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Defoe, I.N.

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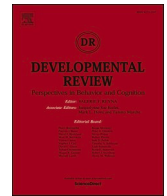
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Towards a hybrid criminological and psychological model of risk behavior: The developmental neuro-ecological risk-taking model (DNERM)

Ivy N. Defoe¹

University of Amsterdam, The Netherlands

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ABSTRACT

Adolescents have long been characterized as *the* stereotypical risk-takers, due to their apparent heightened risk behavior (e.g., delinquency, substance use). Hence, the raising of minimum ages for substance use are common legal actions that presume that limiting the exposure to substances (i.e., “risk exposure”) will decrease such heightened adolescent risk behavior. This ecological concept of risk exposure (access to risk conducive situations) is acknowledged in criminological models—to some extent. However, risk exposure is virtually absent from contemporary psychological models, which focus on neuropsychological development, particularly socio-affective and cognitive control development. Moreover, when theories in these disciplines do consider risk exposure, the ubiquitous developmental (i.e., age-dependent) component of this concept is overlooked. For example, in the real-world, adolescents encounter far more risk conducive situations (both offline and online) than children, which could at least partially account for heightened adolescent risk behaviors compared to children. A meta-analysis (Defoe et al. 2015) on laboratory studies provided suggestive evidence for this assertion. Namely, this meta-analysis showed that in laboratory settings—where risk exposure is equal for all participants regardless of age—children and adolescents are generally equally susceptible to engage in risks. Hence, in the above-mentioned meta-analysis, a hybrid *Developmental Neuro-Ecological Risk-taking Model* (DNERM) was put forward. DNERM emphasizes an interaction between adolescents’ neuropsychological development and their changing physical- and social- ecology, which is further embedded in a cultural context. The current paper further develops DNERM’s aims, which include bridging contemporary psychology models with criminology models to comprehensively describe the development of risk behavior during the youth period (ages 11–24).

In 2014, the Dutch minimum age of purchasing and being publicly in the possession of alcohol was raised from age 16 to 18, in order to combat the maladaptive consequences that this risk behavior poses for youth (rijksoverheid.nl, n.d.). This common legal action presumes that minimizing the *exposure* to substances (i.e., “risk-exposure” and accordingly “risk opportunity”) will limit youth substance use. Is this presumption correct? Surprisingly, this question has remained largely uncharted territory in psychological sciences. This research gap could be attributed to the tendency of past and contemporary (developmental) psychology theories to overlook the role of physical ecological factors (e.g., the physical access to substances) in risk behavior development. However, a precondition for any risk behavior is an “exposure to a risk conducive situation” (i.e., “risk exposure”). Extrapolating further, the

E-mail address: i.n.defoe@uva.nl.

¹ Forensic Child and Youth Care Sciences, University of Amsterdam—Postbus 15776, 1001 NG Amsterdam, The Netherlands.

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puzzle of the rise and peak in some risk behaviors, such as substance use and delinquency, during the youth period could at least partially be explained by exposure to *more* risk conducive situations (i.e., an increase in risk exposure) as individuals grow older. Clearly not everyone faced with a risk exposure eventually takes the risk, however. Thus apparently, risk exposure only increases risk behavior in *some* youth, and thus it is not the only causal factor. Hence, a critical follow-up question is: If risk exposure predicts risk behavior, under which circumstances does this occur? A new person-environment model, *Developmental Neuro-Ecological Risk-taking Model* (DNERM; Defoe, Dubas, Figner, & van Aken, 2015; Defoe et al., 2019) suggests that the answer to this question lies within an individual's *self-control*. Specifically, DNERM underscores the often neglected age-dependent role of risk exposure, while bridging contemporary *developmental psychology models on self-control* with *criminology models on risk exposure* to comprehensively describe risk behavior development during adolescence and emerging adulthood (the “youth” period). This paper further develops new hypotheses of DNERM (see Fig. 1).

Risk behavior development

In the developmental literature, risk behavior is defined as “engagement in behaviors that are associated with some probability of undesirable results” (Boyer, 2006, p. 291). This definition indicates that the exact outcome is uncertain, thus a *desirable* outcome could also be the result. Within the DNERM framework, a more culturally-sensitive variation of the abovementioned definition is used. Namely, “risk behavior” is defined as *behaviors that are associated with some probability of a maladaptive outcome—that is an outcome that can impede the acquisition of culturally-accepted goals*. Maladaptive risk-behaviors such as substance use and delinquency show accelerated growth and/or peak during adolescence (ages 11–18) or emerging adulthood (ages 18–24) (Defoe et al., 2019; Steinberg, 2015). These heightened risk behaviors during the youth period can be maladaptive, as they too often interrupt youth's education, and can also ignite other enduring negative outcomes into adulthood, such as addiction and contact with the judicial system (Defoe et al., 2019). Moreover, such delinquent behaviors continue to cost society billions of dollars annually (Moolenaar, Vlemmings, van Tulder, & de Winter, 2019). Hence identifying which factors predict youth delinquency and substance use is important for multiple layers of society.

Noteworthy is that not all risk-taking is necessarily maladaptive, however. For instance, an adolescent might take a “risk” by enrolling in a challenging course at school instead of an “easier” course. The benefits include a stimulating educational experience and learning something new. Hence, especially in the Western culture, this could be considered as more of an example of adaptive risk-taking (Defoe et al., 2019). Furthermore, recently it has been argued that adolescent risk-taking in general can be considered as an adaptive learning experience (e.g., Romer, Reyna, & Satterthwaite, 2017; see also: Baumrind, 1987).

On the one hand, in psychology, youth development (e.g., the development of risk behaviors) is considered comprehensively, as both individual (e.g., biological, cognitive) and social (e.g., parent and peer) factors are investigated as predictors. On the other hand, the physical environment (e.g., access to alcohol in supermarkets, [more] access to stores with fewer security measures against stealing), is largely under-studied (Defoe et al., 2015). This however, does not imply that risk exposure plays any less of a role in youth risk behavior development. In fact, a recent published meta-analysis (Defoe et al., 2015) did not find that adolescents take more risks than children in the laboratory. This finding provides suggestive evidence for the assertion that adolescents take more risks than children in the real-world, perhaps at least partially due to higher levels of risk exposure during adolescence. DNERM is inspired by the meta-analysis of Defoe et al. (2015) and theorizes that developmental phase (age) and culture predict risk-exposure, which could further interact with an individual's self-control to predict heightened risk-taking.

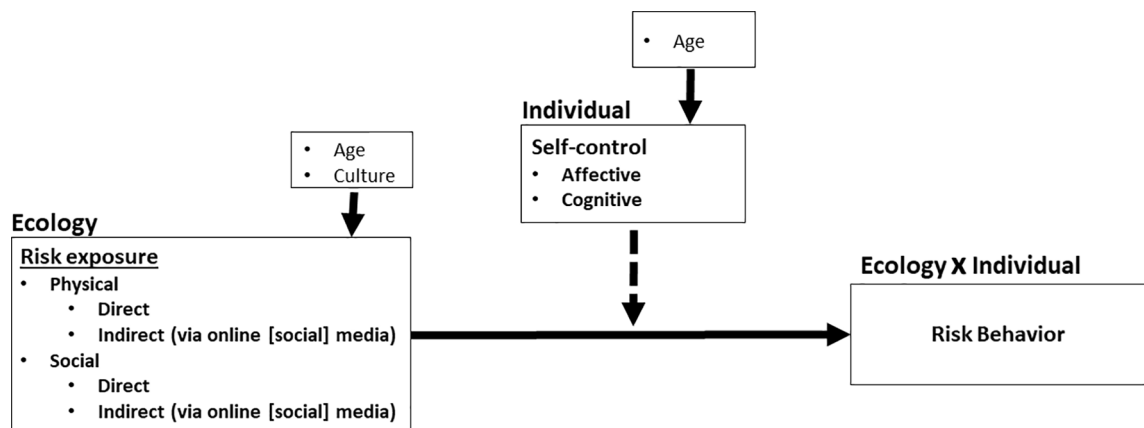


Fig. 1. Diagram depicting the main hypotheses of DNERM. Namely, risk exposure predicts risk behavior during the youth period (i.e., 11–24 years). Additionally, there is a potential interaction between self-control and risk exposure, that is, self-control could potentially moderate the effects of risk exposure on youth risk behavior.

The ecology: Risk exposure

Definitions

An individual exists in the context in which he or she resides, and within this context the individual can be exposed to risk conducive situations, a “risk exposure”, which can result in risk behavior. The term “exposure” in risk exposure is often used synonymously with the term “availability”, of which the definition is “the degree to which something is at hand when needed” (van Hoof, 2010, p. 24). Of note, the term availability is not consistently used in the scientific literature (cf van Hoof, 2010). Alternatively, terms such as “access”, “exposure”, “opportunity” are used interchangeably to denote the availability of a situation. The term exposure is preferred in DNERM, and accordingly, the phrase “risk exposure” is used as it more precisely captures the direct experience of the individual, whereas terms such as “access”, “opportunity” and “availability” are more open for interpretation. In its broadest sense, risk exposure is defined here as being *exposed* to an environment that is conducive to taking a risk (Gerrard, et al., 2008).

As far as known, van Hoof (2010) was the first to explicitly describe different types of (risk) exposure, which he labeled as “availability”. Namely, in his research on predictors of alcohol use, van Hoof (2010) differentiated between four types of alcohol “availability”: economic-, legal-, physical-, and social- availability to alcohol. Henceforth, the phrase “(risk) exposure” will be used to refer to these forms of availability in the context of risk behaviors. Accordingly, the phrases economic risk exposure, legal risk exposure, physical risk exposure and social risk exposure are opted for when describing DNERM. Van Hoof described economic (risk) exposure as the prices of substances (e.g., alcohol) and/or government taxes on substances, whereas legal (risk) exposure referred to the laws related to substance use (e.g., minimum age for alcohol consumption). Finally, physical (risk) exposure included the density and opening hours of outlets that sell substances (van Hoof, 2010). The legal and economic risk exposures to substances directly impact the physical risk exposure to substances, and can accordingly be considered as “proxies” of physical risk exposure. Hence, in DNERM, the term “physical risk exposure” is used as an umbrella term for economic availability, legal availability and physical availability of a risk. General exposure to substances (e.g., how difficult or easy individuals perceive their access to substances) is considered as a form of physical risk exposure (c.f., Haas, et al., 2018) in DNERM as well. Finally, online (social) media can portray “physical cues of risk exposures” (e.g., alcohol on display in a liquor store). This form of risk exposure is overlooked in van Hoof (2010). However, DNERM qualifies this example as “indirect physical risk exposure”, since there is a medium (a computer, television, mobile phone, etc.) between the observer and the risk exposure. Such “physical cue risk exposures” may also lead youth to begin normalizing, accepting and eventually engaging in respective risk behaviors (see, Veilleux and Skinner, 2015).

Physical (online) risk exposure

DNERM predicts that when physical risk exposure leads to risk behavior, this can be attributed to the curiosity and desire that a risk conducive situation can elicit, particularly for youth. In such a case, risk behavior could especially be the result for adolescents who are still exploring their identity and experimenting to learn if one fits with his/her surroundings (see e.g., Erikson, 1968). This DNERM hypothesis also overlaps with *cue reactivity* hypotheses, which suggest that after exposure to a cue (e.g., seeing a liquor shop in person or via a medium), this can elicit the desire (Veilleux & Skinner, 2015) to engage in an analogous behavior (e.g., consume alcohol). Eventually higher levels of exposure to risk conducive situations result in those situations becoming “normalized” and accepted by the adolescent, which could lead to more engagement in risk behaviors. However, as mentioned above, empirical research on physical risk exposure as a predictor of adolescent risk behavior is virtually non-existent in psychology. As for Criminology, prominent ecological/environmental theories do exist on physical risk exposure, which is typically investigated via poor/disadvantaged neighborhoods in that discipline (Gök, 2011). Below, first empirical studies on antisocial behavior are discussed, followed by empirical studies on substance use in the context of physical risk exposure.

Antisocial behavior: The vast majority of criminology studies that have attempted to capture physical risk exposure effects on crimes have investigated whether broad composite scores of “disadvantaged” neighborhoods or “disordered” neighborhoods predict crime. Indeed some of the items in these composite scores show overlap with the concept of physical risk exposure (e.g., Tache et al. 2020; Zimmerman et al., 2015). Findings on whether neighborhood quality predict risk behavior have been inconsistent, however (c.f. Fabio, Tu, Loeber, & Cohen, 2011; Zimmerman, 2010). This can be in part due to the diverse measures used to investigate neighborhood factors (cf. Zimmerman, 2010), but also due to the broad concept of what a “disadvantaged” or “disordered” neighborhood is. Extrapolating from DNERM, this inconsistency could also be the result of the conflation of physical and social risk exposure in measures of neighborhood quality. Indeed, some scholars have already pointed out this lack of precise measurements that taps a more specific conceptualization of physical risk exposure (see e.g., Hay & Forrest, 2008). Moreover, besides neighborhoods, youth can be physically or socially exposed to risks in other contexts too, such as at school (see e.g., Kuntsche, 2010).

Substance use: Various studies (e.g., Fairman et al., 2019; von Sydow, Lieb, Pfister, Hofler, Wittchen, 2002) have investigated whether (proxies of) physical risk exposure to substances such as alcohol and cannabis prospectively predict adolescent use of these substances. For example, one of the few longitudinal studies ($N = 2753$; T1 age = 10th graders; 14–15 years) on state alcohol policies and alcohol availability, showed that weaker state policies and lower beer exercise tax were associated with escalating alcohol use over the subsequent 5 years (Fairman et al., 2019). Fairman et al. (2009) did not find that living near more off-premise liquor stores predicted escalating alcohol use. However, the authors suggested that this non-significant finding is likely because of an inadequate measure of alcohol availability (i.e., risk exposure). For example, other potential sources of alcohol availability such as grocery stores or on-premise outlets (e.g., bars and restaurants) were not taken into account (Fairman, et al., 2019). This is an important suggestion, especially when considering that studies in the Netherlands have shown that persons who live within 20 km of cannabis shops (referred

to as “coffee shops” in the Netherlands) have earlier age of onset for cannabis use (Palali and van Ours, 2015). These cannabis shops in the Netherlands are the main source of supply of cannabis. In fact, although only persons above 18 and older are “legally” permitted in these shops, a study reported that of the 12–17 year olds who used cannabis, 40% of them purchased cannabis in these shops, while 48% received them from friends, relatives, or other acquaintances (Abraham, Cohen, van Til, & de Winter, 1999). This clearly suggests that cannabis shops (or substance use outlets more generally) are substantially linked to more “physical risk exposure” (i.e., the physical access of cannabis) among youth.

As for proxies of physical risk exposure in terms of changes to legal access to substances (i.e., physical risk exposure), one recent cross-sectional study showed that cannabis use increased in early and mid-adolescents after the legalization of recreational cannabis in Washington, but not in Colorado (Cerdá et al., 2017). Additionally, more recent tangential evidence from historical national statistics from the Netherlands show that the proportion of 16-year olds (27.6%) who smoked cigarettes in 2013, was higher than the proportion of 16 year olds (17.6%) who smoked in 2014, when the legal age of 18 was implemented (see also: Defoe, Dubas, Somerville, Lugtig, & van Aken, 2016). These statistics reflect a decline in smoking after the raising of the minimum age. In other words, apparently lower levels of risk exposure were associated with lower levels of risk behavior—at least for *some* youth. Thus, these statistics could imply that raising the minimum age was (partially) successful. However, it is important to note that, although smoking decreased among 16-year olds in 2014, a substantial amount of 16-year olds (and younger) still smoked. Thus apparently, lower levels of risk exposure only reduces risk-taking in *some* youth, and it is not the only factor that predicts risk-taking.

Physical (online) risk exposure and development

Importantly, one aspect of physical risk exposure that has received even less scientific inquiry in both criminology and psychology, is how exposure to physical risk conducive situations ubiquitously increases as individuals transition from childhood to adolescence and from adolescence to emerging adulthood, and how this affects their levels of risk behaviors (Defoe et al., 2015). Nevertheless, physical risk exposure as defined in DNERM is similar to the “risk opportunity” concept in the Prototype Willingness model (Gerrard et al., 2008). However, similar to criminology models, the Prototype Willingness model does not incorporate the *developmental (age-dependent)* aspect of *physical (or social)* risk exposure. For example, in contrast to DNERM, the Prototype Willingness model overlooks that real-world risk behavior is higher during adolescence than during childhood (at least partially) because of age-dependent increases in risk exposure levels during adolescence. Instead, the Prototype Willingness model posits that adolescent’s health risk behavior is a reaction to risk-conducive *social* situations rather than a reasoned or planned action (Gibbons, Stock, & Gerrard 2020). In other words willingness to engage in such risk behaviors is a response to risk-conducive social situations (Gerrard et al., 2008; Gibbons et al., 2020 see also: Reyna & Rivers, 2008).

In sum, both criminology and psychology models have overlooked the developmental aspects of physical risk exposure, and how this can predict increasing levels of risk behaviors during the youth period. Nevertheless, in part due to the findings of the aforementioned meta-analysis (Defoe et al., 2015) psychology scholars are increasingly acknowledging the gap in this field concerning the ubiquitous role of physical risk exposure in heightened adolescent risk-taking (see e.g., Crone & Duijvenvoorde, this issue; Ciranka and van den Bos, 2021; Crone, Duijvenvoorde, & Peper, 2016; Shulman et al., 2016). Namely, Defoe et al. (2015) provided evidence for why risk exposure is important to take into account. In the laboratory studies included in that meta-analysis, adolescents engaged overall in similar levels of risks as children, however, they actually engaged in fewer risks than children on risky decision-making tasks that offered a “sure option” (i.e., the opportunity to avoid risk-taking) in addition to a “risky” option (i.e., an option with variability in outcomes, thus an “uncertain” option) (Defoe et al., 2015). In other words, adolescents chose the “sure option” more often than children. These intriguing laboratory findings of age differences in risk-taking in adolescents versus children are in sharp contrast with differences in levels of risk-taking in the real-world between these two age groups. It should be considered, however, that in laboratory studies, all participants, regardless of age, have equal opportunity (exposure) to engage in risks. Conversely, in the real-world, adolescents encounter greater physical risk exposure than children (e.g., attending parties where drugs are available), and this might at least partially account for why adolescents engage in more risks than children in the real-world (Defoe et al., 2015). These meta-analytic findings imply that age interacted with risk exposure (sure option versus risky option) to predict risk-taking.

Additionally, the meta-analysis found that early adolescents (11–13 years) engaged in more risks than mid-late adolescents (14–19 years) in lab settings. This finding is also in sharp contrast with real-world accounts, where mid-late adolescents engage in more risk behavior than younger adolescents. Defoe et al. (2015) suggested that this discrepancy likely arose because in the real-world, older adolescents encounter more risk conducive situations than younger adolescents, which could at least partially account for higher levels of risk behavior in older adolescents. However, when younger and older adolescents are exposed to the same levels of risk exposure (as was the case in the studies in the meta-analysis of Defoe et al. 2015), younger adolescents could be more inclined to take risks, perhaps due to individual factors such as less mature neuropsychological development (e.g., aspects of self-control; see also: Defoe et al., 2019). Other studies have also shown that younger adolescents could be more inclined to take risks due to additional factors such as developmental trends in reliance on gist-based processing (see Reyna and Brainerd, 2011).

Distinctively, DNERM proposes two developmental hypotheses related to risk exposure. First, DNERM suggests that risk exposure increases with age during adolescence. Secondly, DNERM proposes that higher risk exposure would lead to more risk-taking particularly among young adolescents versus older adolescents (due to younger adolescents’ lower levels of self-control—more about this assertion will follow later). The above-described studies on risk exposure (measured via neighborhood quality) in the prediction of antisocial behavior, did not account for such age or developmental stage effects. Hence the empirical test of this hypothesis of DNERM appears to be non-existent for antisocial behavior. Nevertheless, the empirical substance use literature that is discussed below does demonstrate support for such a link.

As far as known, only a single study (Boyer & Byrnes, 2009) has attempted to investigate the above-described developmental hypotheses on risk exposure with respect to alcohol use. Namely, in a cross-sectional study based on a sample of 15–18 year olds ($N = 94$) and a sample of 18–20 year olds ($N = 110$), the older sample generally reported more risk exposure than the younger sample (as predicted by DNERM). However, at the same time the proportion of those opportunities that were actually used to engage in risk-taking was lower for the older sample versus the younger sample. In other words, it was the younger sample that took more risks when there was the opportunity to do so. That is, older adolescents had more opportunities to drink alcohol (e.g., at parties where alcohol is available), however the younger adolescents more often drank alcohol when such opportunities arose (Boyer and Byrnes, 2009). These results provide suggestive evidence that risk exposure increases with age. At the same time, this does not necessarily imply that this increase is related to increases in risk-taking in adolescents as they become older, since the results showed that the link between risk exposure and risk-taking was particularly relevant for *younger* adolescents (Boyer and Byrnes, 2009).

Similarly, as discussed above a more recent cross-sectional study reported that cannabis use increased after legalization of cannabis (i.e., increased risk exposure) in Washington State, however this increase in cannabis use was only evident in early-mid adolescents but not in late adolescents (Cerdá et al., 2017). The above-described cross-sectional developmental results of Boyer and Byrnes, (2009) and Cerdá et al. (2017) provide suggestive evidence for DNERM, which posits that when confronted with equal levels of risk exposure, particularly *younger* adolescents would be more inclined to take risks. That is, an interplay between age (or developmental stage), risk exposure and risk-taking is expected.

Social (online) risk exposure

In Psychology, the most frequently studied type of risk exposure is social risk exposure. For example, social risk exposure can be used to describe the social context of substance use (e.g., being exposed to peers who are using substances or being exposed to peers who steal) (cf. van Hoof, 2010). Strictly speaking, engaging in risk behaviors *with* others, or at minimum witnessing the risk behaviors of others is considered as social risk exposure within the DNERM framework. These are thus two levels of social risk exposure within the DNERM framework, and observing risk behavior of social contacts via online (social-) media is a third level of more of an “indirect social risk exposure”. According to DNERM, being exposed to risk behaviors of others—whether by (1) witnessing these behaviors by others directly or (2) indirectly via online (social-) media or by (3) engaging in these behaviors *with* others—provide a training ground for youth to adopt risk behaviors, as they can observe and learn these risk behaviors from such social contacts. Hence it is also expected that social risk exposure in the form of engaging in risk behaviors *with* others (e.g., “co-offending” or “co-substance use”), would have the strongest effects on risk behavior versus the other above-mentioned forms of social risk exposure. In any case, these aspects of DNERM’s hypotheses overlap with social learning theory (Bandura, 1977).

Additionally, DNERM posits that witnessing others engage in risk behaviors (social risk exposure), whether directly (i.e., in person) or indirectly via (online [social-] media), can have a “social cue risk exposure” effect, in which youth begin to “normalize” and “accept” these behaviors (cf. Kuntsche, 2010). Consequently, individuals could begin to consider or even desire those risk behaviors that they have observed by others, which could in turn lead to an individual’s own engagement in risk behavior (Veilleux & Skinner, 2015). Especially for adolescents, this process could be challenging to control, in part because of their natural desire to explore and experiment while developing their identity (Barbot & Hunter, 2012; Erikson, 1968). Research on the role of such social (and physical) cue exposure in the prediction of subsequent analogous behavior (i.e., “cue reactivity” hypotheses; Veilleux & Skinner, 2015) is well-established especially in the substance use (addiction) and food literature (for a review see: Veilleux & Skinner, 2015). However, empirical research on other types of risk behaviors is scarce among adolescents.

Antisocial behavior: Studies on antisocial behavior (e.g., stealing) and risk exposure, typically investigate parents’ and peers’ risk behaviors as forms of “social risk exposure” (c.f. Hay & Forrest, 2008). Studies consistently show that (“perceived”) antisocial behavior of friends and peers (for a review see: Brechwald & Prinstein, 2011), as well as of parents (Johnson, Giordano, Longmore, & Manning 2016) and siblings (Defoe et al., 2013) longitudinally predict adolescent antisocial behavior. Accordingly, psychological theories on risk exposure, are typically *social-learning* theories (Bandura, 1977). Moreover, in both psychology and criminology, it has been documented for a long time that especially adolescents tend to engage in risk behaviors (particularly delinquent behaviors) *together* with peers (Warr, 2002). For example, behaviors such as co-offending have been extensively studied in criminology, however the psychological literature has devoted less attention to the empirical investigation of co-offending (but see e.g., Defoe et al., 2021; Goldweber, et al., 2011). Then again, in both sciences, there is a dearth of longitudinal research that directly assesses whether youth are indeed engaging in risk behaviors with their deviant peers (cf. Goldweber, et al., 2011). That is, instead of directly posing this question to youth participants in such research, the status quo is to merely ask participants whether their peers engage in deviant behavior (e.g., risk behavior). The assumption is often that if youth have peers who engage in deviant behavior, then they must be engaging in deviant behavior with their peers (Brechwald & Prinstein, 2011; Warr, 2002). However, such assessments are only an indirect and assumptive measure of co-offending, and of social risk “exposure” more generally. Nevertheless, among the few studies on co-offending, one study cross-sectionally showed that peer delinquency only predicts adolescent delinquency when co-offending is present (Dynes et al., 2015). A similar finding was also replicated longitudinally (Defoe et al., 2021). The findings imply that particularly being exposed to peers while they are engaging in such antisocial behaviors is associated with heightened susceptibility to risk behavior during adolescence. More generally, this *direct* social risk exposure strengthens the relationship between risk behaviors of significant others and adolescent’s own risk behavior—as predicted by DNERM.

Substance use: Substance use during adolescence is known primarily as a social behavior (Roditis, Delucchi, Chang, & Halpern-Felsher, 2016). However similar to co-offending, the vast amount of studies on youth substance use do not assess whether adolescents are in fact using substances together with others, for example with their peers (this often presumed phenomenon is referred to as

“co-substance use” within the DNERM framework). Additionally, most studies do not assess to what extent adolescents are directly exposed to substance use of their peers (with or without the simultaneous use of substances by the adolescent). In other words, in most studies, participants are typically only asked to report on whether their peers use substances—which can thus be considered as “perceived” peer substance use. Hence the studies reviewed below are based on such assessment methods.

The multiple studies that tested the above-described *perceived* form of social risk exposure, demonstrate that the use of substances within adolescents’ social circle, predict subsequent substance use in adolescents. For example, friend substance (Branstetter, Low, & Furman, 2011), peer substance use (Defoe, Khurana, Betancourt, Harm, & Romer, 2019), parent substance use (Rusby, Light, Crowley, & Westling, 2018) and sibling substance use (Low Shortt, & Snyder, 2012) have been consistently shown to longitudinally predict adolescent substance use. As mentioned above, studies on the effects of actual (i.e., *non-perceived*) social exposure (as described within the DNERM’s framework) to substance use are virtually non-existent in the adolescent literature. However studies on (“non-perceived”) “social exposure” via media do show for example that alcohol exposure on social networking sites is associated with adolescent alcohol use (Scott & Barber, 2020)—which is consistent with the online (social) cue reactivity hypotheses of DNERM.

Social (online) risk exposure and development

DNERM distinctively takes the typically overlooked developmental phases of the youth period into account and posits that as youth grow older, their exposure to persons who engage in risk behavior also increases (Defoe et al., 2015). Hence, ultimately, increases in social risk exposure as youth become older (at least up until emerging adulthood), predict increases in risk behavior during the youth period. In this context, exposure to more persons who engage in risk behaviors would likely imply more exposure to peers (and others) who engage in such behaviors. Namely, as youth become older, they begin to spend more time with peers, which could include time engaging in risk behaviors (as well as other types of behaviors) together. DNERM further hypothesizes that younger adolescents (versus older adolescents and adults) would engage in higher levels of risk behaviors when confronted with higher levels of social risk exposure. This hypothesis is extrapolated from neurodevelopmental imbalance models that posit that pubertal changes during early adolescence make this period more susceptible to peer influence (Steinberg 2007).

More recently, psychology scholars have manipulated peer presence in (lab-) experiments to investigate whether this would affect increases in risk-taking particularly among adolescents (Gardner & Steinberg, 2005). A review of this literature found that especially the presence of deviant peers in “social risk exposure” manipulations indeed increases risk behavior among youth (Defoe et al., 2019). Unfortunately, the meta-analysis of Defoe et al. (2015) on age differences in risk-taking in the lab, could not include studies that manipulated peer presence or “social risk exposure”, since those studies were limited at the time of the meta-analysis. However, such affective peer presence manipulations do make experimental paradigms on adolescent risk-taking more ecologically valid, since adolescent risk behavior in the real-world (as well as other “non-risk behaviors” adolescents engage in) typically involves peers. Although peer presence was not investigated as a moderator in the meta-analysis (Defoe et al. 2015), other affective moderators in the meta-analysis did predict higher risk-taking in adolescents versus adults (more on those findings will follow later).

In sum, the social risk exposure hypothesis of DNERM draws upon cue exposure hypotheses as well as social learning theories. Thus, it is hypothesized that especially engaging in risk behaviors with others predict risk behaviors in youth, as a result of learning risk behaviors from others and factors related to exploratory behavior of youth leading to the desire of such risk behaviors (see e.g., the “cue reactivity” hypothesis; Veilleux & Skinner, 2015), and these effects are further expected to be dependent on age or developmental stage.

Selection effects for risk exposure

Of note is that individuals can also actively select the environments they are exposed to. This is particularly true for adults (compared to youth) who have much more freedom to do so. Thus, during adulthood, selection effects for risk exposure environments are expected to be more prevalent and relevant for the prediction of risk behavior. But for youth, there are some limitations over which they select their “risk exposure” environments. For example, adolescents’ home, school, neighborhood, are typically not selected by them. Consider for example, youth who live in neighborhoods where persons can be seen openly selling drugs on the streets (i.e., physical risk exposure)—these youth have little control over such exposure. But as adolescents gain freedom in the way they arrange their time, and as they become adults and leave their parents’ home, they can gradually and more actively choose their environments. For such cases, research shows that persons who condone risk behaviors, are more likely to expose themselves to social contexts in which those behaviors occur (Brechwald & Prinstein, 2011; Moffitt, 1993). Accordingly, whether or not risk exposure (i.e., the *quantity* of risk exposure and the *types* of risk exposure) continues to increase after emerging adulthood, would depend at least partially on such selection effects. In any case, generally, research on youth suggests that they select themselves into peer groups with similar values and behaviors as themselves (selection effects), and that these youth are also influenced by peers (influence effects) within such peer groups (Brechwald & Prinstein, 2011). Thus, it is further conceivable that these two processes (selection and influence) also operate for the physical environment. That is, persons choose their environment, but they are also influenced by their environment.

Two relevant criminology theories in the context of selection effects are the “*snare*” hypothesis (Moffitt, 1993), and the *age-graded theory of informal social control* (Laub, Rowan, & Sampson, 2018; Sampson & Laub, 1993). For example, the *age-graded theory of informal social control* describes that individuals desist from criminal behavior due to culturally-defined turning points (marriage, military service) during *adulthood* that restore or increase their social bonds (which is conducive to informal social control). According to that theory, particularly such selection effects (e.g., choosing marriage) in adulthood, can be associated with fewer antisocial behavior (e.g., crime) during the transition to adulthood (see also the “snare” hypothesis: Moffitt, 1993). This age-graded theory of informal social

control is less specific about transitions from childhood to adolescence and how they affect criminal behavior. In any case, it can further be extrapolated that the above-described informal social controls would diminish the *exposure* of individuals to risk conducive situations (risk exposures), leading to fewer engagements in risk behaviors. In sum, DNERM predicts that especially in adulthood persons will have more opportunity to self-select themselves into certain environments that could have a minimizing effect on the risk exposure that they face. Hence a possible “levelling off in risk exposures” could occur during the transition from emerging adulthood to adulthood, leading to fewer risk behaviors—especially in combination with higher or increasing levels of self-control.

Risk exposure and culture

Besides age, culture could also predict the levels of risk exposure. This is especially the case, since the culture of a country typically reflects the laws of a country, which in turn reflects the available risk exposures (e.g., access to substances). Thus, in some cultures where alcohol is culturally accepted, alcohol exposure would be more common, which could in turn predict heightened youth alcohol use (Defoe, 2016). For example, on the Dutch Caribbean island of Sint Maarten, youth report more alcohol use than youth in The Netherlands (Defoe, 2016). Thus it is to be expected that youth on Sint Maarten are exposed more to alcohol at least in part due to the cultural acceptance of alcohol on Sint Maarten (Defoe, 2016). Hence, such cross-national (“cultural”) differences could further help elucidate why heightened risk-taking occurs. DNERM considers cultural differences by suggesting that cultural norms predict risk exposures, which in turn predict risk behavior. However, the aforementioned suggestive evidence of Boyer and Byrnes, (2009) and Cerdá et al. (2017) show that levels of (culturally-dependent) risk exposures might not tell the full story. DNERM further posits that one individual factor that could moderate the link between risk exposure and risk behavior is self-control. However, as will be demonstrated below, although self-control (or its related inverse “impulsivity”; Duckworth & Steinberg, 2015) is used quite liberally, it is a multi-faceted concept.

The individual: self-control

Definitions

The role of the individual in risk behavior is also important to consider. Contemporary neurodevelopmental imbalance models posit that both slowly developing cognitive-control (e.g., planning, inhibition) and hyper emotional/affective responsiveness (i.e., lower affective control) during the adolescent period, make them most susceptible for heightened risk behaviors such as substance use and delinquency (Somerville & Casey, 2010; Steinberg, 2007). In psychology, lack of self-control is also often termed as “impulsivity”, as these two constructs are considered to be inversely related to each other (see e.g., Duckworth & Steinberg, 2015) and predict youth risk behavior (Duckworth & Steinberg, 2015). DNERM emphasizes the impulsivity aspect of (lack of) self-control, but opts for the term “self-control” instead of “impulsivity”, since “self-control” reflects resilience (as opposed to risk). Namely, self-control is widely hypothesized to be one of the central components of resilience, or at minimum the two are often hypothesized to be inherently related to each other (Artuch-Garde, et al. 2017; Dishion & Connell, 2006).

In criminology, self-control is also linked to criminal behavior, and one of the most used self-control instruments consists of six subscales (i.e., subscales for: impulsivity, simple tasks, risk seeking, physical activities, self-centered orientation, and volatile temper; Grasmick, et al., 1993; Delisi et al., 2003). These multiple sub-scales reflect the multi-faceted structure of self-control. Within DNERM, the proposed impulsivity sub-component of self-control is considered as quintessential for low self-control (see also e.g., Duckworth & Steinberg, 2015). There have been discussions in the psychology discipline about the unidimensionality versus multidimensionality of the impulsivity component of (lack of) self-control, however.

Affective self-control versus cognitive self-control

In psychology, the UPPS impulsive scale (Whiteside & Lynam, 2001) has become known as the most inclusive impulsivity scale (Berg et al., 2015). Recently, a meta-analytic factor analysis (Sharma et al., 2014) found convincing support for the sub-scales of the UPSS. Among studies using the UPSS, Sharma et al. (2014) identified three distinct psychological concepts (“impulsigenic traits) that are thought to underly different expressions of impulsivity (or “low self-control”; Sharma et al. 2014). Specifically, Neuroticism/Negative Emotionality was identified as a distinct impulsigenic trait reflecting “impulsive behaviors” known as (Negative) Urgency. A second trait was “Disinhibition” (versus constraint/conscientiousness), which reflected impulsive behaviors due to lack of Planning/Premeditation. Thirdly, extraversion/positive emotionality reflected Sensation Seeking behavior which is often impulsive, (e.g., joy-riding) but not always (e.g., parachuting) (Sharma et al. 2014). Hence although impulsivity and its related inverse “self-control” is referred to as a unitary construct in the everyday (English) language, meta-analytic findings on items of questionnaires typically used to measure impulsivity reveal distinct types of impulsive behaviors (Sharma et al., 2014). Additionally, Sharma et al. (2014) concluded that only the disinhibition (vs. Constraint/Conscientiousness) trait of impulsivity (i.e., lack of self-control) is “affect-free”, while the other subtypes were identified as affectively laden traits of impulsivity.

The follow-up question is whether such cognitive forms of (lack of) self-control and affective forms of (lack of) self-control are differently related to behavioral outcomes such as substance use and antisocial behavior. Indeed, support has been found for this. Namely, (meta-analytic) studies that have differentiated between cognitive self-control versus affective self-control have shown that for both a wide range of antisocial behaviors and substance use behaviors, *affective* self-control appears to be a more consistent predictor (Berg et al., 2015; Van der Veen, Hershberger, & Cyder 2016; Maneiro, Gómez-Fraguela, Cutrín, & Romero, 2017; see also:

Bresin, 2019).

Building on these recent advances of self-control research in psychology, DNERM considers the affect-free (i.e., cognitive self-control) and affectively laden (i.e., affective self-control) aspects of self-control independently (see also: Wills, et al., 2006). Within the DNERM framework, the identified predominantly cognitive-laden “affect free” aspect of self-control is termed *cognitive self-control*, whereas the other affectively laden aspects of self-control are termed *affective self-control*.

The development of affective self-control and cognitive self-control

Current theoretical advances in brain research suggest that both cognitive control (governed by the prefrontal cortex) and affective control (which is associated with activation in the ventral striatum) develops throughout adolescence, but at different paces (Somerville & Casey, 2010; Steinberg 2007). For example, neurodevelopmental imbalance models suggest that an imbalance between such self-control processes is the largest during adolescence and this contributes to heightened adolescent risk-taking (Steinberg, 2007; see also: Crone & Dahl, 2012). However, empirical studies in psychology on the development of especially affective self-control during adolescence are limited (cf. Wills et al., 2006). That is, despite the “emotions revolution” in the behavioral sciences (Weber & Johnson, 2009), the role of emotions (versus cognition) in risk-behavior is still frequently neglected (cf. Defoe et al., 2015). However, generally findings show that adolescents have lower affective self-control than adults (Silvers et al., 2012). Additionally, multiple empirical longitudinal studies suggest that the “acting without thinking” component of self-control peaks in mid-adolescence for some individuals (for an overview see: Khurana & Romer, 2020).

DNERM takes the above-described development and multi-level nature of self-control into account, and suggests that age predicts self-control. For example, the meta-analysis of Defoe et al. (2015) found that particularly on affectively laden tasks with immediate outcome feedback, adolescents took more risks than adults, which could suggest that compared to adults, adolescents’ affective self-control is still developing. Hence, compared to adults, some adolescents appear to experience more difficulties especially with *affective self-control* (perhaps due to pubertal maturational changes in the brain; Crone & Dahl, 2012). Although research is still needed on the developmental patterns of affective and cognitive self-control (as conceptualized in DNERM), based on prior research on comparable self-control indices, it is expected that age predicts both affective and cognitive self-control (e.g., Defoe, et al., 2021; Silvers et al., 2012), but that this age-dependent development of self-control would show individual differences throughout adolescence and emerging adulthood (see e.g., Khurana & Romer, 2020).

DNERM: The developmental interaction between risk exposure and Self-Control

The hybrid “*Developmental Neuro-Ecological Risk-taking Model*” (Fig. 1) is a person-environment model, that describes an interplay between risk exposure (the ecology/environment) and self-control (the individual). This conceptual frameworks of “person-environment models” have existed for a long time in the field of psychology (e.g., Lewin, 1951). Still, in psychological sciences, the majority of empirical studies have focused on either one of these predictors, and when the two are simultaneously assessed in a study, additive effects rather than an interplay such as an interaction effect between these two factors is analyzed (cf. Menting et al. 2016). Thus what has remained a challenge is determining how exactly these individual and ecological factors *jointly* predict behavior. Moreover, the role of the physical environment (versus the social environment) is typically overlooked in psychology.

On the one hand, at least a handful of existing person-environment models in criminology do consider both “crime conducive situations” (i.e., a combination of physical and social risk exposure) as well as “criminal propensity” in the prediction of criminal behavior. On the other hand, those models have largely neglected the role of youth *development* and culture, as well as the potential influence of indirect (e.g., via onlinemedia channels) forms of risk exposure, however. For example, the first of such criminology person-environment models was the initial formulation of the General Theory of Crime (Gottfredson & Hirschi, 1990), and other criminology theories on *situational opportunity* followed thereafter. Namely, the Life-Developmental Course Model of Interdependence (Wright, Caspi, Moffitt, & Silva, 2001) proposes an interaction between wide-ranging crime propensity and environmental factors. Additionally, the Situational Action Theory (Wikström, 2004), is a theory of moral action that predicts an interplay between crime propensity (morality is central, but self-control is also regarded as important) and the environment. For a critical evaluation of such models see Wilcox and Cullen (2018). Of note, unlike DNERM, the above-mentioned criminology models are not developmentally and/or culturally sensitive, and they do not consider (online) media influences that have been shown to be relevant for predicting behaviors of youth. Additionally, they have relied on unspecific conceptualizations of both self-control and “situational opportunity” (e.g., risk exposure), which complicate direct tests of their hypotheses (cf. Wilcox & Cullen, 2018). For instance, typically broad measures of neighborhood quality are used to measure “exposure to crime conducive situations” in those models (cf. Gök, 2011), which often conflate physical versus social risk exposures. As for development, the above-described criminology models on situational opportunity aim to predict risk behavior (particularly criminal behavior) at one point in time, instead of the developmental course of risk exposure and/or the associated developmental course of risk behavior (but see e.g., the aforementioned *age-graded theory of informal social control* (Laub, Rowan, & Sampson, 2018; Sampson & Laub, 1993) that predicts desistance to criminal behavior in *adulthood*). Thus, whereas DNERM hypothesizes developmental mechanisms (e.g., linked to puberty, and the exploratory behavior of adolescence), past (criminology) person-environment models typically do not. Taken together, DNERM goes a step further by taking youth development into account, which encourages the decomposition of aspects of self-control (i.e., affective versus cognitive) and risk exposure (i.e., [online] physical versus [online] social risk exposure). Such decomposition further allows for specificity and testability of how an interaction between the developing person (younger versus older youth) and his/her developing ecology (including culture) potentially predicts youth risk behavior development.

As far as known, no empirical studies exist that have jointly investigated these DNERM hypotheses. Hence in the following paragraph, studies could only be highlighted that provide assumptive evidence of DNERM's conceptualization of an interaction between self-control and risk exposure. However, investigations of an interaction between *physical* risk exposure and self-control—while taking developmental stage into account—in the prediction of adolescent *antisocial behavior* could not be located. This is perhaps the case because instruments that specifically assess physical risk exposure in the context of antisocial behavior are lacking. Thus, in the following paragraphs, studies that have investigated DNERM-related interaction hypotheses via using “negative” neighbourhood factors as a proxy for physical risk exposure will be discussed instead. As for social risk exposure, DNERM posits that particularly direct forms of this concept (e.g., co-substance use and co-offending) interact with affective and cognitive self-control to predict risk behavior in adolescents. However, as far as known, studies have not tested such direct social risk exposure constructs in an interaction with self-control in the prediction of adolescent risk behavior. Hence below, studies are described that assessed social risk exposure more broadly (i.e., “proxies of risk exposure”). For example, this has been done via measures that merely capture whether adolescent's significant others engage in risk behavior, thus whether adolescents have “perceived” access to risk conducive situations.

Empirical findings on the developmental interaction between risk-exposure and self-control

Substance use

Evidence for significant interactions between risk exposure and self-control in predicting adolescent substance use has been established among the limited studies that have assessed such links. For example, a study of mid-late adolescents ($N = 270$) that investigated both cognitive self-control (non-urgency impulsivity traits) and affective self-control (urgency impulsivity traits) found that perceived peer alcohol use is particularly related to problematic alcohol use in adolescents with lower levels of affective control (Stautz & Cooper, 2014; see also Pocuca et al., 2018). Hence, those results demonstrate the importance of (1) differentiating between cognitive self-control and affective self-control and (2) testing the interaction between these forms of self-control and social risk exposure in predicting adolescent risk behavior. As for *physical* risk exposure, another study using a mid-adolescent sample ($N = 498$) showed that the relationship between self-control and cannabis use was moderated by perceived physical access (physical risk exposure) to cannabis (Haas et al., 2018). Namely, in Haas et al. (2018), adolescents were asked: “How difficult do you think it would be for you to get marijuana, if you wanted?” The results of these two studies (Haas et al., 2018; Stautz & Cooper, 2014) demonstrate tangential support for DNERM as they suggest that proxies of physical and social risk exposure predict (problematic) substance use particularly when there are low levels of self-control. However, these studies did not further examine whether this moderation was equally relevant for different phases of adolescence, and their cross-sectional correlational designs limit temporal ordering of the investigated behaviors.

Antisocial behavior

There have been a handful of attempts to investigate whether *social* risk exposure (e.g., peer delinquency) interacts with self-control to predict antisocial behaviour. For example, a study based on samples from three different European countries found support for similar interaction effects (Hirtenlehner, Pauwels, & Mesko, 2015). However, at least one study has not found interaction effects in a sample of Dutch youth (Franken et al. 2016). Of note, similar to the substance use literature, these studies did not directly assess whether adolescents are actually exposed to their peers while they are engaging in delinquency. Additionally, self-control was not decomposed into its cognitive versus affective components. This lack of decomposition could imply that true interaction effects were masked for example in Franken et al. (2016). Hence studies that focus on decomposing self-control and that specifically assess whether adolescents are directly exposed to their peers when they are engaging in risk behavior are still needed to fully test DNERM.

As far as known, empirical cross-sectional or longitudinal studies do not exist that have investigated whether *physical* risk exposure as described by DNERM interacts with self-control to predict antisocial behavior (e.g., stealing). Nevertheless, studies that approached doing so, used broad composite scores of a wide-ranging neighborhood factors, some of which include items that overlap with physical risk exposure (e.g., Tache et al. 2020; Zimmerman et al., 2015). Based on such studies, tangential evidence in line with DNERM's interaction hypothesis, comes from a recent meta-analysis that found the most support for a stronger link between neuropsychological indices (e.g., impulsivity) and antisocial behavior especially for adverse socio-environmental contexts (e.g., disadvantaged neighborhoods) (van Hazebroek et al., 2019). Yet, it should be noted that van Hazebroek et al. (2019) was not particularly based on studies that assessed direct forms of social and physical risk exposure as described in DNERM, and some studies in that meta-analysis confounded these two types of risk exposures. In any case, extrapolating from DNERM, especially the risk exposure aspects of the neighborhoods constructs in that meta-analysis (van Hazebroek et al., 2019) would be associated with risk-behavior.

Testing DNERM and moving forward

Revisiting the question that was posed at the beginning of this paper concerning the change in the Dutch minimum age law for alcohol use: *Is the presumption correct that this law adjustment will be effective in significantly decreasing youth alcohol use?* DNERM suggests that the answer to this question could further depend on self-control. For example, consider that when the minimum age raised from 16 to 18 in the Netherlands, this resulted in persons who were 17 years, and all of a sudden no longer legally allowed to use alcohol, whereas they were legally allowed to do so a year earlier when they were 16 years. It is conceivable that it would take significant effort to control one's self (i.e., self-control) not to engage in a behavior anymore that you were legally allowed to engage in earlier. Hence,

when there is access to alcohol (e.g., at a party), particularly the 17-year olds who are less capable of controlling themselves, will more likely still drink alcohol versus the 17-year olds with higher levels of self-control. This scenario demonstrates that there would clearly be an interplay between the individual (self-control) and the ecology (risk exposure) in predicting risk behavior. Additionally, there is obviously an age-dependent aspect to such risk exposure. Namely, as individuals grow older, they are exposed to more risk exposures, which could at least partially account for the accelerated rise and peak in risk behaviors during the youth period. Surprisingly, there is no theory that takes these aspects of risk exposure into account, and/or considers how this ecological factor interacts with individual factors such as self-control to predict youth risk behavior development. Hence, in Defoe et al. (2015), DNERM was put forward, and it is further developed in this paper to hopefully guide empirical research to answer pressing questions such as in the scenario illustrated above. Some scholars who have become interested in DNERM, have begun testing related hypotheses (see e.g., Ciranka and van den Bos, 2021) and/or have shown support for DNERM's predictions concerning delinquency (see e.g., Murray, Mirman, Carter, & Eisner, 2021) and risky decision making (Cosenza, Griffiths, Nigro & Ciccarelli, 2017).

A stringent test of DNERM's hypotheses would require at minimum that studies be specific in assessing their constructs of interest, and decomposition (affective versus cognitive self-control; physical versus social risk exposure) is also required. For example, concerning specificity, studies that directly test whether significant others are actually engaging in risk behavior in the presence of youth (e.g., "co-offending" or "co-substance use") are required to investigate to what extent this "social risk exposure" concept of DNERM predicts subsequent adolescent risk behavior. New validated questionnaires would also be needed to measure physical risk exposure more accurately, as such questionnaires are currently lacking (cf. Hay & Forrest, 2008). But scholars interested in this phenomenon could simply begin by incorporating it in their studies by for example asking research participants how often they had been exposed to situations in which easily stealing something or committing fraud would be possible if someone wanted to (see also: Hay & Forrest, 2008 for a discussion). More research on the development of such risk exposures could also aid in clarifying some of the mysteries in risk behavior research, such as why males engage in more delinquency than females. Although gender differences are not discussed in this paper, questions such as—*is delinquency more pronounced in males because particularly males experience heightened levels of risk exposures?*—are questions worth asking and answering. Finally, research on other relevant factors such as genetic influences, and their implications for DNERM are also warranted.

Last but not least, the vast majority of the studies reviewed in this paper— are only based on Western research samples—as is also the case for the vast majority of accessible scientific literature. But as demonstrated in this paper, aspects of culture (e.g., religion, values, norms) are closely intertwined with social and physical risk exposure. Thus, culture should preferably be taken into account when investigating DNERM. This can at least be achieved via capitalizing on ethnically-diverse research samples and/or cross-national research samples.

Conclusion

The Developmental Neuro-ecological Risk-taking Model (DNERM) is a hybrid psychological and criminological model that considers both risk (risk exposure) and resilience (self-control) in the prediction of risk behavior development during the youth period. Furthermore, it uniquely considers that the *developing/maturing* youth lives in a *developing/changing* physical and social environment (both online and offline in "real-life") that either expose them to risks (risk-exposure) or protects them from such harm. Accordingly, DNERM further posits that such *changing* ecological factors interact with an individual's "self-control" to predict heightened risk-behaviors in adolescence or emerging adulthood. Particularly self-control is important to consider because it is malleable and among the most robust individual predictors of risk-behavior (for a meta-analysis see: Piquero et al. (2016)). Hence, DNERM suggests that in the event of risk exposure, interventions should target persons with low levels of self-control. At the same time, it is also important for interventions to focus on fostering coping strategies in youth that can help them deal with and navigate circumstances they might encounter as a result of heightened levels of risk exposure. This is important as in certain circumstances risk exposure could be exceptionally high (e.g., in the most extreme disadvantaged neighborhoods), consequently self-control levels would be less decisive (see e.g., Fine, Mahler, Steinberg, Frick, & Cauffman, 2017; see also Zimmerman, 2010). In such cases, interventions could target lowering risk exposure and/or providing more exposure to non-risky situations (e.g., more positive leisure activities for youth in disadvantaged neighborhoods). Thus, this alternative approach could help keep youth off the "risky" streets in those neighborhoods, for example, which could lower risk exposure and eventually lower maladaptive risk behaviors. Taken together, DNERM emphasizes that development of heightened risk-taking should be investigated while considering the *development* of the individuals' characteristics (e.g., self-control), as well as the individual's *changing* physical and social ecology (e.g., risk exposure), which is further embedded within a ubiquitous cultural context.

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