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Decision-making in patients with temporal lobe epilepsy: Delay gratification ability is not impaired in patients with hippocampal sclerosis

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ABSTRACT

Background: Decision-making abilities have rarely been examined in patients with temporal lobe epilepsy related to hippocampal sclerosis (TLE-HS). We aimed to investigate the ability to delay gratification, a decision-making subdomain, in patients with intractable TLE-HS and to verify the association of delay gratification performance and cool executive function tests.
Methods: We evaluated 27 patients with TLE-HS (mean age: 35.46 [±13.31] years; 7 males) and their cognitive performance was compared with that of 27 age- and gender-matched healthy controls (mean age: 35.33 [±12.05] years; 7 males), without epilepsy and psychiatric disorders. Patients were assessed using the delay discounting task (DDT) and tests of attention, shifting, inhibitory control, and concept formation. Results were correlated with clinical epilepsy variables such as age of onset, epilepsy duration, AED use, history of status epilepticus, febrile seizures, and the presence of generalized seizures. Statistical analysis was performed using one-way ANCOVA with years of education as a confounding factor.
Results: Patients and controls demonstrated similar performance on DDT, showing similar discount rate ($p = 0.935$) and probability rate ($p = 0.585$). Delay gratification was not related to cool executive function tests (Digit Span, Stroop Color Test, Trail Making Test, Wisconsin Card Sorting Test, and Connors' CPT). History of status epilepticus, presence of generalized seizures and higher seizure frequency, age at onset, and epilepsy duration had a significant impact on DDT.
Conclusion: Patients with intractable TLE-HS showed unimpaired delay gratification abilities, being able to accept a higher delay and a lower amount of chance for receiving a higher reward in the future. Clinical variables related to the epilepsy severity impacted the performance on delay gratification. Impairment on cool aspects of executive function was unrelated to this decision-making domain.

1. Introduction

It is well established that patients with temporal lobe epilepsy (TLE) may present deficits in executive functions (EF). Executive functions is an umbrella term for several cognitive subfunctions, including working memory, inhibitory control, decision-making, and task-switching [1]. At present, most studies in epilepsy have focused on the most traditional aspects of EF related to planning, cognitive flexibility, and inhibition — the *cool* domains of EF. The so-called *cool* EF are often associated with lateral prefrontal cortex (PFC) and are elicited by relatively abstract, decontextualized tasks [2–4].

Hot domains of EF are defined as those observed in emotionally and motivationally significant situations since they involve meaningful, self-relevant rewards or punishments [5]. One of the most studied *hot* EF abilities across neurological and psychiatric disorders is decision-making. The ventromedial PFC is frequently associated with this ability [6]. In addition, limbic structures, such as the amygdala, are assumed to be essential for the generation of an automatic emotional state, which is implicated in response to a gain/loss in the context of decision-making

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[7]. Emerging evidence suggests that damage to medial temporal lobes impairs performance on decision-making tasks when choice is influenced by representations of previous experiences [8,9]. It is reasonable to believe that medial temporal lobe-based memory functions may be implicated in the decision-making processes. Nevertheless, these findings are controversial as some studies demonstrated that patients with amnesia with lesions to the medial temporal lobes had a normal performance on a decision-making paradigm [10].

The investigation of decision-making abilities in patients with TLE with lesions located in mesial temporal structures, such as TLE caused by hippocampal sclerosis (TLE-HS), may corroborate the importance of these structures to this subdomain of *hot* EF. Although there might be an overlap between brain regions that participate in decision-making and those related to TLE-HS, this cognitive domain has seldom been investigated in these patients.

It is relevant to have in mind that decision-making is not a unidimensional construct, and the type of decision-making ability can vary according to the precision and predictability of the knowledge of the possible outcomes of a decision (*i.e.*, decision under ambiguity ["implicit"] and under risk ["explicit"] conditions) or the tendency to discount future rewards (*i.e.*, delay discounting). Dual-process models of decision-making suggest that risk-taking decisions can be made by affective or cognitive controlled systems. The first one is automatic, effortless, fast, and emotional while the second is deliberative, controlled, slow, neutral, and reflective [11–13]. Different brain regions are involved in each of these types of decision-making. The neural correlates underlying the affective system are thought to be the amygdala and the striatum. On the other hand, the ventromedial PFC, dorsolateral PFC, the anterior cingulate, and the hippocampus are thought to be implicated in the reflective system [14]. Thus, one may assume that according to the type of decision-making paradigm, and the system required to perform this task, different brain regions may be activated.

The reflective system is assumed to have a more pronounced relationship with *cool* EF. Brand et al. [15] suggested that *cool* EF are important in risk-taking decisions because they are crucial for the categorization of information and options, the implementation of strategies, and the integration of feedback.

Delay discounting is a type of decision-making characterized by a depreciation of the value of a long-term reward with an overvaluation of a short-term recompense. Therefore, the value of a reward is time-related, considering the time that this reward takes to be delivered. Delay discounting is widely used as a measure of impulsiveness. In patients with impulse control impairment, higher rates of delay discounting are documented since these subjects prefer to sacrifice long-term greater rewards in favor of smaller rewards that are available immediately [16].

Emerging evidence suggests that patients with TLE have worse performance on decision-making tasks in which consequences and their probabilities are "implicit" (decision-making under ambiguity or feedback-based decision-making) [17]. In this context, the decision maker has to initially figure out the options' qualities by processing feedback of previous decisions [18–21]. On the other hand, patients with TLE usually show similar performance compared with controls in tasks of decision-making when information is "explicit" about the potential consequences of different options and their subsequent probabilities [18,19,21]. Therefore, there is some evidence that these patients may show impairments in some decision-making domains and not in others [18–21]. To the best of our knowledge, delay gratification abilities have not been investigated in patients with TLE-HS. Moreover, it is still not clear whether a delay discounting paradigm, with no feedback of the consequence of a decision, may be influenced by cool EF impairments in patients with epilepsy. The delay discounting paradigm does not offer an immediate reward or punishment related to the decisions, and does not require updating previous choices before deciding between immediate and delayed gratifications. Thus, we assume that it is more related to the affective system and may not be influenced by cool EF. Based on the hypothesis that delay gratification may be more related to the affective system, but not to the reflective system, we predicted that patients with TLE-HS would show similar performance when compared with healthy subjects in a delay gratification task, and that the *cool* EF performance would not be correlated to delay discounting performance.

2. Methods

2.1. Participants

Patients with TLE-HS were followed in the Outpatient Epilepsy Clinic in Clinics' Hospital — University of São Paulo. All subjects signed an informed consent form approved by the local Ethics Committee. Patients and controls were enrolled in a protocol that included neurological, psychiatric, and neuropsychological evaluations. In addition, patients underwent a neurophysiological (including electroencephalogram [EEG] and video-EEG) and neuroimaging study with 3 Tesla magnetic resonance imaging (MRI — Intera Achieva, Philips). Epilepsy clinical information was obtained from the patient and a relevant other in an interview, close to the time of the neuropsychological assessment.

Patients and controls were interviewed by a psychiatrist, using a structured clinical interview, the Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) Axis I Disorders (SCID-I/P) [22] for the assessment of the presence of any psychiatric disorders. After this evaluation, patients and controls with major psychiatric disorders (major mood disorders, generalized anxiety disorder, conversive/dissociative disorders, or psychosis) were excluded.

Patients with prior history of neurosurgery (including epilepsy surgery), drug intoxication, previous or current history of substance abuse, lack of adherence to treatment, and IQ scores lower than 70 (obtained from Block Design and Vocabulary subtests of the Wechsler Adult Intelligence Scale 3rd Edition — WAIS-III) were not included in the current study. Finally, patients with other lesions, such as dual pathology, previous history of stroke, or any other neurological disorder were excluded from this study.

For each selected patient with TLE-HS, an age- and gender-matched control participant was included. In order to match participants by age, we considered an age difference between subjects of no more than five years.

2.1.1. Patients with TLE-HS

Forty-three patients with TLE were enrolled after neurological and psychiatric evaluation. Four patients with TLE were excluded because of lack of confirmation of hippocampal sclerosis in 3.0 T MRI, one for incomplete neuropsychological assessment, and one with an IQ lower than 70.

Our final sample consisted of 27 patients with TLE-HS who were candidates with refractory epilepsy. All patients were evaluated before the surgical procedure. These patients had an unequivocal diagnosis of TLE-HS according to MRI. The epileptogenic zone was determined by EEG and long-term inpatient video-EEG for surgical purposes.

This group was composed of twenty females and seven males. Participants had a mean age of 35.46 years old (SD: 13.31, ranging from 16 to 58 years old), average length of education of 10.44 years (SD: 3.02, ranging from 4 to 16 years), and showed mean estimated IQ (based on Vocabulary and Block Design subtests of WAIS-III) of 93.19 (SD: 13.05, ranging from 74 to 129). Eight patients (29.6%) had a history of status epilepticus, ten patients (38.1%) had a history of febrile seizures, and three patients (12.5%) were seizure-free at the time of clinical evaluation. Of the remaining patients, seizure semiologies were as follows: dyscognitive seizures (seven patients); generalized tonic-clonic seizures GTC (one patient); autonomic and dyscognitive seizures (five patients); autonomic, dyscognitive and GTC (five patients); autonomic and GTC (four patients); and dyscognitive and GTC (one patient).