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ORIGINAL ARTICLE

Differences in executive functioning between violent and non-violent offenders

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Background. A growing body of neuropsychological and neurobiological research shows a relationship between functioning of the prefrontal cortex and criminal and violent behaviour. The prefrontal cortex is crucial for executive functions such as inhibition, attention, working memory, set-shifting and planning. A deficit in these functions – a prefrontal deficit – may result in antisocial, impulsive or even aggressive behaviour. While several meta-analyses show large effect sizes for the relationship between a prefrontal deficit, executive dysfunction and criminality, there are few studies investigating differences in executive functions between violent and non-violent offenders. Considering the relevance of identifying risk factors for violent offending, the current study explores whether a distinction between violent and non-violent offenders can be made using an extensive neuropsychological test battery.

Method. Male remand prisoners ($N = 130$) in Penitentiary Institution Amsterdam Over-Amstel were administered an extensive neuropsychological test battery (Cambridge Automated Neuropsychological Test Battery; CANTAB) measuring response inhibition, planning, attention, set-shifting, working memory and impulsivity/reward sensitivity.

Results. Violent offenders performed significantly worse on the stop-signal task (partial correlation $r = 0.205$, $p = 0.024$), a task measuring response inhibition. No further differences were found between violent and non-violent offenders. Explorative analyses revealed a significant relationship between recidivism and planning (partial correlation $r = -0.209$, $p = 0.016$).

Conclusion. Violent offenders show worse response inhibition compared to non-violent offenders, suggesting a more pronounced prefrontal deficit in violent offenders than in non-violent offenders.

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Key words: CANTAB, executive function, inhibition, neuropsychology, offenders, prison.

Introduction

Criminal and violent behaviour are increasingly viewed as worldwide public health problems (Glenn & Raine, 2014). To address these problems, it is important to identify risk factors that predispose individuals to exhibit violent and criminal behaviour. More insight into those risk factors may contribute to the prevention of or desistance from criminal behaviour, and to a decreased risk of reoffending, since such knowledge may be integrated in commonly used treatment models such as the Risk Need Responsivity Model or the Good Lives Model (Andrews *et al.* 2011; Ward *et al.* 2012), leading to more individualized and successful treatment.

One of these risk factors is a 'prefrontal deficit': antisocial, criminal and violent behaviour are related to dysfunctioning of the prefrontal cortex (Raine, 2002; Nordstrom *et al.* 2011), which is crucial for self-control and executive functions. Executive functions are higher-order cognitive functions – such as inhibition, set-shifting, planning, working memory and attention – which allow humans to have goal-directed behaviour and self-control (Jurado & Rosselli, 2007; Hofmann *et al.* 2012). Meta-analyses on disturbances in executive functions and antisocial behaviour found the largest deficits in executive functions – i.e. the largest effect sizes ($d = 0.61–1.09$) – in criminal subgroups (Morgan & Lilienfeld, 2000; Ogilvie *et al.* 2011). The meta-analyses included both violent and non-violent offenders, but no separate outcomes were reported for these subgroups. Still, comparing violent and non-violent offenders on executive functions could lead to

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the identification of specific risk factors for aggressive behaviour and violent crimes.

Studies that compare violent to non-violent offenders on executive functions are scarce and often have a limited sample size and a limited neuropsychological test battery, similar to executive function studies in prisoners in general (Meijers *et al.* 2015). The lack of substantial studies may be due to the many obstacles researchers encounter in research in prisons: logistical problems and safety issues make prison studies time-consuming and costly (Vanderhoff *et al.* 2011). Nevertheless, a few studies have compared violent to non-violent offenders. Three smaller studies did not find a significant difference in performance between non-violent and violent offenders on a word fluency test (Baker & Ireland, 2007), a unitary executive function measure that mainly consisted of working memory tasks (Hoaken *et al.* 2007) or a planning task (Greenfield & Valliant, 2007). Two of these studies, however, did report that the violent offender group performed significantly worse compared to a *non-offender* control group on a word fluency test and a unitary executive function measure (Baker & Ireland, 2007; Hoaken *et al.* 2007). A more recent study among 77 prisoners showed that it was possible to distinguish violent from non-violent offenders with a sensitivity of 88.9% and a specificity of 100%, using specific outcomes of the Delis–Kaplan Executive Function System (D-KEFS) neuropsychological test battery, i.e. outcomes on the colour-word task, verbal fluency task and sorting task, which measure specific aspects of inhibition, set-shifting and concept formation (Hancock *et al.* 2010).

In sum, most studies found no difference in executive functions between violent and non-violent offenders. However, those studies were relatively small and underpowered, and administrated only one or a very small number of neuropsychological tests. In the only study that used an extensive neuropsychological test battery (D-KEFS), in a relatively larger sample of 77 detained offenders (Hancock *et al.* 2010), a distinction between violent and non-violent offenders could be made using tests measuring, among other functions, inhibition. More specifically, reduced inhibition appeared to be characteristic for violent offenders. In this study, inhibition was assessed using the Colour Word Interference test, a test similar to the Stroop Colour Word test. However, the Colour Word test does not cover all aspects of inhibition (Bari & Robbins, 2013; Khng & Lee, 2014). Performing the Stroop requires executive attentional capacity to inhibit overlearned automatic processing of information (automatic/unconscious inhibition; Bari & Robbins, 2013) – i.e. to inhibit automatic reading of the words in order to be able to name the colour of the ink – while another test measuring inhibition, known as the Stop-Signal Task (SST), appeals to a person's ability to suppress a motor response that is already in progress (response inhibition; Bari & Robbins, 2013; Kalanthroff *et al.* 2013). Performance on the SST has a low correlation with performance on the Stroop, which might be explained by the different brain functions that underlie the performance of both tasks (Bari & Robbins, 2013; Khng & Lee, 2014). To our knowledge, the SST has not yet been used to assess differences in inhibition in violent and non-violent offenders.

Considering the relevance of identifying risk factors for violent offending, and considering that inhibition encompasses a broad range of more specific inhibitory functions, the goal of the present study is to administer the SST in both violent and non-violent offenders to assess whether reduced response inhibition may be related to violent offending. Next to this specific executive function, we intend to assess possible differences between violent and non-violent offenders in a wide range of other executive functions.

Method

Participants

Participants were recruited at the Penitentiary Institution Amsterdam Over-Amstel – a remand prison in Amsterdam, The Netherlands – in the context of a larger research project. The current study focuses on the baseline data of this project. Data collection took place between May 2013 and September 2015.

To reduce any influence on cognition of (long-term) imprisonment, only newly detained prisoners were included in the baseline measurement. Participants were excluded if their stay was of transient nature, for example when they were scheduled for deportation to their home country, awaiting extradition, or when they were scheduled to be transferred to another facility. On a weekly basis, we approached eligible new prisoners, prioritizing suspects of more serious crimes, in order to account for the lower prevalence of serious crimes (murder, arson, rape and serious violence) compared to less serious, non-violent crimes (e.g. shoplifting). In exceptional cases, the prison staff did not allow us to approach specific prisoners due to safety concerns. Further exclusion criteria were active psychosis, insufficient understanding of the Dutch or English language, visual impairment to such a degree that tests cannot be seen properly, motor impairment to such a degree that tests cannot be executed properly, insufficient understanding of the goal of the study and conditions concerning participation, and aggressive or inappropriate behaviour towards the researcher. All approached prisoners were verbally asked to consider participating in our study, and shortly informed about the study's goal and conditions, the tests that are part of the study and the estimated time it would cost them. They also received a more extensive information letter, which they could read afterwards. An appointment was made with participants who were willing to participate, while emphasizing the right to cancel that appointment and to withdraw from the study at any given time without any consequences.

We obtained written informed consent from all participants. The study received ethical approval from the Ethics Committee for Legal and Criminological Research of the Faculty of Law, Vrije Universiteit Amsterdam. The accredited medical ethical committee of the Vrije Universiteit Medical Centre also reviewed the study protocol and provided an official declaration that this study did not need any further medical ethical approval, because of the low burden and non-medical non-interventional nature of the study. This study is registered in the Dutch Trial Register (NTR5443, www.trialregister.nl). No incentive was given for participation, as the Custodial Institutions Agency did not allow us to do so. Spending time outside the prison cell, however, is often considered as an 'incentive' in itself. The safety of the participants and the researchers was guaranteed by the Penitentiary Institution. All data will be stored for 15 years according to the regulations for scientific research of the Custodial Institutions Agency.

Instruments

Executive functions

Six tests of the Cambridge Automated Neuropsychological Test Battery (CANTAB; Cambridge Cognition, UK) were used to assess executive functions. Extensive descriptions and interactive demonstrations of the tasks are available at the website of the manufacturer (www.cambridgecognition.com). We used a 12.1″ tablet with a touchscreen (screen resolution of 1280×800) running Windows 7 as the operating system. The tablet was acquired through the manufacturer of the CANTAB to guarantee full compatibility with the test battery. The reported test–retest correlations are 0.6–0.9 for the subtests (Lowe & Rabbitt, 1998; Barnett *et al.* 2016). The following tests were used and administered in the following order for all participants:

Stockings of Cambridge (SOC). The SOC is used to measure planning, and is analogous to the commonly used Tower of London task. Participants are presented with a horizontally split screen and verbally instructed to move the coloured balls in the lower half, to copy the pattern of coloured balls in the upper half. Difficulty slowly increases from a minimum of two moves, to a minimum of five moves. The main outcome variable is the *number of problems solved in the minimum required moves*.

Spatial Working Memory task (SWM). The SWM is used to measure working memory. Participants are presented with a number of closed coloured square boxes, and are instructed to search for a smaller blue square, that is hidden within one of the closed boxes. All closed boxes will contain a blue square only once; i.e. participants will have to remember in which box they already found a blue square, and in which they did not. Looking inside a closed box that already contained a blue square once, is considered an error (a 'between error'). Looking inside a closed square twice within the same search is also considered an error (a 'within error'). The main outcome variable is *total errors*.

Stop-Signal Task (SST). The SST is a classic stop-signal response inhibition tests, and is used to measure inhibition. This task uses a two-button press pad instead of the touch screen. In the first part, the participants are instructed to press the left button as fast as they can, when they are presented with an arrow pointing to the left, and vice versa when presented with an arrow pointing to the right. In the second part, participants are instructed to continue as before, but, when they hear an auditory signal (a beep), they should withhold their response and not press any button. The main outcome variable is the *stop-signal reaction time* (SSRT), which is calculated by subtracting the *stop-signal delay* (SSD) from the *mean reaction time* (MRT).

Intra-Extra Dimensional set-shift task (IED). The IED is used to measure set-shifting, and is somewhat analogous to the Wisconsin Card Sorting Test. After a learning period, participants are presented with two clearly distinct types of stimuli, i.e. purple-coloured shapes and white lines, and participants receive feedback to learn which stimulus they should choose. In the first part of the test, after six correct responses, only intra-dimensional shifts occur, i.e. only the purple-coloured shapes are correct answers. In a later part of the test, extra-dimensional shifts occur, i.e. participants need to switch from choosing the purple-coloured shapes to the white lines. The main outcome variable is *total errors* (adjusted for the number of completed stages).

Choice-Reaction Time task (CRT). The CRT is used to measure attention and also uses a two-button press pad instead of the touch screen. The task is similar to the first stage of the SST; participants are instructed to press the left or right button as fast as possible, when the corresponding left/right pointing arrow is presented on the screen. For the CRT, we used the raw response data and fitted an ex-Gaussian distribution model to each individual's response distribution using Lacouture's Matlab (MathWorks, USA) method (Lacouture & Cousineau, 2008). This produces the three variables *mu* (average reaction time corrected for extremely slow responses), *sigma* (fluctuations in reaction time) and *tau* (lapses of attention, representing the proportion of extremely slow responses).

Cambridge Gambling Task (CGT). The CGT is used to measure decision-making and risk-taking behaviour. This task dissociates risk-taking from impulsivity, by slowly increasing the amount of points participants can bet from the minimum to the maximum; participants who want to make a large bet will have to wait patiently. In the second half of the task, however, the amount of points an individual can bet slowly declines from the maximum possible amount to the minimum. The main outcome variables are *risk taking* and *delay aversion*.

Demographics

We collected basic demographic data and information such as criminal history from the prison's administrative databases. Utilizing a commonly used crime severity scale (Kordelaar, 2002; Brand, 2005) in The Netherlands that categorizes severity of crime in a range from 1 (traffic violations and public disorder) to 12 (premeditated murder), participants were classified as a violent offender when the current crime or any crime in the past was scored $\geqslant 6$.

Intelligence

Two subtests of the Wechsler Adult Intelligence Scale – fourth edition (WAIS-IV) – Information and Block Design – were used to estimate intelligence. This short form highly correlates ($r = 0.931$) with full-scale IQ (Girard *et al.* 2015).

Mental health problems

The Mini International Neuropsychiatric Interview v. 5.0.0 (MINI; Sheehan *et al.* 1998; Van Vliet & De Beurs, 2007) – a short, structured diagnostic interview – was used to screen participants for the most common DSM-IV Axis I diagnoses, antisocial personality disorder and addiction.

The Symptom-Checklist-90 (SCL-90) was used to assess general mental and physical symptoms (Derogatis, 1996), such as pain, depression and hopelessness. Test–retest correlations for the SCL-90 were found to range from $r = 0.68$ to 0.80 (Derogatis & Savitz, 2000).

Procedure

The current paper is part of a larger study. For this larger study, a number of measures were assessed – heart rate (VU-AMS) and physical activity (IPAQ and Actical) – which are not used in the main analyses of the current paper. The following section will describe the procedure for the measures that are used in the current paper.

Appointments with participants were planned within 7 days of their arrival in the Penitentiary Institution. Each appointment started with the opportunity for the participant to ask questions about the study and the information letter. Next, the informed consent form was explained, and signed by both the participant and the researcher. Due to external circumstances, recruitment logs which were meant to provide us with a recruitment success rate were destroyed. Anecdotally, we estimate the recruitment success percentage around 60%.

During anamnesis, data on medication history and current use, history with drug abuse, education level, history with traumatic brain injury and other relevant medical history were collected. As an objective drugs test such as a urine sample might have deterred prisoners from participating, participants were solely asked to report recent drug use within the institution – which led to a small number of confessions about recent drug use and subsequent rescheduling or cancelling of the appointment – and were informed beforehand that this information would be held strictly confidential between the researcher and the participant.

After anamnesis, the CANTAB tests were administered, with an average duration of 1 hour. Considering the limited time that could be spent with the participants due to the inherently fixed daily prison operations – we asked participants to complete the SCL-90 at their own convenience, and hand them in at the second appointment.

At the second appointment, we administered the WAIS subtests and the MINI, and answered questions that participants may have had about the SCL-90. Due to the relatively stable nature of psychiatric diagnoses and IQ, the second appointment was planned within 21 days of arrival at the Penitentiary Institution, rather than 7 days.

Statistical analyses

All analyses were performed using SPSS Statistics v. 23 (IBM Corp., USA). Missing values on measures that were used in our models were multiply imputed in SPSS using the fully conditional specification method

(MCMC), with predictive mean matching for scale variables and logistic regression for dichotomous variables. Based on the percentage of incomplete cases (50%), the number of imputations was set to 40 (Graham *et al.* 2007). The number of iterations was set to 100. All variables that we planned to use in the analyses, i.e. all CANTAB measures, age, medication, IQ, number of previous detentions and the group variable violent *v.* non-violent crime, were included in the imputation model (Rubin, 2004). The following auxiliary variables correlating with missing of data were identified and used as predictors in the imputation process: level of education, traumatic brain injury, addiction (specifically cocaine and heroin, as well as a dichotomous yes/no addiction variable), resting heart rate and score on the crime severity scale. Before multiple imputation, a number of outliers that were a result of specific software settings of the CANTAB research suite were removed from the dataset. For further information regarding missing value analyses refer to the tables in the Supplementary material (Appendix B).

We used backward regression analyses to identify which predictors were significantly associated with executive functioning. For each outcome measure on the CANTAB, separate backward regression analyses were conducted. The preselected predictors that were used in the backward regression analysis are violent *v.* non-violent offender, age, estimated IQ, medication (sedatives yes/no), addiction (yes/no), and number of previous detentions. In general, backward regression analysis on a multiply imputed dataset prevents the computation of pooled results, as predictor selection will vary per imputation. To solve this, we used one of the methods suggested by Wood *et al.* (2008), selecting predictors that appear in at least half of the models of the imputations for a final pooled regression analysis. For one variable – CGT Risk Taking – we did not find predictors appearing in at least half of the models, which is why we conducted an explorative analysis for this variable only, selecting predictors appearing in at least 10% of the imputations.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Results

Our sample consisted of 130 detained male participants, aged between 18 and 61 years (mean = 32, S.D. = 11.3), of which 85 were classified as a violent offender. Demographic characteristics are summarized in Table 1 (for more comprehensive characteristics, refer to the tables in the Supplementary material, Appendix A).

For all eight CANTAB variables, separate regression analyses were conducted with the outcome measures of the tests as dependent variables, using the different predictors found through the backward regression analyses and the procedure of Wood *et al*. (2008) as described in the previous section. The predictors that we used are displayed together with the results in Table 2.

As shown in Table 2, violent offenders differ significantly from non-violent offenders in performance on the SST ($p = 0.024$). More specifically, corrected for IQ and age, violent offenders have on average a 20.3 ms higher (i.e. slower) SSRT. Age was also significantly related to SSRT: for each increase of 1 year of age, SSRT increases by 1.3 ms.

Age, controlled for IQ, was also related to SWM Total errors with a semi-partial correlation of $r = 0.259$, $p = 0.002$, and to CRT Mu, with a semi-partial correlation of $r = 0.238$, $p = 0.007$.

Reoffending – represented by the variable *number of previous detentions* – was significantly related to the SOC outcome measure *problems solved in minimum moves*, indicating that for each additional previous detention the number of problems solved decreases by 0.067, resulting in a partial correlation of −0.209. Moreover, reoffending also made it into the final model for CRT Tau, a measure of lapses in attention, with a partial correlation of 0.138, but the effect was not statistically significant ($p = 0.157$).

With regard to the other outcome variables, non-violent *v.* violent was not significant in any of the other regression models. For informative purposes, we show the resulting values of non-violent *v.* violent as a predictor when forced into the full regressional model – including all the earlier mentioned variables that were preselected for the backward regression – in Table 3. Besides the significant relationship with SSRT, no significant relationships were found.

Discussion

We examined executive functions in a relatively large group ($N = 130$) of violent and non-violent offenders and found that violent offenders have worse response inhibition – reflected as worse performance on a classic Stop-Signal reaction-time task – compared to non-violent offenders. This finding is in line with the results of the study of Hancock and colleagues (2010) in which the Stroop Colour Word test was administered, which measures a different aspect of inhibition

Table 1. *Characteristics of study sample*

	Total sample	Non-violent	Violent
Age, years	32.2 (11.26)	35.1 (12.88)	30.9 (10.13)
Education level[a]	4.5 (1.16)	4.6 (1.20)	4.5 (1.15)
IQ	88.7 (19.87)	89.9 (22.44)	88.4 (19.07)
No. of previous detentions	5.0 (5.92)	4.7 (5.34)	5.1 (6.22)
First offenders	24 (18.8%)	8 (18.6%)	16 (18.8%)
SCL-90 Depression	29.40 (11.49)	31.65 (12.70)	28.50 (10.97)
SCL-90 Anxiety	15.85 (7.15)	16.8 (7.68)	15.47 (6.98)
SCL-90 Hostility	9.09 (3.93)	8.75 (3.96)	9.22 (3.95)
Sedative use	20 (15.4%)	6 (14%)	14 (16.5%)

SCL-90, Symptom-Checklist-90.

Values indicate mean (S.D.) or count (%).

[a] Education level according to Verhage (a commonly used scale in The Netherlands), where 1 = did not finish primary school and 7 = master's degree.

Table 2. *Results of main regression analyses with selected predictors*

Dependent	Predictor	*B*	S.E.	Partial correlation	Semi-partial correlation	*p*
SST SSRT	Non-violent *v.* violent	20.309	8.969	0.205	0.193	0.024*
	IQ	0.360	0.235	0.166	0.156	0.127
	Age	1.341	0.377	0.311	0.302	<0.001***
SOC Problems solved in minimum moves	Number of previous detentions	−0.067	0.028	−0.209	−0.209	0.016*
SWM Total errors	Age	0.224	0.073	0.268	0.259	0.002**
	IQ	−0.126	0.052	−0.281	−0.272	0.018*
IED Total errors (adjusted)	Sedatives	17.948	10.816	0.154	0.154	0.097
CRT Mu	Age	0.647	0.241	0.238	0.238	0.007**
CRT Tau	Number of previous detentions	0.737	0.520	0.138	0.138	0.157
CGT Delay Aversion	Sedatives	0.097	0.056	0.192	0.192	0.086
CGT Risk Taking[a]	Number of previous detentions	−0.002	0.003	−0.078	−0.078	0.471
	Sedatives	0.042	0.049	0.093	0.092	0.388

SST, Response inhibition; SOC, planning; SWM, working memory; IED, set-shifting; CRT Mu, attention; CRT Tau, lapses in attention.

For the literal meaning of the abbreviations, see the 'Instruments' section in main text.

[a] Regression analysis with predictors appearing in at least 10% of the models of the imputations, due to lack of predictors appearing in at least half of the models.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

(automatic/unconscious inhibition; Bari & Robbins, 2013). Taken together, the results of both studies suggest that, irrespective of the difference in brain functions required to perform the tasks, violent offenders have reduced inhibition compared to non-violent offenders.

According to the prefrontal deficit theory, criminal and violent behaviour are related to dysfunctioning of the prefrontal cortex (Raine, 2002; Nordstrom *et al.* 2011), and in accordance with this theory, prefrontal deficits have been observed in functional and structural imaging studies in people with antisocial personality disorder and in violent and non-violent offenders (Yang & Raine, 2009) as well as executive function deficits in criminals and prisoners (Ogilvie *et al.* 2011; Meijers *et al.* 2015). The observed difference in inhibition between violent and non-violent offenders in the current study may indicate that the prefrontal

Table 3. *Results for group (non-violent v. violent) in the full models*

Dependent	*B*	S.E.	Partial correlation	Semi-partial correlation	*p*
SST SSRT	20.202	9.062	0.204	0.191	0.026
SOC No. of problems solved in minimum moves	0.506	0.356	0.130	0.124	0.156
SWM Total errors	0.463	1.781	0.025	0.022	0.795
IED Total errors (adjusted)	1.264	8.562	0.013	0.013	0.883
CRT Mu	−4.681	5.968	−0.074	−0.071	0.433
CRT Tau	4.271	6.203	0.065	0.063	0.491
CGT Delay Aversion	−0.025	0.039	−0.064	−0.061	0.517
CGT Risk Taking	−0.014	0.033	−0.040	−0.039	0.686

Only the results for the predictor non-violent *v.* violent are shown, the other predictors are left out of this table as these are not relevant for this specific purpose.

SST, Response inhibition; SOC, Planning; SWM, Working Memory; IED, Set-shifting; CRT Mu, attention; CRT Tau, lapses in attention.

For the literal meaning of the abbreviations, see the 'Instruments' section in main text.

deficit is more pronounced in violent compared to non-violent offenders. This finding emphasizes the need for more research on diminished executive functioning – particularly inhibition – as a risk factor for violent offending. Such findings may also prove clinically useful or useful in reducing recidivism when they are integrated in commonly used treatment models such as the Risk Need Responsivity Model or the Good Lives Model (Andrews *et al.* 2011; Ward *et al.* 2012), leading to more individualized and successful treatment. One could argue that self-report scales such as the Barratt Impulsiveness Scale already provide similar kind of data, and that clinicians may be well capable of observing impulsive character traits, making formal neuropsychological testing superfluous. However, we argue that formal neuropsychological tests may offer a more objective view of the inhibitory ability, as a clinician may, for example, be inclined to observe a positive effect of his own treatment, and patients may try to influence the results of a self-report questionnaire to his/her advantage, while a patient cannot perform beyond his actual inhibitory capacity on a laboratory task. In addition, prisoners may temporarily benefit from the structured, safe environment of prison; improved *behavioural* inhibition in prison may therefore not necessarily coincide with an improved inhibitory *ability*. Prisoners may therefore be unable to sustain their improved behaviour when they return to society, where there are more temptations and provocations that are to be inhibited autonomously. A neuropsychological task may prove to measure the underlying inhibitory ability, rather than the behaviour in a specific environment, and may therefore have the potential to be a better predictor of future violent reoffending.

Another important finding of this study was that planning ability was related to an increased number of previous detentions. This might implicate that worse planning is related to recidivism. In contrast to the earlier mentioned study by Hancock *et al.* (2010) – who found a relationship between executive function deficits and violent recidivism specifically – we observed this relationship with planning in the group as a whole. It is important to note, however, that both studies used retrospective data on previous detentions. Therefore, we cannot use these results to predict future reoffending or make claims about the predictive value of these measures. The results call for prospective studies investigating the use of neuropsychological tasks as predictors for future reoffending. We hypothesize, as executive functions such as planning are crucial for goal-directed self-regulating behaviour (Hofmann *et al.* 2012), that an impaired planning function may cause an inability to successfully plan a sustainable non-criminal lifestyle and thus, indirectly, leads to an increased risk of reoffending. Alternatively, it can also be argued that decreased planning more specifically predisposes to impulsive or violent reoffending, while unrelated to – or even negatively related to – to types of crime that require more careful planning. Last, worse planning may also lead to an increased risk of being apprehended, within the reoffending subgroup, which should be taken into account when conducting prospective studies.

Although not the main objective of our study, we did find that age was significantly related to the performance on three tasks: older inmates had slower reaction times, worse inhibition and worse spatial working memory. A decline in cognitive functions is expected in normal ageing (Hedden & Gabrieli, 2004), although the question arises whether older inmates have executive function deficits beyond the decline found in normal ageing, which was not tested in the present study. In a commentary by Christodoulou (2012), it is clearly illustrated that the ageing prison population is at risk for dementia, with risk factors such as an inactive lifestyle, poor nutrition, smoking and a lack of social interaction. In other words, prison is an impoverished environment with a potential negative influence on mental health and brain functioning (Meijers *et al.* 2015), which may lead to both a decline in executive functions and a higher risk of developing dementia (Volkers & Scherder, 2011). Based on the assumption that the older participants in our sample have spent more time in prison than the younger participants, this mechanism may also play a role in the abovementioned findings. However, as these hypotheses are not within the scope of the current paper, we conclude that further research into the relationship between age and executive functions in prison is warranted, as well as further research into the relationship between the prison environment and executive functions.

A strength of this study is that we managed to obtain a relatively large sample size – i.e. relative to the current studies in this field – in a highly societally relevant but difficult to access population – prisoners – and that we managed to do so using an extensive neuropsychological test battery. Conducting research in prison comes with many, mostly logistical obstacles (Vanderhoff *et al.* 2011), making prison studies more time-consuming and, thus, more costly. Prison logistics also result in a high amount of missing data by interrupting ongoing testing sessions, due to, for example, an unannounced visit by a participant's lawyer, the supervising prison staff being called away to an emergency elsewhere in the institution, unexpected security or fire drills, or even due to reasons that remain unknown to the researcher. Another strength of the study however, is that we used state of the art methods and techniques to handle the missing data, and analyse the data, increasing the reliability of our results. We recommend external researchers to make a substantial effort attuning to, and understanding the prison dynamics before commencing the actual research, which will enable optimization of the data collection strategy.

One limitation of this study is the lack of a control group. We did not distinguish to what extent our sample actually suffers from executive dysfunction, even though the literature strongly suggests a robust relationship between criminality and executive dysfunction (Ogilvie *et al.* 2011; Meijers *et al.* 2015). Although this limitation does not interfere with the main objective of the present study, we recommend that future studies carefully consider adding a control group.

A second limitation is the lack of a Colour Word test in our battery, which could have provided more insight in the unique contribution of each test and the underlying aspect of inhibition in the distinction between violent and non-violent offenders. While we chose for a broad approach by including various executive functions, selecting multiple tests in future studies, measuring separate aspects of (behavioural) inhibition as described in the review article of Bari & Robbins (2013), may improve the ability to distinguish violent from non-violent offenders even further.

A number of variables that could influence performance on neuropsychological tasks were measured in the current study, such as prescribed medication, psychiatric disorders, addiction and recent drug use, which were taken into account in the analyses in some degree, although the sample size did not allow for a comprehensive set of covariates in the model. In addition, the lack of an objective measure of recent drug use such as a urine sample prohibited us from ensuring that no participants were under the influence of drugs during testing. However, as a number of participants did report having smoked cannabis before testing – resulting in rescheduling or withdrawal from participating – we recommend that future studies should carefully weigh the pros and cons of using a mandatory objective drug measure, as it may deter prisoners from participating. Offering complete confidentiality may therefore remain an acceptable or pragmatic alternative to researchers, notwithstanding that an optional objective drug measure could then still be considered of added value.

Finally, we classified offenders as violent or non-violent using a commonly used standardized scale in The Netherlands based on the Dutch Penal code, which may therefore differ from classifications used in studies in other countries. More detailed analysis of the committed offences will allow for more careful classification of violent *v.* non-violent status, and may also allow for a more specific distinction between impulsive and instrumental violent crime. In future studies with a larger sample size, we recommend not only refining this specific variable of interest, but also exploration of the possibility of refining variables such as addiction, medication use, psychiatric disorders and history of traumatic brain injury, i.e. variables that may affect performance on neuropsychological tasks.

Conclusions

In this study, violent offenders showed worse inhibition compared to non-violent offenders. In addition, we found that worse planning ability is related to an

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increase in recidivism. Last, age was negatively related to inhibition, reaction time and working memory.

Future studies should aim at investigating the predictive power of executive functions in violent and non-violent reoffending, taking into account that inhibition can be divided into separate components, and that violent offending should be refined into multiple categories. Prospective studies should also take into account the possible relationship between executive functioning and being apprehended.

Supplementary material

The supplementary material for this article can be found at https://doi.org/10.1017/S0033291717000241.

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Declaration of Interest

None.

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