Computerized latency data correspond with Iowa Gambling Task responses in healthy individuals

Erika Peukert
Dept. of Psychiatry,
St. George Univ. Teaching Hospital,
Szekesfehervar, Hungary
peukert.erika@gmail.com

Aniko Mahler
Pro Rekreatione TOC,
Gardony, Hungary
mahlerne.kofner.aniko@toparti.hu

Jozsef Halasz
Obuda University AMK,
Szekesfehervar, Hungary;
Pro Rekreatione TOC,
Gardony, Hungary
halasz.jozsef@amk.uni-obuda.hu

***Abstract*— In recent years, the most important decision making task was the so-called Iowa Gambling Task, to interpret reward sensitivity and the ability to realize long-term consecquences in a card selection game. Surprisingly, the importance in basic and clinical research in relation with the working of the orbitofrontal cortex did not result latency data in this very important, clinically used context. In the present paper, a computerized version of the Iowa Gambling Task was used focusing on latency issues. The aim of the present study was to describe deck-selection-latency and deck-switching data within the Iowa Gambling Task after selecting different blow-like cards throughout the test. General linear model was used to establish statistical differences within 500 responses. High and low blow card selections resulted in higher deck switching responses compared to non-blow card selections. Interestingly, increased latency was only observed in the case of high blow card selections. While the age was accompanied by significantly higher latency data, card number had the opposite effect. Our data indicate the importance of studying latency data in the interpretation of the working of prefrontal cortex via the Iowa Gambling Task.**

Keywords — beneficial strategy, computerized latency data, decision making, Iowa Gambling Task, prefrontal cortex.

I. Introduction

The prefrontal cortex is an associative neocortical part, what makes us human, and alterations in the working of the prefrontal cortex might result in dysfunction of emotion regulation and violent behavior [1]. The prefrontal cortex is developing slowly in comparison with even other neocortical structures, the full structure might be acquired in individuals within their late twenties. Three diffierent substructures can be described within the prefrontal cortex, the so called dorsolateral part (mainly involved in cold executive functions, like working memory), the anterior cingular part (medially, mainly involved in motivation), and the orbitofrontal prefrontal cortex (mainly involved in social behavior, warm decision making). The famous story of Phineas Gage created famous revival in the mid nineties, when contemporary reconstruction technics were used to describe precisely injured prefrontal regions in the background of later impaired decision making and disrupted social behavior [2]. In 1994, Bechara and coworkers described the first results of the so-called Iowa Gambling Task [3], where a card selection task was used to describe the alteration of decision making in subjects with orbitofrontal damage. The task became famous, as no other task was able to map warm (emotionally involved) decision making in humans, and moreover because of its sensitivity to orbitofrontal damage (Figure 1).

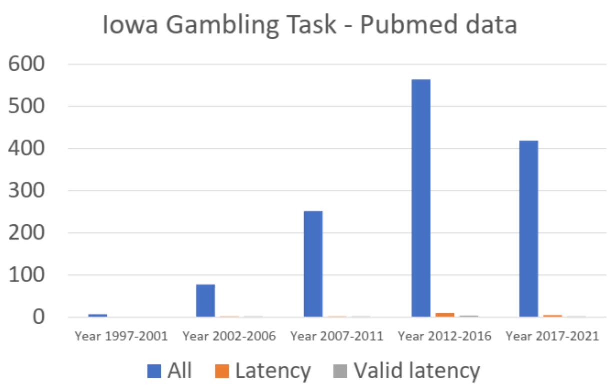

Figure 1. Sum of 5-year Iowa Gambling Task number of publications in the PubMed database (NIH). Albeit a substantial number of publications were present, the analysis of latency data was practically missing from the literature.

Early publications not only described the applicability of the task, but also served as basis for the so-called somatic marker hypothesis. Control individuals began to choose advantageously before they realized which strategy worked best, while patients with prefrontal damage continued to choose disadvantageously even after they knew the correct strategy. Patients never developed anticipatory skin conductance responses [4]. In a very interesting paper describing two adult subjects where the prefrontal lesion was acquired before 16 months, normal basic cognitive abilities were accompanied by defective moral and social reasoning and impaired functioning in the Iowa Gambling Task resembled psychopathic traits [5]. Later the workgroup published a review paper about the concept of the somatic marker hypothesis, to address the problems of decision making encountered in patients with certain kinds of prefrontal damage and with compromised emotions [6]. In their paper, the authors describe the functional alteration of the working of the prefrontal cortex, thus it is not necessary, that the alteration of the prefrontal cortex is caused by organic lesions, but also might be the consequence of maltreatment or social segregation.

Later on the construct validity of the Iowa Gambling Task was examined, also in comparison to other tests examining other domains of the functions of the prefrontal cortex [7-8]. Mainly, executive domains were studied and it seemed that results acquired from the Iowa Gambling Task are largely independent from cold measures (variables without major emotionality, e.g. working memory). Alternative measures of deck choices were also deeply analyzed [9], but latency data were not used as target measures. Executive functions are depending on age and environmental context, and highly connected to certain psychopathologies [10-12], but affected individuals seems to have a different kind of vulnerability then in individuals with functional orbitofrontal prefrontal damage [13]. Biochemical manipulations might subtly modify the performance in the Iowa Gambling Task, but the therapeutic potential of the above operations is highly questionable at present in subjects with functional alteration of the working of the orbitofrontal prefrontal cortex [14-15].

The aim of the present study was to describe deck-selection-latency and deck-switching data within the Iowa Gambling Task after different blow-like responses throughout the test. The analysis of these additional strategical data might reveal subtle differences in populations with altered functioning of the prefrontal cortex. E.g. in children with conduct disorder, the long-term decision making is impaired, thus children with violent behavior do not only have problems with regulation of emotions, but they have serious difficulties to understand the long-term consequencies of simpler and more complicated social decisions, like hitting or bullying someone [16]. Thus, new and more sensitive variables might help in the interpretation and the therapy of the children with the mentioned condition.

II. METHODS

The computerized version of the original Iowa Gambling Task [2] was used, provided by Inquisit (updated in 2013 by K. Borchert for Millisecond), translated and adapted by JH. Instead of only using classical measures, the latency and deck-switching data were analyzed. Inquisit provides highly reliable latency data, thus this Iowa Gambling Task version seemed the best solution for analyzing latency data. Additional to individual click latency data, relative latency data were collected, the so called blow-induced data. Relative post-blow latency data (difference between the click latency of posterior and prior to the click) were also collected. Post-blow latency data were not interpreted for the first and the last click. Five Caucasian healthy adult females aged 26-36 years provided the data, with education of after-high school at least two years. The screenshot of the test start can be seen in Figure 2. 500 latency data were analyzed, and the clicks were grouped according to the blow effect. Non-blow meant zero or less than 100 USD loss by the click (Figure 3), low-blow was considered when the loss was above 100 USD but below 400 USD (Figure 4), and high-blow was considered when the loss was above 1000 USD (Figure 5). In the original task, the gain by click can be 50 USD or 100 USD. In the long run, the smaller gain will be beneficial, thus among the four available decks, the low gain decks will be beneficial (two from the four decks), as the high-gain decks (with 100 USD) will be accompanied by high losses (again, two from the four decks). Interestingly, to our best knowledge, not only the latency data were out of the scope in previous studies, but the deck-switching strategies as well.

Figure 2. Screenshot from the Inquisit version of the Iowa Gambing Task. Each decks represent different strategies, two beneficial and two non-adaptive decks. The players have 2000USD at the beginning, and have 100 draws (clicks).

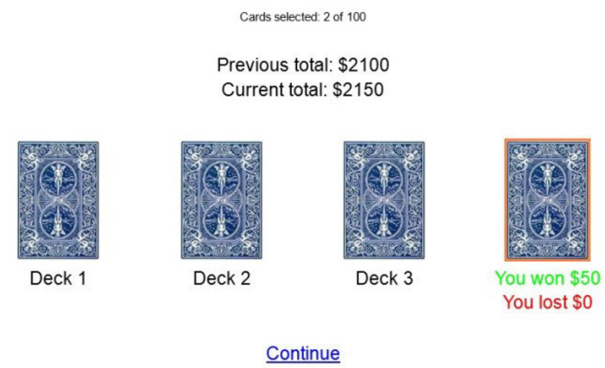

Figure 3. Screenshot from the Inquisit version of the Iowa Gambing Task, non-blow (the loss is 0 USD, only winning was present, 50 USD).

General Linear Model (GLM) was used to analyze between group differences (non-blow, low-blow, high-blow clicks) in terms of relative latencies and deck-switching strategies, while age was used as a covariant. Newman-Keuls post hoc comparisons were also run where appropriate, $p<0.05$ was considered as significant difference. Spearman correlations were used to establish correlation between age and latency data, moreover card number and latency data.

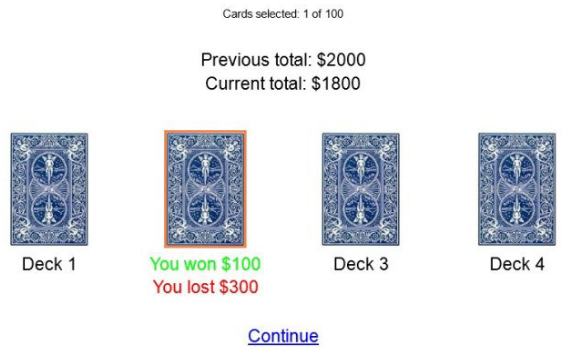

Figure 4. Screenshot from the Inquisit version of the Iowa Gambing Task, low-blow (the loss is 300 USD).

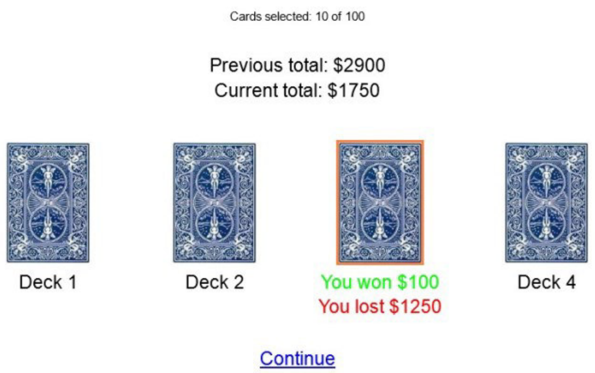

Figure 5. Screenshot from the Inquisit version of the Iowa Gambing Task, high-blow (the loss is 1250 USD).

III. RESULTS

In the deck-switching parameter, non-blow responses resulted a change in 55.7%, while a significant increase was present in low-blow and high-blow deck-switching responses ($F_{(2,497)}=10.953$, $p<0.001$), Figure 6. Newman-Keuls post hoc comparison did not reveal significant differences between low-blow and high-blow responses.

In the relative latency parameter, there was a significant difference between groups ($F_{(2,492)}=4.401$, $p<0.05$). While low-blow responses did not differ from non-blow responses, high-blow responses showed a significant increase to both non-blow and low-blow choices, Figure 7.

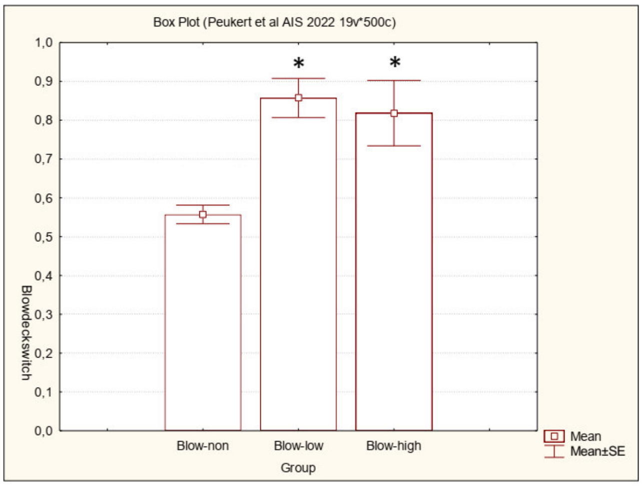

Figure 6. The probability of switching a deck after non-blow, low-blow or high-blow choice. *, significantly different ($p<0.05$) from non-blow card-selection.

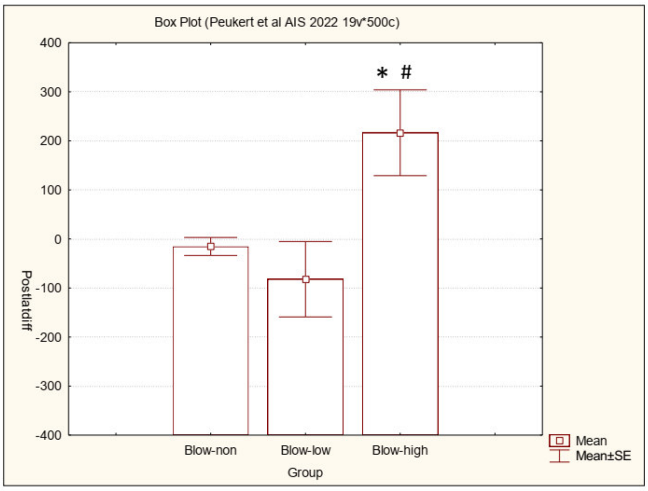

Figure 7. The difference in latencies (milliseconds) after non-blow, low-blow or high-blow choice. *, significantly different ($p<0.05$) from non-blow card-selection; #, significantly different ($p<0.05$) from low-blow card-selection.

Absolute post-blow latency data showed similar trend (average values for the three groups, non-blow: 969.07 ms; low-blow: 961.98 ms; high-blow: 1125.64 ms; ($F_{(2,492)}=2.293$, $p<0.10$), Figure 8.

Spearman correlation revealed small, but significant correlation between the age and general latency data ($R=0.125$, $p<0.01$), and a small, but significant inverse correlation was present between the selection number (number of the card in the task) and general latency data ($R=-0.126$, $p<0.01$).

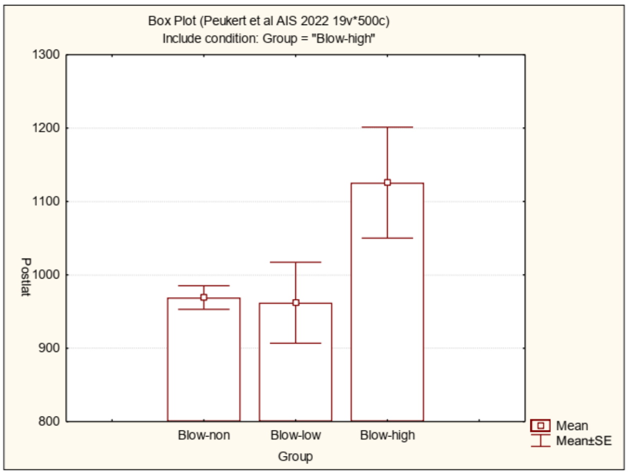

Figure 8. Latencies (milliseconds) after non-blow, low-blow or high-blow choice.

IV. Discussion

The main results of the present study were the following. First, increased deck-switching strategies were observed after high-blow and even low-blow cards compared to non-blow responses. Second, increased latencies were observed compared to low-blow and non-blow selections during high-blow choices. Third, age was significantly accompanied by longer general latency data, and by the end of the test, shorter general latencies were observed.

Technically, early publications on the Iowa Gambling Task [2-6] were using physical card selections, thus measuring latencies could have been difficult to accomplish. Difficult, but not impossible, still, it did not happen. In several tasks related to executive functions, like non-classical go/no-go tests, one can be easily understand the importance of latencies [10-12]. On the stimulus level, executive functions largely depend on work-load related to certain time parameters. Classically, these tests measure performance, scoring not related to latencies. Analyzing latency data in relation of executive functions is out of the scope of the present paper, but could have high relevance in conditions like attention-deficit/hyperactivity disorder (ADHD). On the other hand, ADHD is highly comorbid condition with conduct disorder, and conduct disorder is the most important childhood condition with altered prefrontal functioning [16]. Thus, it is really surprising that no earlier paper analyzed latency data during Iowa Gambling Task in subjects with ADHD or conduct disorder, or even in control subjects. The other surprisingly overlooked Iowa Gambling Task parameter is the description of deck-switching strategies. Understanding the reason and the timing of the deck-switching might help to understand those factors what might modify preformed decisions.

Surprisingly, our defined two parameters together were able to dissect non-blow, low-blow, and high-blow responses. Interstingly, only one parameter was not enough to outline the three kind of responses. In this respect, non-blow choice is inducing a non-switcher low latency response, low-blow choice is inducing a switcher low latency response, while a high-blow choice is accompanied by a switcher high latency response. According to interpreting high latency data, in general, high blow choices induce a longer, more thoughtful cortical response. These kind of data can only be collected in highly precise systems, and the Inquisit is excellent choice for data collection. Inquisit might be used to deliver latency-sensitive responses to the subjects, what might have therapeutic meaning in children with conduct disorder. Of course, the original Iowa Gambling Task can not be directly used for teaching sensitive choice selections. Additional sensorial measures, like heart rate variability, skin conductance responses and even the analysis of prefrontal scalp responses might help in giving choice feedback in real-life input scenarios, thus Iowa Gambling Task can only be used as model system.

The limitations of our study that only healthy adult subjects were involved in the study. As no literature data could be acquired on the measured alternative responses, this study can only be used as preliminary data collection on a valuable and important alternative measure. Definitely, skin conductance measurement would have been a valuable additive variable to the present context.

In a further step, we would like to extend the present concept to control children and children with externalization problems. Decision making ability is a sensitive variable in individuals with conduct disorder [16], and interpreting latency data in their case might add extremely important aspect in evaluating certain scenarios. This therapeutic asset only could work with computerized data collection and feedback, where arteficial barriers could enhance their abilities to interpret non-adaptive decisions, like, visual or auditory enhancement of risky pre-selection scenarios.

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