Natural Visibility Graphs for diagnosing attention deficit hyperactivity disorder (ADHD)

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Background

Reaction times (RT) are described as a measure of perception, decision making and other cognitive processes. RT usually follow an ex-Gaussian distribution [1]. The ex-Gaussian distribution is the convolution of two additive processes: an exponential distribution and a Gaussian distribution. The ex-Gaussian distribution has three parameters: μ, σ (mean and standard deviation of the Gaussian distribution) and τ (mean of the exponential distribution).
However, this approach omits relationships between consecutive answers to tasks geared to evaluate attention. RT is a variable that could be directly assessed and in this sense could help to diagnoses a high prevalent pathology in childhood as ADHD. Our objective is to contribute to its analysis through a mathematical approach.

Methods

The experiment was carried out as follows:

- **Subjects**: 38 students who were 8 years old and came from a public Primary School in the Valencia region (Spain).
- **Task**: Lexical decision task test of type yes/no. Students had to detect the presence or absence of the letter P among a set of letters. A total of 120 stimuli were presented to each student.
- **Time treatment**: A maximum time to answer was set to 2500ms to each item. If the time expires, 2500ms is assigned as answer time. Response times were considered regardless of whether the answer was correct or not.

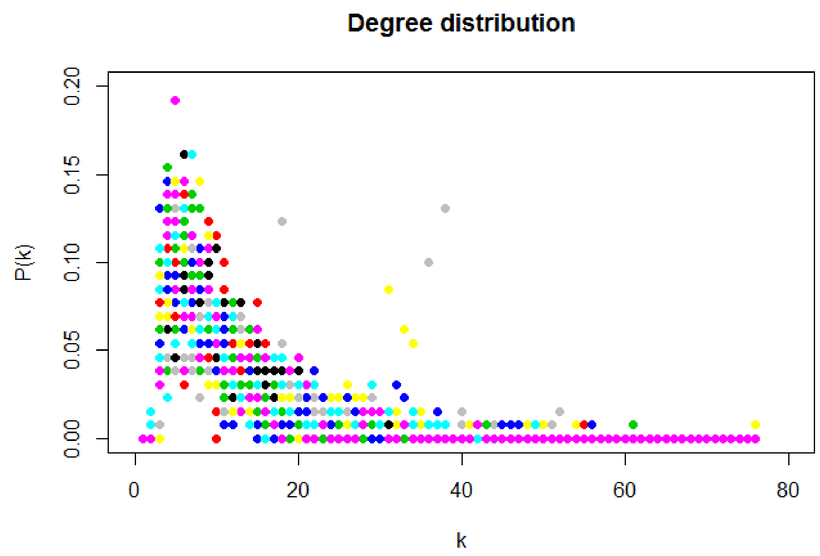
We use the natural visibility graph (NVG) algorithm to convert our time series into a network. For each student, we plot 120 RT (one for each stimulus) by using vertical bars and we link every bar with all bars that can be "seen" from the top of the considered one. Every stimulus represents a node and all nodes and the "visibility lines" between them define a graph for each subject.

Mathematically, two arbitrary RT values (t_a, y_a) and (t_b, y_b) are connected nodes of the respective graph if any other RT value (t_c, y_c) between them complies:

$$y_c < y_b + (y_a - y_b)\frac{t_b - t_c}{t_b - t_a}$$

Results

We have first studied the distribution of the degrees of the nodes of the natural visibility graph (NVG) associated to each participant. NVG's are connected, undirected and invariant under affine transformations of series data. For a detailed description of their properties we refer to [2].

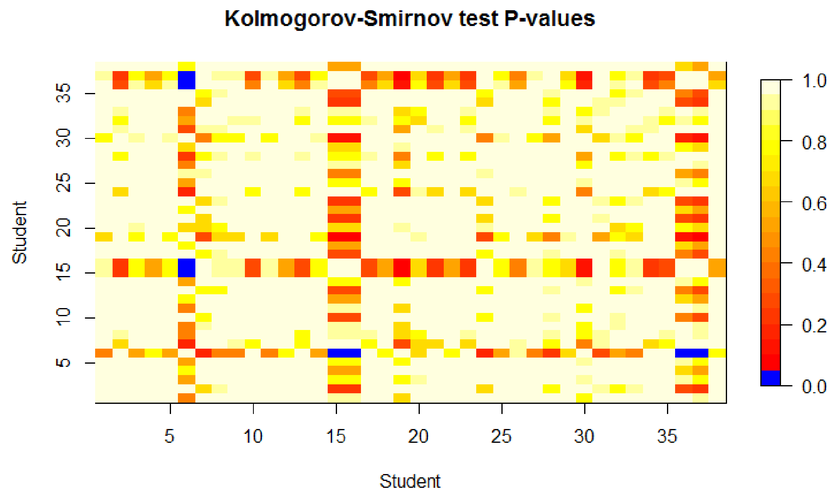


The degrees distributions of the NVG of each participant, which follow a power-law function $\alpha\kappa^{\gamma}$ [3], are represented by different colours. At first sight, one can see that the results for two students (in yellow and grey) are significantly different respect to the others.

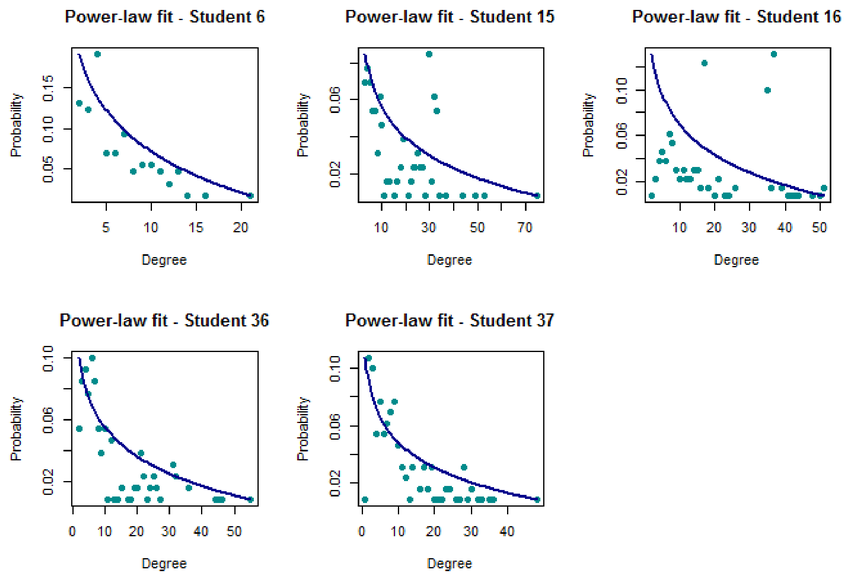
In order to compare the different power-law functions, we have computed the matrix of p-values obtained by the application of the Kolmogorov-Smirnov test to all pairs of participants in the study. This approach is quite similar to the one carried out in [4].

Results

We observe that, at the 5% level of significance, we can reject the null hypothesis which established that any pair of students follow the same distribution.



The following figure shows the power-law fit for these 5 students.



Conclusions and next steps

Using this approach we found a student (6) who differed significantly (Kolmogorov-Smirnov test P-value$<$0.05) from other four students (15, 16, 36 and 37). Firstly, that student did not show any disorder when we analysed the results of the test. Probably, we were not able to detect this difference due to the use of this specific test. Our next goal is to study the results obtained from other kind of tests that we performed and take into account the type of answer: right or wrong.

We point out that these measurements cannot replace a clinical assessment, but they could help to make the the correct diagnosis.

References

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