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Is the Ability to Simulate Chance a Discriminant Property between High Functioning ASD and Typical Subjects?

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INTRODUCTION

The definition of the concept of randomness and the difficulty of humans to simulate it, in the sense of being able to produce unpredictable patterns within reasonably tight margins of error, constitute a profound topic of discussion among neuroscientists, mathematicians and philosophers [1]. The literature has widely demonstrated experimentally the difficulty that humans have in generating random sequences (Chance simulative deficit, CSD) that do not reveal, after an appropriate number of trials, a statistically recognizable response pattern that highlights the dominance of some choice options [2]. Errors in generating random, non-informative and therefore unpredictable sequences are generally explained in terms of prejudices, sometimes misconceptions or in any case with a level of deep structured cognition that prevails in any simulated process [3]. Theories have been proposed as to why there is such difficulty in simulating random sequences by invoking internal languages and, inspired by the artificial intelligence paradigm, recursive information compression algorithms [4]. Although such theories manage to achieve some results in terms of statistical fitting, they certainly require a lot of experimental work to be confirmed. Subjects with Autism Spectrum Disorders (ASD), by virtue of some behavioural peculiarities such as stereotypies, could constitute an important population to test the validity of the algorithmic theory. To date, few studies have investigated the ability to simulate chance in ASD subjects, highlighting a tendency to generate less random, more repetitive sequences and with regular patterns compared to neurotypical subjects [5].

OBJECTIVES

The study tests if the property of simulating chance is discriminating between autistic and typical subjects by introducing an appropriate metric. Given this difference, it can suggest a first-level strategy on a diagnostic level that takes advantage of the different simulative capacities of the two groups. The hypothesis is that the simulative deficit of randomness typical of human beings can constitute a discriminating property in the case of ASD and that this specificity can be applied for achieving diagnostic suggestions.

METHODS

The study is a pilot cross-sectional study with parallel cohorts aimed at evaluating the Chance Simulative Deficit (CSD). The study took place at the Regional Reference Centre for Autism of the Abruzzo Region in Italy. The sample size calculation assumed a Cohen effect size of namely 0.8, using a power of 80% with a type I error of 5%, requests 25 subjects for each group. The recruitment provided 122 typical subjects with and 45 (27%) ASD. The mean age was 23.2 years for typical and 21.8 years for ASD.

The task administered requests that each player, regardless of being ASD or typical, will play against a computer that simulates random choices, displaying icons with fists, paper, scissors on the monitor, after the human player has selected an icon and regardless of the human player's choice. In this game, the optimal strategy, or the strategy that maximizes the possibility of winning, is the least informative. Consequently, the computer optimally simulates the results using a uniform multinomial distribution with probability equal to 1/3 for each of the three states.

ASD and typical players perform many game trials, in our case 80 (about 20 minutes, assuming 15 s for each trial), so that the empirical frequency distributions of the players can be estimated.

These distributions characterize the specific ability of the ASD groups and typical players to simulate randomness,

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namely the distribution used by computer in playing. The performance in the Chance Simulation is defined by the cross-entropy $H(p,q) = \sum_s p_s ln\frac{1}{q_s}$, between the computer distribution ps and the empirical distribution of each player qs. ASD and Typical subjects' groups have been compared without adjustment using the Mann Witney test with α=0.05. This test has been performed to assess the hypothesized difference in chance simulation. A Homogeneous Markov Chain modelled the game. We estimated the transition Matrices of the ASD and Typical subjects. The associated Markov Processes provided different steady states confirming the preliminary non-parametric test. A logistic predictive model adjusted for gender and age has been trained randomly selecting the 80 % of the original sample.

The statistical analysis has been carried using the statistical software R (version 4.5.0).

RESULTS

The mean cross-entropy chance deficit score (CEDS) estimated was 0.49 (SD=0.03; min=0.48; max=0.76) for the typical and 0.48 (SD=0.01; min=0.48; max=0.52) for ASD. The Mann–Whitney test comparison of CEDS in the two groups has been statistically significant (p<0.01). The logit score, sets up using CEDS, gender and sex, reached an AUC=83%. Using the Youden cut-off (0.23) the model estimated a sensitivity of 89% and a specificity of 76%. The Kullback-Liebler divergence between the steady states distributions was statistically significant different from zero (p<0.01).

CONCLUSIONS

The study checked the hypothesis that ASD high functioning and Typical subjects perform differently in simulating chance. The analysis supports the hypothesis though has to pointed out that the study does not adjust for many potential confounders and the sample is strongly unbalanced between ASD and typical.

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