Cognitive chronometric assessment of constructive knowledge: an empirical approach to support formative assessment

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Abstract. A cognitive system using mental chronometry to innovate assessment of students learning outcomes is presented. High school and bachelor students from several knowledge domains are required to use a natural semantic technique to provide mental representations of course schemata contents at the beginning and end of the course. At the end of course, schemata related word pairs due to learning obtained from students’ semantic nets are used to compare recognition times of these concepts against other semantic related concepts. Results showed that specific priming effects are obtained from schemata related concepts after successful learning. Implications to formative constructive knowledge assessment are presented.

1. Introduction

Mapping the time needed to execute specific cognitive operations is at the core of theoretical discussion in cognitive science. This is so because a main assumption of cognitive psychology is that any mental operation in our minds can be typified by the time it takes to realize it [1] [2]. Time footprints of human information processing are assumed to produce useful insights about mental life.

Accordingly, human learning can be analyzed by its temporal attributes. This includes the possibility of using mental chronometry to typify how humans assimilate and organize new acquired knowledge. Take for instance semantic priming studies [3] which are framed by one of the most common approaches to study human memory that measure reactions to lexical stimuli that are usually presented on a computer screen, thereby gaining an external measurement of internal processes of our memory.

It has been argued that by using semantic priming studies it is possible to know if a student has assimilated new course content knowledge into her/his long term memory or if a student only acquired short term retention (to pass an exam) or if the student did not learn the required knowledge to pass a course. Specifically, Morales et al. [4] [5] have presented some evidence suggesting that by obtaining from students conceptual mental representations of a knowledge schema before and after a course, it is possible to identify schemata related concepts that serve for assimilation processes of the schemata
course content. Thus, schema concepts are used to implement semantic priming studies where recognition times of schemata related concepts are compared against other semantic related word pair recognition times. Here, it is assumed that if a priming effect is obtained over schemata related word pairs (schemata priming [6] [7]) then new acquired information is stored in the lexicon. This is relevant since Conway, Cohen & Stanhope [8] [9] have shown through long-term knowledge retention studies that students tend to retain a reduced knowledge schema of previously tested knowledge and therefore, this way to chronometrically evaluate acquired knowledge, immediately reveals which schemata concepts are possible candidates to be retained. Morales, et al. called this way of learning assessment “Constructive/Responsive Assessment (CRA)” [5]. However as far as we know, this is the first time that a schemata time property has been used to predict academic successful learning.

Here it is argued that schemata priming as an assessment of learning is twofold: It serves to evaluate emergent organization of acquired course schemata contents (meaning formation) and at the same time reveals the impact of course instruction students on learning outcomes.

2. Constructive knowledge and mental chronometry.

Students use of concept net graphs to express learning by using semantic networks [10] [11], concept maps [12] [13] [14] and comparable tools (tree diagrams, causal diagrams, etc.; [15] empowers learners with the conscious and controlled externalization of their knowledge in long-term memory through specific representational formats.

Evaluation of these visual expressions subscribes to alternative approaches to establishing what a student knows after learning (formative assessment) as opposed to the current dominant assessment of learning position of only to consider what a student does not know (summative assessment) [16]. Thus, graphic concept nets as an alternative formative assessment method represent a way to visually analyze how students construct knowledge (constructive knowledge analysis). A major benefit obtained from using this way to express learning is obtained by analyzing mental representations due to learning where learners receive input and guiding feedback on their relative academic performance to help them to obtain insight into their own learning.

Moreover, as suggested by Gonzalez et al. [17] by using cognitive mental representation analysis over obtained semantic networks from students after learning there is a chance to determine elusive emergent properties of schemata behavior. In particular, there is the possibility to select schemata related concepts that are relevant for students learning by using computer simulations of schemata behavior. Morales et al. [18] [19] have suggested that this technique to select schemata related concepts has psychological validity since they produce schemata priming whenever they are tested in semantic priming studies. We illustrate these points next.

3. Method

Sample. A first sample of eighty high school students of middle class taking a course on moral development (same number of female and male) whose age ranged from 15 to 18 years old were equally divided into two groups: experimental and control group. A second sample consisted of 15 engineering bachelor students (all male whose age ranged between 19 and 23 years old) who failed a course on computer usability. Finally, 167 high school belonging to five groups taking an introductory course on biology were considered to test if by using a concept map technique student might acquire schemata course contents in their lexicon after the course.

Instruments. All three samples were required to take a Constructive-Responsive approach to assess their learning. In this way to assess constructive knowledge, students’ mental representations of course content are obtained using a natural semantic network. Learners are required to define the target concepts that are related by a schema both before and at the end of a course. These target concepts are provided by teachers and experts on the schema to be learned. Students must define the target concepts using other single concepts (definers).
Computer simulations of schemata behavior based on students’ semantic networks after their specific course allow to select relevant schemata related word pairs to be used in semantic priming studies. Table 1 shows selected stimuli to this purpose.

| SCHEMATA RELATED STIMULI | COMPUTER USABILITY | MORAL DEVELOPMENT | BIOLOGY |
|--------------------------|---------------------|-------------------|---------|
| PRIME | TARGET | PRIME | TARGET | PRIME | TARGET |
| INTERFACE | INTERNET | LOVE | TRUST | NATURE | RECYCLING |
| PROGRAM | IMPROVEMENT | LOYALTY | ORDER | PLANTS | SCIENTIST |
| TEST | USABLE | JUSTICE | GOD | ANIMALS | ENERGY |
| CODE | LANGUAGE | FRIENDSHIP | VALUES | LIFE | POLLUTION |
| SYSTEM | PROJECT | LOGIC | HONESTY | POLICE | ECOLOGY |
| PRIME | TARGET | PRIME | TARGET | PRIME | TARGET |
| INTERFACE | INTERNET | LOVE | TRUST | NATURE | RECYCLING |
| PROGRAM | IMPROVEMENT | LOYALTY | ORDER | PLANTS | SCIENTIST |
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| PRIME | TARGET | PRIME | TARGET | PRIME | TARGET |
| INTERFACE | INTERNET | LOVE | TRUST | NATURE | RECYCLING |
| PROGRAM | IMPROVEMENT | LOYALTY | ORDER | PLANTS | SCIENTIST |
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| CODE | LANGUAGE | FRIENDSHIP | VALUES | LIFE | POLLUTION |
| SYSTEM | PROJECT | LOGIC | HONESTY | POLICE | ECOLOGY |

Table 1. Stimuli obtained from the different computer schemata simulations

4. Results

Figure 1. Section A shows that students from the moral development course presented schemata priming to morally related words only after the course finished. Section B shows this effect for computer usability students only after taking a corrective course. Finally, Section C shows that only the group who used a concept map on biology could integrate in the lexicon schemata information.

![Figure 1](image1.png)

Figure 1. Study’s results

Overall these results support the idea that mental chronometry can be used to test if course contents are integrated in the long run in the students’ lexicom. Furthermore, as we will discuss the context in which this knowledge assimilation occurs can provide useful insights to teachers and students regarding the way they construct knowledge.

5. Discussion

Semantic priming literature supports the idea that cognitive mental chronometry is useful to identify how new acquired knowledge is assimilated and organized into the human lexicon [20] [3]. Accordingly, results presented in the current paper suggest that the use of this experimental paradigm combined with techniques such as natural semantic networks (rather than idiosyncratic) and computer
simulated schemata after a course empower evaluation of knowledge formation and meaning formation of course content in students’ long term memory.

In addition, the CR approach showed that it can be used to test if other visual concept networking techniques like concept maps are useful to assimilate meaningful information in the long run. This is illustrated in Figure 1 Section C where the group who used a concept map technique during a course on introductory biology presented schemata priming after the course. However, one might question on why the control group did not especially if the teacher was the same to all the groups. It looks like even when the teacher was required not be biased on differential motivation to his groups he implicitly could not avoid doing it so. Similar inquiry can be imposed over the teacher who applied corrective instruction over students who failed a course. She had to provide special attention to these students to achieve their knowledge assimilation in the long run and not short-term retention to pass a test.

References
[1] Luce, R.D. 1986 *Response times: Their role in inferring elementary mental organization.* (New York: Oxford University Press)
[2] Jensen, A. R. 2006 *Clocking the mind: Mental chronometry and individual differences.* (Amsterdam: Elsevier)
[3] Mcnamara, T. P. 2005 *Semantic Priming: Perspectives from Memory and Word Recognition. Essays in Cognitive Psychology* (New York, NY: Psychology Press, Taylor & Francis Group)
[4] Morales, M.G.E & Lopez, R.E.O. 2016 Cognitive responsive e-assessment of constructive e-learning. *Journal of e-learning and knowledge society,* 12 (4) 39-49.
[5] Morales, M.G.E, Lopez, R.E.O., Castro, C.C., Villarreal, T.M.G., & Gonzalez, T.C.J. 2017 Cognitive Analysis of Meaning and Acquired Mental Representations as an Alternative Measurement Method Technique to Innovate E-Assessment. *European Journal of Educational Research,* 6 (4), 455-464
[6] Lopez, E.O., & Theios, J. 1996 *Single word schemata priming: a connectionist approach.* The 69th Annual Meeting of the Midwestern Psychological Association (Chicago, IL)
[7] Gonzalez, C.J, Lopez, E.O., & Morales, G.E. 2013 Evaluating moral schemata learning. *International Journal of Advances in Psychology* 2 (2) pp. 130-136, ISSN: 2169-494X.
[8] Conway, M.A., Cohen, G. & Stanhope, N. 1991 *On the Very Long-Term Retention of Knowledge Acquired Through Formal Education: Twelve Years of Cognitive Psychology.* *Journal of Experimental Psychology: General,* 120 pp. 395-409.
[9] Conway, M.A, Cohen, G., & Stanhope, N. 1992 Very long term memory for knowledge acquired at school and university *Applied Cognitive Psychology* 6 pp. 467482
[10] Jonassen, D.H., Beisner K. & Yacci M. 1993 *Structural Knowledge: Techniques for representing, conveying and acquiring structural knowledge.* (Hillsdale, New Jersey, LEA)
[11] Clariana, R.B. 2010 *Multi-decision approaches for eliciting knowledge structures.* In: Dirk Ifenthaler, Pablo Pignay-Dummer & Norbert, M. Seel (eds), *Computer-Based Diagnostics and Systematic Analysis of knowledge.* (New York, Springer Verlag)
[12] Rainer, L. 2005 *Using semantic networks for assessment of learners’ answers.* Proceedings of the sixth IEEE international Conference on Advanced Learning Technologies (ICALT – 06), 1070-1072.
[13] Nesbit, J. C., & Adesopo, O. O. 2013 *Concept maps for learning.* *Learning through visual displays* (Charlotte, NC Information Age Publishing) pp. 303-328
[14] Schroeder, N. L., Nesbit, J. C, Anguiano, C. J., & Adesopo, O. O. 2017 *Studying and Constructing Concept Maps: a Meta-Analysis.* *Educational Psychology Review,* 30(2), 431-455. doi:10.1007/s10648-017-9403-9
[15] Hyerle, D. 2009 *Visual Tools for transforming information into knowledge.* (Thousand Oaks, California, Corwing Press) 2nd Edition
[16] Arieli-Attali, M. 2013 *Formative assessment with cognition in mind: The cognitively based assessment of, for and as Learning (CBALTm) research initiative at educational testing service. Proceeding of the 39th annual conference on Educational Assessment 2.0: Technology in Educational Assessment*

[17] Gonzalez, C.J., Lopez, R.E.O, & Morales, G.E. 2018 *Self organized schemata behavior and meaning formation to evaluate e-learning. International Conference on Distance Education and Learning ICDEL'18*

[18] Morales-Martinez, G. E., & Santos Alcantara, M. G. 2015 *Alternative Empirical Directions to Evaluate Schemata Organization and Meaning. Advances in Social Sciences Research Journal* 2(9) 51-58.

[19] Morales-Martinez, G. E. & Lopez-Ramirez, E. O. 2015 *New approaches to e-cognitive assessment of e-learning. International Journal for e-Learning Security (IJeLS), 5* (2), 449-453.

[20] Becker, S., Moscovitch M., Behrman, M., & Joordens, S. 1997. Long-term semantic priming: A computational account and empirical evidence. *Journal of experimental psychology: Learning, Memory and Cognition, 23* (5), 1059-1082.