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Cognitive architecture of the chaotic patterns during statistical learning

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The ability to find proper patterns in the environment and to understand their logic without external instruction is a vital property of the brain. Our daily existence includes not only structured events but also chaotic ones. Sensitivity to these chaotic patterns in a noisy and continuous world is one of the sources of learning that can be considered statistical. Statistical learning is connected with the ability to extract regularities, structured patterns from the environment over time and space [1].

One of perspective domains in which statistical learning features of the main interest is cognitive architectures field. Cognitive architectures can be represented as a part of research in the Artificial Intelligence, which has the goal of modeling the human mind and to create programs that can reason about different problems, develop new insights, adapt to situations and reflect on themselves [2]. Now, the research aimed at developing cognitive architectures concerns the issues of thinking like humans, thinking rationally; acting like humans, and acting rationally. To the best of our knowledge, cognitive architectures of statistical learning have not been developed. Thus, the aim of the study is to develop a cognitive architecture during statistical learning when presented with chaotic dot patterns.

The initial empirical base was collected using a stationary monitor eye-tracking system (EyeLink 1000 Plus). It was proposed to understand the dots pattern and find it during validation. The experiment included 9 trials with learning (11 dots) and validation (1 correct stimulus and 4 distractors) phases. During the trails, the same pattern of dots was implied, but dots which formed one pattern were presented in random order one by one. Such a way of presenting the stimulus created chaos, in which the only pattern was hidden. In the validation phase, it was proposed to press the button if the dots pattern is correct according to one which was presented during the learning phase. All trials include only one pattern. Stimulus switching was done after 3s. Statistical processing of empirical data was carried in the program «STATISTICA».

87% of subjects noted that it was difficult for them to find the required pattern. 55% did not understand the pattern, although the remaining 45% of subjects indicated in the survey that they understood the pattern, the pattern described by them was different from the correct one.

The initial purpose of the analysis was to specify if statistical learning occurred by comparing the learning and validation results at the beginning and at the end of the experiment. The Mann-Whitney U-Test was used to explore the data in terms of possible differences between groups. The reaction on true patterns in the beginning (2nd trial) and end validation (8th trial) significantly differs in the following eye movement metrics: maximum time of fixation duration ($p = 0,0$, $z = -3,75$), minimum time of fixation duration ($p = 0,0$, $z = -3,75$), time of maximum pupil size ($p = 0,0$, $z = -3,75$) and time of minimum pupil size ($p = 0,0$, $z = -3,75$). Differences in the reaction on false patterns in the beginning and end validation is found in average saccade amplitude ($z = 3,17$, $p = 0,00$), maximum time of fixation duration ($z = -5,94$, $p = 0,00$), minimum time of fixation duration ($z = -5,94$, $p = 0,00$), time of maximum pupil size (z = -6,06, p = 0,00), minimum of pupil size (z = 2,38, p = 0,02), time of minimal pupil size (z = -6,06, p = 0,00), standard deviation of the duration across all fixations (z = 2,10, p = 0,04).

Despite the fact that the participants did not understand this pattern, to find if there were implicit reactions to true and wrong patterns at the beginning of validation (2nd trial), the Mann-Whitney U Test was applied. The statistically significant difference was obtained in average fixation duration (z = -1,98, p = 0,047), the value of these metrics was higher on the wrong pattern. At the end of validation, the 8th trial was taken; there were no differences in average fixation duration (z = -0,79, p = 0,427). Taking all trials together, the average fixation duration also does not differ (z = -0,64, p = 0,52).

At the end of the experiment, subjects were asked to describe what strategy they used to select the correct dots pattern. All the answers can be grouped in two categories: remembering the position of certain groups of dots (G1), creating an image from dots and remembering the created image (G2). But obtained results do not allow to determine exactly what influenced the choice of a particular learning strategy. In other words, the initial condition is unclear. To select which strategy to use in the cognitive architecture, a quantum circuit was used. The quantum circuit contains two qubits and two classical bits. The Hadamard gate is applied to both the qubits, putting them in a superposition of states. In quantum superposition, a qubit can exist in multiple states or positions simultaneously until it is observed or measured; which corresponds with the fact that G1 and G2 strategies can both be used, but in the experiment measurements only one strategy was chosen. Finally, measurements are performed on both qubits and the results are stored in the classical bits. Then the obtained possible outcomes and their corresponding counts are compared, and if the amount of "01" is higher than the "10" value of qubits, the G2 strategy is activated and vice versa.

Since in both strategies the participants memorized only part of the presented dots, the size of such a “window” is to be determined for the architecture. The gradient of the data is used to calculate this window size. From all obtained gradients, the absolute value of the median was taken and was multiplied by 10. Then the float result is converted to an integer value. The obtained window size sets the amount of input data to be processed.

The G2 strategy may be represented computationally in calculation correlations and finding the most persistent ones. Correlations reflect possible connections between the dots which can be expressed as an image. Since the easiest way to remember the dots is to define the most eye-catching ones, the G1 strategy is realized through looping through each unique value and then calculating the Euclidean distance between the first two elements of the unique values dictionary.

Источники и литература

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