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Change in Juvenile Offending Versatility Predicted by Individual, Familial, and Environmental Risks

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Developmental and life-course criminology elucidate the developmental course and change of antisociality over time, considering that longitudinal trajectories differ. Specific relations between risks and different antisociality outcomes are emphasized. We assume that adolescents have different longitudinal trajectories considering the change of offending over time and that risks contribute variably to offending pathways. The current study is based on a German research project in which adolescents (N = 577) were interviewed in two German cities. Based on self-reported crime data, we utilized the slope values of offending versatility (OV) over time as outcome values in regression mixture models capturing the trends for participants over age and exhibiting two components of offending adolescents. We explored the contribution of different risks to OV, defining specific risk patterns: Acceptance of violence and peer delinquency have significant negative effects on the emergence of OV within the group of adolescents with decreasing OV. Acceptance of violence has a significant negative effect, and corporal punishment has a significant positive effect on the emergence of OV within the group of adolescents with increasing or rather stable OV. The results underline the relevance of the violence-related risk factor corporal punishment for the emergence of OV within the last-mentioned group.

Keywords: juvenile delinquency, developmental risks, longitudinal research, developmental criminology, regression mixture models

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Developmental and life-course criminology considers the change of antisociality over time relating to the developmental course (for example, see Farrington, Piquero, and Jennings 2013; Sampson and Laub 2016). Accordingly, Moffitt's well-known taxonomy of *life-course persistent vs. adolescence limited antisociality* (Moffitt 1993, 2006) has been developed to integrate sociological and psycho-biological theories and to explain the *age-crime curve*: "The taxonomy achieved its original goal, to account for the age-crime curve. Its

dual theories of LCP [life-course persistent] and AL [adolescence limited] development met their original goal of drawing from biological, psychological and sociological theories to explain antisocial behaviour" (Moffitt 2018, 184). The age-crime curve represents "one of the brute facts of criminology" (Hirschi and Gottfredson 1983, p. 552) displaying the relations between crime and age and the change of delinquent behavior over time (concerning the lifetime of individuals). According to this, the prevalence of criminal behavior clearly increases from late childhood to adolescence and finally decreases in early adulthood (see Moffitt 1993; Farrington, Piquero, and Jennings 2013). Incidentally, the peak occurs earlier in self-report offending data (including dark figures) than in registered data (official records/reported crime in official crime statistics; for example, see Boers and Reinecke 2007; Loeber et al. 2015). The age-crime curve also shows that many children and adolescents remain trouble-free. Generally, the relations between age and crime in youth and early adulthood can be explained by co-occurring sociological, psychological, and biological changes (for example, see Sweeten, Piquero, and Steinberg 2013). Longitudinal trajectories for antisocial outcomes are quite different, especially in childhood and adolescence. Empirical criminological literature reveals no consistent number of groups of antisociality. For example, according to Broidy et al. (2003), three to four different physical aggression trajectories in childhood were most prevalent. Similarly, Jennings and Reingle (2012) found that studies examining violence, aggression, and delinquency trajectories mostly reported three to four trajectory groups, where the number of groups generally ranged from two to seven. The number and shape of trajectory groups seem to be quite variable (for example, depending on the sample composition, length of follow-up, and geographical location; ibid.). The studies, however, are in accordance with Moffitt's taxonomy and comprise a chronic or life-course persistent group (chronics), a group of escalators or adolescent-limited offenders (desistors), and a group without problem behavior (ibid.). The vast majority of empirical studies examining longitudinal data on antisocial trajectories apply General Growth Mixture Models (GGMM; for example, see Nagin 1999; Stemmler and Lösel 2015).

According to Jennings and Reingle (2012), trajectory research should also focus on the identification of risk and protective factors for differentiating developmental trajectories, raising, for example, the following question: "[D]o the same risk and protective factors that distinguish non-offenders from life-course persistent offenders also distinguish adolescent-limited offenders from life-course persistent offenders, or does this same set of risk and protective factors have a differential effect across trajectory groups?" (486). Overall, empirical studies in developmental and life-course criminology show the importance of numerous risk factors – such as individual characteristics, familial characteristics, environmental characteristics – in the explanation of antisocial behavior in general (for example, see Corrado 2002, 2012; Craig et al. 2017; Farrington, Ttofi, and Piquero 2016; Stemmler, Wallner, and Link 2018; Thornberry et al. 2012; Wallner et al. 2018). Related bio-psycho-social risk models correspond with the life-course-persistent path proposed by Moffitt (see above). The bio-psycho-social risk model of Lösel and Bender (2003) focuses on the relations between different risks, for example, poor child-rearing and low self-control in childhood, deviant peers and beliefs in adolescence, and serious and violent criminality in early adulthood. Of course, other risks are also considered and many other risk combinations are possible. Concentrating on risk/needs management issues, Corrado (2002, 2012) summarizes the risks for serious and violent antisocial behavior, considering environmental, individual, family, intervention, and externalizing behavior contents and risk domains, respectively (see also Stemmler, Wallner, and Link 2018; Wallner et al. 2018). Specifically, concerning different types or trajectories of delinquent behavior, the relevance of risks varies, defining specific risk patterns (in other words, risks are different for different developmental pathways): individual and family risks (for example, concerning personality, child-rearing practices) play a particularly important role in life-course persistent antisociality, whereas predictors of adolescence limited antisociality (for example, problematic peer contacts, peer delinquency) are mainly related to the contemporary maturity gap in adolescence (for example, Moffitt 1993; see also Odgers et al. 2008). Further, life-course persistent antisociality

seems to be associated with versatile and more serious offending, whereas adolescence limited antisociality is associated with less serious, more youth-typical offending (for example, see Moffitt 1993 and Odgers et al. 2008; see also Elliott et al. 2017). Concerning antisocial conduct problems, Odgers et al. (2008) approve the use of variety scores, which are "highly correlated with frequency scores ... and [that] are commonly used in population-based studies" (ibid., 676). Antisocial behavior in adolescence is often influenced by adverse peer contacts (for example, see Battin et al. 1998; Lösel and Bender 2003). A high rate of peer delinquency (offending in groups) and a high rate of co-offending are typical characteristics of juvenile delinquency (Wallner and Weiss 2019). Côté et al. (2006) examined the development of physical aggression in childhood and identified three different developmental trajectories (low desisting, moderate desisting, high stable), and found that, for example, (1) specific risks distinguished between children with physical aggression trajectories and other children, and (2) hostile/ineffective parenting was predictively related to the high level group trajectory. Consistent with previous results, many studies defined specific factors predicting several distinct trajectories of different antisocial outcomes (for example, see Corovic et al. 2017; Gutman, Joshi, and Schoon 2019; Lacourse, Dupéré, and Loeber 2008; Odgers et al. 2008; Seddig and Reinecke 2017, see also Reinecke and Seddig 2011). For example, Lacourse, Dupéré, and Loeber (2008) defined specific factors predicting distinct trajectories of antisocial outcomes (violence and theft) in a sample of young men. Seddig and Reinecke (2017) explored self-reported delinquency trajectories, presented a solution with seven classes, and explained membership in a special class of offenders utilizing patterns of specific variables (for example, peer group, attitudes; see also Reinecke and Seddig 2011). Corovic and colleagues (2017) recapitulated various risk factors in childhood and adolescence and adulthood adjustment outcomes differentiating between specific pathways of crime. However, these studies differ concerning the outcome measure, specific sample characteristics (for example, age), the number of antisocial pathways found and other issues. For example, different facets of antisocial behavior are considered as the outcome measure. Generally, antisociality captures deviant *and* delinquent behaviors (for example, Wittenberg and Wallner 2016). However, studies suggest that diverse antisocial trajectories are mostly defined by different risks; correspondingly, "[r]esearch has begun to demonstrate that there are a number of correlates of offending ... and other adverse outcomes ... that can be considered alongside violence, aggression, and delinquency as manifesting a similar developmental process that can largely be explained by a shared similarity in risk and protective factors" (Jennings and Reingle 2012, 486). More recently, recapitulating previous evidence, Gutman, Joshi, and Schoon (2019) stated that "different influences and processes may explain diverse pathways of conduct problems" (ibid., p. 181).

In the research presented here, we focus on the relations between different risk variables and antisocial outcomes in adolescence over time. Generally, referring to the research described above, the age-crime curve illustrates that the prevalence of crime increases from late childhood to adolescence and decreases in early adulthood. In the current work, we focus on the critical developmental stage of adolescence. As already outlined, the associations between age and crime in adolescence and early adulthood can commonly be explained by co-occurring sociological, psychological, and biological changes (see above). The present work is primarily rooted in risk-factor research. Specifically referring to the empirical findings outlined above, the following core hypotheses were derived. First, adolescents have different longitudinal trajectories considering the change in delinquent behavior over time (in other words, adolescents' trends of offending versatility over age are varying in the course of adolescence). Prior trajectory research commonly relied on GGMM (see above). In the present study (on the basis of our longitudinal crime data), however, we utilize the slope values of offending versatility (see methods section for a definition) as outcome values in a mixture of regression routine (for example, see Benaglia et al. 2009) capturing the trends for adolescents over time and, therefore, applying a method which is not common in current (criminological) trajectory research. Second, individual, familial, and environmental risks in adolescence have distinct

influences on specific delinquent behavior (different risks contribute variably to offending versatility pathways defining specific risk patterns). Therefore, we predict different trajectories of offending versatility (the different slope values of offending versatility; see methods section for a definition) based on different risks for antisociality, contributing more specific and detailed analyses on the prediction of divergent developmental trajectories and, thus, estimating the relations between different predictor effects and various offending versatility trajectories (see results section). Specifically, we assume that the developmental risks – acceptance of violence, impulsivity, peer delinquency, and corporal punishment – are differently associated with distinct pathways of offending versatility. This research therefore focuses on violence-related risks (corporal punishment, acceptance of violence; see methods section for justification). It should also be noted that several violent offenses are considered for the outcome offending versatility (see also methods section for further details). Again, in a nutshell, this work differs from prior work in trajectory research in that it explores the application of a longitudinal method for identifying different developmental pathways that is unusual in this context and applies this method to validate these pathways, using juvenile risks relating to diverse developmental domains, hence, far exceeding the information provided by mere description.

1 Methods

1.1 Research Project

In line with the research project "Chances and Risks in the Life Course" (CURL; research project A2 "The Emergence and Development of Deviant and Delinquent Behavior over the Life Course and its Significance for Processes of Social Inequality"; e.g., Reinecke et al., 2013; Reinecke, Stemmler, and Wittenberg 2016; Wallner et al. 2019) the development of deviant and delinquent behavior is studied. This project is part of the Collaborative Research Center ("Sonderforschungsbereich", SFB) "From Heterogeneities to Inequalities" (SFB 882), which was established at Bielefeld University, Germany, in 2011 and was funded by the German Research Foundation (DFG) until 2016. The study uses a cohort-sequential design that enables the examination of participants' development in childhood and adolescence. One important aim of the current study is to investigate the relations among deviant and delinquent behavior and various meaningful precursors longitudinally. The project data is based on self-reports of male and female students who completed several questionnaires. Participating students were interviewed once a year as part of school-based and postal surveys (Weiss and Wallner 2019).

1.2 Sample

Participants were surveyed in the German cities of Nuremberg and Dortmund with three annual follow-up assessments since 2012, providing a large sample. The Nuremberg sample comprises only students from lower-track schools, whereas the Dortmund sample is composed of a broader range of school types. Importantly, we use the longitudinal sample (*three-wave panel*) of male and female students of the older cohort (9th to 11th grade); the sample comprises only students participating in our study at the first, second, *and* third assessment points (t1, t2, t3; N = 577 adolescents: n = 350 female and n = 227 male). The mean age of the ninth-graders was about 15 years at t1. At t1, 41.9 percent (n = 242) of the students attended a lower-track school. Overall, 53.6 percent (n = 309) of the sample have a migration background (t1). In the current work, we apply to the broad definition of "migration background" used by the Federal Statistical Office (Destatis, Germany; Statistisches Bundesamt 2012): Accordingly, those persons have a migration background who immigrated to Germany after 1949 as well as all persons born in Germany without German citizenship and all persons born in Germany with German citizenship with at least one parent who is an immigrant or born in Germany without a German passport. Generally, the definitions of migration background differ. In any case, regarding the heterogeneity of the present sample, limitations regarding the interpretability of the results have to be considered (see discussion section). For further details of the sample see Weiss and Wallner (2019). The mean t1 offending versatility score of the remaining three-wave panel (M = 1.09, SD = 2.21) was only marginally lower than the mean t1 offending versatility score for the whole sample (M = 1.27, SD = 2.38, N = 1417), providing some in-

formation on dropout issues. See Weiss and Link (2019) for further information on panel mortality in the longitudinal study.

1.3 Measures

The data basis of the present study is derived from the three-wave panel of the older cohort. First, several risk variables (i.e., individual, familial, and environmental risks; independent variables, predictors, t1), were used, also including violence-related risks. To justify the selection of risk variables, we refer to risk-factor research described above, particularly to our own previous work on these topics (for example, Stemmler, Wallner, and Link 2018; Wallner et al. 2018; Wallner and Stemmler 2019). The selection applied were relevance concerning serious and violent antisocial behavior (for example, see Corrado 2002, 2012), age-appropriateness, broad content (to include different risk domains, ibid.), and availability within our research project. Second, delinquency (offending versatility; dark figures, outcome measure, t1 – t3; see section "Offending versatility" below for justification), was utilized, also comprising several violent offences. Further information on relevant measures, items, and scales can be obtained from Arnis (2015) and Meinert, Kaiser, and Guzy (2014). Overall, we also utilized several (partly modified) items and scales from the CrimoC study (Boers and Reinecke 2007, see also Boers and Reinecke 2019). Additional information on that study, particularly information related to trajectory research, can be obtained from, for example, Reinecke and Seddig (2011) and Seddig and Reinecke (2017).

Impulsivity. Self-ratings concerning low self-control were derived from the German version of the *Grasmick Scale* (Grasmick et al. 1993; German version: Eifler and Seipel 2001). At t1, the scale consisted of ten items. Overall, items from the five-point subscales *Risk Behavior, Impulsivity, Temper,* and *Simple Tasks* were utilized ranging from *strongly disagree* through *strongly agree* (see Meinert, Kaiser, and Guzy 2014). One example: "When I am really angry, other people better stay away from me". High scale values indicate low levels of self-control and high levels of impulsivity. In the context of the present work, we use the short label "impulsivity" for this aggregate scale. According to Arnis (2015), Cronbach's alpha was satisfactory (α = .75; 9th grade).

Acceptance of violence. We also assessed acceptance of violence using a scale from the CrimoC study (Boers and Reinecke 2007, see also Boers and Reinecke 2019 for further details on the CrimoC study; see Dünkel and Geng 2003). According to Dünkel and Geng (2003), self-reported violent behavior is substantially positively related to acceptance of violence in adolescence. The measure comprises nine items in a five-point rating format ranging from *does not apply at all* through *does definitely apply* (for example, "When another person attacks me physically, then I fight back"). High scale values represent high levels of acceptance of violence. Further information is provided by Meinert, Kaiser, and Guzy (2014). The corresponding alpha coefficient was satisfactory at α = .76 (9th grade; Arnis 2015).

Corporal punishment. To operationalize parenting practices including parenting deficits we utilized a scale from the modified version of the Alabama Parenting Questionnaire (APQ; see Essau, Sasagawa, and Frick 2006; Shelton, Frick, and Wootton 1996). In our research project we utilized a modified self-report version for children and adolescents (see Meinert, Kaiser, and Guzy 2014) which is based on a German parent version of Lösel et al. (2003). We used four items from the subscale *Corporal Punishment*. The items are answered in a five-point rating format ranging from *never* through *always*. One example: "My parents hit me." High scale values indicate high levels of corporal punishment by parents. The alpha coefficient was excellent (α = .89; 9th grade; Arnis 2015).

Peer delinquency. We assessed peer delinquency (i.e., precisely, the deviant and delinquent behavior of peers) following the CrimoC study (for example, Boers and Reinecke 2007, see also Boers and Reinecke 2019 for more information on the CrimoC study) and PADS+ (Peterborough Adolescent and Young Adult Development Study; for example, Wikström et al. 2012). According to the PADS+ scale *Peer Crime Involvement* and specific CrimoC delinquency items, our measure incorporates different deviant (drug use) and delinquent acts (for example, theft, break-in), respectively, committed by peers (see Meinert, Kaiser, and Guzy 2014). Participating students were asked how

often friends committed particular acts, for example, "Does it often happen that some of your friends press somebody for money?". Seven items capture the frequencies in a five-point rating format ranging from *never* through *very often*. High scale values represent high levels of peer delinquency. The alpha coefficient was quite acceptable (i.e., α = .85; 9th grade; Arnis 2015).

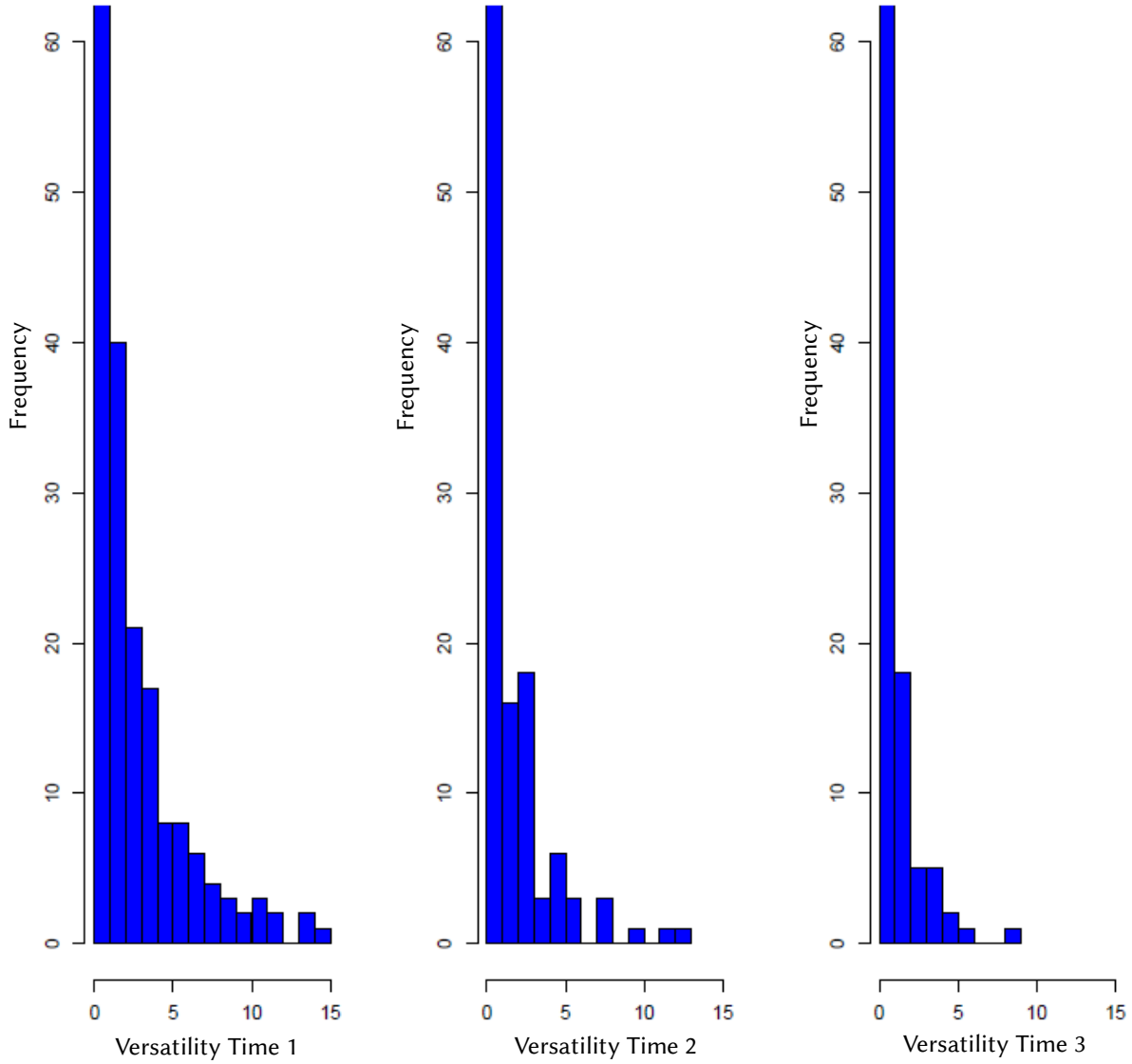
Offending versatility. Delinquency items were based on a modified version of the *Self-Report on Delinquent (and Deviant) Behavior* ("Delinquenzbelastungsskala", DBS; Lösel 1975; available in Weiss, Runkel, and Lösel 2012; for example, theft) and on the *Delinquency Scale* ("Delinquenzskala"; CrimoC; for example, Boers and Reinecke 2007; for example, scratching; see also Boers and Reinecke 2019 for further details on the CrimoC study). The adolescents' self-reports on criminal behavior include dark figures referring to unrecorded crime and providing other information than registered data. As mentioned above (see introduction), the peak occurs earlier in self-report data on offending (including dark figures) than in registered data (for example, see Boers and Reinecke 2007; Loeber et al. 2015). We applied the epidemiological definitions of prevalence and incidence: "Basically, *prevalence* (or prevalence rate) refers to the number of diseases or spells of disease existing at a particular point in time or within a specified time period related to the total number of persons exposed to risk (a population or a defined group of people). *Incidence* (or incidence rate) on the other hand measures the rate of appearance of *new cases* in the group or population, i.e., the number of diseases/spells of disease *beginning* within a specified period of time related to the total number of persons exposed to risk during that period" (Olweus 1989, 187). In the current work, delinquent acts refer to vandalism, property crime, violent crime, and drug dealing (Wallner and Weiss 2019; Wittenberg and Wallner 2016). Nineteen different criminal acts were considered (for example, scratching, bicycle theft, robbery). Partially, several delinquent acts refer to the same crime type, so that some categories are overrepresented. The considered delinquency items varied concerning severity. We employed the versatility of crime (i.e., [offending] versatility) in the past twelve months focusing on the range, heterogeneity, and diversity of criminal behavior – in contrast to, for example, the frequency of crime (for example, see Boman, Mowen, and Higgins 2019) or crime specialization (for example, see Lussier et al. 2017; Tzoumakis et al. 2012). Crime frequencies are widely utilized. However, Bendixen, Endresen, and Olweus (2003, 135) suggest that "using a scale including the (raw) frequencies of antisocial acts committed instead of a variety scale would result in reduced internal consistency, lower stability over time, smaller group differences and weaker associations with conceptually related variables. Similarly, in regression analyses the (raw) frequency scale contributed little to the explained variance in conceptually related variables over and beyond that contributed by the variety scale". Therefore, we utilized a variety index which captures the diversity of offending at each assessment (t1 – t3) and – in some aspects – reveals the intensity of offending over time. Thus, offending versatility represents the number of *different* delinquent acts committed by an individual in the last year at each of the three time points; therefore, high scale values indicate high levels of offending versatility.

1.4 Strategy of Analyses: Capturing Trends in Longitudinally Assessed Offending Versatility Responses

Slope values of offending versatility over time. Initially, self-reported crime data are considered utilizing the slope values of offending versatility over time. The offending versatility response is a count of the number of adolescent-reported offenses during the past year (see methods section). It is easily interpreted, and less likely influenced by memory or guessing. These responses take integer values from zero to fifteen in the first assessment and zero to nine in the third. Figure 1 displays the roughly L-shaped histograms of the offending versatility measures at each of the three assessment points.

One central question is how to model these offending versatility responses in a way that reflects changes in offending versatility response trajectory over the three assessment time points within some regression model. An answer is not obvious, partly because repeated measurements data models often require full specification of the joint distribution of re-

Figure 1: Histograms of offending versatility responses



Notes: Ordinates have been truncated; heights at zero are 354, 458, 484; vectors of mean and variance are (1.09, 4.36), (.48, 1.97), (.26, .67), times one to three respectively; n = 571; Versatility: offending versatility.

sponses and typically under distribution normality. These empirical facts preclude the plausible use of a very large class of possible models including those based on normal or multivariate normality.

The approach selected is the following: Define a linear slope response for each i by linearly regressing each i's three offending versatility integer scores against the time points designated as 1, 2, 3. For individual i, a slope y_i indicates i's offending versatility trajectory over the three offending versatility responses. These slope values take on 19 discrete values from -7 to 2.5, a sufficient number to hopefully be considered continuous outcomes. Still, they will be treated as continuous outcomes. A positive slope, $y_i > 0$, indicates increasing offending versatility over the three years; a negative slope, $y_i < 0$, indicates a decreasing offending versatility, and $y_i = 0$ indicates no change.

The distribution of the y_i slopes, the response variable, reveals large individual differences. Among the 577 individuals, half (287) reported zero offenses at all three times. Because of their consistency, these is are viewed as special and treated as such in the analyses below. An i is an element in the set τ: $i \in \tau$ if and only if its offending versatility scores are (0; 0; 0), or "triple zeros" (with τ denoting triple or three; read $\in$ as "in"

and ∉ as "not in"; τ is a set with elements individuals *i* with triple zeros, in other words, zero offending versatility responses at all three assessment points). These *i* ∈ τ are regarded as following a zero variance mass point distribution (see below).

There were 28 additional *i*s with estimated slopes of zero but not in τ. 174 individuals displayed negative estimated slopes; only 26 had positive estimated slopes, signaling an increase in offenses over time. The remaining 62 = 577 − 287 − 28 − 174 − 26 individuals had missing offending versatility values, denoted NA for "not available" (R Core Team 2017). R software was used for all analyses (see below). Of the 62 individuals with offending versatility NA values, six had NA values on two times. For all but one *i*, these NAs occurred on the second or third time. Of 56 *i*s with NA on one time, most had identical offending versatility values on the other two times or a smaller value on the second time than on the first. This finding suggested that it would be reasonable to impute for those *i*s with a single missing NA their smallest observed values. Most of the imputed values were zero. Following imputation, contained 307 individuals or 54 percent of the usable sample (.54 = 307/571) with 38 zero slopes $i \notin \tau$ and a total of 264 $i \notin \tau$. In summary, following imputation 571 = 307 + 264 individuals had usable slope response values. Consequently, just six of 577 individuals were excluded from all subsequent analyses. Of course, some additional individuals were excluded if they had NA values on a predictive covariate because NA responses are inadmissible in the mixture of regressions in the R package *mixtools* (Benaglia et al. 2009), the source of all mixture routines employed below.

So far our initial empirical results addressed the common gap in research relating to the availability of different methods in the identification of specific developmental pathways (see introduction). The following analyses employ the slope values of offending versatility to explain distinct juvenile pathways over time.

The Regression Mixture Model. Next, we use the slope values of offending versatility (see above) as outcome values in a mixture of regression routine encompassing the trends over time. Therefore, in the following, we refer to the corresponding *Regression Mixture Model.*

There are $i = 1, 2, \ldots, n$ individuals, each with response y_i arranged in a column vector $y_1, \ldots, y_n$ of n independent observations. Recall, y_i is i's slope. The associated covariates for each i are $\mathbf{x}_1, \ldots, \mathbf{x}_n$. Each $\mathbf{x}_i$ has p predictors in a row vector $p + 1$ long, $\mathbf{x}_i = (1, x_{i,1}, \ldots, x_{i,p})$ with the first entry coded one for the intercept. The design matrix $\mathbf{X}$ has n rows and $p + 1$ columns. Thus, there are n pairs of the form $(y_i, \mathbf{x}_i)$ with each i assumed to belong to only one of $m = 3$ three regression mixture components. The first component $j = 0$ denotes those $i \in \tau$, while $i \notin \tau$ were admissible for either of components $j = 1, 2$ in the normal mixture of regressions to be defined explicitly momentarily (see below). To anticipate, using BIC (Schwarz 1978) the data support no more than two normal components. Following Schwarz, the model with the largest BIC is taken as the best model.

$\boldsymbol{\beta}_j$ is a column vector of coefficients associated with components $j = 1, 2$. $\boldsymbol{\beta}_j = (\beta_{j0}, \beta_{j1}, \ldots, \beta_{jp})'$, so there are $p + 1$ values of β for each $\boldsymbol{\beta}_j$, $j = 1, 2$.

Let $N(\cdot|\mu,\sigma^2)$ denote a conditionally normal density function with mean μ and variance σ^2. (Let $N(\mu,\sigma^2)$ denote a normal density unconditionally.) The regression mixture model is:

$$g(y_i \mid \mathbf{x}_i) = \lambda_0 f(y_i \mid \mathbf{x}_i) + I(i)\sum_{j=1}^{2} \lambda_j N(y_i \mid \mathbf{x}_i\boldsymbol{\beta}_j, \sigma_j^2) \quad (1)$$

$I(i) = 1$ if $i \notin \tau$, and zero otherwise. σ_j^2 are variances of components $j = 1,2$; $\lambda_j \geq 0$,

$$1 = \sum_{j=0}^{2} \lambda_j$$

Thus, like conventional regression, model (1) is conditioned on the observed predictors.

$$f(y_i \mid \mathbf{x}_i) = \begin{cases} 1, & \text{if } i \in \tau \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

$f(y_i \mid \mathbf{x}_i)$ is a zero variance mass point at zero with height one. Note that $f(y_i \mid \mathbf{x}_i)$ does not depend on $\mathbf{x}_i$. The proportion of the observations following $f(y_i \mid \mathbf{x}_i)$ is λ_0. Those $i \in \tau$ and consequently their y_is receive no further analysis. It is worth noting that handling the zeros in (2) is similar to a zero-inflated Poisson in parameterization, a model often used in studies with many observed zero values such as Tzoumakis et al. (2012); in both, zeros are viewed as components of mixture distributions.

Intuitively, consider only those $i \notin \tau$, and consider fitting an ordinary multiple regression equation, as in conventional settings, except that it is hypothesized that there is more than one regression equation appropriate for the data. The task is to decide with which regression, $j = 1, 2$, for $i \notin \tau$ the pair $(y_i, \mathbf{x}_i)$ is a partner. The solution "matches-up" the observations with their most probable regression equations via an iterative EM algorithm. Matching is achieved using a Bayes Rule classifier. Rather than least squares, as in conventional regression, the approach is maximum likelihood under normality. If further details are required, there are general discussions of finite mixtures and mixtures of regressions available in many sources (for example, Benaglia et al. 2009; McLachlan and Peel 2000).

The approach in the current setting is not quite standard however, as there is one large component modeling those $i \in \tau$ that must be considered. The zero variance mass point distribution $f(y_i \mid \mathbf{x}_i)$, is quite non-normal in distribution. Consequently, this component is treated in an ancillary fashion. Thus, only those i $\notin \tau$ pairs $(y_i, \mathbf{x}_i)$ are analyzed under the mixtools call *regmixEM*. The λ_1 and λ_2 component weights are then adjusted at the end, so that the three λ estimates sum to one.

The distribution of point mass component at zero $f(y_i \mid \mathbf{x}_i)$ seems easily defended. The assumed conditional normality of components $j = 1$ and $j = 2$ in (1) is more difficult to defend rigorously, but it is hoped a mixture of two normal distributions will hold at least approximately or at least not lead one astray. If the normal regression model holds, the slope distribution is normal (for example, Freedman 2005), so this result would give some hope for the appropriateness of the component conditional normality assumption in (1).

The regression mixture procedure provides estimates for three λ, two σ^2 and $2(p+1)$ estimates of β. The number of covariates p varies, which means the sample size n varies as well because as already noted, only complete data are admissible under the *regmixEM* routine.

Collectively, the adolescents participating in our study show different longitudinal trajectories considering change of offending versatility, hence, adolescents' trends of offending versatility over time are varying. The corresponding slope model described above models the growth trajectory of slopes assessing three occasions over a time span of two years. In addition to the component of non-offending adolescents, two components of offending adolescents were defined. Perhaps there are appropriate alternative approaches to the data modeling perspective employed here. Growth mixture models might seem an obvious candidate, however, these models make strong assumptions, including distributional multivariate normality, assumptions often ignored. Consequently, the results can be misleading (Bauer and Curran 2003). Even univariate normality fails dramatically here as the discrete Figure 1 distributions reveal. The approach taken here is less susceptible to such concerns.

2 Results: Contribution of Risks to Offending Versatility

Finally, the contribution of different developmental risks to offending versatility trajectories is examined, displaying the predictive importance of these risks for distinct components of offending versatility. The contribution of longitudinally assessed individual, familial, and environmental juvenile risks to explain different pathways is brought into focus – going beyond the mere description of pathways. For brevity, we consider the analysis under model (1).

Let $p = 4$, with predictor variables acceptance of violence, impulsivity, peer delinquency, and corporal punishment, with values taken at the first time point (see Table 1 for summary statistics for the variables).

A one-component (conventional) regression model and two-component mixture of regressions were applied to the data. Model selection employed Schwarz's (1978) Bayesian Information Criterion denoted as *BIC(LL; k; n)*, where *LL* is the loglikelihood, *k* the number of estimated parameters, and *n* sample size. The model with the largest *BIC* is taken as the best-suited model (taking the largest *BIC* following Schwarz). For the one- and two-component regression models *BIC* (−346.21, 6, 235) = −362.39 and *BIC*(−316.86, 13, 235) = −351.46. Thus, the mixture model was selected. See Table 2 for the corresponding parameter estimates. The standard errors in parentheses were obtained using standard bootstrap observed data resampling pro-

cedures (Efron and Tibshirani 1993). In addition, λ_0 = 0.540(.020).

functions are nearly identical. Acceptance of violence, for component j = 1, $\beta_{11,acc}$ is negative, and significantly

Table 1: Summary statistics for the predictor variables acceptance of violence, impulsivity, peer delinquency, and corporal punishment (first time point, t1)

	y	acc	imp	pee	pun
variable range	-7 to 2.5	0 to 29	0 to 35	0 to 28	0 to 16
mean	-.87	11.47	17.50	5.02	1.34
var	1.80	38.29	44.90	26.57	9.24

Notes: Predictor variables: acc: acceptance of violence, imp: impulsivity, pee: peer delinquency, pun: corporal punishment. These statistics are all based on n = 237, representing complete data for all five variables.

Table 2: Two-component multivariate mixture of regressions estimates with four predictors: acceptance of violence, impulsivity, peer delinquency, and corporal punishment (standard errors in parentheses)

		Components	
Predictors		*Component 1 (j = 1): Decreasing Offending Versatility*	*Component 2 (j = 2): Increasing/Stable Offending Versatility*
	$\hat{\lambda}_j$	0.228(0.094)	0.232(0.094)
	$\hat{\sigma}_j$	1.391(0.258)	0.282(0.180)
	$\hat{\beta}_{j0}$	0.881(0.264)	−0.495(0.057)
Acceptance of violence	$\hat{\beta}_{j1,acc}$	**−0.099(0.017)**	**−0.013(0.004)**
Impulsivity	$\hat{\beta}_{j2,imp}$	−0.021(0.015)	0.005(0.003)
Peer delinquency	$\hat{\beta}_{j3,pee}$	**−0.077(0.018)**	0.007(0.005)
Corporal punishment	$\hat{\beta}_{j4,pun}$	0.002(0.032)	**0.024(0.007)**

Notes: Parameter estimates relating to the predictors: Values marked in bold are statistically significant (at least at the 0.05 significance level).

Recapitulating, the slopes are modelled as outcomes, whereas the chosen risk factors are predictors within the regression mixture model. The first component standard deviation is again much larger than that of the second component, although the weight

so; thus increasing acceptance of violence is associated with decreasing offending versatility. Similarly for peer delinquency, $\beta_{13,pee} < 0$ and thus has a similar interpretation (increasing peer delinquency scores associated with decreasing offending versatility). Collectively, the risk factors acceptance of violence and peer

delinquency both have a significant negative effect on the emergence of offending versatility within the group of adolescents with decreasing offending versatility, or in other words, the higher the acceptance of violence in this group of adolescents, the smaller the offending versatility slope in this group. This means the higher the acceptance of violence, the more negative the slope, thus the more decreasing adolescents' offending versatility over t2 and t3 in this group. Relatedly, the results concerning peer delinquency have a similar interpretation. Corporal punishment is not different from zero in component one. Impulsivity is not different from zero in either component, suggesting that this variable does not reflect any positive or negative trend when combined with other variables, over the two-year period (t1 – t3). Collectively, component two seems to reflect small changes about zero, with corporal punishment significantly positive, and acceptance of violence significantly negative. Accordingly, corporal punishment has a significant positive effect and acceptance of violence has a significant negative effect on the emergence of offending versatility within the group of adolescents with slightly increasing or rather stable offending versatility. Peer delinquency is not different from zero in component two. Overall, our findings illustrate the importance of different developmental risks for diverging developmental processes explicating risk-related variations in juvenile offending versatility trajectories.

3 Discussion

Evaluating the hypotheses set forth above, it becomes apparent, as expected, that adolescents have different longitudinal trajectories considering the change of offending versatility. In addition to a non-delinquent group, our solution identified two diverging subgroups of offending adolescents: Individuals with decreasing versus individuals with slightly increasing or rather stable offending versatility over time. Generally, regarding different antisocial outcomes, most studies report three to four developmental trajectories (for example, see Jennings and Reingle 2012). In our study, comprising a quite limited two-year span of adolescence, three groups of adolescents emerged, including the non-delinquents. Furthermore, also as expected, different risks contribute variably to these different trajectories of offending versatility constituting diverse patterns of risk in adolescence, so that the divergent developmental pathways are differentially described and externally validated. Comparing our results with the results of other studies, certain similarities emerge. Referring to the fundamental work of Moffitt (1993), risks mostly related to adolescence limited antisociality (for example, delinquent peers) are associated with the contemporary maturity gap in adolescence, whereas individual risks (for example, concerning personality) and family risks (for example, concerning child-rearing practices) are particularly important in life-course persistent antisociality. In our study, we do not have self-report data before the age of about 15 years and beyond the age of about 17 years, so childhood and (young) adulthood have to be neglected and, consequently, certain statements beyond the very limited age period of adolescence are not possible here. Accordingly, the length of follow-up is not adequate to allow extensive conclusions. It has become apparent that peer delinquency has a significant negative effect on the emergence of offending versatility within the group of adolescents with decreasing offending versatility – which assumedly might be limited to adolescence and, hence, related to the late period of the adolescence limited pathway. Results suggest that with increasing peer delinquency there is decreasing offending versatility. As outlined in the introduction, the bio-psycho-social risk model of Lösel and Bender (2003) describes different predictors of serious and violent criminality. Delinquent peers are a developmental risk mainly related to adolescence (for example, see Lösel and Bender 2003; Moffitt 1993, 2006). As already sketched above (see introduction), predictors of adolescence limited antisociality (for example, peer delinquency), are mainly associated with the contemporary maturity gap in adolescence (for example, Moffitt 1993; see also Odgers et al. 2008), adolescent antisociality is often influenced by adverse peer contacts (for example, see Battin et al. 1998; Lösel and Bender 2003), and offending in adolescence is frequently characterized by a high rate of peer delinquency (offending in groups) and a high rate of co-offending (for example, Wallner and Weiss 2019). Restrictively, in the current work, we did not take into account whether the committed offenses were typical

juvenile offenses, which are often committed in groups. Relatedly, however, our empirical findings indicate that having delinquent peers might be associated with offending versatility which is likely to fade in the course of adolescence. Further longer-term and more detailed analyses are required in this context (see above). Corporal punishment (as a familial risk factor relating to parental violence), has a significant positive effect on the emergence of offending versatility within the group of adolescents with slightly increasing or rather stable offending versatility. Corrado (2002, 2012) identifies different risks for serious and violent antisocial behavior, taking into account different risk domains (environmental, individual, family, intervention, and externalizing behavior; see also Stemmler, Wallner, and Link 2018; Wallner et al. 2018). Generally, parental corporal punishment and adverse child-rearing practices are considered important family-based risks for long-term, persistent, and/or severe antisociality (for example, see Corrado 2002, 2012; Farrington, Ttofi, and Piquero 2016; Lösel and Bender 2003; Moffitt 1993, 2006, 2018). In the context of physical aggression in childhood, Côté and colleagues (2006) identified three different trajectory groups (low desisting, moderate desisting, high stable) and showed that hostile/ineffective parenting predicted the high-level group trajectory. With respect to both components as acceptance of violence increases, offending versatility decreases (as can be seen from the significantly negative βs in Table 2). Therefore, unexpectedly, acceptance of violence has a significant negative effect on the emergence of offending versatility within the two groups of adolescents. Indeed, criminological literature commonly suggests that individual risk concerning deviant beliefs and attitudes towards delinquency is meaningful in the prediction of persistent antisocial outcomes (for example, see Lösel and Bender 2003; Seddig and Reinecke 2017). However, a recent meta-analytic review on risk factors for persistent delinquent behavior among adolescents (Assink 2017) revealed relatively small effects for, amongst others, the attitude domain. Thus, substantial and clear effects should not necessarily be assumed in any case. Concerning our own results, the relatively short time span examined should also be noted; for example, no statements can be made with regard to persistent antisociality. Generally, associations between offending and risk might vary according to the selected dependent variable: As described above (see measures section), we used offending versatility, as a variety index that tends to cover the diversity of offending rather than the severity of the individual offenses, as may be the case with violent crime, for example. It could be expected that the relationship between acceptance of violence and violence in adolescence would possibly turn out more as expected. Following Dünkel and Geng (2003), the level of acceptance of violence in youth is positively related to self-reported violent behavior (see measures section). Overall, more specific analyses might be useful to enhance clarity.

Additionally, general limitations of the present study should be mentioned. First of all, the analyses primarily focused on offending adolescents. A large number of individuals with triple zeros on offending versatility measures were considered as a separate component, as explicitly noted in equation 1 (see methods section). They may not be as interesting to consider from a covariance perspective. Another way to think about the triple zeros is that they follow a different probability distribution (i.e., equation 2; see methods section). One general limitation relates to the attrition in the sample of our longitudinal study. We assume that our results are tolerably robust concerning dropout issues. However, we have to consider these issues, even though their influence seems to be minor (see methods section). Another important issue pertains to the sample which contains a high proportion of students from lower-track schools, so that general conclusions concerning the population are not possible on the basis of these unweighted data (see methods section; Wallner and Weiss 2019). Further restrictions are associated with the heterogeneity of our sample: We did not conduct gender-specific analyses, partly because of the small numbers of individuals in single groups of offending adolescents. Moreover, the analyses do not consider other sociodemographic variables (such as migration background, school type, socio-economic status). Additional analyses might include (at least) data concerning late childhood and early adolescence to enable more precise, complete findings relating to the developmental course of anti-

sociality. Restrictions concerning the chosen measures have to be mentioned: The justification for the variables selected is based on theory (see introduction and methods section). Other or additional risks could certainly have been selected as independent variables (for example, see Farrington, Ttofi, and Piquero 2016; Lösel and Bender 2003; Wallner et al. 2018). Moreover, consideration of protective factors would have enabled more precise statements concerning buffering effects and flexibility in development which is marked by certain processes of resilience and desistance (see Rutter 2012; Sampson and Laub 1993). An additional restrictive aspect is that the outcome measure *offending versatility* and the independent variable *peer delinquency* partially refer to similar contents (a similarly structured range of problematic social behaviors and related facets of antisociality). The independent variables *acceptance of violence* and *impulsivity* are strongly behavior-related (see measures section). We preferred offending versatility as an outcome measure (see methods section for justification), however, other possible dependent measures of antisociality refer to, for example, offending frequency, violence, deviant behavior, or conduct problems and should be further analyzed in future work.

In conclusion, we should mention the strengths of our research. We sought associations between distinct developmental risks and different offending versatility pathways over time in adolescence. First, we emphasize the longitudinal design of our study, which provides longitudinal crime data, enables the application of an unconventional longitudinal method in trajectory research, and, hence, allows for testing taxonomic predictions in an unusual way. Although our results support the suggestion that the trends of offending versatility over age vary during adolescence and, relatedly, the identification of different developmental pathways seemed to be quite successful, more methodological research is required concerning additional, alternative methods being useful for comparison purposes. Second, as the strength of the current study might be seen the direct (i.e., immediate) validation of the varying offending versatility trajectories, utilizing a subset of individual, familial, and environmental risks in adolescence and, therefore, going beyond description. Although these risks contributed variably to offending versatility pathways as mostly expected, extensively more research concerning developmental criminology is needed to identify underlying risk patterns in the prediction of heterogeneous antisocial pathways, especially concerning, for instance, the specific antisocial outcome, possible protective effects, and the individual's age.

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