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The ability of executive functions to predict deterioration in social abstraction in adolescents with idiopathic generalized epilepsy

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Abstract

Background: Epilepsy is a prevalent disease worldwide. Executive functions and social cognition are essential in daily living functioning, academic performance, and social adjustment. This study attempts to investigate the executive functions and ability to abstract social concepts in adolescents who have idiopathic generalized epilepsy and assess if the deterioration in executive functions can predict deterioration in the ability to abstract social concepts. Sixty adolescents with idiopathic generalized epilepsy aged between 12 and 19 collected from the neurology outpatient clinic at Sohag University Hospital in Upper Egypt were compared with 60 age- and sex-matched healthy adolescents regarding performance on executive function tests and ability to abstract social concepts tests. We used the Tower test to assess planning, the design fluency test to assess cognitive flexibility, the verbal fluency test to assess verbal fluency, and the Stroop test (overlapping between colour and word test) to assess inhibition and ability to abstract the social concepts test, which is composed of verbal part and performance part.

Results: Adolescents who have idiopathic generalized epilepsy have worse executive function impairment in all executive functions than control adolescents. Adolescents with idiopathic epilepsy have significantly more impairment in the ability to abstract social concepts (verbal and performance) compared to control adolescents. There is a significant correlation between executive functions and the ability to abstract social concepts (verbal and performance) in epileptic and control adolescents. Impairment in some executive functions can predict impairment in the ability to abstract social concepts (verbal and performance) in epileptic and control adolescents. Executive function impairment is correlated with the duration of illness, frequency of seizures per year, time since last epileptic fit, and presence of interictal epileptic discharge in EEG in the patient group.

Conclusions: Executive functions and the ability to abstract social concepts are significantly impaired in adolescents who have idiopathic generalized epilepsy. Impairment in executive functions can predict impairment in the ability to abstract social concepts. There is a need to screen executive functions and social abilities of adolescents with epilepsy and programmes to enhance these abilities.

Keywords: Idiopathic generalized epilepsy, Executive functions, Ability to abstract social concepts, Adolescents

Background

Approximately 50–70 million individuals worldwide suffer from epilepsy [1]. Idiopathic epilepsy is described as an illness with no structural pathology or underlying aetiology other than a probably inherited predisposition for seizures that may be focal or generalized [2].

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Executive functions cover the cognitive abilities required for goal-directed and complex activities, which include all areas including recalling short-term memory, forward-thinking, formulating plans, and initiating/inhibiting, as well as organizing and monitoring everyday life [3]. Executive functions are primarily high-level cognitive tasks regulated by the dorsolateral prefrontal cortex (DLPFC). Cases with neuraxis structural anomalies may be predicted to exhibit executive dysfunction. Surprisingly, similar dysfunctions were detected in epilepsy patients with normal premorbid intelligence and normal neuroimaging examinations [3].

Social cognition (SC) has been characterized as the capacity to recognize, evaluate, and react appropriately to social cues in order to engage more effectively with the external environment [4, 5]. Multiple social cognitive skills can be recognized, and two are frequently studied in psychiatric as well as neurological populations: the first is social cue perception, which denotes our potential to utilize and perceive emotions from various sensory channels, such as peoples' body language (e.g. postures, gestures, and gait), voices, and facial expressions and the second is the theory of mind (ToM) or mentalization, which refers to our thought processes and conceptual knowledge that help us to explain our emotions and others' emotions [6, 7].

Many variables may contribute to cognitive impairment in epilepsy, including (a) seizures happening in cognitive development stages, (b) recurrent epileptiform discharges in interictal EEG, and (c) epilepsy pharmaceutical therapy (particularly polypharmacy). Cognitive impairment in epilepsy is thought to be caused by treatment-related malfunction, symptomatic epilepsy, and permanent, irreversible anatomical alterations [8].

This study attempts to assess the executive functions as well as the ability to abstract social concepts in adolescents who have idiopathic generalized epilepsy and assess the ability of executive functions to predict the deterioration in the ability to abstract social concepts.

Methods

This cross-sectional study was carried out between January 2020 and November 2020. We collected the patients from the neurology outpatient clinic at Sohag University Hospital. Controls were age- and sex-matched students from multiple schools in Sohag.

The population of the study is a convenient sample composed of 60 adolescents aged 12 to 19 years suffering from idiopathic generalized epilepsy and 60 age- and sex-matched healthy adolescents.

Inclusion criteria

Inclusion criteria include the following: age 12–19 years, I.Q (intelligence quotient) score of at least 80, and fluency in reading and writing. Patients were drug naïve (newly diagnosed or not compliant on treatment in the past 6 months) to exclude the effect of antiepileptic drugs on cognition.

Exclusion criteria

Exclusion criteria include the following: the presence of other neurological diseases, any lesion in brain imaging, organic cause of fits, patients with hearing or a visual impairment, patients with a history of substance abuse, or patients who were subjected to similar psychological tests like those applied in our study in the past 6 months.

Tools

Clinical interview with the patients using a preformed sheet covering important epidemiological, socioeconomic, and clinical data.

Brain imaging by computed tomography (C.T) or magnetic resonance imaging (MRI) brain.

Electroencephalography (EEG).

Psychometric tests
Stanford-Binet Intelligence Test fifth edition [9]

Assessment of the executive functions

1. Tower test to assess planning [10], which was first developed by Shallice in 1982. The participant moves discs of different sizes to form a specific shape presented by the examiner with respect to two rules: first, moving one disc at a time, and second not putting a larger size disc above a smaller size one. Total scoring by measuring f total time during performing all shapes.
2. Design fluency test to assess cognitive flexibility. First developed by Regard et al. in1982 [11]. We used the Arabic version by Khalil (2010) [12]. The participant draws as many shapes as possible for 60 s. Each participant has three trials. The test's total score is the total number of shapes drawn in the three trials.
3. Verbal fluency test to assess verbal fluency. The participant has to find words initiated with particular letters as much as possible during 60 s. The total score is the number of words said by the participant. We utilized the Arabic version [11, 12].
4. Stroop test (overlapping between colour and word test) to assess inhibition Stroop (1935) [13]. We used

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the Arabic version by Al-Ghatani et al. (2010) [14]. The participant reads the colour of the ink or the actual word as demanded by the examiner. The total score is the total time spent in completing the test.

Assessment of social abstraction   We used the ability to abstract the social concepts test, which is composed of two parts [15]:

1. The ability to abstract the social concepts verbal test. This test is composed of 20 items. Each item is a sentence representing a social situation, and the participant is asked to choose the correct interpretation for this situation. The final score is determined by the number of right answers.
2. The ability to abstract the social concepts performance test. This test is composed of 85 cards; each card contains a picture representing a social situation. The cards are divided into 17 groups, and each group contains 5 cards, 4 of them are related to a specific social theme such as cooperation, selling, and rescue. The participant is asked to interpret why these cards are grouped together and which card does not belong to the group. The total score is the number of correct answers.

Steps and sequence of examination

At first, the consultant neurologist refers the cases with a confirmed diagnosis with idiopathic epilepsy with the exclusion of symptomatic causes and abnormal findings in C.T or MRI brain, then an interview by the researchers is done with the patients and their caregiver to collect the demographic and clinical data. Then, an I.Q test is done to the case, then the application of the executive functions tests, and then the social abstraction tests.

The control subjects were selected from multiple schools in Sohag, with an interview at the beginning, then I.Q testing, executive functions testing, and social abstraction testing. The interview was done in the psychologist's room in the school.

We examined 65 epileptic patients, and we excluded 5 of them due to the presence of hysterical fits comorbidity or learning disabilities. We examined 62 controls and excluded 2 of them due to the presence of learning disabilities.

Ethical consideration

The research was authorized by the Faculty of Medicine's Scientific Research Ethical Committee, Sohag University. Moreover, all subjects as well as their parents provided

Table 1 Sociodemographic and clinical characteristics of patients and control subjects

	Patients (*N*=60)	Controls (*N*=60)	*P* value
Age (mean ±SD)	15.43±2.25	15.27±2.47	0.34
Sex			
Male	29	27	0.14
Female	31	33	
Handedness			
Right	58	59	0.26
Left	2	1	
Years of education (mean + SD)	8.38+2.28	8.2+2.47	0.18
I.Q (mean ± SD)	96.83±15.32	98±10.62	0.063

p value of 0.05 or less is deemed significant

informed consent. Also, we got the agreement of the Ministry of Education for recruiting the control students.

Statistics analysis

The 16th version of SPSS software was utilized for data analysis. For descriptive statistics, quantitative data were expressed as standard deviation (SD) and mean, whereas qualitative data were expressed as percentages as well as frequencies. The study depended on the statistical analyses as follows: (1) independent sample *t*-test to compare between mean and standard deviations of the studied variables, (2) Pearson linear correlation coefficient, (3) Mann-Whitney test, and (4) stepwise multiple regression analysis. Statistical significance was set as a *p* value < 0.05.

Table 1 shows that there is no statistically significant difference between controls as well as patients in terms of sex, age, handedness, education years, or total I.Q score. The minimum I.Q score in both groups was 90 and the maximum score was 117 in patients and 120 in controls.

Table 2 shows that all patients had normal C.T and MRI brain. Thirty-eight (63.33%) of patients had interictal epileptic discharge in EEG.

Table 3 shows that there is a negative statistically significant correlation between duration of illness and cognitive flexibility and inhibition (cognitive flexibility and inhibition decrease as the duration of illness increases). There is a negative statistically significant correlation between cognitive flexibility and frequency of seizures per year. There is a positive statistically significant correlation between all executive functions (planning, cognitive flexibility, inhibition, and verbal fluency) and the time since the last epileptic fit.

Table 4 shows that patients with interictal epileptic discharge in EEG have more impairment in cognitive flexibility and verbal fluency.

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Table 2 Clinical characteristics and brain imaging findings in the patient group

	Patients ($N = 60$)
Duration of illness in months (mean ± SD)	11 ±4
Frequency of seizures per year (mean ± SD)	8±3
Last fit in days (mean ± SD)	90±16
C.T and MRI brain	
Normal	60 (100%)
Abnormal findings	0 (0%)
EEG	
Normal	22 (36.66%)
Interictal epileptic discharge	38 (63.33%)

Table 3 Correlation between executive functions and clinical variables of the seizure

	Executive function	Correlation coefficient
Duration of illness	Planning	− 0.076
	Cognitive flexibility	− 0.615[a]
	Inhibition	− 0.723[a]
	Verbal fluency	− 0.211
Frequency of seizures per year	Planning	− 0.0471
	Cognitive flexibility	− 0.557[a]
	Inhibition	− 0.092
	Verbal fluency	− 0.002
Last fit	Planning	0.452[a]
	Cognitive flexibility	0.556[a]
	Inhibition	0.721[a]
	Verbal fluency	0.436[a]

Correlation coefficient (0=no correlation, −1 or +1=perfect correlation, between ±0.50 and ±1=strong correlation, between ±0.30 and ±0.49=moderate correlation, between zero and 0.29=weak correlation)

[a] Significant at 0.05

Table 4 Effect of interictal EEG findings on executive functions in the patient group

	Normal EEG N=22	Interictal epileptic discharge N=38	*P* value
	Mean±SD	Mean±SD	
Planning	5.52±3.32	5.92±3.193	0.062
Cognitive flexibility	4.88±1.31	5.78±1.13	0.041*
Inhibition	5.11±2.76	5.12±3.11	0.073
Verbal fluency	15.87±5.233	16.48±5.45	0.022*

p value of 0.05 or less is deemed significant

Table 5 Comparison between means of executive functions in patients and controls

	Patients Mean ±SD	Controls Mean ±SD	*p* value
Planning	5.67±3.193	8.47±3.213	0.000*
Cognitive flexibility	5.48±1.780	7±2.548	0.000*
Inhibition	5.18±3.877	7.67±3.007	0.001*
Verbal fluency	16.37±5.396	22.93±5.860	0.000*

p value of 0.05 or less is significant

Table 6 Comparison between means of ability to abstract social concepts in patients and controls

	Patients Mean ±SD	Control Mean ±SD	*P* value
Ability to abstract—verbal	14.88±4.017	17.45±2.807	0.000*
Ability to abstract—performance	9.57±3.011	12.27±2.497	0.000*

p value of 0.05 or less is deemed significant

Table 7 Pearson linear correlation coefficient between each executive function and ability to abstract social concepts in epileptic adolescents

Executive function	Ability to abstract social concepts (verbal)	Ability to abstract social concepts (performance)
Planning	0.327[a]	0.286[a]
Cognitive flexibility	− 0.115	0.059
Inhibition	0.277[a]	0.064
Verbal fluency	0.302[a]	0.317[a]

Correlation coefficient (0 = no correlation, −1 or +1 = perfect correlation, between ±0.50 and ±1 = strong correlation, between ±0.30 and ±0.49 = moderate correlation, between zero and 0.29 = weak correlation)

[a] Significant at 0.05

Table 5 shows that the mean scores of executive functions in epileptic adolescents are significantly lower than in control adolescents.

Table 6 shows that the mean scores of patients' ability to abstract social concepts (both verbal and performance tests) are significantly lower than the scores of controls.

Table 7 shows that there is a significant positive correlation of moderate degree between planning and verbal fluency as executive functions and the ability to abstract social concepts (verbal and performance tests).

There is a significant positive correlation of weak degree between inhibition and the ability to abstract social concepts (verbal test only).

Table 8 Pearson linear correlation coefficient between each executive function and the ability to abstract social concepts in the control group

Executive function	Ability to abstract social concepts (verbal)	Ability to abstract social concepts (performance)
Planning	0.538[a]	0.277[a]
Cognitive flexibility	0.399[a]	0.372[a]
Inhibition	0.055	0.257[a]
Verbal fluency	0.277[a]	0.189

Correlation coefficient (0 = no correlation, −1 or +1 = perfect correlation, between ±0.50 and ±1 = strong correlation, between ±0.30 and ±0.49 = moderate correlation, between zero and 0.29 = weak correlation)

[a] Significant at 0.05

Table 8 shows that there is a significant positive correlation between planning and cognitive flexibility as executive functions and the ability to abstract social concepts (verbal and performance tests). There is a significant positive correlation between inhibition and the ability to abstract social concepts (performance test only). There is a significant positive correlation between verbal fluency and the ability to abstract social concepts (verbal test only).

Table 9 shows that deterioration in planning or verbal fluency can predict deterioration in the ability to abstract social concepts (both verbal and performance tests).

Deterioration in inhibition can predict deterioration in the ability to abstract social concepts (verbal test only).

Deterioration in cognitive flexibility is not a significant predicting factor for deterioration of the ability to abstract social concepts.

Table 10 shows that deterioration in planning or cognitive flexibility can predict deterioration in the ability to abstract social concepts (both verbal and performance tests).

Deterioration in inhibition can predict deterioration in the ability to abstract social concepts (performance test only).

Deterioration in verbal fluency can predict deterioration in the ability to abstract social concepts (verbal test only).

Discussion

Main findings of our study

Adolescents with idiopathic generalized epilepsy have more executive function impairment compared to

Table 9 Multiple linear regression analysis in patients

		r	r²	Unstandardized coefficient	Standardized coefficient	t	f	p value
Planning	Ability to abstract—verbal	0.327	0.107	0.412	0.327	2.638	6.959	0.01*
	Ability to abstract—performance	0.286	0.082	0.270	0.286	2.275	10.436	0.03*
Cognitive flexibility	Ability to abstract—verbal	0.115	0.013	− 0.260	− 0.115	− 0.883	0.780	0.381
	Ability to abstract—performance	0.059	0.003	0.099	0.059	0.448	0.201	0.656
Inhibition	Ability to abstract—verbal	0.277	0.077	0.287	0.277	2.193	4.809	0.032*
	Ability to abstract—performance	0.064	0.004	0.049	0.064	0.485	0.235	0.630
Verbal fluency	Ability to abstract—verbal	0.302	0.091	0.225	0.302	2.415	5.831	0.019*
	Ability to abstract—performance	0.317	0.100	0.177	0.317	2.543	6.465	0.014*

p value of 0.05 or more is considered significant

Table 10 Multiple linear regression analysis in controls

		r	r²	Unstandardized coefficient	Standardized coefficient	t	f	p value
Planning	Ability to abstract—verbal	0.538	0.290	0.474	0.538	4.862	23.640	0.000*
	Ability to abstract—performance	0.277	0.077	0.188	0.277	2.192	4.508	0.032*
Cognitive flexibility	Ability to abstract—verbal	0.399	0.159	0.440	0.399	3.314	10.984	0.002*
	Ability to abstract—performance	0.372	0.138	0.316	0.372	3.053	9.319	0.003*
Inhibition	Ability to abstract—verbal	0.055	0.003	0.052	0.055	0.420	0.177	0.676
	Ability to abstract—performance	0.257	0.066	0.186	0.257	2.023	4.094	0.048*
Verbal fluency	Ability to abstract—verbal	0.277	0.077	0.134	0.277	2.198	4.832	0.032*
	Ability to abstract—performance	0.189	0.036	0.070	0.189	1.468	2.154	0.148

p value of 0.05 or more is considered significant

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control adolescents. Adolescents with idiopathic epilepsy have significantly more impairment in the ability to abstract social concepts (verbal and performance) compared to control adolescents. Executive function impairment is correlated with the duration of illness, frequency of seizures per year, time since last epileptic fit, and presence of interictal epileptic discharge in EEG in the patient group.

There is a strong correlation between executive functions and the ability to abstract social concepts (verbal and performance) in both epileptic and control adolescents. Impairment in executive functions can predict impairment in the ability to abstract social concepts (verbal and performance) in epileptic and control adolescents.

Comparison to previous studies

Impairment in executive functions in epilepsy patients is well studied in several studies. These studies differed in the type of epilepsy syndrome, patients' age, or the battery utilized to assess executive functions.

Gelziniene and his colleagues in their study detected executive impairment in trail-making test, Stroop test, and verbal fluency in adolescent patients with idiopathic generalized epilepsy, similar to our findings. Fifty-nine patients and 59 normal subjects were compared in this research [16].

Lima et al. [17] compared the executive skills of adolescents as well as children with idiopathic epilepsy to those of controls using the Wisconsin Card Sorting Test (WCST). According to the findings of this research, people with epilepsy exhibited worse executive function outcomes.

Modi et al. found that 30%, 18%, and 17% of adolescents suffering from epilepsy experienced impairments in working memory, planning, and cognitive flexibility, respectively [18].

In their study, Shehata and Bateh [19] assessed cognitive functions among 71 adult men with idiopathic epilepsy and 58 controls. This study found that patients with epilepsy reported highly significant impairment in all cognitive measures.

Chowdhury et al. [20] used a battery of neuropsychological tests sensitive to frontal lobe impairment to investigate 36 patients with idiopathic generalized epilepsy (IGE), 38 first-degree relatives, and 40 healthy controls. They also found that patients with IGE have deficiencies in working memory, attention, verbal generativity, and nonverbal reasoning. According to Tian et al. [21], children with IGE have a severe deficiency in their total response time as well as executive control network. They did not, however, reveal any deficits in their orienting or

alerting networks. These findings imply that IGE substantially impacts the executive control network.

Motamedi et al. [22] assessed neuropsychological functions such as backward and forward digit spans, orientation, logical memory, visual memory, mental control, associative learning, Stroop test, preservative errors, and IQ score. They illustrated that generalized epilepsy is linked to dysfunction in particular cognitive skills, especially in the prefrontal, frontal, and memory domains.

Koganti and his colleagues found problems in planning (Tower of London), verbal fluency (verbal n-back, category fluency, and word fluency), and inhibition (Stroop test) in 75 idiopathic generalized epilepsy adults [23].

Kumar and colleagues found that 54% of adults with idiopathic generalized epilepsy have impairment of executive functions [24].

Sherif and colleagues found impaired executive functions (planning, cognitive flexibility, and working memory) in adults with generalized epilepsy [25].

Consistent with our findings, Turaga et al., Black et al., and Kim et al. all found that executive functions are impaired in epileptic patients [26–28]. These studies, however, are not similar to ours. Turaga et al. studied chronic mesial temporal lobe epilepsy, Black et al. studied temporal lobe epilepsy, and Kim et al. studied the cognitive effects of specific antiepileptic medication.

The ability to abstract social concepts is considered one of the domains of social cognition. Previous studies that assessed social cognition in cases with epilepsy stressed two primary abilities: theory of mind (ToM) as well as facial emotion recognition. Operto et al. compared 62 children and adolescents aged between 7 and 16 years with 32 age- and sex-matched controls regarding executive functions and social cognition (theory of mind as well as facial emotion recognition). They found that epileptic patients have significantly more defects in social cognitive tests (theory of mind and facial emotion recognition) and that deficits in social cognition correlate to deficits in executive functions [29].

Multiple previous studies found that epileptic cases experience more impairment in some advanced as well as primary elements of social cognition like theory of mind and facial emotion recognition than their peers [30, 31]. Seizures may disrupt the functioning of temporal and frontal areas, which are thought to be important in facial and ToM emotion perception [32].

In our study, we found that the duration of illness and frequency of seizures per year have an impact on executive functions in epileptic adolescents; these results are in concordance with the findings of Holmes [33] and the findings of Morad et al. [34].

In our study, we found that the time since the last epileptic fit before the application of cognitive tests has an

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impact on all executive functions studied; this is in line with the findings of Agah et al. [35] who found that the occurrence of a seizure within a week before application of cognitive tests affected the performance of the patients on these tests.

In our study, we found that epileptic adolescents with interictal discharges in EEG have more impairment in cognitive flexibility and verbal fluency, which is in line with the findings of Lenck-Santini and Scott [36] and findings of Aldenkamp and Arends [37] who found that the presence of interictal discharges in EEG is correlated with cognitive impairment in epileptic patients. Theoretically, harm could come in two ways: (1) interictal discharges (IDs) could alter ongoing cognitive processes (this will be referred to as "transient cognitive impairment" [TCI]), and (2) IDs could lead to long-term structural changes. Therefore, if IDs do alter neural substrates in the form of molecular changes, cell death, or sprouting of axonal projections, it is also possible that, in the long term, these changes alter the network functions involved in cognitive processing (Lenck-Santini and Scott).

Limitations

The number of participants is relatively small, so the results obtained cannot be generalized. This study is a cross-sectional one, so we did not conclude cause-effect relationship (we are not certain if some of these cognitive defects were present before illness or not). The control group was collected from multiple schools in the Sohag Governorate which may affect the accuracy of the results.

Recommendation

The study recommended the necessity of developing protective, guiding, treatment, and rehabilitation programmes for generalized epilepsy patients and the people surrounding them. These programmes should consider all aspects of the patient's life: the psychological, cognitive, physical, and social ones.

Conclusions

Executive functions and the ability to abstract social concepts are significantly impaired in adolescents suffering from idiopathic generalized epilepsy. Impairment in executive functions can predict impairment in the ability to abstract social concepts. There is a need for screening of executive functions and social abilities of adolescents with epilepsy and programmes to enhance these abilities.

Abbreviations
C.T.: Computed tomography; DLPFC: Dorso-lateral prefrontal cortex; EEG: Electroencephalography; IDs: Interictal discharges; I.Q: Intelligence quotient; IGE: Idiopathic generalized epilepsy; MRI: Magnetic resonance imaging; SC: Social cognition; ToM: Theory of mind; WCST: Wisconsin Card Sorting Test.

Availability of data and materials
The datasets used and/or analysed in this work are available after a reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate
The present research protocol was approved by the Faculty of Medicine's Medical Research Ethics Committee, Sohag University. Informed consent was obtained from parents and research participants (both controls as well as patients).

Consent for publication
The authorization to publish was obtained.

Competing interests
The authors declare that they have no competing interests.

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