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Neurophysiological correlates of cognitive flexibility and feedback processing in violent juvenile offenders

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ABSTRACT

The persistence of aggressive criminal behavior is recurrently observed in offenders despite being previously advised on the negative consequences of their actions. One possible explanation for the continuation of aggressive behaviors could be that they are the consequence of either possible deficits in cognitive flexibility (set-shifting) or in altered feedback processing. Event-related brain potentials (ERPs) were used to investigate both processes in non-psychopathic violent juvenile offenders. A modified version of the Wisconsin Card Sorting Test (WCST) was used to disentangle the ERP components associated with cognitive set-switching processes (P3) from feedback processing (Frontal-Related Negativity, FRN; P3). The results showed a reduction in the amplitude of the P3 component for the presentation of switch informative signals, related to set-switching processes, in the offender group. Interestingly, a larger amplitude of the P3 related to feedback processing as well as the FRN was observed in this population, probably indicating increased reliance on external feedback processing. At the behavioral level, the offender group presented a larger amount of issues with failures in implementing the new sorting rule. This behavioral pattern could be related to deficits in the ability to switch to another behavior and an altered pattern in processing the feedback information related to the precision of their performance. These observations highlight the possible role of cognitive set-switching and reward sensibility in the maintenance of harmful behaviors in juvenile offenders.

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1. Introduction

A significant proportion of offenders persist in their aggressive and criminal behavior regardless of being advised about the possible negative consequences of their actions, this continues to occur despite the investments in delinquency rehabilitation programs (Greenwood, 2008). One possible explanation is that criminal offenders are impaired in their ability to use environmental feedback-related signals in a flexible manner in order to socially adapt and regulate their behavior. The accommodation of information coming from different sources in a flexible manner is related to what is known as high-level metacognitive and cognitive control functions, which refers to a range of cognitive processes that subserve goal-directed behavior, such as planning, problem-solving, cognitive flexibility, inhibition, working memory and performance monitoring (Luria, 1966; Shallice, 1982; Damasio, 1995; Grafman and Litvan, 1999; Burgess et al., 2000; Miyake et al., 2000; Miller and Cohen, 2001; Lehto et al., 2003; Braver and Hannes, 2005; Huizinga et al., 2006; Fuster, 2014).

In clinical neuropsychology one of the most frequently used tasks to assess cognitive control is the Wisconsin Card Sorting Test (WCST; Grant and Berg, 1948; Heaton et al., 1993). The WCST requires participants to flexibly adapt their behavioral responses to simple geometrical stimuli on the basis of signals provided by the experimenter (Milner, 1963; Stuss and Picton, 1978; Heaton, 1981; Heaton et al., 1993; Braver and Hannes, 2005). In the traditional versions (WCST; Grant and Berg, 1948; Heaton et al., 1993), participants have to infer the current rule about three possible sorting rules (color, shape, or number), on the basis of positive (correct) and negative (incorrect) feedback provided by the examiner after each choice. In order to respond correctly, participants have to match the target card (with a specific color, shape and number) with one of the four key cards (each one with one different color, shape and number). When participants discover the new correct rule, they have to maintain it, however after some trials, the sorting rule changes again, requiring participants to find the new correct sorting rule.

The WCST is commonly used as an index of perseveration, which is understood to be the persistence in responding to the previous rewarded choice, which is currently no longer rewarded (Heaton et al., 1993). Two abilities are crucial to correctly perform the task (Huizinga and van der Molen, 2007):

(i) *Set-switching abilities*, indexed by either the errors occurring when a participant fails to switch to another sorting rule (perseverative errors) after receiving the feedback indicating a switch from the previous trial (Heaton et al., 1993).

(ii) *Set-maintenance* ability, which is evaluated by measuring non-perseverative errors (set-maintenance errors), involving occasional failures to maintain the chosen, correct rule. Several functional neuroimaging studies using the WCST have revealed the activation of a widely distributed brain network encompassing several prefrontal regions (i.e., inferior frontal gyrus, dorsolateral prefrontal cortex, anterior cingulate cortex) and posterior association areas (i.e., supramarginal gyrus, intraparietal sulcus) when task sets need to be changed (Nagahama et al., 1997; Volz et al., 1997; Monchi et al., 2001).

Despite the apparent perseverative behavioral tendencies observed in the offender population, and the frequent use of the WCST in the clinical population, there are few investigations which have used this task to assess offenders performance without the presence of psychopathy. Interestingly, initial studies revealed no differences between non-psychopathic offenders and healthy controls. For example, Gorenstein (1982) showed a larger amount of perseverative errors in psychopathic offenders, but not in non-psychopathic offenders when compared to control participants. Likewise, Appellof (1985) did not encounter lower performance in juvenile offenders when compared to controls using the WCST. More recently, however, several studies have reported the first evidence of existing differences between juvenile offenders and controls, with the former group showing more perseverative errors (Syngelaki et al., 2009). In a similar vein, Van Goozen et al. (2004) using the Door Opening Task (DOT; Daugherty and Quay, 1991; Matthys et al., (1998)), a task related with the sensitiveness to reward, found that children classified with conduct disorder incurred more perseverative responses than control participants, despite this behavior being less efficient in terms of monetary gains. These authors considered that this pattern indicated an altered inhibitory function in conduct disorder children under conditions in which a monetary reward was presented. In a more recent study, Dolan (2012) showed a set-switching dysfunction in a population of offenders, compared to controls, and importantly, this dysfunction was not associated with the extent of their psychopathic traits, indicating that it could not possibly be related to psychopathy. Overall, although the results are not completely clear or concordant across studies (Tuominen et al., 2014), this review of the existing literature suggests that offenders might have several difficulties at a cognitive level that might explain their non-adaptive behavior.

Even though the WCST has been commonly considered to be associated to perseverative behavior (Heaton et al., 1993), the encountered results in offenders are difficult to interpret because of differing executive functions, e.g., set-switching, inhibition, etc. Working memory capabilities have also been identified as contributing to performance in this task (Ozonoff, 1995; Miyake et al., 2000). One way to better elucidate the different cognitive control processes involved in WCST and which may be altered in juvenile offenders is by using fine-grained electroencephalographic measures (Event-Related Brain potentials, ERPs) (Barceló et al., 2002; Cunillera et al., 2012). In the current study, and for a selected sample of violent juvenile offenders, we evaluated their performance in a modified ERPs version of the WCST (Cunillera et al., 2012), which allows us to disentangle the role of *set-switching* (rule-based behavior) and *feedback processing* (outcome-based behavior), in the same task (see Figs. 1A for task illustration), two processes with results that are typically entangled in the WCST. Thus, in this version of the task, two types of signals are separately presented to participants: (i) cue signals: indicating whether to either *repeat* the same sorting rule or *switch* to another rule at the beginning of each trial; and (ii) *feedback signals*: appearing after the participants' response, indicating