Neurocognitive and behavioral markers in DUI recidivists

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ABSTRACT

Objective

Driving under the influence (DUI) of alcohol recidivism may be a risk-taking behavior motivated by a change in decision-making capacity. Decision-making capacity has been investigated by event-related potentials (ERPs) acquisition and specifically by analyzing feedback-related negativity (FRN) reflecting the activity of medial prefrontal cortex. Thus, the aim of our study was to test the role of FRN as a possible neurophysiological marker of underestimation of risk associated with DUI recidivism to provide novel insights into the influence of neurocognitive aspects of driving ability.

Methods

The research was structured as a case-control study. The total cohort (30 Italian male subjects) was divided into two groups, according to positive or negative history of DUI recidivism. The protocol included informed consent collection, medical history and clinical examination, ERP registration, and sensation-seeking scale administration. ERPs were acquired during a gambling task. The data were analyzed with two ANOVA repeated-measures. Statistical analyses were conducted using the R Development Core Team to test the participants' risk behavior. A multivariate ANOVA was run to compare the personality traits of the groups. ANOVAs and planned comparisons were performed with StatSoft software.

Results

FRN amplitude analyses showed that the interaction Reward Magnitude ×Valence (large vs. small×gains vs. losses) was significant for Recidivists ($F(1,13) = 11.75$, $p < 0.01$) but not for controls ($F(1,14) = 0.04$, $p = 0.84$). The results of the logistic generalized linear models analysis showed that the two groups differed in risk-taking behavior ($z=-3.65$; $p<0.001$) with an average of 70 risky choices for recidivists) and 63 for controls. Both groups were homogeneous for personality traits.

Conclusions

The FRN and gambling task results suggest that DUI recidivists are characterized by a research of gross gains and appeared unable to recognize small losses read as wins. These results, if confirmed in a larger sample, could indicate the usefulness of ERP analysis in clinical and forensic evaluation of DUI subjects.

Key words: alcohol use disorders; DUI recidivism; risk taking behavior; Decision-making capacity; event related potentials; Feed-back related negativity

INTRODUCTION

Driving under the influence (DUI) of alcohol recidivism may be a risk-taking behavior motivated by a change in decision-making capacity.

DUI recidivism is in some cases the result of a series of decisions made when sober despite awareness of past negative consequences (e.g., license suspensions) and increased risks (e.g., fatal road accidents).

Decision-making capacity has been investigated by event-related potentials (ERPs) acquisition. ERPs represent a series of changes in brain electrical activity temporally related to specific events such as exogenous stimulation (auditory, visual, electrical), the preparation of motor or cognitive processes that depend on the task in which the subject is engaged.

The Iowa Gambling Task, a computerized test that mimics real-life affective decision-making (Kasar et al, 2010), can be used to evoke the cognitive processes implied in decision making and measure related brain electrical activity.

Each evoked potential is characterized by its own latency, amplitude, and a wave polarity, indicated with the letter N if the peak is negative and P if the peak is positive. Studies on decision-making processes using ERP mainly concern feedback-related negativity (FRN), which reflects the activity of the medial prefrontal cortex, such as the anterior cingulate cortex (ACC). Some authors (Yu & Zhou, 2009) have suggested that the ACC may indicate the level of risk associated with certain choices, working as a first alarm system that alerts the brain in order to prepare the potential negative consequences associated with risky actions. In particular, the ACC is involved in assessing the impact of motivational outcomes (Gehring & Willoughby, 2002), and might be able to integrate this affective information to examine the risk associated with a choice (Yu & Zhou, 2009). The FRN reflecting the activities of the ACC could differentiate favorable versus unfavorable outcomes (Hajcak, Moser, Holroyd, & Simons, 2005).

The risk signal detectable by FRN is also consistent with the somatic marker hypothesis of decision-making (Damasio, 1996), according to which the external or internal stimuli trigger a state associated with pleasant or unpleasant somatic markers to guide the person’s behavior.

Therefore, the aim of this study was to test the role of FRN as a possible neurophysiological marker of underestimation of risk associated with DUI recidivism in order to provide novel insights into the influence of neurocognitive aspects on driving ability.

METHODS

Population and Experimental Procedure

This is a case-control study. The total cohort (30 Italian male subjects), was divided into two groups, according to positive (n=15) or negative (n=15) history of DUI recidivism.

The protocol included informed consent collection, medical history, clinical examination, ERP registration and sensation-seeking scale administration.

A urine sample was collected before the experimental procedure to exclude recent alcohol or drugs intake.

ERPs were recorded during a gambling task. Electroencephalography (EEG) was recorded from 32 scalp sites according to the International 10–20 system.

A gambling task that involved choices between risky and safer options, similar to that suggested by Gehring and Willoughby 2002 (see Polezzi et al.,2010, for similar tasks), was used. To ensure ecological validity of the task, participants were informed in advance that they would receive remuneration corresponding to what they won in the game. Participants were told that during each trial, they had to choose between two options yielding different outcomes and that they should try to earn as much money as possible. During each trial, two colored circles with the values "25" and "5" appeared on a black computer screen. The circles were located to the left and right of the center of the screen. The position changed randomly across the trials. The "25" circle represented the risky option whereas the "5" circle represented the safer option. Participants were instructed to press a left-sided ("C") or a right-sided ("V") key, depending upon the option they chose for this particular trial. The safer option yielded a gain or a loss of 5 cents while the risky option yielded a larger gain or a larger loss of 25 cents; the gains were indicated with two upward-oriented green arrows while the losses were indicated with downward-oriented red arrows.

The local ethics committee approved the study protocol.

Statistical Analysis

FRN amplitude was analyzed with one mixed model ANOVA with Group as a between-participants factor and Valence and Magnitude as within-participants factors, planned comparisons and two repeated-measures ANOVAs, one for each group.

On the ANOVAs, there were two within-participants factors, i.e., Valence, consisting of two levels (gains. vs. losses), and the Magnitude of the reward, also consisting of two levels (large vs. small) as the independent variables related to the outcome of the participants' choices. The voltage (microvolts) of the FRN was the dependent variable.

Statistical analyses concerning the task were conducted using R (R Development Core Team, 2008) to test the participants' risky behavior, assuming that recidivists make more risky choices compared to the control group. To test the hypothesis on behavioral data, linear and logistic generalized linear models (GLMs) (McCullagh & Nelder, 1989) were chosen for the analyses because generalized linear models deal with dependent variables that do not have a normal distribution. The independent variable was the between-participants factor Group (recidivists vs. controls). Four analyses on the dependent variable number of risky choices were carried out. Statistical analysis was performed with StatSoft software (StatSoft, 2013).

RESULTS

Mean age and standard deviations (SD) for recidivist and control were respectively 33±4.97 and 30±5.55. All subjects were negative for alcohol and substance use disorder according to DSM criteria. Acute alcohol or other substance intoxication were excluded at time of testing. The most part of recidivists were found DUI two times. In the overall ANOVA the factors Group and Valence reached significance with $F(1,27)=6.53$, $p<0.05$ and $F(1,27)=21.58$, $p<0.001$ respectively. Recidivists showed a larger FRN response (less positive values) than Controls (6,8vs.11.2) and losses elicited a larger FRN response that gains (7.9vs10.1). Since we hypothesized different ability, in recidivists and controls, to discriminate between gains and losses through FRN, then we compared, through planned contrasts, FRN in gains vs. losses separately for large and small reward magnitudes, in each group. Contrasts showed that FRN discriminates between gains and losses with both large ($p<0.05$) and small ($p<0.05$) magnitude rewards in controls, but only with large magnitude rewards in recidivists ($p<0.01$).

We decided to carry out two separate ANOVAs, one for each group. The factor Valence (gain vs. loss) reached statistical significance in both groups. The amplitude of the FRN was larger for the monetary losses compared to gains (Figure 1) in recidivists ($F(1,13)=9.81$, $p<0.01$; 5.8vs.7.9) and controls ($F(1,14)=11.85$, $p<0.01$;10.0 vs.12.3). The voltage (μV) of the wave showed a greater negative deflection, which resulted in a more pronounced FRN in both groups in the losses condition.

Reward Magnitude (large vs. small) was not significant for either group, indicating that FRN is not sensitive to the magnitude of the results per se.

The interaction reward Magnitude×Valence (large vs. small×gain vs. loss) was significant for recidivists ($F(1,13)=11.75$, $p<0.01$) but not for controls ($F(1,14)=0.04$, $p=0.84$).

Using planned contrasts, we compared the difference in FRN between gains and losses depending on the magnitude of the amount. Results are shown in Figure 2.

Gambling Task Results are summarized in Figure 3 with significant difference in the second and third block (respectively $z=-2.55$, $p<0.05$ and $z=-2.15$, $p<0.05$).

DISCUSSION

The present study is innovative due to the population considered and the methodology used.

The participants completed the gambling task while their neural activity was recorded using EEG.

FRN was analyzed because, according to previous studies (Gehring&Willoughby, 2002), it arises when a neural system detects that the outcomes of an action are worse than expected and the signal associated is used to facilitate the development of adaptive motor programs in accordance with the principles of learning by reinforcement (the reinforcement learning system). FRN probably reflects the impact of phasic dopamine decreases in the ACC region that occur when the system detects that ongoing events are worse than expected, allowing it to adapt the behavior aimed at reward.

The results of studies that analyzed risky behaviors and FRN are consistent with the somatic marker hypothesis (Damasio, 1996), which postulates that external or internal stimuli may trigger an emotional state, pleasant or unpleasant, to guide human behavior. Gehring and Willoughby's results suggested that the primary function of the FRN is assessing the penalty or loss associated with an incorrect response.

Changes in the somatic marker systems could result in changes in the decision-making process (Verdejo-García, Pérez-García, & Bechara, 2006). In this study, we analyzed a group of subjects (DUI recidivists) characterized by conduct that could reflect a change in the decision-making process. Our results are consistent with our initial hypothesis postulating a neurophysiological change in participants with previous documented risky behaviors. Even if both groups differentiated losses from gains, recidivists showed significantly more pronounced FRN at losses involving larger amounts of money (25 cents) compared to small losses (5 cents). Consequently, evaluating the interaction between Valence and Magnitude and the outcomes differentiates the two groups, FRN data could suggest the reason for DUI recidivism. Recidivists appeared to be insensitive to small losses, and read this outcome as a win. In contrast, controls differentiated wins from losses and seemed to consider small and large losses in the same way, and thus avoided risky behaviors. The behavior of controls is consistent with previous results concerning FRN.

The gambling task results based on the comparison of the two groups for each block showed a higher number of risky choices for recidivists, blocks 2–4. This result confirms that even behaviorally the two groups differed significantly in risk-taking behaviors.

In conclusion, the present study indicates that a) FRN acts as a neurocognitive marker used to quickly determine the positive and negative outcomes that drove the participants' actions, able to affect the decision-making process by directing attention to different components of the same stimulus. Participants in the control group seemed more attracted by the prospect of a smaller loss, which would induce the individuals to pay more attention to less risky choices. This, in turn, would result in the avoidance of excessive punishment. In contrast, recidivist seemed attracted by the prospect of a large reward, and preferred the riskier options. Due to impairment of the neural processing system of environmental feedback (FRN), the recidivists did not recognize the loss of small amounts as a threat; thus, they engaged in these actions to persevere in behaviors that would be assessed as "dangerous" in the normal population. b) The trend of behavior over time was determined by a constant and smaller number of risky choices in the controls and an increase in risky choices in recidivists. That is in line with the interpretation of a defective "adaptation" to the task and to the environment.
Our results, if confirmed in a larger sample, could indicate the usefulness of ERP analysis in clinical and forensic evaluation of DUI subjects.

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Figure 1. Valence. Both groups show the ability to differentiate gains from losses.

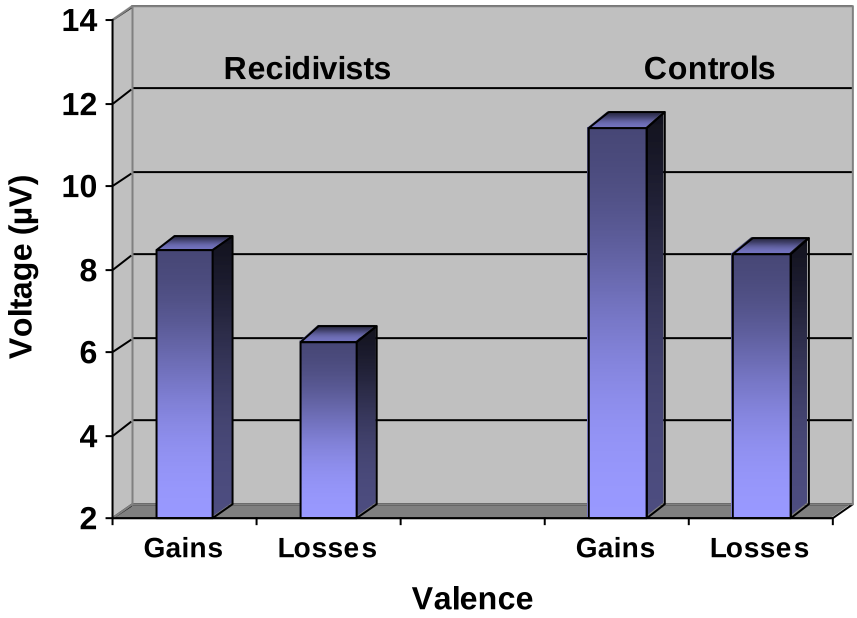

Figure 2: Grand average waveforms of FRN on Fz, elicited by gains (**black lines**) and losses (**gray lines**) as a function of the reward magnitudes, separately for recidivists and controls. As shown by planned comparisons, for large reward magnitudes, the FRN wave is significantly more pronounced in losses than in gains in both groups (left panels). Conversely, for small reward magnitudes, FRN wave is significantly more pronounced in losses than in gains only in controls (top right panel), and not in recidivists (bottom right panel).

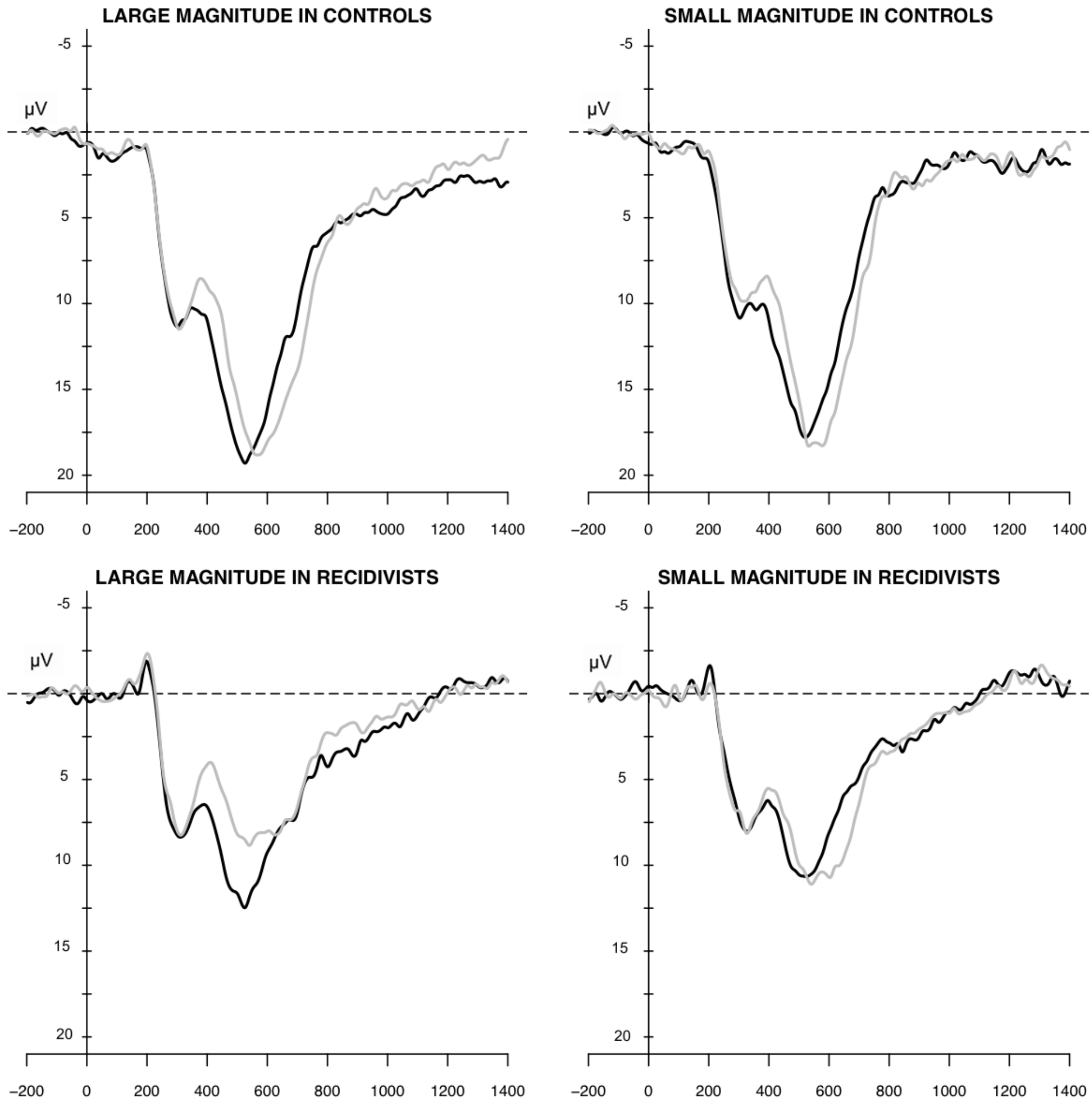

Figure 3. Comparison of risky choices between the two groups in the three blocks.