Tailoring Practice for Individualized Learning via Cognitive State

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Introduction
Regardless of whether instruction is delivered explicitly or learning is expected to emerge from discovery, a key component of future computer-based learning environments will be simulacrums of the performance environment that enable practice of the concepts and skills that are the subject of training. These practice environments offer the student rich environments for developing their knowledge and skill. However, an open question is how to structure training experiences in these environments so that proficiency goals are met and the student remains engaged in the learning process [1]. Although theoretical debate continues, emerging consensus assumes that dynamic adaptation of the practice to enable targeted, individualized experience will be critical in delivering computer-based training that more closely approximates the best human instruction [2].

The goal of dynamically tailoring learning is not novel, but its effectiveness has been limited by the sparse information a training system gets about the student’s actual learning progress and attitude toward it. This
limitation is especially acute in training domains with narrative content, which are typically more open-ended and ill-defined than the classic mathematics and physics ITS domains. Narrative domains often include other actors, such as virtual or non-player characters (NPCs), which further increase the complexity of tailoring requirements.

Given these constraints, we take the position that narrative, tailored practice environments require transparent, non-invasive techniques for capturing a student’s cognitive state. Cognitive-state assessments have the potential to enable training systems to better diagnosis student errors and assess progress and also to enable adaptations that seek to engage and motivate the learner. We outline our rationale for the criticality of cognitive-state assessment in future practice environments and define some specific examples of ways in which cognitive-state assessments can be used for individualizing practice, based on our current work.

**Cognitive State for Tailoring Practice**

Good one-on-one instruction is effective because it addresses two important factors: 1) a good teacher will tailor instruction and feedback to a student’s specific level of mastery and learning needs and 2) interpersonal interactions can enhance motivation thru rapport and a shared sense of achievement. Although sophisticated methods have been developed to deliver instruction and model and monitor student progress [3], attempting to characterize and computationally simulate the motivational aspects of teaching are only recently being explored [4, 5].

Rather than attempt to reproduce the social connection between instructor and student, we are exploring the use of sensors that can provide real-time correlates of a student’s cognitive state to then tailor practice based on this richer understanding of the student’s learning context. Sensors and signal-processing methods are available that can be used to sense workload, learning affect, attention, and other relevant factors. Emerging technologies (such as EDR, ECG, EEG, fNIR, camera-based facial expression and gesture recognition, body movement sensors, etc.) can provide dynamic correlates of the neurophysiological state of the learner. These sensors can thus be employed to enhance the diagnostic capabilities of training systems. With better and more refined diagnoses, the practice experience can be tailored to individual learner differences and used to increase student motivation. This approach “short circuits” the detection of cues a human instructor picks up in interactions with students, making near-term use of adaptive methods focused on improving affect feasible today [5, 6].

**Adaptive Tailoring Strategies**

There are many reasons and mechanisms available for tailoring practice generally [7]. These manipulations can include scaffolding learning when the deficit is greater than can be met, and taking action to keep a student engaged and within the zone of proximal development for learning. We are exploring the use of cognitive-state assessment to tailor practice across all of these different dimensions, focusing primarily on identifying and evaluating adaptations enabled by the availability of cognitive state.

On-going work is situated in practice environments that facilitate development of interpersonal communication skills, especially intercultural competence. These domains are ill-defined, have narrative arc, and require interaction with virtual characters. To highlight the role of cognitive-state assessment in these practice
environments, we outline several use cases that illustrate how cognitive state assessments can enable improved diagnosis of student behavior and, as a consequence, more appropriate, timely, and individualized adaptations based on the diagnoses.

**Engagement tailoring:** Via cognitive-state assessment the system observes that the student’s arousal level has steadily decreased coupled by low cognitive load. The monitoring system concludes from these observations that the student is not engaged in the practice. In this situation, traditional remediation strategies, such as making instructional material available, are not likely to be helpful. Instead, the tailoring system directs the student’s conversation partner (an NPC) to be insulted and point out that the student is not being polite and not engaged in their conversation. This verbal scolding provides negative feedback and is contextualized by its utterance by the NPC. The system has responded to a student who superficially appeared to be using the practice environment appropriately but who is not correctly behaving how a person actually should (i.e. paying attention) when in a similar real life situation. This engagement tailoring can be combined with models of student proficiency to customize the response further as well (e.g., more negative consequence for students with greater proficiency).

**Reducing gaming:** Because every practice environment is a simplified simulation of the real-world performance context, students will sometimes take advantage of these simplifications to “game” the learning experience. Gaming is unavoidable, but becomes problematic when the focus of student learning becomes fixated on elements of practice that will not transfer to the performance setting. As an example, the conversational training testbed is a turned-based system and the character determines its reaction based only on the current exchange. This greatly simplifies the character modeling requirements but clever students may discover that they can repeat actions or utterances to which the character responded positively. For example, if a character was known to have an affinity for soccer, bringing up a mutual interest in soccer is a good thing for the student to do and the character reacts positively. Gaming occurs when the student brings up soccer repeatedly, to which the character continues to react positively. The student in this case is not engaged in the conversation but, unlike the prior example, is engaged in her actions.

Cognitive state measures can be used to recognize a pattern of arousal, load, and affect not matching the expected pattern for a student engaged in the intended learning experience. When the student is recognized to be in a different mental context than the one appropriate for learning, the system can address this condition with adaptations focused on gaming. One example is to have a virtual tutor interrupt the character conversation and ask a question about the student current goals. The answer may help the system understand what the student is doing. More importantly, the interruption makes the student aware of being monitored and helps reorient the student mentally back to the appropriate learning context. Such reorientation is an important strategy in human instruction [4]. This style of intervention could not be activated from observing the clickstream alone, because the student was executing valid game actions.

**Eliciting student emotion:** One component of conversational skill development is learning how to manage situations with intense emotional content, such
as confrontation. In these cases, the student may get frustrated or aroused, but still have to maintain composure and make good decisions. One of the goals of a practice environment should be to elicit an analogous emotional response from the student, which is important for transfer of the skill. For example, a student can be interacting with an NPC and the NPC becomes agitated and starts verbally attacking the student (insults, invective, etc.). The goal of the system is to get the student into a highly aroused state, to test their ability to make a good decision, but also to match the level of arousal to the student’s capacity to handle it. If the system notices that a student is not responding (arousal remains low), the insults can increase (e.g. becoming physically threatening) until the student’s arousal increases sufficiently. If the student never becomes sufficiently aroused, then the lack of response will serve as a good diagnostic and can be discussed in an after action review. If the student does respond to the mediation, then the system has validated that they have been tested in a stressful situation, which could not be done without having a clear measure of how stressed / aroused each individual student gets. When coupled with cognitive states inputs corresponding to basic emotions [8], this kind of adaptation can also be used to recognize gaming behavior, as above.

Conclusions
We are presently developing functional demonstrations of these adaptation strategies. For example, we have implemented a prototype of engagement tailoring within a conversation-training testbed, using a, commercially available, simple EEG sensor to gauge rough measures of arousal. In general, the use of cognitive-state assessment appears to be both feasible and effective, although additional research and evaluation challenges remain to be met.

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Citations