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**Individual and developmental differences in delinquency: Can they be explained by  
adolescent risk-taking models?**

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## **Abstract**

Delinquency shows an increase in adolescence and is hence often cited as a behaviour explainable in terms of adolescent risk-taking models. In this review we summarise contemporary developmental models of adolescent risk-taking as they apply to delinquency and evaluate the extent to which they are supported by empirical evidence. Dual Systems theory, Fuzzy Trace Theory, the Lifespan Wisdom Model (LWM), and the Developmental Neuro-Ecological Risk-taking Model (DNERM) are all discussed. We highlight that there have been very few direct empirical evaluations of developmental risk-taking models as applied to delinquency; however, indirect evidence supports the core Dual Systems theory claim that a developmental imbalance between sensation-seeking and self-regulation contributes to an adolescent peak in offending. However, this appears to apply particularly to a sub-group of vulnerable youth, as implied by the LWM. Further, risk-taking propensity likely interacts with age-related changes in exposure to risk-conducive situations, as implied by DNERM. There is little evidence to suggest that Fuzzy Trace Theory alone explains developmental changes in risk-taking, though it may help explain how young people learn about risk, as outlined in LWM. Better integration of risk-taking models with criminological perspectives as well as further longitudinal research using appropriate operationalisations of developmental imbalance, modelling individual differences in trajectories, and incorporating measures of exposure to risk-conducive situations will be essential for advancing knowledge of the drivers of engagement in delinquency in adolescence.

Keywords: adolescence; delinquency, offending; risk-taking

Adolescence is widely recognised as a critical period and among the multitude of changes that occur in this time, engaging in delinquent behaviours such as theft, vandalism, and violence, has been considered one of its ‘hallmarks’ (Barbot & Hunter, 2012). Estimates from the US-based National Longitudinal Study of Youth 1997, for example, suggest that by age 23, as many as 30.2-41.4% of youth have been arrested as a result of their delinquent behaviour, with the biggest increase in cumulative prevalence occurring in late adolescence and emerging adulthood (Brame et al., 2012). While engagement in delinquent behaviours in adolescence is often perceived to be quite normative (e.g., Barbot & Hunter, 2012; Ellis et al., 2012; Moffitt, 2003; Sercombe, 2014), it is, at the same time, a major societal concern. Offending during this period places adolescents at risk of becoming ensnared in anti-social lifestyles and/or experiencing life-altering consequences such as sanctions by school (including permanent exclusion) or criminal justice systems (Lopes et al., 2012; Makarios et al., 2017). It can also have long-term negative impacts on crime victims and significant costs to society (Arseneault, 2018; Mahuteau & Zhu, 2016). Robust evidence on the nature, function, and individual differences in engagement in delinquency in adolescence is, therefore, important for informing strategies to prevent and/or mitigate the harms of delinquency.

A promising approach to illuminating adolescents’ delinquent behaviour has been in terms of adolescent risk-taking models (Armstrong et al., 2020; Vazsonyi & Ksinan, 2017), motivated by the observation that delinquent behaviour typically involves both potential reward (e.g., thrills, peer approval, material gain) and a risk of serious consequences (e.g., formal legal sanctions, sanctions imposed by schools, victim retaliation, and negative reactions by peers), which adolescents place varying weight on (Burt & Simons, 2013; Shulman et al., 2017). While there have been various reviews critiquing major contemporary adolescent risk-taking perspectives such as Dual Systems theories, Fuzzy Trace Theory, the

Lifespan Wisdom Model, and the Developmental Neuro-Ecological Risk-taking Model, none has yet evaluated and compared them in relation to their ability to explain the increase in engagement in delinquent behaviour in adolescence (Defoe et al., 2019; Rosenbaum et al., 2018; Shulman et al., 2016). In this review we thus summarise these models and evaluate the extent to which they are consistent with existing empirical findings on offending behaviour in adolescence.

### **Dual systems theories of adolescent risk-taking**

There are several variants of dual systems theories, including the Dual Systems (DS) Model (Steinberg et al., 2008), the Maturational Imbalance Model (Casey et al., 2008), and the Driven Dual Systems Model (Luna & Wright, 2016), though the DS Model has been the most influential and will thus be our primary focus here. In the DS Model, the development of the socioemotional system served by limbic motivational regions of the brain outpaces that of the cognitive control systems served by the prefrontal cortex. The former is assumed to show a peak in activity triggered by puberty and is associated with heightened reward drive in adolescence while the latter still continues to mature. These differential development rates are proposed to result in a period during adolescence characterised by heightened reward-related processing concurrent with poor top-down control, manifesting psychologically as heightened sensation-seeking that is inadequately matched by self-regulation. This ‘developmental imbalance’ is assumed to lead to an adolescent peak in the behaviours referred to as ‘risk-taking’, typically understood as behaviours which carry some possibility of a negative outcome (e.g., injury, overdose, arrest, sexually transmitted infection). According to the DS Model, engagement in risk-taking occurs particularly in emotionally arousing decision contexts that activate the socioemotional system, including when peers are present.

The DS Model has been extensively evaluated in relation to a range of lab-based and real-world risk-taking behaviours (see e.g., Crone et al., 2016; Defoe et al., 2019; Duell et al., 2016; Meisel et al., 2019; Pfeifer & Allen, 2016; Shulman et al., 2016 for reviews); however, direct evaluations of its predictions in relation to delinquency have been surprisingly lacking. As implied above, the DS Model predicts that there will be a peak in offending around mid-adolescence mapping to a period of developmental imbalance between the socioemotional and cognitive control systems following puberty onset and that this will occur particularly in affectively arousing situations (including those where peers are present).

Evidence broadly supports the claim that antisocial behaviour peaks in adolescence, though there is variation across behaviours and context (Eisner & Malti, 2015; Farrington, 1986; Farrington et al., 2008; Piquero et al., 2003; Sweeten et al., 2013; Willoughby, this issue). For example, physical aggression (e.g., hitting, kicking) peaks in early childhood and declines continuously until late adolescence (e.g., Campbell et al., 2006; Tremblay et al., 1999) while most forms of serious violence (e.g., homicide, sexual assault) and family violence, as well as crimes that require access to financial opportunities such as fraud and embezzlement, peak in adulthood (Steffensmeier et al., 1989; Willoughby, this issue). Similarly, contrary to the ‘invariance’ hypothesis proposed by Hirschi and Gottfredson (1983), there can be substantial variation between societies and within societies across time in age patterns of offending (Collishaw, 2015; Lu & Luo, 2020; Payne & Piquero, 2020). In India, for example, Steffensmeier et al. (2019) found a much later peak age of offending than has been observed in Western countries and a flatter age curve for all major types of crime, with a median age of offending of around 37 years. Similarly, analyses of offending rates in Taiwan (Steffensmeier et al., 2017) and South Korea (Steffensmeier et al., 2020) suggest a later onset, a later peak age, and a flatter decline with increasing age in collectivistic Asian societies as compared to Western individualistic societies. Steffensmeier et al (2017) argue

that Asian societies show no peak of offending in adolescence because they are not culturally supportive of adolescent rebellious behaviour, have a higher emphasis on filial piety and respect, and have more comprehensive protective social monitoring until early adulthood. Taken together, the peak of offending around mid-adolescence predicted by the DS Model appears to best encapsulate the age patterns of much common property and violent delinquency in Western Societies. In contrast, age patterns of serious violence, white-collar crime, and intimate partner violence tend to peak at a later age. It is also important to note that much of the evidence cited in support of an adolescent peak in delinquency relates to group-level trends, which do not necessarily reflect individual-level developmental trajectories (Mirman et al., 2019). When person-centred methods that map individual trajectories over development are applied, it becomes clear that aggregate-level trends conceal considerable individual differences in delinquency trajectories (Jennings & Reingle, 2012); a point we return to when we discuss the Lifespan Wisdom Model.

Regarding the predicted neurodevelopmental basis of an adolescent peak in offending, a large body of research has highlighted the roles of socioemotional system (e.g., sensation- or thrill-seeking) and cognitive control (e.g., self-regulation) constructs, in both individual and age-related differences in offending, (Burt et al., 2014; Forrest et al., 2019; Fosco et al., 2019; Monahan et al., 2009; Ribeaud & Eisner, 2006; Vazsonyi et al., 2017). However, these studies have most often been inspired by criminological frameworks such as the general theory of crime (Gottfredson & Hirschi, 1990; Grasmick et al., 1993), which do not consider *imbalances* between cognitive control and socioemotional systems. As such, only a handful of studies have attempted to evaluate whether a mis-match between levels of these constructs drives engagement in heightened offending in adolescence and even fewer have examined the role of a *developmental* imbalance (Armstrong et al., 2020; Burt et al., 2014; Burt & Simons, 2013; Forrest et al., 2019; Vazsonyi & Ksinan, 2017; Wojciechowski, 2020).

In one study, Forrest et al. (2019) used a moderated regression approach to operationalise imbalance and found a significant three-way interaction between sensation-seeking, impulse control, and age in predicting delinquency over adolescence (age 10 to 18 in their sample). Specifically, they found that increases in sensation-seeking or impulsivity (self-regulation reversed) had greater effects when adolescents were older and had experienced relative increases in the other component. These findings provide important insights into age-related changes in the joint effects of sensation-seeking and impulse control. However, as Meisel et al. (2019) argue, in general, demonstrating that the effect of one component of a DS model (e.g., self-regulation) is moderated by the other (e.g., sensation-seeking) is not sufficient to conclude that an imbalance between these constructs is responsible for the risk-taking outcome. In particular, within these statistical models, predicted risk-taking propensity can differ for participants with the same magnitude of imbalance (but different socioemotional and cognitive control scores).

Other studies have used an observed difference score approach in which individual imbalance is operationalised in terms of the difference between a cognitive control score and sensation-seeking score. Vazsonyi & Ksinan (2017), for example, found that scores constructed this way predicted deviant behaviour among adolescents. However, as discussed elsewhere (Meisel et al., 2019), difference scores confound the effects of the difference score components (sensation-seeking and self-regulation) with the imbalance between them, and impose implicit constraints on the relations between these components and the outcome (e.g., delinquency), constraining the effects of the components to be of equal but opposite sign. These issues render evidence from difference score approaches similarly ambiguous to evidence from a moderated regression approach.

Meisel et al., (2019) provided a detailed critique of moderated regression and observed difference score approaches to testing DS theories, also emphasising that their



predictions are developmental in nature and thus critically dependent on a longitudinal specification of imbalance. They recommended using latent difference score modelling or growth mixture modelling with longitudinal data to assess DS theories. While a few studies have used this or a similar approach to examine the relations between developmental imbalance and substance use (Khurana et al., 2018; Meeus et al., 2021; Meisel et al., 2019), there has been limited application of these approaches to delinquency. The only study using this approach to study delinquency to date, Murray et al. (2021) found that across ages 11-20, individuals assigned to a developmental trajectory characterised by a developmental imbalance between sensation-seeking and self-regulation showed an adolescent peak in delinquency, whereas youth assigned to trajectory groups characterised by a lack of developmental imbalance showed stably low levels of delinquency across this developmental period. Further, when they stratified analyses by gender, they found that only males showed strong evidence of a trajectory group characterised by a developmental imbalance and an adolescent peak in delinquency.

The DS Model prediction that heightened adolescent offending should occur particularly in affectively arousing situations (including with peers present) can also only currently be evaluated on the basis of primarily indirect evidence, though this evidence does appear to be consistent with the claim. In particular, adolescents show a strong tendency to engage in co-offending (i.e., offending with peers) in preference to solo offending (Barbot & Hunter, 2012; Defoe et al., 2021; Piquero et al., 2007). This tendency to co-offend peaks around age 17 and declines in adulthood as offenders increasingly switch to offending alone (Goldweber et al., 2011; Piquero et al., 2007). Again, importantly, this switch has been confirmed using person-centred approaches that show that this is not merely reflecting changes in the composition of offenders in the age-co-offending curve (e.g., increased

desistence of co-offenders compared to solo offenders) but at least partially reflects individual-level changes in offending mode (Goldweber et al., 2011).

However, there are a number of alternative explanations that have been offered for the adolescent peak in co-offending. It has been suggested, for example, that adolescents need more peer support than adults to offend, that the types of offences committed by adolescents (e.g., vehicle theft) benefit more from co-operating with others, or that adolescents prefer to do things in groups, with co-offending merely one example of this general preference (e.g., Van Mastrigt & Carrington, 2019). All of these developmental differences in peer-related factors offer alternative explanatory accounts to a DS-based Model that attributes the effects of peers to a reward sensitisation process mediated by the activation of the socioemotional system (see e.g., Albert et al., 2013). Further research will be required to directly compare the predictions of this with alternative accounts.

### **Fuzzy Trace Theory**

Fuzzy Trace Theory (FTT) is a major alternative theory to DS theories that seeks to explain developmental differences in risk-taking in terms of shifts in decision-making processes (Chick & Reyna, 2012; Reyna et al., 2015). FTT makes the distinction between verbatim- and gist-based decision making, where the latter relies more on cognitive control, is facilitated by experience, and promotes choosing less risky decision options, where ‘risky’ is defined in similar terms to in the DS Model. As individuals develop, it is proposed that they undergo a shift characterised by decreased reliance on verbatim decision-making and increased reliance on gist decision-making. This shift promotes less risk-taking because decision-makers using gist-based reasoning are more likely to categorise a decision option associated with even a small probability of a negative outcome as undesirable. Owing to the presence of the possibility of sanctions and other costs, offending is thus an example of a behaviour where gist-based reasoning would be liable to lead to lower risk-taking (Reyna et

al., 2018). As such, FTT predicts that children should show the highest offending propensities, adolescents intermediate offending propensities, and adults the lowest offending propensities. However, whether developmental changes in verbatim- versus gist-based reasoning track developmental changes in offending has yet to be tested. Further, while (as noted above) some forms of delinquency peak in childhood (physical aggression; Tremblay et al., 1999), most peak in adolescence or adulthood (Eisner & Malti, 2015). This is in direct contradiction of the predictions of FTT and suggests that verbatim- versus- gist reasoning cannot be the primary cause of developmental differences in offending. FTT is discussed further in the context of the Lifespan Wisdom Model, which incorporates it as a mechanism by which adolescents become increasingly capable of reasoning adaptively about risk.

### **The Lifespan Wisdom Model**

The Lifespan Wisdom Model (LWM) integrates elements from both the DS Model and FTT (Romer et al., 2017). LWM proposes that while sensation-seeking peaks in adolescence, an imbalance with cognitive control occurs only for those adolescents who have stable (pre-existing) weaknesses in this latter domain (Romer et al., 2017). It is only this subgroup who engage in ‘maladaptive’ risk-taking, defined as behaviours where insufficient consideration has been given to potential negative outcomes. These youth are consequently at risk of adverse outcomes such as substance addiction. For the majority of adolescents, risk-taking is presumed to be ‘adaptive’, i.e., explorative, controlled, and leading to learning (Romer & Khurana, 2020). In the context of LWM, risk-taking thus, for the majority of youth, facilitates the acquisition of ‘wisdom’ that contributes to better decision-making, ultimately supporting a decline in risk-taking behaviour into adulthood. The mechanism by which risk-taking experiences lead to better decision-making is through engendering a shift from verbatim-to-gist- based decision-making, as described in FTT.

A primary testable prediction of LWM that differentiates it from DS theories is that there will be only a small subgroup of youth with chronically low cognitive control and higher levels of problematic delinquency in adolescence. Indeed, though not framed in terms of LWM there is a wealth of relevant data on delinquency that speaks to the idea of a subgroup of individuals with a long-term vulnerability for problematic risk-taking, accounting for the majority of the societal costs of crime (Allard et al., 2014). It has long been known that there are important individual differences in the developmental trajectories of delinquent behaviours among those who engage in delinquency in adolescence, and several influential taxonomic theories have been proposed to explain them (Loeber & Stouthamer-Loeber, 1998; Moffitt, 1993; Patterson et al., 1989). One particularly influential perspective is the dual taxonomy theory, which proposes that an adolescent peak in delinquent behaviour is attributable to two main types of offenders: those with life-course persistent offending and those with adolescent-limited offending (Moffitt, 1993, 2018). Those in the life-course persistent category are assumed to be characterised by early emerging behaviour problems that are the outcome of negative transactions between neurodevelopmental risk factors (e.g., attention-deficit/hyperactivity disorder; ADHD) and early socio-environmental factors (e.g., harsh parenting). Their behaviour problems are assumed to be of greater severity, characterised by more aggressive behaviours, and to persist into adulthood. Members of the adolescent limited category are assumed to be considerably more numerous than those in the life-course persistent category and characterised by behaviour problems that emerge in adolescence due to the imitation of antisocial peers. Their engagement in delinquency is proposed to be driven by a ‘maturity gap’ whereby adolescents perceive themselves to be biologically mature yet lacking access to adult privileges. Their anti-social behaviour is, therefore, employed as a means to demonstrate maturity and autonomy. Their behaviour is characterised primarily by rule-breaking (non-aggressive) conduct problems and while it is

acknowledged that some adolescents may encounter 'snares' e.g., drug addiction, school dropout, or a criminal record, it is generally assumed that their delinquency is transient and expected to desist in the transition to adulthood.

Recent reviews have highlighted that the distinction between the life-course persistent and adolescent limited categories is almost certainly more one of degree than kind, with the groups showing similar risk factor and neurocognitive profiles (Fairchild et al., 2013). However, evidence supports the basic contention that adolescents who engage in delinquency can be usefully divided based on whether these behaviour problems existed prior to adolescence, with those with a childhood onset being more likely to have neurodevelopmental vulnerabilities and more severe and persistent behaviour problems (e.g., Fairchild et al., 2013; Fairchild & Smaragdi, 2018; Jennings & Reingle, 2012). Once recent study (also discussed earlier) examined subgroups of delinquency trajectories specifically in relation to sensation-seeking and self-regulation trajectories from ages 11 to 20 and found that only a small subgroup (~7%) of the (normative) sample (10% of males) were characterised by a developmental imbalance and pronounced escalation of delinquency in adolescence (Murray et al., 2021). The remainder of the sample showed little evidence of an escalation in delinquency, even for one subgroup where there was a spike in sensation-seeking. This provides supportive evidence for the LWM as an account of individual differences in the development of delinquency. Evidence also supports the LWM idea that those with the most severe offending behaviour in adolescence have stable cognitive control/self-regulation deficits. One longitudinal study, for example, found that youth with poorer impulse control showed a more pronounced adolescent offending peak than their peers (Loeber et al., 2012). Another reported that juvenile offenders differed from the average in their cognitive control developmental trajectories and did not show the expected

improvements in cognitive control over development identified in normative studies (Wojciechowski, 2020).

### **Developmental Neuro-Ecological Risk-taking Model**

While DS theories recognise that situational (primarily affective context/peer presence) and opportunity factors may play a role in explaining some aspects of age patterns of risk-taking, the explanatory weight is on a presumed neurodevelopmental imbalance, making a peak in risk-taking behaviour in mid-adolescence a core testable prediction (Steinberg et al., 2008). However, growing evidence suggests that risk-taking does not peak at this time. A meta-analysis of laboratory-based tasks found that, contrary to the predictions of the DS Model, adolescents engage in the same level of, or less risk-taking than children, depending on task demands (Defoe et al., 2015, 2019). Real world risk-taking behaviours and their sequelae show developmental patterns that diverge from those in laboratory-based risk-taking tasks but these, too, are often inconsistent with the predictions of DS theories. Binge-drinking, fatalities due to drink-driving, substance use, sexually transmitted infections, and unintentional injuries, for example, all tend to peak around or shortly after the transition to adulthood (Willoughby, this issue; Willoughby et al., 2013) and not in mid-adolescence and, as discussed above, some forms of offending also show a later peak than expected based on a neurodevelopmental maturation model alone.

The Developmental Neuro-Ecological Risk-taking Model (DNERM; Defoe et al., 2015; Defoe, this issue) was proposed help reconcile the discrepancies between the age-related risk-taking propensities observed on laboratory-based tasks and real-world risk-taking patterns. The model proposes that real-world risk-taking opportunities increase over the course of development due to factors such as decreased adult supervision, greater opportunities to affiliate with deviant peers, and increased access to restricted activities (e.g., alcohol consumption, driving, gambling) and stabilise after emerging adulthood. As such,

DNERM proposes that while risk-taking propensity (lack of cognitive and affective self-control) is lower in emerging adulthood versus adolescence, real-world risk-taking behaviour could still increase over the same time-course because of greater physical and social risk opportunity exposure. DNERM, therefore, suggests that developmental differences in exposure to risk-conducive situations and psychological maturation determine delinquent behaviours.

The idea, formalised in DNERM, that real-world risk-taking behaviour is the outcome of an interaction between propensity and exposure to risk conducive situations has long been thought critical for understanding antisocial behaviour and its variations over development (see e.g., Sampson & Laub, 2017 for a review); however, DNERM itself has not been tested directly in relation to delinquency. Efforts such as DNERM to bridge exposure/opportunity and propensity theories of delinquency are; however, needed as it clear that neither purely neurodevelopmental nor sociological theories can explain age-related patterns of delinquency. Indeed, as well as the evidence on neurodevelopmental drivers of risk-taking discussed above, there is much evidence suggestive of the fact that exposure to risk-conducive situations plays a role in the differential expression of delinquent behaviour over development. There is evidence, for example, that delinquency levels increase as adult supervision declines over the course of development. Indicators of parental monitoring are developmentally correlated with delinquency and predict subsequent delinquency in cross-lagged panel models (Laird, Pettit, Bates, et al., 2003; Laird, Pettit, Dodge, et al., 2003). Further, when parental monitoring is successfully increased via intervention, it tends to be accompanied by a reduction in adolescent engagement in delinquency (see Racz & McMahon, 2011 for a review). The forms of delinquency that peak at different ages also map approximately to opportunity, with physical aggression and offenses such as vandalism and theft which have been noted to be less ‘restricted’ by lack of opportunity (e.g., Duell et al.,

2018) peaking at earlier ages than those that require access to adult privileges and roles (e.g., embezzlement and domestic violence). Indeed, DNERM is perhaps unique among contemporary risk-taking perspectives in being able to accommodate the observation that physical aggression, as a form of delinquency, peaks in childhood (FTT also predicts a childhood peak in risk-taking but cannot explain why most other risk-taking behaviours do not peak at this time).

### **Future directions in risk-taking perspectives on adolescent delinquency**

#### **Improving specificity of risk-taking perspectives and their integration with criminological perspectives**

The above discussions highlight that while many contemporary risk-taking perspectives offer important insights into individual and developmental differences in offending behaviour, further work is required to develop them and to rigorously test them specifically in relation to delinquency. One way to interrogate the utility of these different models is to evaluate *how* they would answer the who, what, and when questions of delinquency – in other words, who will offend (i.e., what is the distribution of delinquency risk in the population?), what kind of offenses will they commit (i.e., what domains of delinquency will they engage in and how severe will the offending be?), and when are they most likely to do it (e.g., in what contexts is offending most likely to occur, how frequently will offending occur, and at what stage, developmentally, would offending be most likely?). At present; however, only some of these questions can be clearly answered in terms of predictions from the risk-taking perspectives discussed in the present review. The difficulty of making specific testable predictions from adolescent risk-taking models that has been noted previously (e.g., Meisel et al., 2019; Pfeifer & Allen, 2016; Shulman et al., 2016) and is one that applies as much to delinquency as a specific form of risk-taking.



A major area where greater specificity would be beneficial is in the question of what, precisely, is meant by ‘risk-taking’ in the context of delinquency. As noted above, in most developmental approaches to risk-taking, the concept of risk-taking is merely defined as a behaviour for which there is some probability of a negative consequence; however, this diverges from more formal economic definitions sometimes used in lab-based tasks in which risk-taking is defined as choosing an option with greater outcome variance (Romer & Khurana, 2020). Generally, lab-based tasks, even those designed to mimic ‘real-world’ risk-taking more closely (e.g., the Stoplight task), show at best modest correlations with self-reported delinquency (e.g., Defoe et al., 2020). To better illuminate the role of risk-taking and its drivers in delinquency, it is, therefore, likely to be helpful to draw on the offender decision-making literature to consider what ‘risk-taking’ means in a real-world context. This literature delineates specific costs and benefits that are considered by potential offenders, such as ‘self-related’ (e.g., feelings of fun vs guilt), social (e.g., admiration vs rejection by peers) and external or material costs and benefits (e.g., material gains vs arrest or other sanctions/retaliation by the victim) (Matsueda et al., 2006; Nagin, 2007; Pogarsky et al., 2018; Van Gelder & De Vries, 2014). Definition and measurement of risk associated with delinquency informed by offender decision-making theory and evidence is likely to be helpful for illuminating how risk-taking in this domain changes and is shaped over the course of development.

Another issue that should be addressed in applications of risk-taking models to delinquency will be delineating predictions relating to different forms of delinquency. Delinquency is a broad term that encompasses a wide range of behaviours that vary across contexts (e.g., with different laws relating to minimum age of alcohol purchase). Given the hypothesis that adolescents are prone to heightened risk-taking especially in affectively arousing contexts (Rosenbaum et al., 2018) and perhaps only in a subgroup of youth with

long-term stable deficits in impulse control (Romer et al., 2017), it is likely that developmental and individual differences affectively hot/impulsive forms of delinquency such as reactive aggression (see e.g., Lickley & Sebastian, 2018) will be better captured by risk-taking models than more affectively cool and instrumental forms of delinquency, such as proactive aggression. However, the same surface behaviour can have either or both instrumental or affective underpinnings (e.g., stealing for material gains versus thrills), therefore, capturing the underlying motivations of adolescents committing (or not committing) delinquent acts must also play a role.

Finally, with the exception of a handful of studies, mostly from a DS perspective (Barbot & Hunter, 2012; Duell et al., 2018; Icenogle et al., 2017; Shulman et al., 2015; Vazsonyi & Ksinan, 2017) and some recent discussions in the DNERM framework (Defoe, this issue), there has been little specific hypothesising regarding sex and gender differences in delinquency within risk-taking perspectives. Alongside the crime-age curve the sex difference in offending belongs to the most important and best replicated facts of delinquency (Chen et al., 2015; Fairchild & Smaragdi, 2018). Males are overrepresented at every level of crime and delinquency, though sex differences are smaller for occasional offending and for minor and statute offenses. They account for at least 80% of all convictions for serious crimes, with imprisonment rates between 12-50 times higher than those of females (Boppre et al., 2019). Age patterns of self-reported delinquency and recorded crimes; however, tend to follow the same basic pattern for males and females with peak rates around ages 15-18 (Liu, 2015). Certainly, each perspective discussed in the current review can accommodate these sex differences (e.g., by positing different levels of sensation-seeking and self-regulation or risk exposure in males versus females); however, that they are such an important and well-replicated finding, it is reasonable to expect that risk-taking models of offending should not only be able to accommodate sex and gender differences but address them up front.

The risk-taking perspectives discussed could benefit from greater integration and/or direct comparison with existing criminological perspectives to better reflect contemporary knowledge of offending and make more specific predictions when in this domain (see Defoe, this issue). Indeed, though they may be approached differently, the issues that are at the core of adolescent risk-taking models are also of central importance in dominant criminological approaches with offending behaviour as their specific focus. These issues include the roles of cognitive control and sensation-seeking in creating a (developmental) vulnerability; the modulating impact of opportunity/exposure; individual differences in delinquency trajectories; the function of delinquency in development; and the influence of peers (Defoe et al., 2019; Romer et al., 2017; Steinberg et al., 2008). For example, it could be considered whether the vulnerable sub-group of LWM corresponds to the life-course persistent group of dual taxonomy theory, implying that the vast body of criminological evidence on the factors that determine membership in that sub-group can be drawn on in further developing and applying LWM to offending (Fairchild et al., 2013; Moffitt, 2018). Similarly, while LWM and the DS Model focus on cognitive control and sensation-seeking (and DNERM focuses on affective and cognitive self-control); it is well-known that there are many further developmental differences that are relevant for crime, including – as discussed above – social factors related to risk exposure and opportunity that are extensively discussed in the criminological literature (Sweeten et al., 2013), as well as other dimensions of psychological maturity such as empathy/perspective-taking and future orientation that may have some basis in the socioemotional and cognitive control systems but are distinct from sensation-seeking and self-regulation (Monahan et al., 2009, 2013).

Of course, criminological perspectives can also benefit from better bridging of these two worlds. For example, major criminological offender decision-making (e.g., rational choice theory) (e.g., Loughran et al., 2016) and individual difference models (e.g., self-

control theory) are not directly developmental in nature and could usefully draw on contemporary risk-taking perspectives to address this shortcoming. One recent study using data from the Pathways to Desistance Study illustrated the value of integrating criminological perspectives with developmental risk-taking models. It synthesised adolescent risk-taking approaches that emphasise adolescence as a time of heightened reward sensitivity with rational choice theory to show that adolescent offender engagement in severe violence is driven more by perceived rewards than perceived costs (Shulman et al., 2017). Their finding that anticipated social costs were unrelated to engagement in severe violence also supports the idea that adolescents may be aware of the consequences of offending and yet fail to utilise this knowledge in their ‘in-the-moment’ decision-making.

A second major area where risk-taking perspectives can offer new insights through integration with other existing perspectives is in advancing multi-timeframe perspectives on delinquency that bridge long-term developmental influences and short-term momentary influences on offending (Eisner & Malti, 2015). Regarding peers, for example, better integration of developmental psychopathology perspectives that emphasise the long-term developmental roles of peer rejection, selection, and deviancy training on delinquency (Chen et al., 2015) with risk-taking perspectives that describe how peers influence delinquency in the moment could help achieve a more comprehensive multi-timeframe theory of peer influences on delinquency (also see Hoeben & Thomas, 2019).

Models such as LWM and DNERM can also be helpful beyond illuminating delinquency increases in adolescence. The fundamental DNERM principle of propensity-exposure interaction could also be useful for understanding cultural differences in adolescent risk-taking given that geographically and temporally local policies (e.g., restrictions on alcohol availability, age of driving) and norms (e.g., degree of social control and parental supervision) create social ecologies with differing levels of exposure to risk-conducive

situations for adolescents. Cross-national comparisons of age curves for risk-taking suggest that there is greater similarity in curves for risk-taking propensity as measured by laboratory-based tasks than for real-world risk-taking behaviour (Duell et al., 2018). This suggests that age-related propensities may be similar across societies (also see Steinberg et al., 2018) but their expression is culturally constrained.

The causes of this contextual variability in delinquency are poorly understood and it is difficult to disentangle the effects of the multitude of factors that vary in concert across societies (Collishaw, 2015; Eisner, 2014). In principle, the variation could be mediated by the constructs of DS theories, for example, through differences in survival of neurodevelopmentally vulnerable preterm infants, in the detection and treatment of ADHD, or in prenatal exposures to substances, all of which could affect cognitive control and sensation-seeking (but see Collishaw, 2015) and these factors should be explored in interaction with factors related to exposure such as laws, norms, and background crime rates (e.g., Duell et al., 2018). Given how poorly understood these cross-society (across time and culture) differences in delinquency across development remain, application of frameworks such as DNERM may be particularly valuable for informing macro-level policies that aim to reduce offending behaviour in adolescence (Eisner et al., 2016).

Similarly, LWM may be helpful for generating hypotheses regarding not only increases in delinquency in adolescence for at-risk youth but also at other developmental stages and for individuals following other developmental trajectories. For example, within LWM the desistance that occurs in adulthood for persistent offenders (Sampson & Laub, 2017) could reflect the delayed effect of wisdom acquisition counteracting the impact of stable low cognitive control. Similarly, evidence suggests that a common developmental trajectory of conduct problems is a 'childhood-limited' pathway in which behaviour problems peak in childhood and resolve by adolescence (Odgers et al., 2007, 2008). This could

potentially explained by an early exploration peak and more rapid growth in the wisdom and/or earlier maturation of the cognitive control components of the LWM.

Finally, a risk-taking perspective could also be helpful for enhancing programmatic interventions within adolescent delinquency which are, overall, effective but modestly so (Farrington et al., 2017). Though some programmes target constructs that are core to risk-taking models (e.g., self-control, impulsive decision-making; Piquero et al., 2010, 2016), there are none to our knowledge, that are direct translations of the principles from adolescent risk-taking models. For example, LWM's emphasis on taking risks as essential to learning about risk implies that interventions that allow experiential learning in a controlled environment (e.g., virtual reality) could help reduce maladaptive risk-taking (also see e.g., Rosenbaum et al., 2018).

### **The next generation of empirical studies of adolescent risk-taking models of delinquency**

Aside from the theoretical developments that can benefit the generation of fruitful specific testable hypotheses regarding delinquency, there is also a strong need for further longitudinal evaluations of the joint roles of developmental changes in the neural and psychological underpinnings of adolescent offending and their interaction with exposure to risk conducive environments. While there are many very high quality studies in the fields of developmental criminology and adolescent risk-taking, there are too few studies that use appropriate longitudinal operationalisations of key concepts such as developmental imbalances between sensation-seeking and self-regulation, their individual differences, and their relation to risk-taking behaviours such as delinquency (Meisel et al., 2019; Murray et al., 2021) and effectively none that have, in addition, examined modulation by level of exposure to risk-conducive environments. Similarly, there is a need to better bridge 'in-the-moment' influences on offending (e.g., the proposed influences of risk situation exposure,

affective arousal, and peer presence) with long term developmental trajectories research that can determine the presence and extent of developmental imbalance. This aim can be achieved through, for example, embedding of experimental lab-based and experience sampling studies in longitudinal studies to test whether those with a developmental imbalance are more prone to delinquency when in a (real-world) risk-conducive situation.

### **Comparing the predictions and policy implications of different risk-taking models**

A second important future direction will be to compare and test the predictions of different risk-taking perspectives against one another. Fundamentally, the DS Model rests on claims about between asynchronous development of neural systems. To this, DNERM adds an exposure-propensity perspective such that individuals' exposure to risk-conducive situations will naturally influence the expression of that propensity, though DNERM itself remains agnostic about developmental differences in propensity. LWM further specifies that a maturational imbalance leads to persistent and serious risk-taking for a subgroup of individuals with trajectories characterised by low cognitive control, while for most risk-taking serves a healthy and adaptive purpose. FTT is proposed to be the mechanism by which that adaptive purpose is served. None explicitly excludes important tenets of the others. As such, the theories reviewed can be seen to be to some degree complementary, with differing emphases on the neural and psychological bases of developmental differences in risk-taking (DS), individual differences in these in these developmental differences (LWM), the mechanisms by which exposure interacts with propensity (DNERM), and the mechanisms by which risk-taking impacts development (FTT within LWM).

That said, there are some important differences and these correspond to divergent policy implications. For example, a major area in which risk-taking models have influenced how youth are treated within the criminal justice system is in showing that adolescents are not psychologically mature in terms of their ability to make decisions regarding risk. This

insight has led to changes in sentencing and age of criminal responsibility reflecting reduced adolescent culpability (Monahan et al., 2015; Steinberg, 2013). While most risk-taking perspectives agree on this point, there are differences in the extent to which individual differences are emphasised. For example, LWM suggests that there is a vulnerable sub-group of youth who are particularly and stably prone to problems with risk-related decision-making. This being the case, do these youth require different treatment within the criminal justice system, just as neurodevelopmental evidence has suggested that adolescents require different treatment compared to adults? At a minimum, an implication of LWM is that these youth are likely to benefit from efforts at early identification and prevention, whereas universal prevention efforts would be potentially wasteful since most youth receiving these interventions would not be at risk (Meeus et al., 2021; Murray et al., 2021).

LWM also differs in an important way from traditional perspectives that implicitly or explicitly view engagement in risk-taking as an entirely negative outcome to be prevented. It, in fact, suggests that most youth depend on some engagement in risk-taking for optimal development, specifically, by promoting exploratory behaviours that support learning about the world (and risk). The question of whether risk-taking has some developmental benefits has been much debated and indeed many benefits beyond learning about risk (e.g., contributions to development of identity and autonomy and social relationships) have been mooted (see e.g., Barbot & Hunter, 2012; Sercombe, 2014 for reviews). The implication of these and LWM is that by preventing risk exposure, adolescents could be deprived of essential developmental input. Therefore, prevention efforts would need to not only consider how to minimise risk-taking opportunities, but how to accompany this with provision of alternative inputs that can serve the same function. Here, emerging discussions of ‘positive’ risk-taking, defined as behaviours that are risky but are not socially unacceptable nor



associated with health risks may be helpful for considering how hypothesised needs for risk-taking can be channelled into more adaptive behaviours (Duell & Steinberg, 2019, 2020).

### **Conclusions**

There is a rich literature on developmental risk-taking models but there have been few direct tests of contemporary adolescent risk-taking theories as applied to delinquency, especially newer generation models such as LWM and DNERM. Indirect evidence supports the idea that sensation-seeking, self-regulation and their developmental imbalance contributes to an adolescent peak in offending, consistent with the DS Model. However, developmental propensity is likely to interact with by risk exposure (as predicted by DNERM) and to apply particularly to a sub-group of vulnerable youth (as predicted by LWM). Better integration of criminological and risk-taking perspectives and further longitudinal research using appropriate operationalisations of developmental imbalance, modelling individual differences in trajectories, incorporating measures of risk exposure, and linked to measures of 'in-the-moment' risk-taking behaviour can advance knowledge in this field and provide a robust evidence base to inform intervention and policy.

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