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Research article

A biologically inspired cognitive skills measurement approach

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ABSTRACT

Cognitive Skills (CS) are essential for job interviews and government policymaking. We have no existing work that can predict CS during interviews and policymaking. The current work proposes CS measurement method that simulates the nonlinear relationship between CS and Basic Human Factor (BHF) (aging, infection, emotions, awareness, personality, education, and experience). Firstly, the method obtains conditional probabilities of CS with respect to BHF using training data set. Secondly, particular domains and ranges are define for BHF. Based on the conditional probabilities of CS, the technique divide training data set into three partitions that result in three model equations for CS measurement method. Moreover, the propose method divides into three algorithms. The first algorithm estimates values for BHF. The second algorithm verifies the estimated values of BHF while the third algorithm predicts CS values by using the estimated values of BHF. During the experiment, the propose method test on test data set. We achieve the prediction accuracy of the method through Mean Forecast Error (MFE), Mean Absolute Deviation (MAD) and Tracking Signal (TS) measures. The results show that the accuracy of the method is 91%. Finally, we discuss these results as well as the comparison of the current method with competitive methods.

Introduction

Cognitive Skills (CS) is the brain-based abilities to process the information received from experience, awareness, perception, and education, etc. To perform a cognitive task, an individual needs CS as an essential human factor. Hundreds of neuroscience, cognitive science, and psychological literature studies relate CS with many other human factors. Literature provides a large volume of research findings which define cognition and CS as a function of human factors (Biswal et al., 2010; Cabeza, Anderson, Locantore, & McIntosh, 2002; Colcombe et al., 2006; Hillman, Erickson, & Kramer, 2008; Lupien, McEwen, Gunnar, & Heim, 2009). Thus, these findings provide clues for the assumptions of the correlations between CS and Basic Human Factors (BHF) as negative and positive emotions, emotional severity, infection, infection severity, age, gender, education, experience, personality, and awareness. More importantly, the sensitive nature of CS performs an exclusive role during cognitive tasks. We have no existing technologies that can simulate cognitive functions of an individual. As we know that thinking about the modulation of CS as a function of human factors is quite obvious, but to precisely explore the quantitative impact of a set of human factors on brain skills are inspiring. CS measurement can provide a solution to different problems (i.e., CS prediction during an interview, driving, flying, and firefighting, etc.). Working beyond the scope of computer science and psychology is the main challenge in CS measurement. The related CS measurement methods tried to simulate CS using different approaches which can extend to more general CS measurement problems (Carroll, Solity, & Shapiro, 2016; Fonteyne, Duyck, & De Fruyt, 2017; Hornung, Schiltz, Brunner, & Martin, 2014; Matsuda, Cohen, Sewall, Lacerda, & Koedinger, 2007; Potharst et al., 2012). Moreover, we cannot find a precise CS measurement problem description which can predict CS beyond the scope of computer science. Studying the idea of automatic discovery of the CS of students (Lindsey, Khajah, & Mozer, 2014), we observed new challenges which given below.

- Estimate Basic Human Factors.
- Validate the estimated Basic Human Factors.
- Measuring Cognitive Skills.

Highlighting the above challenges explain the problem statement of the current research. Additionally, the efficient exploration and simulation of the relationship between BHF and CS is the main module of the current study. Thus, working with the selected factors and its effects, the literature studies reveal heterogeneity in the relationship between CS and BHF (Greenberg, 2017; Korniotis & Kumar, 2011; Rook & Charles, 2017; Torres & Mata-Greve, 2017; Turner & Spreng, 2012;

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Wilmoth, London, & Parker, 2010). For the unbiased estimation of correlations between the selected factors and CS, we use three type of datasets. The first dataset obtains from the psychological experiments and the second dataset is create by over sampling that based on the psychological experiment and semantic analysis of literature studies while the third dataset obtains during psychologist clinical work. To learn about the impact of the actions of BHF on CS, we use nonlinear regression models (Michaelis Menten model, Gradient Descent Algorithm and Marquardt algorithm) which explore the relationship between every factor ∈ BHF (along with its effects on CS) and CS. The regression analyses manifest that BHF connected through conditional probabilities which ecologically overlap during cognitive activities of an individual.

Learning from the nonlinear regression analysis, we present a novel CS measurement method which contributions are three fold. Firstly, the method obtain the relationship between CS and each factor ∈ BHF. The analysis findings demonstrate that emotion can extensively influence CS of an individual which is also highlighted by literature studies (Craske, Hermans, & Vansteenwegen, 2006; Kiosses et al., 2017; Knyazev, Savostyanov, Bocharov, & Kuznetsova, 2017; Mikulincer & Shaver, 2010; Parent & Bradstreet, 2017; van Noorden, Cillessen, Haselager, Lansu, & Bukowski, 2017). As according to the investigation of nonlinear regression analysis, these basic emotions can influence mental abilities differently. Another factor that can be able to change the influence of emotions is, emotional severity which can have both negative and positive effects on the CS of an individual (Cardoso, Matsushima, Kamizaki, Oliveira, & Da Silva, 2001; Mohammad & & Bravo-Marquez, 2017). But this factor is beyond the scope of the current work. Emotion is also associated with the education level of the individual. The analysis shows that education reduces the negative effect of emotions regularly. Moreover, education loosely connected with awareness and personality factor. Next is the age and gender of an individual which have a remarkable influence on CS. Our regression analysis reveals that gender factor is conditionally dependent on age of a person which also investigated in literature studies (Hofmeier et al., 2017; Lindau et al., 2007; Siegel, 2005).

As a second contribution, a particular domains and ranges are define for BHF that based on calculated conditional probabilities of CS. Thirdly, the particular training data set is divide into three partitions for nonlinear least square method. The partitioning of data set result in three algorithms for the propose CS measurement method. The first algorithm analyses the expected value of each effect of BHF. It takes a set of BHF (every factor ∈ BHF mapping to a set of expected effects of that particular factor) as an input and produce estimated values for BHF (based on the expected effects of the factor). The task of the second algorithm is to validate the estimated values of BHF. The primary goal of the second algorithm is to improve the efficiency of CS prediction by comparing each effect with psychological and neuroscience findings. Finally, the third algorithm uses the estimated values of each BHF for the prediction of CS.

The rest of this work has categorized as follow. Section ‘Related work’ represent literature studies and Section ‘Method’ shows the method and problem formulation. Section ‘Experiment’ describes accuracy and comparative analysis while Section ‘Discussion’ shows discussion and conclusion of the study.

Related work

In this section of the current study, we are synthesizing the implications of BHF on cognitive processes. Literature reveals that human natural cognitive system is connected with the particular behaviors of BHF. We explored the basic problem statement beyond the boundaries of computer sciences and machine learning. Moreover, we divided related work into different subsections as BHF and cognitive methods. Thus, in BHF subsection, we investigate the relationships of BHF, and cognitive abilities, as well as we, describe the negative and positive impacts of BHF concerning CS of an individual. On the other hand, in the cognitive methods subsection, we talk about the recent trends as well as the outstanding achievements in cognitive systems, cognitive architectures, and CS measurement circumstances.

Basic human factors

Literature studies manifest that researchers tried to relate pair of mediating beliefs and mental abilities to different BHF (Caramazza, Anzellotti, Strnad, & Lingnau, 2014; Forbes & Grafman, 2010; Geuter, Koban, & Wager, 2017; Hines, 2011; Luna, Marek, Larsen, Tervo-Clemmens, & Chahal, 2015; Toga & Thompson, 2005). The most important and complex BHF is emotion. It plays a crucial role in influencing our lives by applying a specific type of force (Ochsner, Bunge, Gross, & Gabrieli, 2002; Metz et al., 2017; Mickley Steinmetz, Sturkie, Rochester, Liu, & Gutchess, 2017; Scheibe & Carstensen, 2010). This is also supported by recent technology as Electroencephalography (EEG) (Candra, Yuwono, Chai, Nguyen, & Su, 2017; Liu, Sourina, & Nguyen, 2011a; Thammasan, Moriyama, Fukui, & Numao, 2017a). By studying electrode signals, one can understand that brain signal change by the change in human emotions and its severity. Moreover, CS is conditionally dependent on other factors ∈ BHF i.e. age, gender, personality, education, awareness, experience and infections as well as its severity.

On the other hand, cognitive functions, emotions, and other factors in BHF as gender, education, age, personality, experience, and awareness connected which each other. There is enough amount of difference in the performance of male and female individuals. Studies (Brandner, 2013; Feng, Spence, & Pratt, 2007; Hoffman, Gneezy, & List, 2011; Jackson & Rushton, 2006; Liu et al., 2011a; Miller & Halpern, 2014; Parsons et al., 2004; Reilly, 2012; Stumpf, 1993; USER & Meyer, 2006) show that gender difference is an independent biological factor which magnitude is sometimes dependent on other factors as cultures, socio-economic condition, language, and age, etc. But instead of this facts, gender differences play a key role in mental abilities and cognitive processing as mathematical tasks, physics, research, reading, and writing. These issues create a big gap between male and female individuals which referred as natural and biological differences. These biological differences increase and decrease the through the contributions of factors as cultures, education, age, awareness, personality, experience as well as economic prosperity.

Related cognitive methods

The extensive study of the human cognitive system shows that cognition use information (that information which obtained during the interaction of human being with external world) to guide and initiate the expected actions of a person (Proulx, Todorov, Amanda, & De, 2016; Seegelke & Schack, 2016a). In addition, the human cognitive system is information processing system which can make a person unique in a community. Thus, such structure leads to the unique characteristic of human being. Here the most important thing is the identical structure of information processing system of humans. Therefore, in turn, this identical structure can be used for the construction of learning algorithm (cognitive architecture). In Sweller and Sweller (2004) and Sweller (2016, 2017), the researchers listed the essential characteristics of information processing system of a human being. Firstly, a considerable amount of information needs to be processed in a multifaceted environment. Secondly, information transformation from one factor to another factor. Thirdly, dealing with newly created information while retaining the effectiveness of old data and finally establishing a relationship between all the elements of this particular body of knowledge with external entities of the world. Cognitive architecture assesses and highlights the expected reaction of a person by specifying the underlying structure of the natural cognitive system. Moreover, it paves the way for the development of the intelligent