). In fact, the sex gap grows wider as more extreme antisocial behaviours (measured for frequency and severity) are considered.

The results of these trajectory analyses illustrate the usefulness of examining the magnitude of sex differences while accounting for the heterogeneity in the population- i.e., the existence of distinct groups. Indeed, these studies suggest that the widening of the PA sex gap over the course of childhood may be attributed to the relatively large proportion of boys who follow a high-level PA trajectory from their early infancy. Because most children cease to use PA, the fact that more boys than girls follow a high, stable trajectory instead of a low, declining trajectory appears to account, in large part, for the widening PA sex gap during childhood. This said, patterns of change in the growing gap between the sexes may also be masked when the heterogeneity in the population is not accounted for, or when cross-sectional data is used.

What about the sex differences in PA after childhood? Archer's meta-analysis (2000) indicates that the sex gap continues to widen at puberty, increasing from 0.26 (CI: 0.20–0.31) during middle childhood to 0.35 (CI: 0.28–0.41) at 11–13 years and 0.37 (CI: 0.35–0.38) at 14–17 years (Archer 2000). The widest gap during the life course is observed in adulthood, between the ages of 18 and 30 years of age (d=0.66–CI: 0.62–0.69–between ages 18–21 and 0.60–CI–between ages 22–30). These are peak years for the development of a constellation of characteristics which enable young men to successfully compete with other males (Archer and Côté 2005). Studies of violent crime and of homicides show that there is a distinct peak in males between 20 and 29 years of age (Daly and Wilson 1990; Courtwright 1996; Quetelet 1984). After these peak years for physical violence, the sex gap decreases to 0.25 (CI: 0.20–0.30) between 30 and 55 years of age (Archer 2000).

Therefore, existing evidence suggests that boys and girls differ little in their use of physical aggression during infancy, although boys exhibit slightly more physical aggression than do girls as early as the first year of life (Alink et al. 2006). The PA sex gap widens over the life-course, reaching a peak in adulthood between ages 18 and 30, when males use PA more frequently than do females. This increasing gap between males and females is attributable to the fact that adult females are generally more successful than adult males in regulating and inhibiting their physically aggressive behaviour.

IA: Sex Differences in the Development of Indirect Aggression

Over the past 3 decades, there has been a growing interest in the empirical study of forms of more covert, indirect aggression (IA). Since the study of IA is more recent than that of PA, less information is available concerning its development (Vaillancourt 2005). As mentioned earlier, IA refers to socially manipulative and circuitous forms of aggression (Lagerspetz et al. 1988). IA may be physically manifested in acts such as destroying another person's property. Verbal manifestations of IA may include deliberately attacking a person's social standing, partaking in malicious gossip or practising social ostracism (Archer 2000). IA does not usually involve direct confrontation, and due to its covert nature, is more difficult to measure than PA. In this paper, we focus on the interpersonal use of indirect aggression, manifested in behaviours such as betraying trust, divulging secrets, encouraging others to dislike another person, befriending a person as a form of revenge, making derogatory

remarks about a person behind his or her back, and telling others to avoid a person (Lagerspetz et al. 1988; Underwood et al. 2001). There has been much discussion about the extent to which social (Underwood 2003), relational (e.g., Crick and Grotpeter 1995) and indirect aggression (Bjorkqvist 2001) are distinct constructs. In a recent meta-analysis, Archer and Coyne (2005) concluded that these two types of aggression are essentially part of the same construct. In this paper, our use of the term *indirect aggression* is in line with that of Feshbach's pioneering work (1970).

Lagerspetz et al. (1988) were the first to carry out a systematic study of indirect aggression using peer ratings, a particularly well suited method for measuring covert forms of aggression. They documented considerable sex differences in IA during adolescence, which were corroborated in later studies (Björkqvist et al. 1992a,b). The magnitude of the sex differences in IA, and even the direction of the sex differences (i.e., males of females using more IA), appears to depend on the source of information (e.g., self-report, vs peer report vs parent report), the type of sample (e.g., school, college student, community) and the developmental period at which IA is measured (Archer 2000). In this paper, our primary focus lies in the latter of these three factors.

Several cross-sectional studies have shown that females are already more indirectly aggressive than males during their preschool years (Crick et al. 2004; Ostrov and Keating 2004; Tremblay et al. 1996). There is evidence that the IA sex gap gradually widens over the course of childhood and adolescence (Archer 2000; Björkqvist 1994; Björkqvist et al. 1992a,b). This finding is born out when IA is reported by peers. Archer (2000) reports no sex differences in children under age 11 years, but reports subsequent negative effect sizes, indicating a more frequent use of IA by females. More specifically, the effect size was -0.13 (95% CI: -0.19 -0.06) for studies including children from ages 12–13 years and -0.35 (95% CI: -0.46 -0.24) for studies including ages 14–17 years (Archer 2000). Interestingly, there is evidence that the IA sex gap narrows substantially during adulthood, to the point where males and females do not significantly differ in their use of IA by age 22 years (Archer 2000).

Recent studies explain the widening gap between the sexes by the fact that girls are more likely to follow rising IA trajectories during middle childhood than boys (Côté et al. 2007; Vaillancourt et al. 2007). Whereas girls' use of PA gradually declines over the course of childhood, the use of IA appears to increase in frequency with age. In fact, while the peak frequency of PA appears to occur in toddlerhood, the peak frequency in IA is likely to occur in adolescence. Vaillancourt et al. (2007) modelled the development of IA in children from ages 4 to 10 years and identified 2 groups of children who followed distinct IA trajectories. More specifically, most children (65%) rarely used indirect aggression from ages 4 to 10 years, while others (35%) used indirect aggression with increasing frequency during this period of development. The latter group is mostly comprised of girls (57.5%). Figure 2 presents the trajectories of IA.

PA + IA: Sex Differences in the Joint Development of Physical and Indirect Aggression

Björkqvist et al. (1992a,b) modelled the development of PA and IA during childhood and adolescence. These authors hypothesized that children's use of aggression is normative, and that the different types of aggression used are determined by specific developmental stages. For instance, children's first expressions of aggression are typically manifested through PA. Hence, this hypothesis predicted that toddlers would use PA to fulfil their needs, since they are limited in their capacity to express themselves verbally. As children mature cognitively,

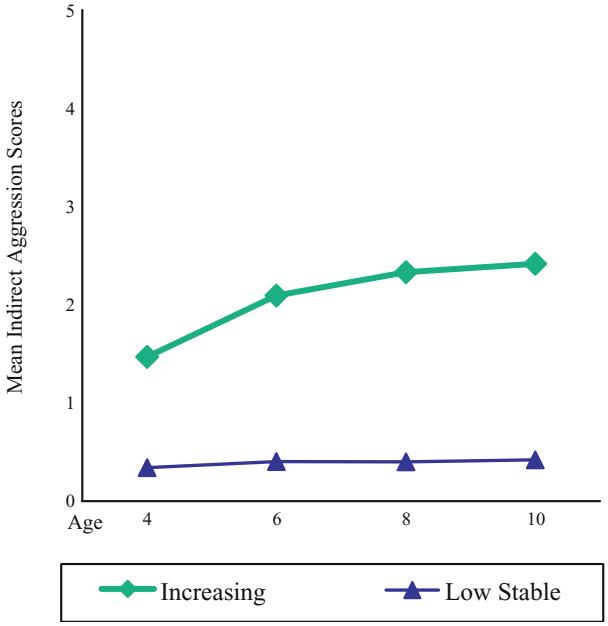

Fig. 2 Developmental trajectories of indirect aggression. From Vaillancourt et al. (2007)

they are expected to reduce their use of direct (physical or verbal) forms of aggression and to increase their use of indirect forms of aggression. It was further hypothesized that IA represents a more sophisticated form of aggression, one that would be used more often by older rather than younger children (Björkqvist 1994; Björkqvist et al. 1992a,b; Lagerspetz et al. 1988). Thus, this model predicted that direct, physical forms of aggression would become less prevalent as childhood progresses, while indirect, relational forms of aggression would become increasingly more common during middle childhood. In other words, children are expected to switch from using PA to using IA.

In order to test Björkqvist et al. (1992a,b) developmental hypothesis, PA and IA development need to be examined jointly. While most studies have examined the exclusive use of PA and IA, recent empirical evidence on the joint development of PA and IA provides some support for Björkqvist et al.'s hypothesis. Using a person-oriented approach, NLSCY, Côté et al. (2007) studied children's exclusive and joint use of PA and IA during their preschool and elementary school years. The 1183 study participants were 2 years of age when the initial assessment took place and were followed over 6 years. Children followed either low or declining PA trajectories, but 14.6% followed high, stable trajectories. Approximately two-thirds of participants, followed low IA trajectories (67.9%), and one-third (32.1%), followed high, rising IA trajectories. If we combine both PA and IA groups, most children (62.1%) exhibited desisting levels of PA and low levels of IA. A significant proportion of participants shared moderately desisting PA trajectories and rising IA (14.2%) trajectories. Among 13.5% of the participants, there were high-level trajectories in both forms of aggression. Virtually no children scored high in one form of aggression and low in the other. Significant sex differences were found: Girls were 2.66 times more likely than boys to follow a trajectory of desisting PA and rising IA. These results suggest that PA and IA sex differences between boys and girls diverge increasingly

as childhood progresses, with PA in boys being more likely to remain on a high-level trajectory, and PA levels in girls being more likely to decrease as their use of IA increases.

Summary of Sex Differences in Physical Aggression and Indirect Aggression

Existing empirical evidence indicates that most children cease to use physical aggression over the course of childhood, but that a minority fails to do so. This group is mostly comprised of male children with high, stable PA levels. Overall, most children of both sexes use low levels of IA, but one group of children uses this type of aggression with increasing frequency. This group is mostly female. Significantly, the differences between the sexes do not remain stable over time. Rather, while the gap between males and females is present during preschool years, it widens considerably during childhood and preadolescence. In the following section, we will review three hypotheses based, respectively, on the fields of evolution, biology and social learning to provide critical insight into the origins and development of sex differences in aggression.

Hypotheses on the Development of Sex Differences in Aggression

Why are boys generally more likely to exhibit PA and girls generally more likely to exhibit IA? And why does the magnitude of the differences between the two sexes vary over the life-course? Broadly, three hypotheses should be considered: First, some sex differences in aggression may be a manifestation of *evolutionary* traits (e.g., age- and gender-related survival mechanisms in nature). Second, individual *biology* may also play a part (e.g., genetics, hormones and anatomy). Third, *social learning* factors (e.g., socialisation or societal norms) may also constitute crucial factors. Some characteristics in aggression may be attributable to evolutionary adaptation (e.g., defenceless babies scratching and biting), others to biological processes (e.g., the presence of a uterus or penis), whereas others may be a matter of social learning and custom (e.g., girls nurturing their dolls). However, many sex differences, including differences in aggression, appear to be influenced by all three factors. The evolution hypothesis examines the contexts and conditions that have established some of our hard-wired sex differences over thousands of years. The biological hypothesis posits that because of our biological differences, males and females have varying propensities to aggression. The social learning hypothesis posits that the contemporary social context in which males and females interact has conditioned human sex differences in the area of aggressive behaviour.

It is our contention that valuable hypotheses should account for: a) variations in the IA-PA sex gap in the course of development; and b) sex differences in prevalent types of aggression. In the next section, we will consider the relative value of these hypotheses in explaining the development of sex differences in aggression.

The Evolution Hypothesis

The evolution hypothesis recognizes that males and females are born with an internal program for development established through a process of natural selection that began with our primate ancestors. One key principle of this hypothesis is that some types of behaviour manifested during childhood serve the function of preparing individuals in our species for a particular role in adulthood (Archer and Côté 2005). Sex differences in aggression and rough-and-tumble

play are likely examples of this preparatory function in humans (Bjorklund and Pelligrini 2002). Rough-and-tumble play allows humans to learn techniques for fighting that may have proved valuable in young adulthood, and to learn the cues associated with situations when it is advantageous not to fight (Archer 1994).

The evolutionary hypothesis also recognizes that environmental variables may not affect behaviour with evolutionary origins at one point during development, but may be highly influential at another stage in development. For instance, although the onset of physical aggression early in life may not be successfully countered through environmental modification, the subsequent development of PA is more likely to be determined by social and physical environments (Archer and Côté 2005).

In a particularly influential account of PA and IA sex differences, Campbell (1999) posits that females tend to use forms of aggression that carry low risks for physical injury, such as indirect or social aggression (see also Björkqvist 1994). In evolutionary terms, this tendency was related to women's greater concern for the protection of their own lives, since the survival of offspring was more dependent on a mother's care and defence than that of the father. Viewed in this light, the cost of direct PA, which poses a significant risk to personal safety has typically been significantly higher for women than it is for men. Similarly, Archer and Coyne (2005) offer a functional hypothesis for the use of IA. They describe IA as an alternate strategy to direct aggression, enacted when the costs of direct aggression are high, and whose aim is to socially exclude, or harm the social status of a victim.

The Biological Hypothesis

In biology, sexual differentiation takes place during the development of male or female physical traits in an undifferentiated zygote (fertilized egg). As male and female zygotes develop into foetuses, infants, children, adolescents, and then into adults, sex differences appear at all levels: genes, chromosomes, gonads, hormones, anatomy, and social behaviour. At the most basic level, males and females genes encode dichotomous development paths, determining a host of biological configurations. These factors include obvious differences in physical size and strength, reproductive functions and (prenatal and postnatal) hormone levels. All of these factors are important considerations in measuring aggression.

Sex differences in the gametes (i.e., sperm and ovula in humans) are determined by the presence or absence of the Y chromosome. The Y chromosome triggers prenatal chemical reactions that result in a) marked sex differences through the production of the hormone, *testosterone*; and b) differences in sensitivity to this key, masculinising hormone. In the first weeks of life, a foetus has no anatomic or hormonal gender, and only sex chromosomes differentiate females (XX) from males (XY). Early in foetal life, specific genes induce gonadal differences, thereby producing hormonal differences which lead to anatomic differences. Since the hormone testosterone is mostly responsible for the process of masculinisation, the pre-natal influence of testosterone on the developing brain is probably the most important source of sexual differentiation. During puberty, hormones (testosterone in males and oestrogen in females) have a different function, triggering the onset of reproductive functions. Thus, it may be said that dramatic differences between the sexes are established at birth, differences that form the basis of further sexual differentiation as psychological and behavioural differences develop.

Genetic and hormonal sex differences also lead to important brain differences. In fact, the brains of males and females differ both in their structure and function (Cahill 2005). With technologic advances in brain imaging, researchers have now increased their capacity

to detect sex differences in brain morphology and functioning. These new-found differences will greatly help in understanding sex differences in behaviour and aggression.

At a structural level, major sex differences have been discovered in the brain lobes and the regions involved in cognitive functions, including the hippocampus, amygdala and neocortex (Goldstein et al. 2001). The hippocampus, a region associated with learning and memory, is sexually dimorphic in its structure and function (Cahill 2005). Sex differences in the amygdala are also substantial. The amygdala plays a vital role in memory functions, especially in memories of emotional events. The sex-related lateralization of the amygdala has been documented in humans. Studies indicate a preferential involvement of the left amygdala in emotional memory for women, but a preferential involvement of the right amygdala for males (Cahill 2005). In addition, differences in the size of the amygdala have been documented, with male amygdala being larger than that of females (relative to the size of the cerebellum).

Most sex differences are functional differences, and some have considerable implications in determining normative levels of aggression between the sexes. For instance, important sex differences were found with respect to serotonin synthesis following tryptophan depletion. More specifically, Nishizawa et al. (1997) found the mean rate of serotonin synthesis to be 52% higher in males than in females. Higher serotonin synthesis leads to low levels of serotonin in the cerebrospinal fluid, and low serotonin is a strong correlate of impulsive aggression (e.g., Haberstick et al. 2006; Halperin et al. 2006).

With regard to sex differences in pathological aggression, sex differences in the prevalence of dysregulated neurochemical functioning may have significant implications for impulsive behaviour, and especially a predisposition to impulsive violence, has been correlated with a low brain serotonin turnover rate, as indicated by a low concentration of 5-hydroxyindoleacetic acid (5-HIAA) in the cerebral spinal fluid (CSF) (Virkkunen et al. 1995). Such types of central serotonin metabolism deficits have been found in both humans and other primate species (Higley et al. 1996; Suomi 2003). In his influential work with Rhesus monkeys, Suomi (2005) finds that low 5-HIAA appears to be related to aggressive and impulsive behaviour among both males and females. Two important points should be noted regarding violence and low 5-HIAA concentrations. First, in primates, there are many more males than females with low CSF 5-HIAA concentrations. Second, compared with members of their own sex, aggressive males and females with low 5-HIAA concentrations engaged in a disproportionate number of aggressive interactions. This said, these females typically engaged in fewer overt acts of PA than did the males (Higley et al. 1996). Therefore, while low CSF 5-HIAA concentrations are associated with aggressive behaviour among both sexes, there are a) more males with low CSF 5-HIAA levels, and b) more manifestations of aggression among low-level CSF 5-HIAA males than females (Suomi 2005). The example of low CSF 5-HIAA as a risk factor for aggression illustrates how a risk factor common to both sexes can produce significant sex differences with regard to the proportion and severity of aggression.

In humans, X-linked genotypes representing risk for antisocial behaviours are related to sex differences aggression. For instance, genetic deficiences in MAOA activity have been linked with aggression in mice and humans, and the MAOA gene is located on the X chromosome. Males, having a single X chromosome, yield two MAOA genotypes: high activity and low activity. Females, however, having two copies of the X chromosome, fall into 4 groups, one of which is the rare combination of low-low MAOA genotype. Thus, the proportion of females with this risk for aggression is much smaller (Caspi et al. 2002).

Biological hypotheses on sex differences do not necessarily explain changes in the magnitude of these differences over the course of development. However, there is evidence

indicating that at least some changes in sex differences could result from differential rates of maturation between males and females. For instance, girls experience faster cognitive development during the preschool years. This accelerated maturation may lead to a faster rate of inhibition and regulation of PA in girls, and may produce sex differences in development of IA. Faster language development in girls is of particular interest, since verbal requests may facilitate the regulation of physical aggression.

The Social Learning Hypothesis

The social learning hypothesis has provided an influential account of the development of social behaviour, including aggression (Bandura 1973; Loeber and Stouthamer-Loeber 1998; Reiss and Roth 1993). According to this hypothesis, aggressive and violent behaviour is learned during childhood and adolescence through exposure to social influences such as violent television programs, aggressive role models, or deviant peers (Johnson et al. 2002; Patterson et al. 1984; Thornberry 1998). Based solely on this hypothesis, children would logically become more aggressive and violent as they grow older.

As summarized in the first section of this paper, recent longitudinal studies indicate that children become less, not more physically aggressive and violent over time (Broidy et al. 2003; Côté et al. 2006; Cairns et al. 1989; Nagin and Tremblay 1999; Tremblay et al. 1999). In fact, developmental trajectory studies have found that most children followed declining trajectories of physical aggression between kindergarten and grade 6. If the development of aggression were solely based on the cumulative effects of social influences that purportedly promote aggressive behaviour, we would expect a significant group of children to begin their use of physical aggression during their elementary school years. Such a group has not been identified (Broidy et al. 2003; Côté et al. 2006; NICHD-ECCRN 2004; Nagin and Tremblay 1999).

Furthermore, the evidence reviewed in the first section of this paper clearly indicates that physical aggression appears during the first 12 months after birth and seems to be a normal part of early social interaction. Rather than learning to aggress over time, children apparently learn not to aggress. This learning curve appears to be supported by brain maturation, but is also most likely the result of social learning. Children learn from their environment to control their emotional responses. They also learn to use alternatives to physical aggression (Tremblay 2003).

Indeed, in its explanation of the developmental progression of aggression, social learning theory places a heavy emphasis on how specific forms of aggressive behaviour are learned. However, while it is true that specific aggressive actions may be learned from peers, parents and the media, they do not account for broad changes in the frequency of aggression manifested at different ages (Archer and Côté 2005). In reality, it is more plausible that social factors such as coercive parenting, violent models, or violent media account for the failure, for a minority of children, to fail to learn how to regulate and inhibit their aggressive behaviour.

Social learning theory may produce sex differences in aggression through four mechanisms. First, social factors may have a stronger impact on girls than on boys in learning alternatives to physical aggression. For instance, parents proposing an alternative strategy to aggression (e.g., asking for a toy instead of grabbing the toy), may be more successful with girls than boys in modifying the behaviour, as girls are less inclined to aggression and have generally better verbal abilities in early childhood. Second, compared with boys, girls may be exposed to more social influences conducive to learning alternatives to physical aggression. For example, given the segregation of the sexes during middle childhood, girls are exposed to many more friendships

which involve verbal negotiation instead of physical aggression. Third, social factors against aggression may have a stronger disinhibitory impact on boys than on girls. For instance, boys exposed to a violent television program may be more likely to act out aggression than are girls. Fourth, compared with girls, boys may be exposed to a larger number of social influences that encourage the dishinhibition of aggression. For instance, socializing agents (such as peers and parents) may be more likely to encourage, rather than discourage, the inhibition of aggression among boys, compared with girls.

While few studies have formally tested these hypotheses, there is evidence that socializing agents (such as parents) selectively encourage traditional sex-typed behaviours (e.g., shyness, fearfulness and withdrawal in girls) and/or discourage non-sex-typed behaviours (e.g., aggressive behaviour in girls) (Maccoby 1998). There is also evidence supporting the importance of same-sex peer group influence during childhood, and the values of these groups, in explaining sex differences in PA. For instance, boys' play is more active, physical, group-oriented and competitive than is girls' play, thus creating more opportunities for physical contact and likely facilitating the expression of physical aggression (Maccoby 1998). Conversely, play among girls is typically more nurturing, occurs in smaller groups (e.g., dyads or triads), and is oriented towards intimacy and social inclusion. Consequently, the structure of female friendships, which tends to be based on closeness and cohesiveness, is the basis for a more efficient use of indirect and relational forms of aggression among girls (Crick and Grotpeter 1995; Green et al. 1996; Maccoby).

As peers play a significant role in reinforcing preferred modes of aggression, social interactions with a peer group is likely to account for some of the observed changes in the magnitude of sex differences during childhood. For instance, Fagot and Hagan (1985) showed that, as early as toddlerhood, aggressive actions (grabbing or taking objects, and hitting or verbally assaulting others) are more prevalent in boys than in girls and that when girls do act aggressively, their actions are ignored significantly more than are those initiated by boys. Boys have been shown to respond more to the actions of other boys than to the actions of girls, while girls responded more equally to the actions of boys and girls. It is suggested that responses to aggressive actions are seen as information sources for the child. The higher response rate to a boy's actions informs the child that this kind of behaviour will produce an effect on his world, while the lack of response to a girl's actions suggest the opposite. Over the course of development, if the sexes experience specific types of reinforcements for their aggressive behaviours, the inhibition of these behaviours will be modified accordingly.

Conclusions

In this paper we have described the development of physical aggression and indirect aggression. We have reviewed hypotheses based on evolution, biology and social learning. The evolution of aggression can be understood in terms of its origins in the natural world, and its costs and benefits in particular situations. Longitudinal studies of large, representative samples that trace the trajectories of physical aggression have all shown a gradual decline in physical aggression over time, suggesting that rather than having to be socialized to be aggressive, children gradually learn to inhibit physical aggression as they learn alternative means to achieve their goals. More boys than girls had high-level PA trajectories, and more girls than boys had the lowest-level PA trajectories. These studies found that indirect (relational) aggression appeared later in development, and girls were more likely to follow rising IA trajectories, a finding that corroborates other research on sex

difference showing that IA is particularly elevated among adolescent girls. The contrasting developmental pathways in aggression among girls and boys do not constitute absolute differences, but show an overlap between the sexes. Nevertheless, they can be understood in terms of the different forms of social relations typical of social groups among girls and boys, and also in terms of the different selection pressures brought to bear on males and females in sexual selection.

Implications for Intervention: Starting with Mothers

Although males are responsible for the most severe and negative social consequences of violence and aggression, the solution to reduction of pathological aggression may be to start with females, and specifically with mothers. Females are largely responsible for providing care to the next generation and experimental studies on animal and humans subjects have repeatedly shown that adequate maternal care early in life is fundamental to the healthy development of offspring (Meaney 2001; Repetti et al. 2002; Weaver et al. 2004).

The central role of females in the intergenerational transmission of aggression and prosocial behaviours is vividly illustrated by Suomis's research in rhesus monkeys. Suomi (2005) suggested that a major biological vulnerability for impulsive and violent behaviours (low 5-HIAA concentrations) is passed on to the next generation of rhesus monkeys, primarily through the female genome. He showed that young female rhesus monkeys with low 5-HIAA concentrations are, like low 5-HIAA males, impulsive, aggressive, and generally maladapted socially (Westergaard et al. 2003). Aggressive males, however, are rapidly expelled from their native troop and have a high risk of mortality prior to puberty, while aggressive females remain in their respective families for the rest of their lives. Moreover, unlike low 5-HIAA males, low 5-HIAA females engage in relatively normal reproductive behaviour. The offspring of mothers with low CSF-5HIAA have a double dose of risks for pathological aggression. First, they have the genetic risks associated with being born to a mother with low CSF 5-HIAA. Second, they have the environmental risks associated with living with a mother who may exhibit significant abnormalities in maternal behaviour, behaviour which often results insecure and/or disorganized bonding patterns in parent-child relationships. Thus, the inter-generational transmission of risks for aggression is likely to occur via genetic transmission through the female genome, inadequate maternal care, or both (Suomi and Levine 1998).

Studies with primates and rodents showed that the effects of poor maternal care and genetic vulnerabilities could be reversed by transferring the offsprings to a mother who would provide better care (Meaney 2001; Weaver et al. 2004; Kippin et al. 2004; Suomi 2003). In humans, exposure to a high risk family environment is reduced when children receive child care services (CCS). Results from experimental studies offering high-quality CCS to at-risk children provide robust evidence for the protective role of high-quality CCS. For instance, the children of mothers with low levels of education and low SES (socio-economic status) benefited from receiving intensive, high-quality CCS during their children's preschool years. More specifically, CCS services in the form of preschool education was shown to have a long-term positive impact on violence and unemployment in adulthood (Campbell et al. 2002; Schweinhart et al. 1993).

Correlational studies show similar result patterns. Recent longitudinal studies have shown that young Canadian children born to high-risk mothers (i.e., mothers with low levels of education or low socio-economic status) benefited from receiving CCS early in life (Borge et al. 2004; Côté et al. in press a,b). More specifically, toddlers exposed to high levels of family risks were less likely to exhibit high levels of physical aggression if they were in SMC than if

they remained in MC (Borge et al. 2004). Furthermore, Geoffroy et al. (2007) showed that children from low-SES families receiving regular CCS in infancy had better cognitive performance prior to school entry as compared with low-SES children who remained in maternal care. Other studies stress the importance of providing high quality care (e.g., NICHD 2005a,b; Peisner-Feinberg et al. 2001; Geoffroy et al. 2006).

These studies suggest that early and high-quality CCS constitute an effective means of intervention that could significantly contribute to preventing the intergenerational transmission of risks for aggression. The effects of CCS could be larger, however, if interventions targeted females earlier, namely, during pregnancy. Indeed, animal studies have shown that an in-utero environment provided by an at-risk mother represents a greater risk for offspring than an in-utero environment provided by a low-risk mother (Francis et al. 1999, 2002, 2003; Harper 2005). In humans, high-risk mothers such as those with conduct problems are more likely to smoke, to abuse alcohol and to experience stress (Zoccolillo et al. 2005). These are health behaviours or environmental conditions known to be risk factors for poor developmental outcomes in offspring. Interventions providing support to at-risk mothers during pregnancy, including the promotion of healthy behaviours, may significantly reduce the risk of poor developmental outcomes. In fact, one of the rare randomized controlled trials in which psychosocial support was provided to pregnant women showed that there was a significant long-term impact on both mother and child (Olds et al. 1998, 1999, 2002). More specifically, researchers offered a program of prenatal and early childhood home visitation by nurses to high-risk mothers (isolated and living in poverty). The aim of the program was to improve parental behaviours and environmental conditions during pregnancy and early childhood. The program was effective in improving parental care (as reflected in the lower numbers of injuries and accidental ingestion of foreign substances by infants), and in reducing the number of convictions, arrests, emergent substance abuse and promiscuous sexual activities among adolescents (15 years old) whose mothers were home visited by nurses. Furthermore, this intervention led to a reduction in the mothers' subsequent number of pregnancies and their use of public assistance, and improved their work force participation. In sum, the reviewed evidence indicates that although a much greater proportion of males than females present severe aggression problems, intervention with mothers is the most promising avenue for the prevention of the intergenerational transmission of aggression problems.

Future studies should adopt experimental design in order to formally test the timing hypothesis, i.e.: that an intervention received earlier in life is more beneficial and cost-effective than intervention received later in life. Such an experiment would involve comparing the efficacy of an intervention during pregnancy (focussed on maternal behaviour during pregnancy) versus in infancy (focussed on high-quality SMC) versus latter in childhood (focussed on preschool education). Interventions involving these different timing and modalities have shown their efficacy. They have not, however, been compared within a single study. Such a comparison is necessary in order to gain a better understanding of the most efficient and cost effective preventive intervention for aggression.

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