Summary

Neuroscientific applications in the juvenile criminal justice system
An inventory of measurement instruments, prevention and intervention methods

Why this report?

This report investigates how neuroscientific research could be applied in the juvenile criminal justice system. Neuroscientific research on antisocial behavior has gained more attention in the last decades. This has resulted in a better understanding of neurobiological characteristics that presumably underlie antisocial behavior, such as alterations in hormone levels and deficits in brain functioning. In the field of criminal justice, there is an increasing demand for neuroscientific knowledge concerning antisocial behavior. Of particular interest is how neurobiological mechanisms and processes contribute to juvenile delinquency. Knowledge of the neurobiological mechanisms underlying behavior may be viewed as a piece of the puzzle, just as knowledge about psychological and social factors in relation to behavior. Recent studies show that incorporating neuroscientific knowledge, in addition to traditional psychosocial perspectives, may lead to a more effective and efficient approach of juvenile criminal behavior.

For whom is this report intended?

This report is aimed at everyone working in the juvenile criminal justice system or otherwise involved in targeting antisocial behavior in children and adolescents. This includes the Ministry of Security and Justice, judicial institutions, the Child Care and Protection Board, the Juvenile Probation Service, the Council for the Judiciary, the Prosecution Service and the police. This report is also intended for municipal institutions and schools. Since the inception of a new juvenile law in 2015 in the Netherlands, the legal responsibility for the welfare of children and adolescents has been decentralized and secured at the municipal level. This includes the provision of basic and specialized intervention for behavioral problems. This report is also for the benefit of scientists. Collaboration between societal and scientific communities is crucial, as many of the measurement instruments and methods of prevention and intervention described in this report could be implemented as pilots in practice, requiring scientific scrutiny in the process.
The study

Current measurement instruments, prevention strategies and intervention methods for juvenile delinquents are based on social and psychological models of antisocial behavior that do not yet incorporate knowledge, methods and practices from neurobiology. The present study aims to provide an update on the current application of neuroscientific research in the juvenile criminal justice system and comprises three areas of interest: measurement instruments, prevention and intervention.

Research questions

In order to obtain a perspective on how neuroscience can be used in these three areas, the following research questions were formulated. In what way could neuroscience be applicable:
1. ...to the use of measurement instruments in the juvenile criminal justice system?
2. ...to the prevention of antisocial behavior in juveniles?
3. ...to the intervention of antisocial behavior in juveniles?

Research methods

To answer these questions a systematic literature review was carried out. In addition, meetings and workshops were organized with experts from science and forensic practice.

Main objective of this report

This report concerns an inventory of possible neuroscientific applications in the juvenile criminal justice system. Its primary function is to serve as a reader’s guide in the field of neuroscience involved with criminal justice, and to give examples of neuroscientific applications in the juvenile criminal justice system. For the actual implementation of neuroscientific practices in the juvenile criminal justice system, specific expertise is required. As the application of neuroscientific knowledge in the juvenile criminal justice system is still in development, it is important to continue studying the neurobiological mechanisms involved in antisocial behavior in order to optimize its usability and methodological quality. Finally, much is still unknown about the neurobiological correlates of antisocial behavior. Therefore, in order to develop a firm and innovative basis for the application of neuroscience in the juvenile...
criminal justice system, recommendations for additional scientific research are provided.

Current state of knowledge

A systematic literature search concerning the neurobiology of antisocial behavior was carried out. Key findings are summarized for each domain we surveyed (Table S1).

Table S1  Key findings of the neurobiology of antisocial behavior

<table>
<thead>
<tr>
<th>Neuroscientific domain</th>
<th>Key findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>There appears to be a relation between antisocial behavior and less activity and smaller volume of specific brain regions, including frontal brain areas and the amygdala.</td>
</tr>
<tr>
<td>Neuropsychology</td>
<td>Antisocial behavior has been linked to deficits in neuropsychological functions, including those pertaining to self-control, planning, problem solving and social cognition.</td>
</tr>
<tr>
<td>Neurotransmitters</td>
<td>There is some evidence linking low serotonin levels to antisocial behavior.</td>
</tr>
<tr>
<td>Hormones</td>
<td>Antisocial behavior may be associated with low or altered cortisol concentrations and possibly with high concentrations of testosterone.</td>
</tr>
<tr>
<td>Psychophysiology</td>
<td>There is a robust association between antisocial behavior and low resting heart rate.</td>
</tr>
<tr>
<td>Genetics</td>
<td>The combination of genes and environmental factors play an important role in the development of antisocial behavior.</td>
</tr>
</tbody>
</table>

The findings mentioned above are to be considered in concert. For example, research shows that individuals who exhibit callous-unemotional traits appear to be less sensitive to stress and punishment. This may be due to a less responsive stress system which, in turn, may be associated with lower resting heart rate, lower concentrations of cortisol and less activity of the amygdala compared to individuals without callous-unemotional traits. In addition, results indicate an association between antisocial behavior and specific neurobiological markers or mechanisms. However, much is still unknown about why certain neurobiological markers are different or deficient in individuals with antisocial behavior. Furthermore, there is limited research available on the predictive value of neurobiological markers in relation to antisocial behavior. Nevertheless, despite these limitations, neuroscientific knowledge may enhance our understanding of individual problems and can be of additive value to the knowledge obtained in other areas of expertise.
Neuroscience and measurement instruments

The following three neuroscientific measurement methods may be implemented in the juvenile criminal justice system in the short term (table S2):

<table>
<thead>
<tr>
<th>Neuroscientific domain</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuropsychology</td>
<td>Neuropsychological tests that assess working memory, attention, self-regulation, emotion regulation, empathy and cognitive flexibility.</td>
</tr>
<tr>
<td>Hormones</td>
<td>Saliva samples to determine cortisol and testosterone levels.</td>
</tr>
<tr>
<td>Psychophysiology</td>
<td>Heart rate instruments to assess resting heart rate.</td>
</tr>
</tbody>
</table>

Neuroscientific measurement instruments should be viewed as an *additional* source of information to methods that are already being used in the juvenile criminal justice system (including (self-report) questionnaires, file records and third-party information). Combining neuroscientific and psychosocial information could aid in establishing *biopsychosocial profiles* (figure S1).

These kinds of *multidimensional* profiles can be used to:
- Assess risk; by integrating neurobiological risk factors (such as lower resting heart rate) and protective factors, (such as better neuropsychological functioning), tools intended to assess risk of for instance criminal behavior can be improved;
- plan interventions; neuroscientific knowledge could contribute to the prediction, monitoring and evaluation of treatment outcome, and therefore enhance personalized treatment for juveniles with antisocial behavior;
– enhance treatment and supervision; neuroscience could offer an extra perspective in providing insight in general functioning and needs of juveniles, with this knowledge treatment and supervision can be better adapted to the needs of juveniles.

Finally, a number of innovative developments could be of interest for the juvenile criminal justice system. An example is the development of ‘wearables’, sensors carried on the body that allow easy measurement of physiological functions, such as heart rate (the Empatica wristband for example, see figure S2).

**Figure S2  Empatica wristband**

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**Neuroscience and prevention**

Research shows that four neuroscience-based prevention methods could be effective in improving self regulation and reducing antisocial behavior later in life. These may be applied as *primary* (with juveniles from the general population) or *secondary* (with at risk juveniles or those with antisocial traits) prevention methods (table S3):

| Table S3  Neuroscience-based prevention methods |
|--------------------------|---------------------------------------------|
| Prevention method       | Examples                                    |
| Environmental enrichment| Influencing environmental factors to exert a positive effect on neurobiological traits. |
| Self regulation training| Reward training, meditation techniques or self regulation training. |
| Dietary supplements      | Omega-3 supplements.                        |
| Family interventions     | Training aimed at developing and improving the parent-child relationship. |
In addition to the implementation of neuroscientific prevention methods, neuroscience may be of help in:

- biopsychosocial screening to determine which individuals are at risk for developing antisocial behavior and for whom preventive intervention should be indicated;
- improving existing prevention methods to accommodate the individual needs of the child, based on knowledge about possible neurobiological deficits;
- monitoring the early neurobiological development of the child.

Experts in the field agree on the importance of raising awareness in parents, teachers and adolescents about the development of brain and behavior during childhood and adolescence, in order to gain a better understanding of behavior and to prevent problematic behavior. Knowledge about neurobiological mechanisms and processes can help in the early identification of risk factors for the development of antisocial behavior. However, this calls for an ethical discussion about at what age prevention should take place and how far we, as a society, are willing to go in this respect.

**Neuroscience and intervention**

A number of neurobiological interventions could be implemented in the short term in the juvenile criminal justice system (table S4):

<table>
<thead>
<tr>
<th>Table S4</th>
<th>Neurobiological interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>Examples</td>
</tr>
<tr>
<td>Neuropsychological training</td>
<td>Training specific brain functions that show deficits in persons with antisocial behavior (e.g., serious gaming).</td>
</tr>
<tr>
<td>Mindfulness training</td>
<td>Stimulating heightened awareness through meditation.</td>
</tr>
<tr>
<td>Food supplements</td>
<td>Including omega-3 fatty acids (figure S3).</td>
</tr>
<tr>
<td>Psychophysiological feedback</td>
<td>Monitoring and influencing one’s own heart rate.</td>
</tr>
<tr>
<td>Medication</td>
<td>Restoring balance in certain chemicals (neurotransmitters) in the brain.</td>
</tr>
</tbody>
</table>

Aside from implementing neurobiological interventions, neuroscience may also contribute to:

- providing insight in treatment motivation and readiness;
- prediction of treatment outcome and thereby improve selection of appropriate interventions;
– monitoring and evaluation of treatment progress and outcome;
– improving the content of traditional interventions by, for example, adding a module designed to improve working memory or emotion recognition.

In the long term, innovative neurobiological interventions currently under investigation and in development, may be implemented. An example of such an intervention is neurofeedback.

Regarding the implementation of neurobiological interventions, it is important that certain practical and ethical challenges are addressed. First of all, the precise working mechanisms and effectiveness of some of the neurobiological interventions are unknown. Second, it is important that the aforementioned interventions are implemented under scientific guidance and are carried out by properly trained personnel. Furthermore, adequate attention should be given to avoidance of strenuous side-effects (of medication for example).

**Figure S3**  **Omega-3 fish oil as treatment**

Neuroscientific knowledge could contribute, on the one hand, to a more personalized treatment approach and, on the other hand, provide individuals with a better insight in their own behavior. This is particularly relevant given the large individual variation in adolescent brain development. Measuring (with neuroscientific methods) and influencing (with prevention and intervention methods) individual neurobiological characteristics, aside from psy-
chological and social characteristics, contributes to a more personalized approach. Also, attaining more insight in one’s own neurobiological functioning could be important. When a person knows that neurobiological factors play a role in behavior, he or she might make different choices compared to when the influences of these factors are unknown or not considered.

How to bring neuroscientific instruments, prevention and intervention methods into practice?

The following should be considered:
- having regard for the question as to which expertise is required to apply neuroscientific instruments or prevention/intervention methods;
- raising awareness and stimulate transfer of knowledge to prevent misunderstandings about the interpretation and meaning of neuroscientific outcome measures;
- promote scientific guidance or supervision during the implementation of neuroscientific instruments and prevention/intervention methods;
- paying attention to ethical aspects such as side-effects of medication, stigmatization due to early prevention, and privacy issues concerning the use of organic material (e.g., hormones);
- adhering to guidelines regarding the handling of neuroscientific data, particularly with respect to ownership, data administration, and storage of material.

Recommendations for further research

This report brings forth a number of recommendations for further research. These issues aim to provide more substance and depth to the evidence indicating an added value of neuroscience to the juvenile criminal justice system and beyond. Some of the recommendations are given below (please see chapter 7 of the report for the full set of recommendations):

a For the screening and training of juveniles, develop neuropsychological tests that are more attractive and closer resemble real life situations.

b Develop a neuropsychological test battery designed to determine neuropsychological deficits that are specific to adolescents with antisocial behavior.

c Promote research that uses new technologies to study cognitive, emotional and psychophysiological characteristics of adolescents with antisocial behavior.

d Start research to evaluate the effectiveness of innovative neurobiological prevention and intervention methods targeting antisocial behavior and underlying neurobiological mechanisms.
Study potential neurobiological indices (e.g., neuropsychological functioning, psychophysiology, gene variants) of treatment outcome and their added value in assigning treatment programs to individuals.

Stimulate development of new (preventive) interventions using new techniques such as biofeedback, serious gaming, hormone treatment and possibly brain stimulation.

Study the developmental stages of different brain regions during adolescence to gain more insight in the development of antisocial behavior.

Attempt to determine within which developmental stage the largest effects can be reached with specific prevention and intervention methods.