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Predicting youth reoffending after incarceration: added value of protective factors and heart rate variability

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ABSTRACT

This study examined a biopsychosocial approach on risk assessment in a clinical sample of youth offenders. In search of enhancing the validity of prediction of recidivism through risk factors alone, the added value of protective and neurobiological factors was measured. In 209 male youth offenders (age 15-24), risk and protective factors were assessed with the Structured Assessment of Violence in Youth (SAVRY) and the Structured Assessment of Protective Factors for violence risk-Youth Version (SAPROF-YV). Autonomic nervous system (re)activity was assessed, and cortisol and testosterone levels were measured in saliva. Recidivism data were obtained from official criminal records. As expected, risk factors alone provided moderate predictive validity for general and violent recidivism. Incorporating protective factors and Heart Rate Variability (HRV) reactivity significantly improved prediction models. Risk assessment may gain by adopting a broader, biopsychosocial perspective. Including neurobiology and protective factors in risk assessment could improve release decision-making, offer guidance for better tailored interventions, and enhance chances of successful community reintegration.

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A large body of research has focused on the prediction of antisocial behavior, and recidivism. Risk factors for offending behavior in youth and adult offenders have been incorporated in several risk assessment tools showing predictive validity for (violent) recidivism in meta analyses (Fazel et al., 2012). More recently, evidence is emerging concerning the role of protective factors in risk assessment (i.e. factors that promote desistance) (e.g., Shepherd et al., 2016), as well as neurobiological determinants (de Vries-bouw et al., 2011).

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Supplemental data for this article can be accessed here.

Combining a diversity of predictors makes sense from a biopsychosocial perspective (Adjorlolo, 2016; Dodge & Pettit, 2003), and likely improves the validity of predicting recidivism. The current study examines the incremental predictive value for (violent) recidivism of combining traditional risk-focused assessment with strengths-focused protective factors and neurobiological factors.

Predictive validity of risk assessment

The central role of risk assessment is to understand a person's risk level and the nature of risk to then determine implications for interventions that are needed to reduce this person's risk level. In order to effectively apply interventions to reduce the risk of recidivism in offenders, it is essential to adequately determine the risk of reoffending, both qualitatively and quantitatively. For example, Campbell and colleagues recommend close imbedding of risk assessment in treatment and forensic rehabilitation programs to reduce recidivism rates (Campbell et al., 2016). As these instruments inform legal decisions (Skeem & Monahan, 2011), and the consequences for offenders and public safety are high, research on their predictive accuracy is of considerable importance. Especially in youth[1] offenders, predicting future behavior is challenging. Their neurobiology and behavior develops rapidly and the risk of offending often depends on situational effects like peer pressure (Moffitt, 1993). One specific instrument is the Structured Assessment of Violence Risk in Youth (SAVRY) (Borum et al., 2002), which is widely used internationally and throughout the Dutch juvenile justice system. The SAVRY produced the highest rates of predictive validity in a comparative study of different risk assessment tools (Singh et al., 2011; Yang et al., 2010). While structured risk assessment has substantially improved the predictive validity of unstructured clinical predictions (Andrews et al., 2006), reviews comparing the predictive validity of juvenile risk assessment tools found that tools overall show moderate predictive validity for (violent) reoffending (Schwalbe, 2007), suggesting a 'glass ceiling' may have been reached (Coid et al., 2011). The SAVRY and other commonly used risk assessment tools primarily focus on risk factors (i.e., factors that increase the likelihood of recidivism), under the assumption that addressing these risk factors will reduce recidivism rates. In recent years, evidence has accumulated that two distinct approaches may be of additive value: the use of protective factors, and of neurobiological factors.

Added value of protective factors

Violence risk can be viewed as the product of an interplay between factors that increase (i.e., risk factors), and factors that decrease the likelihood of reoffending (i.e., protective factors) (Borum & Verhaagen, 2006). Based on this

assumption, professionals increasingly express the need for including protective factors in prediction models of future offending (Campbell et al., 2016; Lodewijks et al., 2010; Rennie & Dolan, 2010). Indeed, the predictive validity of risk assessment in adults increases when doing so (De Vries Robbé et al., 2013). Moreover, the emphasis on protective factors parallels the tendency to include positive treatment goals, which is believed to increase motivation for treatment and behavioral change in offenders (De Vogel et al., 2012). However, few studies examined the added value of protective factors in the prediction of recidivism among youth offenders. The SAVRY includes a separate subscale with six protective factors for violence, yet results on the predictive validity of this subscale are mixed (Dolan & Rennie, 2008; Lodewijks et al., 2010, 2008; Viljoen et al., 2017). Additionally, the protective factors in the SAVRY are rated on a dichotomous scale (present/absent) which poorly reflects their dynamic nature (Fougere et al., 2012). Several studies found that SAVRY protective factors are mainly absent in high risk or incarcerated youth (Shepherd et al., 2016). Recently, a new tool for the assessment of protective factors for violence in youth has been developed: the Structured Assessment of Protective Factors for violence risk – Youth Version (SAPROF-YV) (de Vries Robbé et al., 2015). First results suggest that the SAPROF-YV has added value in the prediction of (violent) re-offending in youth (Rowe; Schell & Rowe; de Vries Robbé et al., 2020Kleeven et al., 2020). The SAPROF-YV overlaps in content with the SAVRY protective factors, but can be viewed as a more comprehensive assessment of protective factors (see Tables 1 and 2). For example the SAVRY has one item concerning resilience and one item on social support. The SAPROF-YV includes several items on aspects of resilience and social support. It also includes items on protective aspects (such as future orientation, medication, pedagogical climate) that are not rated in the SAVRY. Finally, as the SAPROF-YV factors are rated on a three-point or seven-point scale, these factors might be more effective in capturing the dynamic nature of protective factors in youth offenders than the dichotomous SAVRY protective factors.

Neurobiological factors in risk assessment

A second promising approach is the addition of neurobiological factors in prediction models. To date, predicting violent behavior is typically performed by focusing on psychological and environmental factors. Risk assessment may gain by adopting a biopsychosocial perspective, since the development of antisocial behavior is acknowledged as driven by combinations of psychological, environmental and (neuro)biological factors (Beauchaine et al., 2008; Raine, 2002). One of the most replicated neurobiological correlates of antisocial behavior is low heart rate (HR), as a measure of low Autonomic Nervous System (ANS) activity and

Table 1. Risk and protective factors in the SAVRY.

Historical risk factors	**Individual/clinical risk factors**
1. History of violence	17. Negative attitudes
2. History of non-violent offending	18. Risk taking/impulsivity
3. Early initiation of violence	19. Substance use difficulties
4. Past supervision/intervention failures	20. Anger management problems
5. History of self-harm or suicide attempts	21. Low empathy/remorse
6. Exposure to violence in the home	22. Attention deficit/hyperactivity difficulties
7. Childhood history of maltreatment	23. Poor compliance
8. Parent/caregiver criminality	24. Low interest/commitment to school
9. Early caregiver disruption	**Protective factors**
10. Poor school achievement	P1. Prosocial involvement
Social/contextual risk factors	P2. Social support
11. Peer delinquency	P3. Attachment and bonds
12. Peer rejection	P4. Positive attitude intervention/authority
13. Stress and poor coping	P5. Strong commitment to school
14. Poor parental management	P6. Resilient personality traits
15. Lack of personal/social support	
16. Community disorganization	

Note. SAVRY = Structured Assessment of Violence Risk in Youth.

Table 2. Protective factors in the SAPROF-YV.

Resilience items	**Relational items**
1. Social competence	11. Parents/guardians
2. Coping	12. Peers
3. Self-control	13. Other relationships
4. Perseverance	**External items**
Motivational items	14. Pedagogical climate
5. Future orientation	15. Professional care
6. Motivation for treatment	16. Court order
7. Attitude towards agreements and conditions	
8. Medication	
9. School/work	
10. Leisure activities	

Note. SAPROF-YV = Structured Assessment of Protective Factors for violence risk – Youth Version.

decreased arousal (Karnik et al., 2008; Ortiz & Raine, 2004; Portnoy & Farrington, 2015; Raine et al., 1997, 1990). When distinguishing the individual branches of the ANS, aberrant parasympathetic nervous system (PNS) activity, (often measured as heart rate variability/HRV), has been found to be related to impaired emotion regulation in antisocial behavior (Beauchaine et al., 2013; Gao et al., 2009; Raine et al., 1990). HRV is thought to be a biomarker of emotion regulation and cognitive control that explains a diversity of psychopathology (Beauchaine & Thayer, 2015; Koenig, 2020). As for sympathetic nervous system (SNS) activity, a decreased activity as indicated by lengthened pre-ejection period (PEP) and lower Skin Conductance level (SCL), has previously been found in relation to antisocial behavior (Beauchaine et al., 2013; Graziano & Derefinko, 2013; de Vries-bouw et al., 2011). In a large cohort,

it was assessed whether electrodermal fear conditioning was related to crime in adulthood. Individuals registered as adult criminals showed significantly reduced electrodermal fear conditioning early in life (Gao et al., 2009; Raine et al., 1990). Furthermore, low levels of cortisol and increased levels of testosterone have been linked to antisocial behavior (Alink et al., 2008; Book et al., 2001; Shoal et al., 2003). Decreased levels of cortisol are often associated with externalizing behavior (Alink et al., 2008). Moreover, increased levels of testosterone have been associated with later assaultive behavior and adult crime (Tarter et al., 2009; van Bokhoven et al., 2006).

Neuroprediction

Few studies have focused on the predictive value of neurobiological factors for youth reoffending. Lower resting HR, decreased HR reactivity and a stronger PNS response to stress were found predictive for reoffending (Jennings et al., 2013; de Vries-bouw et al., 2011). Moreover, lower resting HRV has been related to increases in delinquency (El-Sheikh & Hinnant, 2011; Hinnant et al., 2015). A recent study in delinquent young adults showed resting HR to be strongly associated with reoffending, and that adding neurobiological factors improved predictive power of the model with demographic and behavioral factors (Zijlmans et al., in press). As the body of evidence regarding neurobiological factors for risk assessment practice is still small, the potential value of this novel approach requires further investigation. Moreover, since neurobiological measures exert their influence in combination with, for example, social and psychological factors, it appears appropriate that research including neurobiological measures is effected in combination with other factors (Beauchaine et al., 2008; Hinnant et al., 2015).

Aim of the current study

The current study aims to examine the incremental value for predicting (violent) recidivism through combining traditional risk-focused assessment (SAVRY risk factors) with strengths-focused protective factors (SAVRY protective factors and SAPROF-YV) and neurobiological (endocrinological and ANS) factors. To our knowledge, this will be the first study investigating such combination in a large sample of youth and young adult offenders released from juvenile justice institutions. We will analyse the predictive value of the different measures for violent and general offending in four steps: 1) the predictive value of SAVRY risk factors; 2) the added value of SAVRY and SAPROF-YV protective factors over and above SAVRY risk factors; 3) the added value of neurobiological factors (ANS activity: HR, HRV, PEP, SCL, as

well as cortisol, and testosterone) over and above SAVRY risk factors; 4) the combined model of risk factors, protective factors, and neurobiological factors.

Methods

Participants

Youths were recruited from five juvenile justice institutions in the Netherlands. Data collection started in February 2014 and was completed in March 2016. Youths were approached from 3 weeks after entry, as during these first weeks the institution performs several interviews and tests. All youths that consented to participating were included in the larger neurobiology study. Of the 393 youth in the larger sample, 209 were eligible for the current study. There were several exclusion criteria for participating in the current study. Figure 1 shows these exclusion criteria. The sample included 209 male youth offenders between 15 and 24 years of age (mean age 18.72, *SD* = 1.68, 56 between 15 and 18 years, and 153 youth were 18 years or older) with a history of violent behavior that were incarcerated and eventually

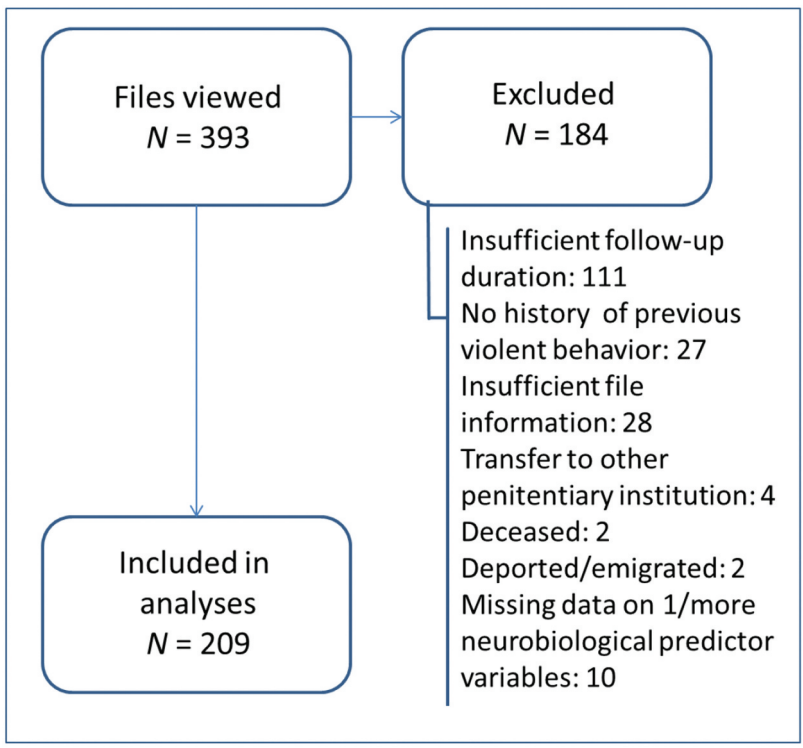

Figure 1. Flow-chart of inclusion and exclusion.

released from a juvenile justice institution in the Netherlands. The majority of participants were of non-western descent, defined as one or both parents being born in a non-western country (62%). For 4% no information on the place of birth of one or both parents was available. Remaining participants were of western descent (34%). Concerning socioeconomic status (SES), 27% had a low, 61% had a middle, and 4% had a high SES. For 8% SES could not be determined. The majority of participants (68%) completed vocational education or higher secondary education, 32% completed only primary school or lower secondary education, and 1% received a bachelor or master degree. In line with the guidelines for the risk assessment tools used in the current study, youths with no history of violent behavior were excluded (Borum et al., 2002). Included and excluded participants did not differ significantly on age, ethnicity, SES, education, or length of stay in the institution.

This study was approved by the Ethics Committee of the University of Amsterdam (2013-DP-3142) and performed in accordance with the ethical standards described in the 1964 Declaration of Helsinki. Participants (and when under the age of 18 also parents/caregivers) provided written informed consent. The participants received a compensation worth €5 for their time.

Materials

Risk assessment

Risk assessment instruments were rated retrospectively from patient files by one of a group of fifteen trained Master level students, based on the available file information upon release. All researchers received a 1-day training in the use of the risk assessment instruments. In addition, during a period of two weeks researchers were trained in the use of the file system, coding of the risk assessment tools and other procedures. During this period several practice cases were rated in consensus to examine if risk assessment tools were rated as intended and if the agreement between the different researchers was acceptable. The participants' files usually consisted of demographic data, treatment plans and evaluations, psychological and psychiatric reports, reports from the child protection services, and personal and judicial historical information. At the time of rating, researchers were blind to recidivism data. In order to determine the accuracy and consistency of coding the files, the interrater reliability was calculated (see SAVRY and SAPROF-YV section below). Twenty-eight randomly selected cases were rated by two independent raters in mixed pairs and consensus scores were agreed upon. The consensus scores were used for the predictive validity analyses, while the individual ratings were used for interrater reliability analysis.

SAVRY. The Structured Assessment of Violence Risk in Youth (SAVRY) (Borum et al., 2002), a risk assessment instrument which has been developed to determine violence risk, was used. While the SAVRY has been developed for use in adolescents, several studies support the use of the SAVRY in offenders up to 25 years old (Hilterman et al., 2018; Kleeven et al., 2020; Vincent et al., 2019). The SAVRY is composed of 24 risk factors in three risk domains (historical scale, social/contextual scale, and individual/clinical scale), and a protective factor domain including six protective factors (for an overview of the SAVRY items see Table 1). The risk factors of the historical scale are rated regarding someone's entire past, while the risk factors of the dynamic scales reflect functioning in the past six months, and past twelve months for the protective factors. Each risk factor has a three-point rating structure with specific rating guidelines (low = 0, moderate = 1, or high = 2), and each protective factor is rated as either present (1) or absent (0). In the current study, SAVRY total risk scores (range 0 to 48) and total protection scores (range 0 to 6) were composed by adding up the scores on risk and protective factors in the SAVRY. Missing values were replaced by mean scores on the remaining items for the individual. The predictive validity of the SAVRY total scores for actual (violent) recidivism has been investigated in several studies using Receiver Operating Curve (ROC) analysis, and ranged from .74 to .80 across studies (Borum et al., 2014). In a review conducted by Borum and colleagues (Bartel et al., 2000), the area under the curve (AUC) for the SAVRY total risk scores ranged from .74 to .80 across studies (these can be perceived as large effect sizes) (Rice & Harris, 2005). Interrater reliability (ICC) for the SAVRY total risk scores ranged from .81 to .97 across studies (Borum et al., 2014). In the current study, an excellent interrater reliability of .84 (n = 28, ICC single measures, random two-way model) was found for the SAVRY total risk score, and an interrater reliability of .80 (n = 28, ICC single measures, random two-way model, absolute agreement) for the SAVRY protective factors.

SAPROF-YV. The Structured Assessment of Protective Factors for violence risk – Youth Version (SAPROF-YV) (de Vries Robbé et al., 2015) was included for a more elaborate assessment of protective factors. The SAPROF-YV is a relatively new tool for the comprehensive assessment of protective factors that should be used in conjunction with a predominantly risk-focused tool, such as the SAVRY. It consists of 16 dynamic protective factors on four domains (resilience scale, motivational scale, relational scale and external scale, see Table 2). All of the SAPROF-YV items are rated for the anticipated future context in the coming six months. The items are rated as follows: clearly present (2), present to some extent (1), or not or hardly present (0). In order to allow for more nuance in the rating, assessors have the possibility to add a plus or minus to the 0 – 1 – 2 SAPROF-YV ratings if they feel that the rated construct is slightly more or

slightly less present than indicated in the described rating category. This results in a 7-point scale (0, 0+, 1-, 1, 1+, 2-, 2). For the analyses in the current study, these ratings were recoded (0 = 0, 0+ = 1, 1 − = 2, 1 = 3, 1 + = 4, 2 − = 5, 2 = 6). The scores on the 16 protective factors were summed up in a SAPROF-YV total score ranging from 0 to 96. Missing values were replaced by mean scores on the remaining items for the individual. A recent study among Dutch offenders found an excellent interrater reliability of the SAPROF-YV total score (ICC = .85), and moderate to good predictive validity for violent reoffending in both adolescent and young adult offenders (AUC's ranged from .71 to .74) (de Vries Robbé et al., 2020). In the current study, an interrater reliability of .78 (n = 28, ICC single measures, random two-way model, absolute agreement) was found for the SAPROF-YV total score.

Final risk judgements. The SAVRY and SAPROF-YV are risk assessment tools that follow the Structured Professional Judgement (SPJ) method. In practice, the final risk judgment is used to determine the youth's ultimate violence risk. This final risk judgement is based on the rater's professional judgement informed by a critical appraisal of the risk and protective factors, and the relevance of these factors for youth in a particular situation. In this study, an integrative summary risk rating was composed based on the combined findings within the SAVRY and SAPROF-YV, in addition to the total scores on both of these tools. Final risk judgements were made on a five-point scale: low, low-moderate, moderate, moderate-high, or high risk of violent behavior, reflecting the structured clinical judgment regarding the estimated risk of violence within the first six months after discharge. Previous studies found good to excellent interrater reliability, and moderate to good predictive validity (AUC ranged from .64 to .89) for the SAVRY final risk judgement (Borum et al., 2014). In the current study, an interrater reliability of .65 was found for the final risk judgements (n = 28, ICC single measures, random two-way model, absolute agreement), which can be interpreted as good (Fleiss, 1986).

Neurobiological assessment

Neurobiological data were collected during detention (days between neurobiological testing and release from the institution: M = 120.06, SD = 131.30). Participants were assessed individually in a test room inside the institution. Researchers were trained with regard to electrode placement and procedures of the tasks. Autonomic Nervous System (ANS) parameters were measured using the VU-Ambulatory Monitoring System device (VU-AMS) (Klaver et al., 1994). The portable VU-AMS device enables assessment of physiological measurements in a fairly straightforward manner in a wide range of settings, including non-medical settings. Placement of the ECG Micropore electrodes (H98SG) for electrocardiography (ECG) and impedance cardiography (ICG)

was done in accordance with the VU-AMS manual (http://www.vu-ams.nl/support/instruction-manual/). To measure skin conductance level (SCL), two SCL electrodes (skin resistance Trans, TP – TSD203) were placed on the medial phalanx surface of the middle and index fingers of the non-dominant hand using isotonic electrode gel (4 OZ, GEL101). Participants were instructed to sit still and asked not to touch the electrodes. During the next ten minutes participants were asked to complete questionnaires on the computer to allow them to acclimatize to the setting. After completion of the ANS measurements, participants were asked to collect saliva in a plastic tube. Then they continued with questionnaires and tasks on the computer for the remainder of the session. The total session lasted approximately 90 minutes. As the assessment of the neurobiological factors studied is relatively easy, this could relatively easily be integrated and performed in daily practice after a short training in the use of the assessment devices.

ANS measures. Data preparation was performed conform instructions in the VU-AMS manual (http://www.vu-ams.nl/support/instruction-manual/). HR, HRV (measured as respiratory sinus arrhythmia/RSA), and pre-ejection period (PEP) were derived from ECG and ICG measures. All ANS data preparation was performed using VU-AMS software. Support was offered by the VU-AMS department of the VU University. HRV in rest was log-transformed (Lg HRV) due to a skewed distribution, other measures were (approximately) normal in their distribution of score.

Resting levels of the ANS were assessed during a 5-min excerpt from an aquatic video (five-minute resting protocol; Scarpa, Haden, & Tanaka, 2010; Coral Sea Dreaming, Small World Music Inc.). Additionally, participants viewed 1-minute excerpts from the same video in between tasks, to ensure recovery from arousal induced by the previous task or film clip. Piferi, et al. (Piferi et al., 2000) have shown that watching this relaxing video is more effective than simply sitting quietly, and better able to achieve recovery to resting state following a task. ANS reactivity was measured while viewing two sadness-inducing film clips (Mohammed, The Champ) (de Wied et al., 2012). To assess reactivity of the ANS, change scores were computed for HR, HRV and PEP; baseline averages (during 1-minute baselines preceding the film clip) were subtracted from task averages (target scenes of film clips). Change scores were then averaged over the two film clips. Thus, for HR, HRV and PEP both the resting levels and the change scores (reactivity) were used as measures in this study, while for skin conductance level (SCL) only the resting state variable was used.

Cortisol and testosterone. Saliva (at least 0.1 ml) for cortisol and testosterone assessment was collected using a Salivette® (Sarstedt, Nümbrecht, Germany). All saliva samples were obtained on weekdays,

between 12:00, 18:00 PM. A day before, as well as the hour before sampling, all participants were reminded of the sampling procedure. They were reminded not to eat, drink (with the exception of water), smoke or brush their teeth during the hour before the start of the appointment. Ten minutes before sampling, participants were asked to rinse their mouth with tap water. All samples were stored in the freezer the same day. Uncentrifuged samples were stored at −20°C until analysis. Analyses were performed at the Endocrinology Laboratories of the University Medical Centre Utrecht.

Cortisol in saliva was measured without extraction using an in-house competitive radio-immunoassay employing a polyclonal anti-cortisol-antibody (K7348). [1,2–^{3}H(N)]-Hydrocortisone (NET396250UC, PerkinElmer) was used as a tracer. The lower limit of detection was 1.0 nmol/L and inter-assay variation was < 7% at 3.3–30 nmol/L (n = 80). Intra-assay variation was < 4% (n = 10).

Testosterone in saliva was measured in duplicate using an in-house competitive radio-immunoassay employing a polyclonal anti-testosteron-antibody (Dr. Pratt AZG 3290). [1,2,6,7–^{3}H]-Testosteron (NET370250UC, PerkinElmer) was used as a tracer following chromatographic verification of its purity. The lower limit of detection was 10 pmol/L. Inter-assay variation was 9.1, 4.3 and 5.6% at 95, 200 and 440 pmol/L respectively (n = 12, LKCH SL protocol 1610). Intra-assay variation was 7–3% at 38–92 pmol/L respectively (n = 10).

Recidivism

Recidivism data were obtained from official records in the Judicial Documentation register of the Dutch Ministry of Justice. A fixed follow-up duration of twelve months post release was used in the current study. Offenses committed within twelve months after the release date were classified as violent or general offending. Violence was defined as any (attempted) act intended to cause physical or psychological harm to others that led to official judicial conviction (Borum et al., 2002). General recidivism was defined as any incident (including violent offenses) that led to official judicial conviction, excluding technical breaches of order. Recidivism data were coded for the follow-up time of 12 months post release. To ensure that new offenses within twelve months after discharge had been processed accurately, recidivism data was retrieved on 1 February 2019, which was over 30 months post the last release date. This ensured that youths' new offenses had been processed effectively in their criminal record since recidivism was defined as a new conviction for violent offense committed within 12 months post release.

Statistical analyses

Data were analyzed using IBM SPSS statistics version 22 and Rstudio version 3.4.2. Pearson's correlations were calculated between the outcomes (violent and general recidivism), SAVRY, SAPROF-YV, and neurobiological factors (see Table S1 in Supplement A). ROC analyses were performed to determine the predictive validity of the SAVRY risk and protective factors, the SAPROF-YV protective factors, the final risk judgment, and the neurobiological factors (HR, ΔHR, HRV, ΔHRV, PEP, ΔPEP, SCL, cortisol, testosterone) for violent and general recidivism over 12 months follow-up after release. Rice and Harris (Rice & Harris, 1995) recommend the use of ROC analysis as measure for predictive validity in forensic psychology, because ROC analysis is less dependent on the base-rate of the outcome variable. An area under the ROC curve (AUC) of .50 indicates a prediction at chance level, while an AUC of 1.00 would reflect perfect prediction. AUC's above .64 and .71 were perceived as either medium or large (Brower & Price, 2001).

Due to the relatively low base-rate of (violent) recidivism and the large number of neurobiological predictors to be investigated, it was decided to first perform univariable logistic regression analyses with the neurobiological factors, before including them in multivariable logistic regression analyses. In case there are many candidate predictor variables it is customary to perform the analysis with a selection of variables in this manner (Altman, 1990). A critical value of .10 was used, as traditional levels (such as .05) can fail to identify relevant predictors (Mickey & Greenland, 1989). In addition, it must be noted that since the focus of this paper was on building a multivariate prediction model for reoffending, we did not account for multiple testing in the univariate analyses (as they were used for variable screening).

Subsequently, multiple hierarchical logistic regression analyses were performed to obtain the best predictive model of risk factors, protective factors and neurobiological factors for violent and general reoffending. It must be noted that the final risk judgements were not used in these analyses because they were composed based on integrative findings from both SAVRY and SAPROF-YV, which means that they do not differentiate between risk and protective factors. To analyze the predictive validity of a model for risk and protective factors combined, two hierarchical logistic regression analyses (one predicting violent and one predicting general recidivism at 12 months follow-up) were performed. The SAVRY risk factors were added in the first step. In the second step, the SAPROF-YV and SAVRY protective factors were added to the SAVRY risk factors (FORWARD method). The FORWARD method was applied in order to maintain sufficient statistical power. Subsequently, To analyze the predictive validity of a model for risk and neurobiological factors combined, two hierarchical logistic regression analyses were performed in which the neurobiological factors were added to the SAVRY risk factors using a FORWARD procedure. Third, to obtain the

best overall model using risk factors, protective factors and neurobiological factors, two hierarchical logistic regression analyses were performed in which the SAVRY risk factors were entered in the first step, the SAVRY and SAPROF-YV protective factors were added in the second step (FORWARD method), and the neurobiological factors were entered in the third step (FORWARD method). To assess and quantify the improvement of the new prediction models, ROC analysis was performed using the predicted probabilities from the final hierarchical logistic regression models. This procedure was adopted from prediction studies addressing key risk factors for cardiovascular disease or other medical conditions (Schisterman et al., 2004). A two-sided significance level of 5% was used for the hierarchical logistic regression analyses. Possible multi-collinearity amongst these variables was not considered as the predictive validity of separate variables in the multivariable analyses was not examined and multi-collinearity does not affect the overall fit of the models (Neter et al., 1996). Treatment duration and age at release were added as covariates to all multivariable regression analyses. Furthermore, as advised by Grossman and Taylor (2007) and by Prätzlich, et al. (Prätzlich et al., 2018) we corrected for the effect of respiration rate in the assessment of heart rate variability (HRV) and smoking (number of cigarettes on an regular day). No significant effects of the covariates emerged, therefore these results are not reported.

Results

At 12 months follow-up, 91 participants (44%) in total had committed a new general offense, of which 39 participants (19%) had committed a new violent offense. Descriptive statistics for SAVRY, SAPROF-YV and neurobiological (autonomic nervous system and endocrinological) factors are shown in Table 2.

The predictive value of individual predictors

ROC analyses for the SAVRY risk and protective factors, the SAPROF-YV protective factors, the final risk judgments, and the neurobiological factors (HR, HRV, PEP, SCL, cortisol, testosterone) are shown in Table 3, for violent and general recidivism at twelve months follow-up after release. Table 4 shows the results for the baseline prediction models from the logistic regression analyses with the SAVRY risk factors as sole predictor, for violent and general recidivism respectively.

The predictive value of risk factors and protective factors combined

The multivariable logistic regression analyses revealed that neither the SAVRY protective factors or the SAPROF-YV protective factors did significantly increase the predictive power for violent reoffending in addition to the

Table 3. Descriptive statistics SAVRY, SAPROF-YV, and neurobiological factors.

	N	Min	Max	*M* (*SD*)
Age	209	15.11	23.93	18.72 (1.68)
Treatment duration in days	209	16.00	2309.00	283.53 (372.61)
Risk Assessment				
SAVRY risk factors	209	3.00	36.00	20.19 (6.96)
SAVRY protective factors	209	0.00	6.00	2.11 (1.51)
SAPROF-YV protective factors	209	5.33	78.93	41.26 (15.08)
Final Risk Judgement	209	1	5	2.64 (1.03)
ANS measures				
HR				
Rest	209	50.31	103.08	71.20 (9.93)
Reactivity	209	−13.04	3.38	−3.39 (2.62)
HRV				
Lg Rest	209	1.03	2.46	1.85 (0.21)
Reactivity	209	−95.39	61.60	−5.46 (20.51)
PEP				
Rest	208[a]	60.00	147.00	99.57 (20.09)
Reactivity	208[a]	−8.33	9.03	0.38 (3.00)
Lg SCL Rest	208[a]	−0.34	1.08	0.61 (0.25)
Endocrinological measures				
Lg Cortisol	209	0.54	1.41	0.97 (0.14)
Testosterone	208[a]	142.00	510.00	289.69 (69.09)

Note. SAVRY = Structured Assessment of Violence Risk in Youth; SAPROF-YV = Structured Assessment of Protective Factors for violence risk – Youth Version; ANS = Autonomic nervous system; HR = Heart rate; HRV = Heart Rate Variability; Lg = transformed logarithmically; PEP = Pre-ejection Period; SCL = Skin Conductance Level.
[a]= *n* is smaller due to a missing value on this variable.

Table 4. Recidivism within 12 months following release: area under the curve SAVRY, SAPROF-YV, HR, HRV, PEP, SCL, testosterone, and cortisol.

	Violent offenses		General offenses	
	AUC	95% CI	AUC	95% CI
Risk Assessment				
SAVRY risk factors	.67**	[.58 –.77]	.68***	[.61 –.75]
SAVRY protective factors[a]	.56	[.46 –.66]	.62**	[.55 –.70]
SAPROF-YV protective factors[a]	.64**	[.55 –.74]	.72***	[.65 –.79]
Final Risk Judgement	.60	[.50 –.70]	.68***	[.61 –.76]
ANS measures				
HR rest[a]	.53	[.42 –.63]	.53	[.45 –.61]
ΔHR[a]	.57	[.46 –.67]	.55	[.47 –.63]
Lg HRV rest	.51	[.41 –.60]	.56	[.48 –.63]
ΔHRV	.65**	[.56 –.74]	.52	[.44 –.60]
PEP rest	.51	[.42 –.61]	.50	[.42 –.58]
ΔPEP	.41	[.31 –.51]	.50	[.42 –.58]
Lg SCL rest[a]	.53	[.43 –.64]	.45	[.37 –.53]
Endocrinological measures				
Testosterone	.53	[.43 –.63]	.55	[.47 –.63]
Lg Cortisol	.50	[.41 –.59]	.42	[.35 –.50]

Note. AUC = Area Under the Curve; CI = Confidence Interval; SAVRY = Structured Assessment of Violence Risk in Youth; SAPROF-YV = Structured Assessment of Protective Factors for violence risk – Youth Version; ANS = Autonomic Nervous System; HR = Heart rate; Lg = transformed logarithmically; HRV = Heart Rate Variability; PEP = Pre-ejection Period; SCL = Skin Conductance Level; *N* = *197*.
[a]= AUC values and confidence intervals for prediction of non-recidivism.
* = p <.05. ** = p <.01. *** = p <.001.

SAVRY risk factors. For general reoffending, the SAVRY protective factors did not contribute significantly to the prediction model. However, the SAPROF-YV protective factors did show a significant increase in the prediction model for general reoffending in addition to the SAVRY risk factors, (model: X^2 (2, N = 209) = 34.07, p < .001; incremental predictive validity: ΔX^2 (1, N = 209) = 10.58, p = .001, see Table 5). These results were similar when we controlled for treatment duration and age. ROC analysis revealed an AUC value of .72, 95% CI [.66 – .79] for the combined model with the SAVRY risk factors and SAPROF-YV protective factors for general recidivism, see Figure 2. For general recidivism, combining the SAVRY risk factors with the SAPROF-YV protective factors increased the sensitivity with 19.8% (from 57.1% to 76.9%) but decreased the specificity with 8.5% (from 67.8% to 59.3%).

The predictive value of risk factors and neurobiological factors combined

Based on univariable analyses, the neurobiological predictors HR reactivity, HRV reactivity, PEP reactivity and cortisol were selected for the multivariable models. When these neurobiological predictors were entered in the hierarchical logistic regression with violent recidivism as outcome, three predictors did not add significantly in step 2 of the analysis in addition to the SAVRY risk factors: HR reactivity, PEP reactivity, and cortisol. However, HRV reactivity did significantly increase the prediction model for violence in step 2 (model: X^2 (2, N = 209) = 23.80, p < .001; incremental predictive validity: ΔX^2 (1, N = 209) = 9.25, p = .002, see Table 6). Controlling for treatment duration, age, respiration rate (RR) and smoking (daily cigarette use) did not alter these results. ROC analysis revealed an AUC value of .73, 95% CI [.64 – .81] for the model with SAVRY risk factors and HRV reactivity for violent recidivism, see Figure 2. For violent recidivism, combining the SAVRY risk factors with HRV reactivity decreased the sensitivity with 5.2% (from 66.7% to 61.5%), but increased the specificity with 11.1% for violent recidivism (from 62.4% to 73.5%). For general recidivism, none of the four neurobiological factors significantly increased the prediction model.

The predictive value of risk factors, protective factors and neurobiological factors combined

The final stepwise logistic regression analysis for general and violent offending included SAVRY risk factors (step 1), SAVRY and SAPROF-YV protective factors (step 2), and neurobiological factors (step 3). For violent recidivism, the stepwise logistic regression showed that the SAVRY protective factors and SAPROF-YV protective factors did not add significantly to SAVRY risk factors in step 2. Therefore, these variables were not further included in step 3 of the

Table 5. Estimates resulting from hierarchical logistic regression for general recidivism at 12 months follow-up.

Predictors	$X2/\Delta X^2$)	*df* (*N*)	*p*	) R^2	*B*	*SE*	Wald	*df*	*p*	*OR*	95% CI
Risk factors	23.49	1 (209)	<.001	.14							
SAVRY risk factors					.11	.02	20.34	1	<.001	1.11	[1.06–1.16]
Risk and Protective factors	10.58	2 (209)	.001	.20							
SAVRY risk factors					.05	.03	2.94	1	.09	1.05	[0.99–1.11]
SAPROF-YV protective factors					−.04	.01	9.87	1	.002	0.96	[0.93–0.98]

Note. R^2 = Nagelkerke R Square; SAVRY = Structured Assessment of Violence Risk in Youth; SAPROF-YV = Structured Assessment of Protective Factors for violence risk – Youth Version.

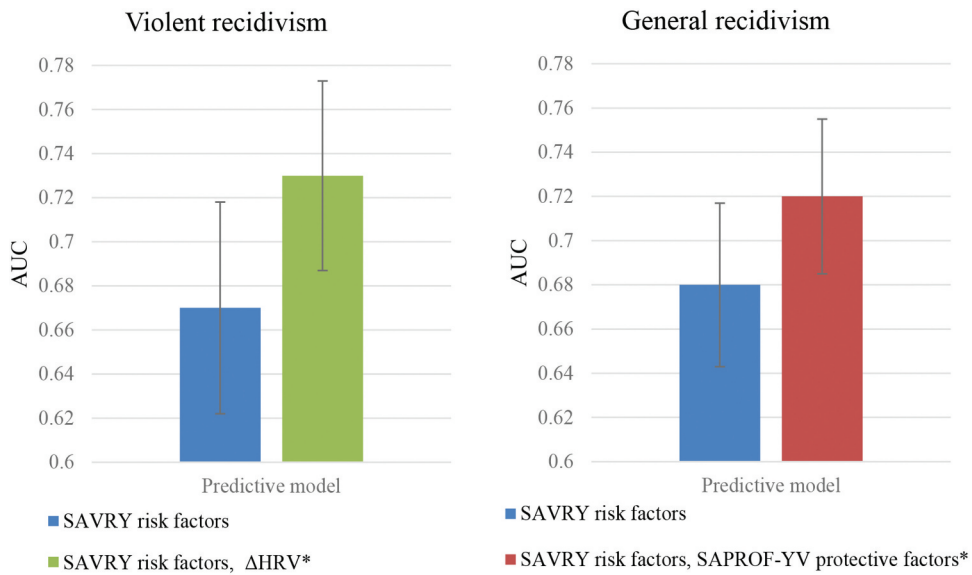

Figure 2. Area under the curve for violent and general recidivism 12 months follow-up. SAVRY = Structured assessment of violence risk in youth; SAPROF-YV = Structured assessment of protective factors for violence – youth version; ΔHRV = Heart rate variability reactivity; Lg = Logarithmically transformed. * Predicted probabilities resulting from logistic regression have been used.

Table 6. Estimates resulting from hierarchical logistic regression for violent recidivism at 12 months follow-up.

Predictors	$X2/\Delta X^2$	*df* (*N*)	*p*	R^2	*B*	*SE*	Wald	*df*	*p*	*OR*	95% CI
Risk factors	14.30	1 (209)	<.001	.11							
SAVRY risk factors					.10	.03	12.74	1	<.001	1.11	[1.05–1.17]
Risk factors and NB	9.25	1 (209)	.002	.17							
SAVRY risk factors					.12	.03	14.58	1	<.001	1.13	[1.06–1.20]
ΔHRV					.03	.01	7.83	1	.005	1.03	[1.01–1.05]

Note. R^2 = Nagelkerke R Square; SAVRY = Structured Assessment of Violence Risk in Youth; NB = Neurobiological factors; ΔHRV = Heart Rate Variability Reactivity.

analysis. HRV reactivity, entered in step 3, did however add significant to the prediction model. This resulted in the exact same prediction model including the SAVRY risk factors and HRV reactivity as described above, and presented in Table 6.

For general recidivism, the logistic regression analysis showed that the SAVRY protective factors did not significantly add to the prediction model. However, the SAPROF-YV protective factors, entered in step 2, did significantly increase the predictive power for general recidivism in addition to the SAVRY risk factors. Step 3 of the analysis revealed that none of the four neurobiological predictors added significantly to the overall prediction model. Therefore these predictors were not included in the final model. As a result, the final model was the exact same as the model including the SAVRY risk factors and SAPROF-YV protective described above, and presented in Table 5.

Discussion

The aim of this study was to examine the added predictive value of protective and neurobiological factors for violent and general reoffending, in addition to established risk factors in youth released from juvenile justice institutions. Risk factors alone had moderate predictive validity for predicting reoffending within 12 months after release. The addition of protective factors significantly improved the predictive value of the risk prediction model for general recidivism, but not for violent recidivism. The addition of heart rate variability (HRV) reactivity, the sole neurobiological factor with significant predictive value in the current study, improved the predictive value for violent recidivism, but not for general recidivism.

The predictive value of risk factors

The risk factors in the SAVRY were moderately related to general and violent reoffending at 12 months follow-up. In a meta-analysis, a moderate to good median Area Under the Curve (AUC) was found for several violence risk assessment tools for youth including the SAVRY (Fazel et al., 2012). Moderate heterogeneity was found, meaning that the discriminative ability of the SAVRY varied substantially between studies (Fazel et al., 2012). In line with this, a review by Borum, et al. (Borum et al., 2010) found AUC values of the SAVRY total risk score varied between .64 and .80 for general and violent recidivism respectively. Considering the heterogeneity of findings, the moderate predictive validity of the SAVRY risk factors in the current study is in line with previous research.

The added value of protective factors

In the present study, SAPROF-YV protective factors separately showed moderate predictive validity for desistance from violent reoffending, and high predictive validity for desistance from general offending. In addition, the SAPROF-YV provided incremental predictive validity on top of risk factors for general reoffending. Several studies among adult offenders demonstrated incremental predictive validity for violent reoffending of the SAPROF protective factors (adult version) over well-established risk factors (e.g., those in the HCR-20) for various offender samples (Coupland, 2015; Kashiwagi et al., 2018; De Vries Robbé et al., 2013). Our results support a small but growing body of empirical evidence for the added value of protective factors over risk assessment based on risk factors alone.

By comparison, the predictive validity of the SAVRY protective factors was low for general as well as violent reoffending. Several previous youth studies using the SAVRY did find better predictive validities for the SAVRY protective factors, and some even found incremental predictive validity over risk factors (Lodewijks et al., 2010; Rennie & Dolan, 2010). However, in line with the current study, others did not (Dolan & Rennie, 2008; Hilterman et al., 2014). The current results suggest that the SAPROF-YV adds a more comprehensive evaluation of protective factors than is captured by the SAVRY protective factors subscale alone. In addition, these results might indicate that the SAVRY protective factors were not as suitable in the current sample; a sample with a relatively high risk level. The SAVRY is rated on a two-point scale, where protective factors are only present if they were clearly present in the past year. This leaves little room for protective factors that are partly present. In the majority of the current sample, the protective factors of the SAVRY were predominantly absent (four of the six protective factors were absent on average, and 41.2% of the sample showed one or none protective factors). Although these results reflect the relative high risk level of the current sample, this predominant absence of protective factors seems to have no added value on top of risk factors when predicting recidivism. It is possible that the SAVRY protective factors are more applicable in samples with a lower risk level, such as community samples.

The predictive validity of SAPROF-YV protective factors alone was better for general recidivism than for violent recidivism, while incremental predictive validity was only found for general recidivism and not for violent recidivism. These results were surprising, since incremental predictive validity for protective factors in adults has been found especially for violent recidivism. However, our results are in line with the only currently available study (to our knowledge) on the incremental predictive validity of the SAPROF-YV for violent recidivism in youth (de Vries Robbé et al., 2020): while the SAPROF-YV showed good predictive validity, no incremental predictive validity was found for violent reoffending. Notably, the base-rate for violent reoffending

in the outpatient study by De Vries Robbé and colleagues was relatively low, as was the case in the current study. Moreover, studies by Rowe (Rowe) and Bhanwer (Bhanwer, 2016) also found better predictive values for the SAPROF-YV for general misconduct than for physical violence. Shepherd, et al. (Shepherd et al., 2016) and Rennie and Dolan (Rennie & Dolan, 2010) generally found stronger predictive accuracy with the SAVRY protective factors for general recidivism than for violent recidivism. Although research in this area is still scarce and requires support from future studies, it could be speculated that for youth protective factors have a more general favorable effect on abstaining from recidivism in general and positive life functioning rather than on violent behavior specifically. Additionally, it could be argued that a lower base-rate for violent recidivism, in combination with a relatively strong association between risk- and protective factors, likely hampers statistical power for finding incremental predictive validity for violent recidivism. Future research is needed to demonstrate whether protective factors have additional value over and above risk factors in the prediction of violent recidivism in the same way as has been demonstrated for the prediction of general recidivism.

The added value of HRV reactivity

In the current study, HRV reactivity provided incremental predictive validity for violent recidivism over the SAVRY risk factors. Some aspects of emotion regulation (i.e. problems with handling anger) are also addressed in the SAVRY. However, the physiological measure HRV reactivity provides added predictive validity in addition to SAVRY, indicating that HRV might capture other information than is captured by the SAVRY risk factors. As a result, HRV reactivity could provide a unique contribution on top of the other (psychological/behavioral) predictors in the prediction of violence.

Overall, HRV decreased in response to negative mood induction, which is in line with previous research (Bazhenova et al., 2001; Beauchaine, 2001; Kreibig et al., 2007). In the current study, violent reoffending was associated with blunted HRV withdrawal. Weaker responses in the parasympathetic nervous system (PNS) have repeatedly been associated with emotion regulation problems and externalizing symptom severity (Blandon et al., 2008; Calkins et al., 2007; Fortunato et al., 2013; Willemen et al., 2009). Seemingly in contrast with our finding of blunted HRV withdrawal, a previous study examining the predictive value of neurobiological factors for reoffending showed that increased HRV withdrawal was predictive for a higher reoffending rate (de Vries-bouw et al., 2011). However, methodological differences between the current study and that of de Vries-Bouw, et al. (de Vries-bouw et al., 2011) complicate comparison of the results (differences in types of task used, sample characteristics, and recidivism outcome measures). However, these findings do show

that PNS reactivity seems to be related to reoffending, improving the prediction thereof, which may provide new targets for treatment that aims to reduce recidivism. Notably, studies in community samples show that HRV (reactivity) can be influenced through intervention (e.g., yoga, mindfulness and interaction therapy) (Ditto et al., 2006; Fishbein et al., 2016; Graziano et al., 2012; Tyagi & Cohen, 2016). Together with findings from other studies in forensic populations relating to different aspects of lifestyle, this could prompt us to promote a healthier lifestyle in youth residing in judicial institutions. For example, it has been found that insufficient sleep is related to violent delinquency (Clinkinbeard et al., 2011), and antisocial and aggressive behavior has been shown to be mitigated through nutrition (Raine et al., 2015).

The added value of other neurobiological factors

Apart from HRV, other neurobiological factors did not increase the predictive value for recidivism. No relationship between heart rate (HR), HR reactivity, and recidivism was found, which is remarkable, given their status as relatively robust markers of antisocial behavior (Ortiz & Raine, 2004; Portnoy & Farrington, 2015). Notably, not all previous (cross-sectional) studies confirm the relationship of HR to (future) antisocial behavior (Baker et al., 2009). Furthermore, de Vries-Bouw, et al. (de Vries-bouw et al., 2011) similarly found no evidence of resting HR as a predictor for reoffending. However, in their study stronger HR reactivity to stress did predict a higher rate of reoffending. As different markers of recidivism were used, studies are only partly comparable. Additionally, perhaps a stress task (de Vries-bouw et al., 2011) is a more effective method of exposing differences in HR reactivity. Another study showed that reduced electrodermal response was related to crime in adulthood (Gao et al., 2009). In the present study we have applied a resting measure of electrodermal activity, which again complicates comparison. The added value of neurobiological factors was not examined for all markers in the present study. There were only three markers with a $p < .1$ in univariate analysis of which the added value was subsequently examined. Future research should establish whether other markers (besides HRV) can be of added value in addition to risk assessment. Thus, further research is required in order to allow for conclusions about the predictive value of neurobiological factors for different types of reoffending. For future studies it is advisable to examine the different branches of the autonomic nervous system, under different challenging situations and in different antisocial populations, preferably including multiple measurements of these markers. Finally, research is needed in which neuroscience is applied in interventions (Fishbein & Dariotis, 2017), for example specifically targeting self-regulation (Bradshaw et al., 2012). Crime prevention programs that are partly inspired by

and that address biological risk factors, already show that this approach can be effective in reducing crime (Rocque et al., 2012).

Study strengths and limitations

To our knowledge, this is the first study approaching ecologically valid risk assessment from a biopsychosocial perspective by combining risk factors, protective factors, and neurobiological factors. A common problem in studying the prediction of recidivism is a relatively small sample size and/or low base-rate of recidivism. Given our relatively large and representative sample of discharged individuals from juvenile justice institutions in the Netherlands, we had sufficient statistical power to assess multiple predictors simultaneously.

However, the results of this study should be appreciated in the light of several limitations. First, risk assessment instruments were rated retrospectively based on file information available at release. The anticipated future context after release was sometimes unclear (e.g., with respect to housing, school, relations etc.), which may have affected the reliability and validity of the SAPROF-YV ratings and final risk judgements. Also, there was no face-to-face contact with the participants during the risk assessment process which could have altered the examination of some risk or protective factors that rely heavily on clinical observation (e.g., empathy). It is possible that practitioners in the field rate these instruments differently. Therefore, it is advisable to repeat this study with data from clinical practice (risk assessment instruments rated by practitioners). Furthermore, as shown in Figure 1, risk assessment instruments could not be rated for a large part of the original sample (51%). Therefore, generalizability of the current study may be limited. However, this seems unlikely since the included and excluded participants did not differ on relevant variables.

Second, there was an average of 120 days between neurobiological assessment and release (timing of risk assessment). The possibility exists that participants' risk levels and/or neurobiological characteristics changed during treatment/stay at the institution. However, HRV was found to have predictive value despite a time gap between neurobiological measurement and release, suggesting that HRV could be a sufficiently stable trait to serve as a predictor. In order to further investigate whether timing of the assessment influences predictive value of neurobiological factors, future studies could include multiple neurobiological measurements, e.g., at a minimum at the start of incarceration and shortly before release, and if possible several times during incarceration.

Third, official measures of recidivism were used which reflect the crimes that were noticed by law enforcement. This likely results in an underestimation of the true number of offenses. Future studies could attempt incorporating other measures of recidivism (e.g., self-report) to overcome this obstacle. However, these methods have their own imperfections (e.g., self-report is thought to reflect an overrepresentation of property offenses and an

underrepresentation of serious violent offenses) (Wittebrood, 2000). Therefore, we have chosen to use what is considered to be the most objective measure of recidivism. Finally, we used the same sample to both build the prediction models and assess their performance with ROC analysis. The AUCs reported for the final models may therefore show some over-optimism bias. Performance of the models should be externally validated in a new sample before their use in clinical practice.

Finally, in the current study we included youth between 16 and 24 years of age. The SAVRY and SAPROF-YV have originally been developed for youth up to 18 years. Recently, several studies suggest that the predictive validity of these tools is also acceptable in young adult offenders (Hilterman et al., 2018; Kleeven et al., 2020; Vincent et al., 2019; de Vries Robbé et al., 2020). However, it is still possible that current results would be different when a sample under 18 years of age is studied. Future studies are needed to investigate age differences in the predictive validity of the SAVRY and SAPROF-YV.

Implications and future recommendations

Predicting future behavior is difficult, particularly in a period of life that is accompanied by many changes (puberty, transition to adulthood, transition back into the community). Our results contribute to the advancement of knowledge concerning critical factors in predicting reoffending in this challenging stage of life. Adding protective factors and HRV reactivity to standard risk factors increase the prediction accuracy at group level. Notably, these results should be replicated in different samples with different ages. Preferably this is performed with risk assessment instruments rated prospectively and with a longer follow-up duration and different recidivism types. In addition, it is advised that these studies include youth with different ages, including youth over 18 years, as several recent studies seem to indicate that the SAVRY and SAPROF-YV could be used with youth up to 24 years. Nevertheless, the gap between group-level findings and individual use in clinical practice remains. As a first step to bridge this gap, the predictive accuracy could be examined in latent subgroups or subgroups that differ in gender, offense type and psychopathology. For each of these subgroups there may be different risk and protective factors that are the most valuable in predicting (desistance from) future offending, and that could be targeted in specifically tailored interventions.

When more clarity has been obtained about the value of these measures, including protective factors and HRV reactivity into youth risk assessment may result in a more accurate prediction regarding which offenders are at high risk for reoffending and in need for intensive rehabilitation programs. Ultimately, the central role of risk assessment in clinical practice lies not in predicting violence risk, but in how this risk could be managed effectively. In clinical practice, protective factors may inform positive treatment strategies and increase

motivation amongst clinicians and offenders (Viljoen et al., 2017; de Vries Robbé & Willis, 2017). How HRV reactivity could be used in practice at the individual level will have to be examined in the coming years. Moreover, further research is needed to address the extent to which autonomic functioning is malleable in youth, and whether physiological alterations are accompanied by behavioral change.

Contemplating on the findings of this study, we argue that risk assessment may gain by adopting a broader, biopsychosocial perspective. The inclusion of protective factors and neurobiological factors in addition to the current psychosocial risk factors in risk assessment research should be embraced. This may possibly contribute to a more accurate prediction of recidivism at individual level, which could inform treatment that is better tailored to the individual needs and ultimately leads to increased desistance from offending among youth who return to the community.

Note

1. In line with research by Hall (1916) and Arnett (2000, 2007), in the current paper, the term youth includes both adolescents (roughly 10–18 years) and young adults (roughly 18–25 years).

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