

# Chapter 119

## Using High-Frequency Interaction Events to Automatically Classify Cognitive Load

**Tao Lin**

*Sichuan University, China*

**Zhiming Wu**

*Sichuan University, China*

**Yu Chen**

*Sichuan University for Nationalities, China*

### ABSTRACT

*There is still a challenge of creating an evaluation method which can not only unobtrusively collect data without supplement equipment but also objectively, quantitatively and real-time evaluate cognitive load of users based the data. The study explores the possibility of using the features extracted from high-frequency interaction (HFI) events to evaluate cognitive load to respond the challenge. Specifically, back-propagation neural networks, along with two feature selection methods (nBset and SFS), were used as the classifier and it was able to use a set of features to differentiate three cognitive load levels with an accuracy of 74.27%. The main contributions of the research are: (1) knowledge about what detailed features may be predictive of cognitive load changes; (2) demonstrating the potential of using the HFI features in discriminating different cognitive load when suitable classifier and features are adopted.*

### INTRODUCTION

Cognitive load refers to the amount of mental effort required to process a given amount of information and has been associated with the limited capacity of working memory (Jimison, Pavel, McKanna, & Pavel, 2004; Plass, Moreno, & Brünken, 2010). In many complex systems (e.g. air traffic control, crisis management, military command and control, massively multiplayer role playing games), a competition for

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the users' attention is going on between many different information items, possibly leading to cognitive overload. This overload originates in the limitations of human attention and constitutes a well-known bottleneck in human information processing (Arciszewski, De Greef, & Van Delft, 2009; Tan, Meyers, & Czerwinski, 2004). For example, whilst playing massively multiplayer role playing games (MMORPGs), players tend to experience cognitive overload because they must learn to deal with the social dynamics around the game in addition to having to interact with the virtual space and game objects (Ang, Zaphiris, & Mahmood, 2007). Prolonged periods of low activity (i.e., underload), on the other hand, also lead to performance degradations because users tend to get out of the information processing loop as they become a passive monitor (Arciszewski et al., 2009; Eirinaki & Vazirgiannis, 2007).

Adaptive systems (e.g. (Coleman & Parker, 1996; de Tjerck, Henryk, & Neerincx, 2010; G. F. Wilson & Russell, 2003)) have been proposed as one of effective solutions to keeping the human within a bandwidth of cognitive load for optimum performance (Arciszewski et al., 2009), and the nature of adaptation is to provide the best match between task demands and cognitive resources of the human (Badros, Nichols, & Borning, 2000; Parasuraman, Mouloua, & Molloy, 1996). Many studies have shown that adaptive systems can enhance performance (Badros et al., 2000; Beaudouin-Lafon, 2001), reduce workload (Funke, Neal, & Paul, 1993; Misue, Eades, Lai, & Sugiyama, 1995), and improve situation awareness (Purchase, Hoggan, & Görg, 2007). However, trigger strategy is still one of the challenging factors in developing successful adaptive systems (Tan et al., 2004) (Rowe, Sibert, & Irwin, 1998), since there still lack effective evaluation methods for cognitive load and a clear understanding of cognitive load. The last decade has witnessed a growing interest in evaluating and understanding users' cognitive load (D.R. Hutchings & Stasko, 2002; Dugald Ralph Hutchings & Stasko, 2004; Lin, Imamiya, & Mao, 2008; Sweeney, Maguire, & Shackel, 1993; Tan et al., 2004; G. M. Wilson & Angela Sasse, 2004). For example, Neerincx (D.R. Hutchings & Stasko, 2002) presented a cognitive task load (CTL) model with the aim of exploring load factors. The CTL model is comprised of three load factors (percentage time occupied, the level of information processing, and task-set switching) and the three factors constitute a three-dimensional space in which all human activities can be projected as a combined factor (i.e., it displays the workload due to all activities combined). Recent several studies have also highlighted the necessity of managing and evaluating cognitive load educational game environments (Kalyuga & Plass, 2009), explored different types of cognitive overload in MMORPGs and presented strategies to overcome them (Ang et al., 2007). Several traditional methods have been adopted, with some success for evaluating cognitive load (Kramer, 1991; F. Paas, Tuovinen, Tabbers, & Van Gerven, 2003), including physiological, subjective (self-report) (F. G. W. C. Paas & Van Merriënboer, 1994) and performance measures (Jameson et al., 2009). The three measures have their own advantages and disadvantages (see section 2 for details) and the current challenge in cognitive load evaluation mainly lies in how to develop a method which can not only unobtrusively gather data without supplement equipment but also objectively, quantitatively and real-time evaluate cognitive load based the data. Also, the method should be suitable for deployment in real-life scenarios.

The potential of behavioral features (e.g. speech features (Ruiz, Taib, & Chen, 2011; Bo Yin, Ruiz, Chen, & Khawaja, 2007), linguistic features (Khawaja, Chen, Owen, & Hickey, 2009), and pen stroke features (Ruiz, Feng, Taib, Handke, & Chen, 2010; Ruiz et al., 2011; Ruiz, Taib, Shi, Choi, & Chen, 2007)) to assessment cognitive load has recently been exploited. Using features from high-frequency interaction (HFI) events to evaluate cognitive load is of main interest in our study, since they offer a convenient way to implicitly capture changes in interaction behavior without affecting task completion. Interaction events are classified as low-, mid-, or high-frequency (Martínez & Yannakakis, 2010; Quinlan,

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