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Response perseveration in adolescent boys with stable and unstable histories of physical aggression: the role of underlying processes

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Background: It was unclear whether response perseveration and underlying processes, often related to antisocial externalizing disorders, were also related to histories of physical aggression. **Method:** Boys of age 13 years were selected on the basis of childhood histories of physical aggression: stable, unstable, and non-aggressive. Performance on a Card Playing Task provided a perseveration index. **Results:** Physical aggression, regardless of history, predicted perseveration in adolescence. However, qualitative differences revealed that Neuroticism increased the risk for perseveration only in the unstable aggressive group relative to the other groups. Perseveration in the stable aggressive group maybe related to a more fundamental information-processing deficit. **Conclusion:** The identification of these processes has implications for developmental theories of physical aggression; they may help discriminate those children who show early physical aggression and who will remain aggressive from those who will only show occasional physical aggression during later childhood. **Keywords:** Aggression, violence, perseveration, information processing, working memory, executive function, hyperactivity, personality, neuroticism, extraversion, psychoticism, trajectory. **Abbreviations:** CPT: Card-Playing Task.

Although the number of children who use physical aggression, as well as the frequency at which they aggress physically, tends to decline during childhood, some children remain highly physically aggressive over time relative to their same age peers (Nagin & Tremblay, 1999; Tremblay, 2000). Such differences in physical aggression history have been described using the concepts of continuity and desistance (Loeber, Tremblay, Gagnon, & Charlebois, 1989; Nagin & Tremblay, 1999), and of stability–unstability over time (Loeber & Stouthamer-Loeber, 1998; Séguin, Boulerice, Harden, Tremblay, & Pihl, 1999; Séguin, Pihl, Boulerice, Tremblay, & Harden, 1996; Tremblay et al., 1991). The concepts of chronic, stable, or persistent physical aggression refer to a high likelihood of physical aggression from one assessment to the next. The concept of occasional or unstable physical aggression encompasses histories of physical aggression that are not at a relatively constant level across time. Research on continuity–stability–persistence of physical aggression has shown that a chronic course of physical aggression begun in early childhood, as opposed to other histories of physical aggression over time, is qualitatively distinct (Nagin & Tremblay, 1999; Séguin et al., 1999; Séguin et al., 1996; Tremblay et al., 2002), and predicts the poorest outcome (Moffitt & Silva, 1988; Nagin & Tremblay, 1999). It is thus crucial to understand more fully the processes differentiating histories of physical aggression. One characteristic of chronic physical aggression is the high likelihood to perseverate in the use of physical aggression over time. The question for this study is whether perseveration in using physical aggression is related to perseveration observed in the laboratory. If it is, an understanding of processes associated with perseveration in the laboratory may inform research about processes underlying perseveration in using physical aggression over time.

Perseveration and externalizing behaviour problems

One measure of perseveration that has been extensively applied to antisocial behaviour, externalizing disorders, and psychopathy comes from the Card-Playing Task (hereafter, CPT; Siegel, 1978) that was further developed by Newman and colleagues (1987). Briefly, the CPT initially reinforces card playing. However, the initially high rate of reinforcement gradually tapers off at the cost of increases in the rate of punishment. The implicit goal is to maximize rewards and minimize punishment. Perseveration occurs when playing continues past the point where the rate of punishment outweighs the rate of reward, which results in losses of the maximum possible earnings. Although the CPT is sensitive to antisocial behaviour problems, it may elicit motivation without giving rise to antisocial action per se. In this way, the CPT taps into a more general set of processes that can be linked to actual observations of antisocial behaviour.

Results from studies using the CPT or close variants (such as the door-opening task, see Daugherty & Quay, 1991; Matthys, van Goozen, de Vries, Cohen-Kettenis, & van Engeland, 1998; O'Brien &

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Frick, 1996) show that several antisocial or impulsive groups of individuals play more cards than non-antisocial or non-impulsive control groups. This was the case for incarcerated psychopaths (Newman, Patterson, & Kosson, 1987), individuals with high psychopathy scores from a community sample (Belmore & Quinsey, 1994), non-anxious psychopathic children (O'Brien & Frick, 1996), children in therapeutic schools for externalizing problems (Kindlon, Mezzacappa, & Earls, 1995), delinquents (Fonseca & Yule, 1995; White et al., 1994), children with emotional and behavioural difficulties (Fisher & Blair, 1998), multigenerational sons of alcoholics (Giancola, Peterson, & Pihl, 1993), conduct-disordered children (Fonseca & Yule, 1995; Shapiro, Quay, Hogan, & Schwartz, 1988), and conduct-disordered children with or without comorbid hyperactivity (Daugherty & Quay, 1991; Matthys et al., 1998). Interestingly, the number of cards played on the CPT was not sensitive to Attention Deficit Hyperactivity Disorder symptomatology alone (Milich, Hartung, Martin, & Haigler, 1994), or for hyperactivity–impulsivity–inattention alone (Lynam, 1998). However, the combination of hyperactivity–inattention and conduct problems has been predictive of perseveration in relatively severe cases (Lynam, 1998; Matthys et al., 1998), whereas others failed to find this relation in less severe cases (Daugherty & Quay, 1991). In sum, poor performance on the CPT appears to be associated especially with a proclivity towards *antisocial* externalizing disorders or psychopathy, but not so much with hyperactivity alone.

Although many antisocial behaviour problems have been associated with poor performance on the CPT, we do not know if such poor performance could a) be characteristic of physical aggression and b) change as a function of the history of physical aggression. We would first predict that physically aggressive individuals also show perseveration, and second, if perseveration on the CPT has any relevance to perseveration in using physical aggression over time, we would also predict that perseveration in adolescence would be strongest in those whose history of physical aggression has been stable. Further, some studies have identified several processes underlying performance on the CPT and other similar paradigms (Goldberg, 1986; Newman, 1998; O'Brien & Frick, 1996; O'Brien, Frick, & Lynam, 1994; Sandson & Albert, 1984; Wallace, Bachorowski, & Newman, 1991). However, the study of such processes has been the exception rather than the rule.

Processes underlying perseveration

The study of processes underlying perseveration may be important, particularly if, as we hypothesized, perseveration on the CPT during adolescence shares underlying processes that also contribute to perseveration in using physical aggression over time. A first set of processes that may underlie perseveration is relevant to executive function. The executive function refers generally to psychological processes involved in the self-regulation of thought and action. One important characteristic of measures of executive function is that they often involve competition among different underlying processes, one of which is correct and a default one that is incorrect (Zelazo, Carter, Reznick, & Frye, 1997). Because of this, executive function failures are often manifested as perseveration, or responding that is consistent with a pre-potent/default process. Our work (Séguin et al., 1999; Séguin, Pihl, Harden, Tremblay, & Boulerice, 1995) and that of others (Barkley, 1997; Giancola, Mezzich, & Tarter, 1998; Toupin, Déry, Pauzé, Mercier, & Fortin, 2000) has indicated that difficulties in basic processes implicated in executive function are important in externalizing disorders in general and in physical aggression in particular. Using measures of working memory, which assess the active, on-line, effortful and controlled processing of information involved in inductive and deductive reasoning, we have found that physically aggressive boys performed worse than non-aggressive boys (Séguin et al., 1995). However, physical aggression groups did not differ. In the context of perseveration tasks such as the CPT, we argue that if relevant feedback information is attended to during the game, working memory abilities will facilitate monitoring of the game outcome, evaluation of ongoing behaviour, on-line reformulation of a new plan and execution of a coherent response strategy. Although the measures of working memory we used in prior studies were conceptually related to executive function abilities as described above, and poor working memory could contribute to response perseveration, we have not examined response perseveration explicitly. Further, the addition of a measure of perseveration may discriminate better between chronic and occasional physical aggression than did our measures of working memory alone.

A second set of processes involves emotional reactivity and its manifestation through personality. Processes such as sensitivity to reward, to punishment, and to threat or anxiety, have been implicated in the study of perseveration in antisocial behaviour and have been useful in distinguishing psychopathy subtypes (Newman, 1998; Wallace et al., 1991). Individuals scoring high on Neuroticism have been shown to be sensitive both to reward (Wallace & Newman, 1997), and to punishment cues (Zuckerman, Joireman, Kraft, & Kuhlman, 1999), which results in impulsive and poorly regulated behaviour. Theoretically, Neuroticism facilitates the automatic, involuntary, deployment of attention, which impairs adaptive information processing. Alternately, the tendency to Extraversion is associated with increased sensitivity to reward but not to punishment (Gray, 1991; Newman & Wallace, 1993; Zuckerman et al., 1999). Among other characteristics, extraverts

will show impulsivity when cues for reward are present (Bachorowski & Newman, 1990). Because of an overlap between these dimensions of personality, greatest impulsivity has been expected when Extraversion and Neuroticism interact, i.e., in individuals who score highly on both dimensions (Gray, 1991; Newman & Wallace, 1993). Psychoticism is believed to represent Impulsive Unsocialized Sensation Seeking (Zuckerman, 1993) and to be characteristic of psychopathy (Newman & Kosson, 1986; Thornquist & Zuckerman, 1995) and other antisocial behaviour. Individuals scoring high on Impulsive Unsocialized Sensation Seeking have been described as showing poor passive avoidance learning, i.e., difficulties withholding punished responses, because they would also show high impulsivity and heightened sensitivity to reward. Conversely, Gray (1991) sees Psychoticism as reflecting functions of the fight/flight motivational system. This system theoretically responds to unconditioned stimuli. However, the CPT functions on the basis of cues/conditioned stimuli. Thus it is unclear whether Psychoticism would be related to perseveration on the CPT or not. Finally, sensitivity to punishment per se may increase as a function of greater Negative Affectivity and result in less perseveration, similar to individuals with high anxiety scores (Newman, Schmitt, & Voss, 1997; O'Brien & Frick, 1996; Séguin et al., 1996). An individual with high Negative Affectivity has been described by Tellegen (1985) as distressed, fearful, hostile, jittery, nervous, and scornful.

Specificity of perseveration to antisocial behaviour problems

Lastly, although poor performance on the CPT appears to be associated specifically with a proclivity towards antisocial externalizing disorders, the role of non-antisocial externalizing behaviours, such as problems of hyperactivity and inattention, has not been *consistently* examined in studies of perseveration on the CPT and externalizing behaviours. It may be difficult to make sound predictions regarding the additional role of hyperactivity and inattention in perseveration in a community sample. However, Barkley (1997) proposed that hyperactivity should be more sensitive to executive function problems than inattention. Thus, to the extent that perseveration can be an outcome of poor executive function (Zelazo et al., 1997), we would then expect perseveration to be associated more strongly with hyperactivity than with inattention. Nonetheless, we would not expect hyperactivity alone to be predictive of perseveration once physical aggression history has been taken into account because the literature reviewed above suggests that perseveration is specific to antisocial behaviour problems or psychopathy.

Summary

In sum, four main hypotheses guided this study of physical aggression: a) perseveration in adolescence is expected to be related to childhood physical aggression, b) because perseveration in adolescence may reflect processes that contributed to the maintenance of maladaptive behaviour in childhood, perseveration is expected to be strongest in stable aggressive boys relative to unstable aggressive and non-aggressive boys, c) processes associated with perseveration should be the same across groups, d) hyperactivity is expected to be associated with perseveration but not once history of physical aggression has been taken into account. These questions will be addressed with the CPT and with concurrent assessments of working memory and emotional reactivity as defined by Extraversion, Neuroticism, Psychoticism and Negative Affectivity.

Method

Participants

Participants were selected from an *initial sample* of 1,037 boys who had been recruited in kindergarten from 53 schools in low socio-economic areas of Montréal and followed since (Tremblay, Pihl, Vitaro, & Dobkin, 1994). These boys were French speaking, their mother tongue was French, and their parents were born in Canada. Teacher-based measures, including those used for the sampling procedure, are described next, followed immediately by the sampling procedure itself. Other measures of interest complete the method.

Instruments and procedure

Teacher-rated behaviour. Scales were derived from teacher responses to the Social Behaviour Questionnaire based on analyses from the initial sample (Tremblay et al., 1991). Teachers were invited to complete the Social Behaviour Questionnaire in the spring of each school year when the boys were aged 6, 10, 11, 12, and 13.

The physical aggression scale used to select boys included 3 items: 1) fights with other children; 2) kicks, bites, hits other children; 3) bullies other children. For a sample of 10-year-olds, the internal consistency for this factor (Alpha) was .86 ($n = 991$) and the test–retest reliability after two months was .83 ($n = 44$) (Tremblay et al., 1991). Correlating the teacher-rated physical aggression score to peer-rated physical aggression at ages 10, 11, and 12 provided validity for this scale (i.e., correlation coefficients varied between .52 and .57) (Tremblay et al., 1991). Group assignment was made prior to obtaining age 13 physical aggression data. Three groups were selected based on the stability of physical aggression at 6, 10, 11 and 12 years of age. Across the entire sample, 893 boys could be classified. Boys who had scores above the 70th percentile at age 6 and on at least two out of three other assessments were considered stable aggressive (19%). That group was created to tap early physical aggression that has a

relatively high probability of recurrence. Boys who never had a score over the 70th percentile during those assessments were classified as non-aggressive (35%). All participants who did not meet these criteria were considered unstable aggressive (46%); they had not been rated as deviant on physical aggression at age 6 *and* at two other times but were deviant at least once. The defining characteristic of this latter group is its circumscribed heterogeneity of patterns of deviant aggression over time. This group was initially created to examine if having an irregular profile of deviance over time could be distinguished from stable aggression. In previous studies we found unstable aggressive boys to report highest pain sensitivity (Séguin et al., 1996), and to show specific deficits on tests of posterior dorsolateral frontal lobe function (Séguin et al., 1999).

The Negative Affectivity scale included five items: 1) fearful; 2) distressed; 3) worried; 4) solitary; and 5) cries. It closely approximates the characteristics of high negative affectivity as outlined by Tellegen (1985) but without the problematic item 'hostility' (Gray, 1991). The internal consistency (Alpha) at age 10 was .75 ($n = 991$) and the test–retest reliability after two months was .66 ($n = 90$). The scale was found to be associated positively with avoidance of pressure pain and could therefore serve as an index of sensitivity to punishment (Séguin et al., 1996). The inattention scores were derived from a four-item scale: 1) inattentive; 2) poor concentration; 3) stares into space; and 4) gives up easily (age 13 alpha = .85, $n = 820$). The hyperactivity scores were derived from a two-item scale including 1) restless, runs about, or jumps up and down; 2) does not keep still, squirmy, fidgety (age 13 alpha = .88, $n = 817$). Raw means, standard deviations, and range for these variables were: Negative Affectivity $M = 2.46$, *SD* 2.26, Min/max = 0/10, Inattention $M = 3.49$, *SD* 2.57, Min/max = 0/8, and Hyperactivity $M = .89$, *SD* 1.24, Min/max = 0/4.

Missing data for age 13 Negative Affectivity ($n = 15$), Inattention ($n = 15$), and Hyperactivity ($n = 16$) were replaced by the participant's own average of age 11 and 12 data on these measures. Correlations between age 13 and the age 11–12 average on Negative Affectivity, Inattention, and Hyperactivity were respectively .38 $p < .01$ ($n = 812$), .47 $p < .01$ ($n = 812$), and .43 $p < .01$ ($n = 811$).

Sampling procedure. The main sampling criteria in the selection of boys for which we could derive developmental histories of physical aggression and of Negative Affectivity (see scale definitions below) consisted of teacher ratings at the ages of 6, 10, 11, and 12 years. Our final sampling goal, based on a combination of statistical and practical considerations, was to recruit about 200 participants with a relatively equal representation of different histories of physical aggression. To do this we removed unavailable cases due to attrition ($N = 116$), cases who had more than one missing value or for whom Negative Affect over time was in the middle range ($N = 262$), and cases that did not meet various other inclusion and exclusion criteria ($N = 326$). These 326 boys did not meet priority criteria such as (a) stability of physical aggression or non-aggression, (b) having already come to the laboratory, or (c) showing a history of late rise in physical aggression or negative affect. Boys who did not meet criteria (a) but met (b) or (c) were classified as unstable aggressives. We thus identified a *selection sample* of 333 participants. After contacting 272 of these in the summer and early fall, we met our sample size objective and obtained participation of 203 boys that constitute the final *laboratory sample*. Of the 69 boys who were contacted but did not come to the laboratory during that time, 13 could not be scheduled for various reasons, and 56 refused to participate. A listwise selection of cases based on the variables included in the analysis yielded an $n = 197$ once missing laboratory data for 6 participants had been taken into account. No differences were found on age 13 teacher ratings of prosociality, inattention, hyperactivity, and Negative Affectivity between the boys who came to the laboratory ($N = 203$) and those from the remainder of the sample for whom this data was available ($N = 630$), nor on mother-ratings of family adversity in kindergarten ($N = 203$ vs. $N = 834$). The proportions of boys per groups (from $N = 197$) were 35.5% stable aggressive ($N = 70$), 29.5% unstable aggressive ($N = 58$), and 35% non-aggressive ($N = 59$). The participants' age at the time of their visit was $M = 13.33$ years, $SD = 0.30$. Written informed consent was obtained from the parents and the boys themselves prior to laboratory activities. Written informed consent from the parents was obtained at each yearly assessment. The boys and their families were treated in accordance with the American Psychological Association ethical guidelines.

Response perseveration. The Card-Playing Task was adapted by Newman and colleagues (1987) and served as the measure of response perseveration. It is a computer-controlled behavioural laboratory task designed to create a response set with the help of an initially high rate of rewards. As the game progresses, responding is gradually followed by monetary loss. The task comprises 100 playing cards, including number and face cards, presented in a prearranged order on a colour monitor. The backs of the cards were all the same and included a question mark as a prompt for action. Two buttons allowed either playing a card or stopping the game. Sample face and number cards were shown to the participant to ensure comprehension. Participants were instructed that if they turned a face card they would win and that if they turned a number card, they would lose. Participants began the task with ten 5-cent coins ($0.50) and were instructed to stop playing when they wished. The boys were given 5 cents immediately after the appearance of a face card and 5 cents were taken away immediately after a number card was presented. In other words, each time boys decided to see a card, they were betting 5 cents that it would be a figure card. At the beginning of each trial (i.e., before each card was displayed), the words 'DO YOU WANT TO PLAY?' appeared over a rectangle representing the back of the playing card. If participants wanted to see the card, they pressed button 1. If they preferred to stop the game, they pressed button 2. Participants were thus instructed to play until they decided to stop and were not given any goals or suggestions that could have biased their playing strategy. When the participants decided to play they saw either a face card with the words 'YOU WIN!' or a number card with the words

'YOU LOSE!'. Participants were not told how many cards there were in the deck but were instructed that the deck was not a normal 52-card deck and that there was no point in counting cards. Boys took approximately 15 minutes, on average, to complete the game.

The underlying structure of the task was as follows. The proportion of losses (i.e., seeing a number card) increased by 10% with every block of 10 cards, from 10% during the first block to 100% during the last block of cards. The curves from Figure 1 show trial-by-trial changes in cumulative rewards (+ +), cumulative punishments (– –), and an index of cumulative earnings (o o) that are built into the game. These curves show an initially high reward rate that was gradually reduced at the cost of an increase in the rate of punishment. Because the relationship between rewards and punishments was inversely proportional, the possible earnings were pre-determined. Thus, the net outcome of the reward and punishment curves, the index of cumulative earnings, is indicated by the inverted U curve for a hypothetical individual who would play all 100 cards.

The initial dependent measure for this study was the number of cards played before ending the game. However, that number may not accurately reflect perseveration. The principal characteristic of most tasks of perseveration involves a switch in underlying rule. Perseveration occurs when there is a failure to respond appropriately to the rule switch. Participants are unaware of the specific underlying rules: 'The more you play, the greater your earnings, but up to a point. Then the more you play, the more your earnings drop.' In other words, the implicit goal of this task is to quit, i.e., respond 'no' instead of 'yes' to the question: 'Do you want to play?', at an optimal point in order to minimize punishment (passive avoidance) and maximize rewards. Individuals who perseverate will go past that optimal point before stopping, will consequently play more cards, and lose more money. Traditionally, however, studies used the number of cards played as their dependent variable but may not have focused on perseveration as defined here. In order to define perseveration one must look *a priori* at the curve of earnings as a function of number of cards played. A priori examination of the inverted U curve in Figure 1 reveals that the optimal point to inhibit responding would be situated at around 75 cards. The rate of earnings clearly begins to decline from this point and the objective information required for making the decision to quit should no longer be ambiguous. Individual differences in card playing before that optimal point are less likely to be a function of perseveration; perseveration begins at that optimal point.

Working and general memory. The assessment of working memory in this sample was done with a number randomization task (a.k.a. subjective ordering; Wiegersma, van der Scheer, & Human, 1990). In this task a range of numbers (e.g., from 1 to 10) was given verbally to the participant with a starting number (e.g., 2). The participant was instructed to begin from that number and select verbally and without feedback all the remaining digits from the range while avoiding any apparent order, without missing any digit, without repeating a digit twice, and without using more than two consecutive numbers. Examples of apparent orders to avoid were provided to the boy, e.g., 2, 4, 6, 8, 10, 1, 3, 5, 7, and 9. Thus, a typical correct response for a 10-digit trial would be 2, 3, 7, 9, 1, 8, 10, 4, 6, and 5. Ranges used were of 4, 6, 8, and 10 digits, with two trials at each level. There were practice trials with feedback using 4 digits. A failure was defined as two consecutive trials with at least one error at a given

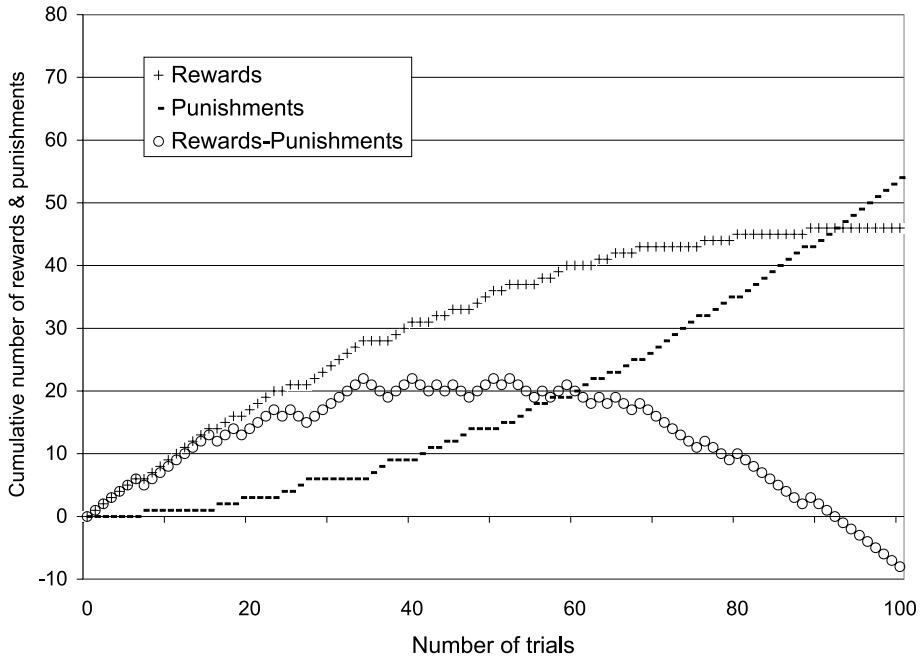

Figure 1 Cumulative number of rewards and punishments, and their difference across trials. The curves representing cumulative number of rewards, punishments and rewards–punishment, reveal the underlying predetermined nature of the game.

level. The dependent variable was number of successful trials to failure. This task has been validated with Positron Emission Tomography and Magnetic Resonance Imaging technology within a double-dissociation paradigm as being specifically sensitive to the function of the mid-dorsolateral frontal cortex in normal participants (Petrides, Alivisatos, Meyer, & Evans, 1993). It correlates highly and specifically with other validated frontal lobe tasks and an executive function factor (Séguin et al., 1995). This task theoretically assesses *Verbal Working Memory*. Working memory is theoretically dependent on *General Memory* functions that are associated with the hippocampi and temporal lobes from a neuropsychological perspective (Luria & Homskaya, 1964; Petrides, 1989; Petrides & Milner, 1982). In contrast to working memory, which typically requires effortful processing and on-line manipulation of information, the concept of general memory refers here to the less active storage and retrieval of information that is subject to less processing. This position implies that poor performance on General Memory tasks will necessarily affect performance in working memory whereas the converse is not necessarily true. Thus, failures in General Memory could also result in perseveration as new or past learning may be poorly stored or retrieved. The digit span subtest from the Wechsler Memory Scales (Wechsler, 1987) was used to control for General Memory functions as recommended by Petrides (1995). Raw means, standard deviations, and range for these variables were: General Memory (digit span) $M = 6.17$, $SD = 1.62$, Min/max = 2/11, Verbal Working Memory (number randomization) $M = 3.36$, $SD = 1.97$, Min/max = 0/8. Thus, on average, boys of this age completed the 6–8 digit trials on the number randomization task. In comparison, using a slightly different methodology, adults with higher education make an average of 1 error per trial on a series of 10-digit trials on the Working Memory task (Petrides et al., 1993).

Extraversion, Neuroticism, and Psychoticism. Extraversion, Neuroticism, and Psychoticism were assessed with the Junior Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975). The reliabilities for age 13 boys with the long form are as follows. For the Extraversion scale they are .81 for internal consistency, and .75 and .67 respectively for 1 and 6 months test–retest. Neuroticism reliabilities are .85 for internal consistency, and .74 and .72 respectively for 1 and 6 months test–retest. Reliabilities for Psychoticism are .69 for internal consistency, and .69 and .63 respectively for 1 and 6 months test–retest. In the current sample the internal consistency of the Extraversion scale was .64, that for the Neuroticism scale was .84, and that for the Psychoticism scale was .71. Raw means, standard deviations, and range for these variables were: Extraversion $M = 17.9$, SD 3.4, Min/max = 7/24, Neuroticism $M = 8.95$, SD 4.79, Min/max = 0/19, and Psychoticism $M = 4.8$, SD 3.04, Min/max = 0/14. The means and standard deviations for the Junior Eysenck Personality Questionnaire scales are roughly in the same range as recently published means (Zuckerman et al., 1999), with Extraversion being the highest followed by Neuroticism and Psychoticism.

Results

Because the data was based on how many trials participants played until they withdrew from the game, we used a survival analysis to test all hypotheses. This analysis allowed examining the proportion of participants still playing as a function of the various predictors, including physical aggression group status, across the 100 trials, and to examine whether predictors have the same strength across the whole curve, i.e., if there is a point where the strength of some effects differs. We used a Cox proportional hazard regression model to test for differences in the survival curves with respect to the hypothesized predictor variables and their interactions, which are summarized as follows: A) underlying processes, A1) cognitive processes (General Memory and Verbal Working Memory), A2) personality-motivation processes (Negative Affectivity, Neuroticism, Extraversion, and Psychoticism); B) behaviour, B1) physical aggression, B2) interactions between physical aggression and Working Memory, Negative Affectivity, Neuroticism, Extraversion, and Psychoticism, and the interaction between Extraversion and Neuroticism, and B3) discriminant behaviours relevant to perseveration (Inattention and Hyperactivity).

We found no order effect by controlling for the time at which participants played the game during the day and that variable was not included in subsequent analyses.

As a first step in testing our hypotheses, we verified the assumption of proportionality using the test of Grambsch and Therneau (1994) and tested for non-linearities with penalized splines. The assumptions of proportionality and linearity were satisfied, $\chi^2_{(14)} = 16.04$, $p = .31$. In the first model, the effect of predictors on the general rate of withdrawing was significant, Likelihood Ratio$_{(14)} = 33.6$, $p = .002$, $R^2 = .157$. The second model tested whether the differences found in the general rate of withdrawing were specifically at around 75 cards as we proposed earlier. In Figure 2, a plot of the survival curves shows constant rates in each group with a change at around 75 cards. We thus entered a dummy variable dichotomizing the card playing score at > = 75 cards and observed that all predictor effects observed in the first model vanish, Likelihood Ratio$_{(14)} = 12.5$, $p = .57$. The R^2 for the predictors of the first model dropped from 15.7% to a non-significant 6% in the second model. We calculated that 61% of the variance explained by that first model was accounted for by this cutoff. Then, in order to ensure that 75 cards was the optimal cutoff, we compared models with various cutoffs. The second model using a cutoff at 75 cards had not only the best fit but also accounted most for the predictors. If we choose to plot the curves from Figure 2 as a function of those who withdraw before, versus at or after, 75 cards we obtain the curves in Figure 3. This graph shows constant rates of withdrawing within each group, before and after the cut-

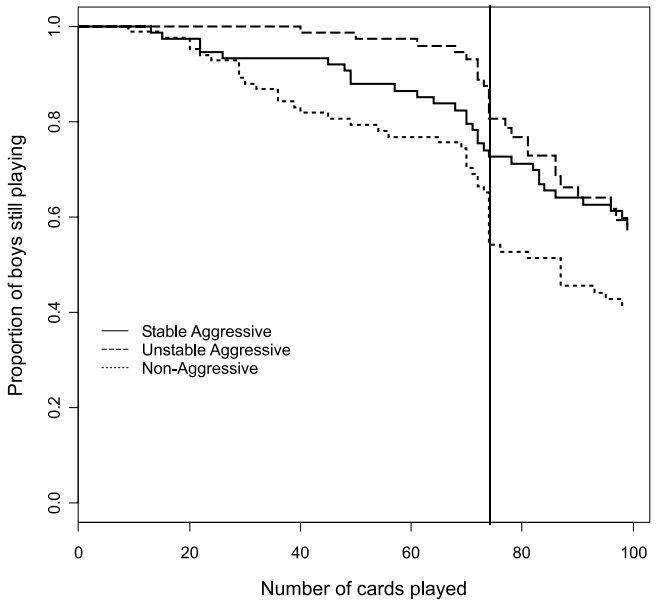

Figure 2 Proportion of boys per group still playing as a function of number of cards

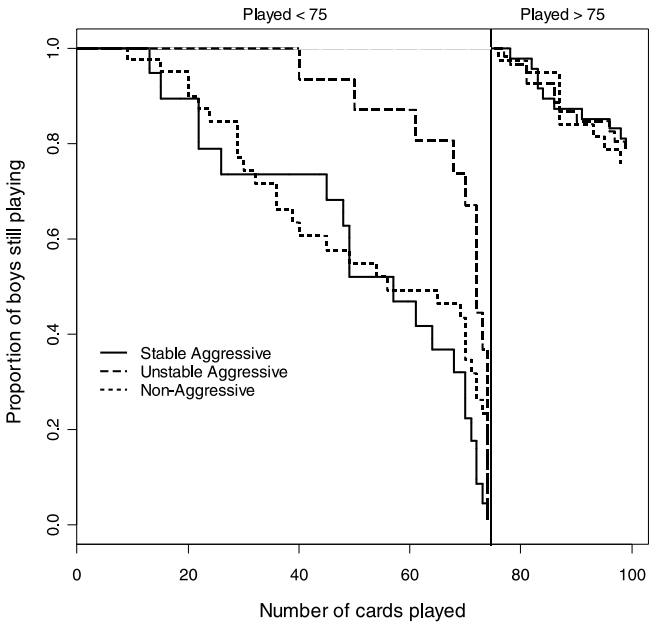

Figure 3 Proportion of boys per group still playing as a function of number of cards, before and after number of cards > = 75

off. Figure 3 also reveals a difference in onset of withdrawal for the unstable aggressive group before the cutoff. These analyses confirm that a change in the curves occurs at 75 cards and that the rates of withdrawing of each curve as a function of predictors are constant otherwise. Under such conditions, survival analysis is no longer the tool of choice to examine a dichotomous outcome. Therefore, to better understand what explains the break at 75 cards, we entered the dichotomized perseveration score as a dependent variable in a logistic regression described below.

Using this definition of perseveration, we classified participants on the dichotomized score as follows: Boys who played more than 75 cards were considered perseverative, and the others non-perseverative. A cross-tabulation of perseveration by groups indicated that 51.4% of non-aggressive boys played fewer than 75 cards, whereas the proportions for Unstable Aggressive boys and Stable Aggressive boys were 22.2% and 27.8% respectively. Overall, a little over half of the sample ($n = 103$) played to the end. Means and standard deviations for number of cards played by group were $M = 85.01$, $SD = 23.87$ for the stable aggressive group, $M = 90.37$, $SD = 14.55$ for the unstable aggressive group, $M = 73.19$, $SD = 28.30$ for the non-aggressive group.

Independent variables were ordered as follows. Because we already know that cognitive processes are poorer in physically aggressive boys, and because of their conceptual proximity to perseveration, we will enter these first followed by personality-motivation processes. Also, because our focus is to further an understanding of physical aggression, physical aggression groups will be entered next, followed by the other discriminant behaviours theoretically relevant to perseveration. More specifically, order of entry for blocks of variables was as follows: Block 1: General Memory and Verbal Working Memory; Block 2: Negative Affectivity, Neuroticism, Extraversion, and Psychoticism; Block 3: physical aggression; Block 4: interactions between physical aggression and Working Memory, Negative Affectivity, Neuroticism, Extraversion, and Psychoticism, and the interaction between Extraversion and Neuroticism; and Block 5: Inattention and Hyperactivity. All variables were forced in the model at their respective steps except for the interactions, which were left free to enter in a forward stepwise fashion. The non-aggressive group was used as the comparison group except where a contrast between both aggressive groups was required, as indicated. For greater clarity of interpretation of odd ratios, all independent variables except group classification were standardized for the logistic regression.

Table 1 shows the correlations between the variables included in the logistic regression. Intercorrelations among variables were in expected directions. However, we note that only Verbal Working Memory, physical aggression, hyperactivity and inattention correlate with perseveration at this stage of analyses. Table 2 shows results from the logistic regression. At the first step, Verbal Working Memory predicted response perseveration but General Memory did not. That effect indicated that a decrease of one standard deviation in Verbal Working Memory was associated with an increased risk of 1.41 (or 1/.71) of being in the perseverative group. This supports the hypothesis that performance on the CPT and the number randomization task do share Verbal Working Memory components. At the second step, we found no significant effects of the covariates Negative Affectivity, Neuroticism, Extraversion, or Psychoticism. This indicated that emotionality-motivation did not influence perseveration

Table 1 Correlations between variables included in the model

Variables	A	GM	VWM	NA	Ex	Psy	N	I	H
Perseveration	.21**	−.06	−.17*	.08	−.07	.04	.09	.18**	.22**
Aggression groups (A)		−.26**	−.32**	.25**	−.02	.30**	.08	.30**	.40**
General Memory (GM)			.29**	−.39**	.38**	−.18**	−.11	−.29**	−.17*
Verbal Working Memory (VWM)				−.02	−.03	−.20**	−.10	−.16*	−.26**
Negative affectivity (NA)					−.36**	.09	.02	.36**	.01
Extraversion (EX)						−.05	−.03	−.05	.13
Psychoticism (Psy)							.34**	.40**	.32**
Neuroticism (N)								.23**	.16*
Inattention (I)									.38**

All correlations two-tailed Pearson except for Spearman correlations with the variables. Aggression groups ordered as follows: Non-aggression < Unstable Aggression < Stable Aggression, and Perseveration ordered as follows: non-perseverative < perseverative.
$n = 197$.
H = Hyperactivity.
* $p < .05$. ** $p < .01$.

overall. However, the effect of Working Memory remained significant.

When physical aggression groups were entered in the third block of the analysis using the non-aggressive group as the comparison group, Verbal Working Memory became non-significant. This indicated that physical aggression and Verbal Working Memory shared a part of the variance that explained response perseveration. More specifically, the share explained by Verbal Working Memory was contained in the share explained by physical aggression groups. Physical aggression groups significantly predicted response perseveration (7.2% of variance). Boys in the stable physical aggressive group were more than two and a half times at risk than the non-aggressive group of belonging to the perseverative group. Boys in the unstable physical aggressive group were about three and a half times more likely than boys in the non-aggressive group to belong to the perseverative group. Although the risk for perseveration was higher in the unstable aggressive group than the stable aggressive group, contrary to prediction, a test of that difference obtained by re-running the model using the unstable aggressive group as the comparison group failed to reach significance. This indicates that stable and unstable aggressive boys perseverate equally.

In the fourth block of the analysis, the interactions between physical aggression groups and Verbal Working Memory, Negative Affectivity, Extraversion, and Psychoticism, and the interaction between Extraversion and Neuroticism did not reach the statistical level to enter in the analysis and were removed from the last two models presented in Table 2. However, the interaction between physical aggression groups and Neuroticism accounted for an additional 3.4% of the variance beyond the effect of aggression groups. This interaction indicated that Neuroticism was related more positively to perseveration in unstable aggressive boys than in non-aggressive boys. This effect was not found among the stable aggressive boys when compared to the non-aggressive boys. We further examined if both the main effect of aggression groups and this interaction would remain significant if we used the unstable aggressive groups as the comparison instead of the non-aggressive group. This alternate way of looking at the same model revealed no difference in perseveration between the unstable and stable aggressive groups. However, the significant interaction effect indicated that Neuroticism was related more positively to perseveration in unstable aggressive boys than in stable-aggressive boys (odds ratio = 3.67, $B = 1.30$, $SE = .48$, Wald = 7.43; $df = 1$, $p = .006$). Further, we examined if any differences in range of Neuroticism could have caused this interaction and found no difference in range across the three groups, no mean difference between the aggressive groups, but a significantly lower score for the non-aggressive group ($F = 3.87$, $p < .05$, $\chi^2 = .04$, power = .69). This effect of Neuroticism on card perseveration was thus specific to unstable aggressive boys and Neuroticism had no impact on perseveration in the other groups.

In the fifth block of the analysis, we entered teacher-ratings of hyperactivity and inattention. Although both were correlated to perseveration in Table 1, only hyperactivity reached significance in the logistic regression, accounting for an additional 2.5% of the variance. This indicated that increases of one standard deviation in hyperactivity resulted in an increased risk of being classified perseverative by a factor of 1.6. However, contrary to our prediction, the introduction of hyperactivity and inattention in the model resulted in a relatively uniform attenuation of the effects of physical aggression groups. Specifically, the change in odds ratio from before to after the entry of hyperactivity in the equation was 1.38 for the stable aggressive group and 1.14 for the unstable aggressive group. We then re-ran the logistic regression by entering hyperactivity before entering physical aggression to examine whether or not physical aggression would have an attenuating effect on the relationship between hyperactivity and perseveration. The change in odds ratio for hyperactivity entered right before entering physical aggression versus right after entering physical

Table 2 Results of logistic regression analyses predicting perseveration

Step	Variables	χ^2	*df*	Pseudo R^2	*B*	*SE*	Wald	*df*	odds
1.		5.31	2	2.1%					
	General Memory				−.03	.16	.03	1	.98
	Verbal Working Memory				−.34	.16	4.59	1	.71*
2.		2.81	4	3.2%					
	General Memory				.09	.18	.24	1	1.09
	Verbal Working Memory				−.37	.17	5.12	1	.69*
	Negative Affectivity				.11	.17	.39	1	1.11
	Neuroticism				.19	.16	1.35	1	1.21
	Extraversion				−.15	.17	.75	1	.86
	Psychoticism				−.05	.17	.07	1	.96
3.		10.28**	2	7.2%					
	General Memory				.11	.19	.34	1	1.12
	Verbal Working Memory				−.26	.17	2.33	1	.77
	Negative Affectivity				−.01	.18	.00	1	1.00
	Neuroticism				.15	.17	.73	1	1.16
	Extraversion				−.19	.18	1.11	1	.83
	Psychoticism				−.17	.18	.85	1	.85
	Physical Aggression[a]								
	a) Stable				.98	.41	5.64	1	2.67*
	b) Unstable				1.26	.43	8.72	1	3.53**
4.		8.60*	2	10.6%					
	General Memory				.13	.20	.43	1	1.14
	Verbal Working Memory				−.29	.18	2.68	1	.75
	Negative Affectivity				−.02	.19	.01	1	.98
	Neuroticism				.02	.26	.01	1	1.02
	Extraversion				−.25	.18	1.80	1	.78
	Psychoticism				−.19	.19	.98	1	.83
	Physical Aggression[a]								
	a) Stable				1.02	.43	5.75	1	2.78*
	b) Unstable				1.21	.44	7.50	1	3.37**
	Neuroticism × Physical Aggression[a]								
	a) Stable				−.25	.38	.42	1	.78
	b) Unstable				1.05	.47	5.07	1	2.87*
5.		6.46*	2	13.1%					
	General Memory				.21	.21	1.04	1	1.23
	Verbal Working Memory				−.27	.18	2.20	1	.77
	Negative Affectivity				−.01	.20	.00	1	.99
	Neuroticism				−.02	.27	.00	1	.98
	Extraversion				−.32	.19	2.89	1	.73
	Psychoticism				−.31	.20	2.40	1	.73
	Physical Aggression[a]								
	a) Stable				.70	.45	2.44	1	2.01
	b) Unstable				1.08	.45	5.78	1	2.95*
	Neuroticism × Physical Aggression[a]								
	a) Stable				−.20	.39	.26	1	.82
	b) Unstable				.96	.47	4.18	1	2.60*
	Inattention				.14	.20	.50	1	1.15
	Hyperactivity				.47	.22	4.44	1	1.60*

* $p < .05$.
** $p <= .01$.
[a] reference group is the Non-Aggressive group.

aggression was 1.05, a barely noticeable change. A closer examination of the hyperactivity data revealed that most boys who had a positive score on hyperactivity were in the physically aggressive groups (about 2/3 of the stable aggressive boys and about ½ of the unstable aggressive boys). In the non-aggressive group, more than 75% of cases had a hyperactivity score of 0. Group means and standard deviations were as follows: for stable aggressive $M = 1.45$, $SD = 1.32$, for unstable aggressive $M = 0.92$, $SD = 1.32$, and for non-aggressive $M = 0.35$, $SD = 0.81$. Thus, the stable aggressive group was most strongly characterized by hyperactive behaviour, whereas this was less the case for the unstable aggressive group, and not at all the case for the non-aggressive group. A t-test limited to aggressive groups revealed that level of hyperactivity was significantly higher in the stable aggressive group compared to the unstable aggressive group ($t_{(126)} = 2.27$, $p = .025$). However, despite a difference in levels of hyperactivity across groups, the relationship between hyperactivity and perseveration in both aggressive groups did not appear to differ. Spearman correlations between hyperactivity and

perseveration in the stable and unstable aggressive groups were, respectively, $r = .29$, $p = .015$, and $r = .31$, $p = .016$, and the correlation was non-significant for the non-aggressive group. In conclusion, although hyperactivity attenuated the effect of physical aggression on perseveration, the association between hyperactivity and perseveration appeared to be independent from the association between physical aggression and perseveration. Nonetheless, hyperactivity was confounded with physical aggression groups in this sample.

Discussion

The main findings of this study support the general hypothesis that a history of physical aggression is a strong predictor of perseveration in adolescence. However, contrary to our prediction, stable and unstable aggressive boys perseverate equally. Nonetheless, groups differed qualitatively in the processes underlying perseveration: Neuroticism was associated with perseveration but only for the unstable aggressive group relative to the other groups. Finally, hyperactivity was related to perseveration, but contrary to our prediction, this association was not straightforwardly explained by physical aggression as hyperactivity was confounded with aggressive groups. Because of this, the addition of hyperactivity to our models attenuated the relation between physical aggression and perseveration overall. Despite this confound, perseveration remained a characteristic of the unstable aggressive group compared to both the stable aggressive and non-aggressive groups. Neuroticism also remained associated with perseveration in the unstable aggressive group relative to the other groups.

Besides the interaction with Neuroticism, only the Verbal Working Memory score was negatively associated with perseveration, as predicted. This indicated that Verbal Working Memory abilities are likely to allow an individual to monitor relevant information on-line, re-evaluate ongoing action, change strategy, and reduce the likelihood of perseveration. However, the effect of Verbal Working Memory on card perseveration was included in the aggressive group status in this sample. In sum, general findings regarding response perseveration in a context of heightened motivation can now be extended to boys with different histories of physical aggression. However, there may be multiple pathways to perseveration, which vary between groups of individuals. In this study, pathways diverged as a function of histories of aggressive behaviour.

Mechanisms associated with perseveration and different histories of physical aggression

The hypothesis devised to contrast histories of physical aggression was based on the assumption that processes involved in perseveration on the CPT measured in adolescence may be similar to those that contributed to a high likelihood to perseverate in the use of physical aggression over time. We had expected that, if perseveration were to be found in adolescents with a history of stable aggression in childhood, frequency of perseveration would have been higher in that group than in a group of adolescent boys with an unstable history of childhood physical aggression. Instead of the expected quantitative difference, we found a qualitative difference between those two physically aggressive groups: age 13 Neuroticism did discriminate between those histories. Neuroticism increased the risk of perseveration in the unstable aggressive group only, and no other process included in this study could explain perseveration in the stable aggressive group. Two hypothetical models may help understand these qualitative differences in the absence of a quantitative difference.

The model proposing that dysregulation of behaviour is due to Neuroticism (Wallace & Newman, 1998) may explain perseveration on the CPT in unstable aggressive boys. Neuroticism may increase the risk of impulsive responding, and therefore, of perseveration as a function of the presence of either cues for reward or punishment or both. The sensitivity to such cues would directly increase arousal, which would, in turn, impair attentional systems and optimal information processing. Thus on the CPT, unstable aggressive boys may initially get aroused by the high reward rate. They may notice the increasing rate of punishment, and this may heighten their arousal as well. Nonetheless, the level of arousal would rise beyond a point where they could gain perspective on the game, particularly as they approach the optimal cutoff point where they could maximize gains. Neuroticism impairs information processing and resulting behaviour in other contexts as well. For example, one study suggests that Neuroticism may increase vigilance in situations involving threat and where escape is possible but, alternately, increase emotional numbness when escape from threat is not a perceived option (Wilson, Kumari, Gray, & Corr, 2000).

Another model could then explain why stable aggressive boys perseverated as much as the unstable aggressive group despite a lack of association of Neuroticism, or of any other relevant process. This model and the previous hypothetical model presented above have both been integrated in recent formulations of the response modulation hypothesis proposed by Newman and colleagues (Newman & Lorenz, 2002) to characterize syndromes of disinhibition. In general, response modulation involves the automatic ability to attend to peripheral cues, use them to inhibit a dominant response set and shift responding. This brief shift in attention to relevant peripheral information is thought to be sufficient to engage controlled processing and access prior

experience. Specifically, Newman and Lorenz (2002) suggest that two pathways may lead to deficient response modulation. Neuroticism may be involved in one pathway that would impair response modulation following the process we outlined above.

The alternate, second pathway represents a fundamental and more general information-processing deficit involving cognitive-attentional problems that would be observable across many settings, as long as a predisposed individual is absorbed by a primary task (Newman & Lorenz, 2002). When engaged in such goal-oriented action, that individual would fail to attend to secondary or latent characteristics of the activity in which he or she is engaged. However, when explicitly told to look for secondary or latent information, performance would be adequate. Thus in contrast to the first pathway where high emotional reactivity is involved in the dysregulation of attention, the second pathway involves a form of attentional rigidity. Adopting this framework suggests at least two implications for the observed perseveration of stable aggressive boys.

A first implication is that when engaged in goal-directed behaviour, stable aggressive boys would be more likely to experience difficulties in attending to and/or integrating relevant peripheral information that would have prevented perseveration. Given an incentive to move forward, they have little to go on to stop their action. Thus on the CPT, once these boys have begun turning cards, they would not process the increasing rate of punishment and just keep turning cards (their primary task) regardless of contingencies or consequences. A second implication is that reward and punishment cues that could otherwise impair self-regulation as a function of Neuroticism in this group may not get processed. This in turn may explain why Neuroticism is not related to perseveration in this group although average Neuroticism levels between both groups do not differ. This interpretation is consistent with findings that individuals whose response modulation problems are related to the second pathway have typically been identified in situations where their information processing failures could not be accounted for by emotionality, although these individuals were not without emotionality otherwise (Newman & Lorenz, 2002; Schmitt & Newman, 1999). More specifically, psychopaths and controls do not differ when deliberately attending to emotional stimuli (Newman, 1998; Newman & Lorenz, 2002). However, psychopaths show little emotional response when their goal-oriented behaviour does not initially require them to attend to emotion-related cues (Arnett, Smith, & Newman, 1997). Together these elements suggest that, if we had instructed our boys specifically to attend to both rewards and losses, either the perseveration of stable aggressive boys would have become a function of Neuroticism like for the unstable aggressive group, or this information would have enabled all boys to derive the underlying implicit rule of the game and stop playing sooner than they did in general.

To recapitulate, the data supports that emotional reactivity to rewarding or punishing stimuli in the environment, as captured by the concept of Neuroticism, may be involved in the perseveration of the unstable aggressive group whereas, and more speculatively, a more fundamental information processing limitation would characterize perseveration for the stable aggressive group. Thus one important contrast between both pathways to perseveration is that the more fundamental information processing limitation would necessarily lead to perseveration of goal-oriented action independently of sensitivity to reward–punishment contingencies, while Neuroticism would only do so under circumstances that contribute to heighten arousal.

One limitation of the data, however, does not permit us to directly address the relevance of these models for aggression per se. Nonetheless, if we assume that the characteristics that underlie perseveration in stable aggressive and unstable aggressive boys are relatively constant over time and since early childhood, then the aggression of the unstable aggressive group may be occasional because both reward and punishment have greater impact on these boys' behaviour. It is likely that under some circumstances, this sensitivity could have led them to avoid escalation of a potentially aggressive encounter more often than stable aggressive boys for whom perseveration may have little to do with reinforcement contingencies. The stable aggressive boys, because of their presumed fundamental information-processing problem, may more likely fail to avoid these encounters from one time to the next. Recent research reports on the development of psychopathy in non-incarcerated and young samples are consistent with this position (Lynam, Whiteside, & Jones, 1999). Thus this impairment in information processing could then partly explain why these boys, like some psychopaths, tend to be more often violent and recidivistic than the unstable aggressive boys (see also Hemphill, Hare, & Wong, 1998).

Hyperactivity and history of physical aggression

Although the models presented above may to some extent account not only for the occurrence of physical aggression, but also for the differences in stability of physical aggression over time, an alternative and possibly complementary explanation for differences in stability lies in the role of hyperactivity. We first noted that teacher-rated hyperactivity at age 13, not inattention, predicted perseveration, as expected. Second, the relation between hyperactivity and perseveration was the same in the physically aggressive groups. Third, physical aggression did not account for the relation between hyperactivity and perseveration because hyperactivity was largely confounded with physically

aggressive groups. Fourth, the highest levels of hyperactivity were found in the stable aggressive group, followed by the unstable aggressive group and the non-aggressive group. This would preclude use of this sample to test a hyperactivity by groups interaction in which hyperactivity could increase the likelihood of perseveration but only in some groups. Nonetheless, these results are consistent with theories that link hyperactivity levels and presence of physical aggression to chronicity of antisocial behaviour (Lynam, 1996). Therefore, it is reasonable to propose that, although hyperactivity may put unstable aggressive boys at risk for aggressive encounters, this risk would be lower than for stable aggressive boys because their overall level of hyperactivity is also lower.

Measurement of perseveration in early adolescence

The high number of boys who played fully to the end of the CPT initially surprised us. However, a closer look at several published studies indicates that a high number of boys playing all cards is common. Several other studies report means and large standard deviations comparable to those reported herein (see, for example, Kindlon et al., 1995; Shapiro et al., 1988). Further, one group clearly reported that 40% of their participants (mean age of about 11 years) played all 100 cards with an average number of cards = 71.3 (see Kindlon et al., 1995). The fact that we found about 50% of 13-year-old adolescent boys to play 100 cards also remains in a similar range although there are several important differences between sample characteristics. As one reviewer suggested, it is possible that perseveration on the CPT decreases with age. This is certainly seen in younger children (Zelazo et al., 1997). In our sample, adolescents were all 13 years old, whereas other samples that have found a lower rate of cards played also included older adolescents. This raises the option of a developmental delay account of group differences. Cross-sectional studies could help examine developmental components of perseveration on the CPT. However, age was not found to be predictive of number of cards played in one study despite a range spanning from 6 to 16 years (Kindlon et al., 1995). Nevertheless, that same study showed that experience was related to a significant decrease in average perseveration from time 1 to time 2. Presumably, true problematic perseveration would involve those children who fail to learn from one time to the next. Testing this hypothesis would require longitudinal data. We may also question if a ceiling of 100 cards on the CPT for age 13 boys may be low. This does make sense considering the optimal point at which sufficient objective information is available to participants to make a decision to quit is around 75 cards and that the average number of cards played by the non-aggressive group was about the same figure. However, it is unlikely that a higher ceiling would have made a difference in the current study because the rates of withdrawal from the game of all three groups from 75 to 100 cards did not differ. Therefore, it is unlikely that rates would change if the game allowed exceeding 100 cards. In other words, beyond the cutoff, all groups perseverate equally.

Conclusion

This study indicates that, although physical aggression is a predictor of perseveration, the processes underlying perseveration in adolescence distinguish those who have been stable from those who have been unstable in their childhood history of physical aggression. If we accept the assumption that those processes are themselves stable over time we can derive two implications. First, the combined factors of early physical aggression, hyperactivity, and perseveration that is not a function of heightened emotionality to rewards and punishment may be indicative of risk for a chronic course of physical aggression. Although these factors are not at all seen as causal, they could very well contribute to the maintenance of maladaptive behaviour. Second, the combined factors of early physical aggression, moderate hyperactivity, and signs of perseveration that are a function of heightened emotionality to rewards and punishment may be indicative of an occasional course of physical aggression. In order to address these hypotheses we need to broaden our measurements of response modulation, and examine if deficient response modulation has any bearing whatsoever on childhood perseveration and if childhood perseveration is also linked to childhood physical aggression, hyperactivity, and impulsivity.

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