The Interplay between Affect and Engagement in Classrooms Using AIED Software

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Abstract. Affect has been hypothesized to play a significant role in triggering engagement/disengagement during learning. In this paper, we study the inter-relationships between students' affect (boredom, confusion, frustration, engaged concentration) and their engaged and disengaged behaviors (off-task, on-task solitary, on-task conversation, gaming the system). We study these relationships in the context of four different software programs, involving students of different ages, in order to increase confidence in the generalizability of the findings. Understanding these relationships might assist in maintaining students' engagement over time.

Keywords: Affect, disengagement, quantitative field observations

1 Introduction

Disengaged behaviors have been shown to lead to poorer learning outcomes in both computer-based learning and traditional curricula. Recent research has suggested that affect - emotion experienced in context – can contribute to student disengagement [1-2]. In this paper, we study these relationships in the context of four different learning systems, used by four different populations; the systems are all being used as part of routine instruction. By studying this relationship across multiple data sets, a more nuanced understanding of affect-engagement patterns during routine learning may be achieved, potentially contributing to the improvement of both theoretical knowledge and practical applications.

2 Measuring Disengagement and Affect during Learning

Engagement and disengagement are challenging to measure. We followed the paradigm of studying specific behaviors which are indicative of engagement or disengagement, and which are associated with differences in students‘ learning outcomes: a) **Off-task** behavior, where a student disengages from the learning task; b) **On-task solitary work** within the learning system; c) **On-task conversation**, where the student talks to an instructor or peer about the educational software or its domain, rather than interacting solely with the educational software; and d) **Gaming the system**, where students engage in behaviors such as systematic guessing or help requests in order to obtain answers without thinking through the learning material.

The four affective states studied in this paper are known to be common during learning, and have been demonstrated or hypothesized to have strong links to learning: a) **Boredom**, **Confusion**, c) **Frustration**, and d) **Engaged concentration**, the affective state associated with Csikszentmihalyi's construct of flow [3].

We study the fine-grained temporal relationships between affect and disengagement using quantitative field observations (QFO) of student affect and disengaged behaviors conducted by trained field coders who observe students‘ interaction with the educational software [cf. 1]. The same protocol as in [1] was used; the observers based their judgment on the student's work context, actions, utterances, facial expressions, body language, and interactions with teachers or fellow students.

3 Data Sets, Likelihood of Transitions, Co-occurrences

To increase the generalizability of our results, we studied these issues within four learning enviroments (*The Chemistry Virtual Laboratory*, *Cognitive Tutor Algebra*, *Cognitive Tutor Geometry*, and *ASSISTments*) that differ by populaion (middle school to undergraduates), region (rural and urban Pennsylvania, urban Massachusetts), learning topic (Chemistry, Mathematics), and learning software design (simulation-based virtual laboratory, intelligent tutoring systems). Students were observed during natural use of these systems, in the schools' computer labs, classes lasted 45-60 minutes. Overall, 518 students were observed in 58 class sessions.

D'Mello's Likelihood (L) [1] was used to determine how likely a transition (or a co-occurrence) is to occur, from one base state to another. D'Mello's L can be a value between $-\infty$ and 1. We calculate L values at the student-level for each transition/co-occurrence and each learning environment. We can determine if a given transition is significantly more/less likely than chance (i.e., above/below 0), using the two-tailed t-test for one sample. Significance for a given transition/co-occurrence can be calculated across learning environments using Stouffer's Z. As a substantial number of statistical analyses are made, we adjust for potential Type I errors using a False Discovery Rate (FDR) post-hoc correction, using the QVALUE software package within R. This procedure gives a q-value, which can be interpreted the same way as a p-value. All Z values reported below as significant had $q<0.05$; all values reported as marginal had $q<0.1$.

4 Results

Co-occurences of Behavior and Affect. Off-task was more likely than chance to co-occur with Boredom, across environments (Z=8.31) and in all but one system, Cognitive Tutor Geometry, a finding that replicated previous findings that used self-reported questionnaires [4]. Off-task was less likely than chance to co-occur with Engaged Concentration (Z= -11.01) and with Confusion (Z= -7.79) across environments, a finding that was true in each environment. Off-task was less likely than chance to co-occur with Frustration across environments (Z= -4.32) and in two systems (Cognitive Tutor Algebra, ASSISTments).

On-task was more likely than chance to co-occur with Engaged Concentration, across environments (Z=18.15) and in each system separately, in line with flow theory [3] Across systems, On-task was more likely than chance to co-occur with Confusion (Z=2.73) and Frustration (Z=3.18). Taken separately, these relationships were found only in ASSISTments. On-task was less likely than chance to co-occur with Boredom, across environments (Z= -5.16) and in two systems (Cognitive Tutor Algebra, ASSISTments).

On-task Conversation was more likely than chance to co-occur with Confusion, across environments (Z=4.63) and in two systems (Chemistry Virtual Lab and ASSISTments). It is possible that students seek on-task conversation to relieve their confusion, or alternatively, perhaps students become confused during on-task conversation, due to the cognitive disequilibrium arising from confronting different ideas. On-task Conversation was less likely than chance to co-occur with Boredom, across environments (Z= -4.04) and in two systems (Chemistry Virtual Lab, Cognitive Tutor Algebra).

Behavior to Affect Transition. Across environments, only two transitions were significantly different from chance: On-task behavior was somewhat surprisingly more likely than chance to be followed by Boredom (Z = 2.77) (taken separately, this finding was seen only in Cognitive Tutor Algebra), and less likely than chance to be followed by Engaged Concentration (Z = -3.30) (which holds also for two systems, Cognitive Tutor Geometry and ASSISTments). These findings might imply that it can be difficult to keep students attentive over significant periods of time, even when using advanced AIED systems. Two relationships were marginally significant across environments. The transition from Off-task to Bored was marginally less likely than chance (Z= -2.18), and the transition from On-task Conversation to Frustrated was marginally less likely than chance (Z = -2.07), which highlights the importance of on-topic social interactions with teacher/peers.

Affect to Behavior Transition. Only one transition was significant different from chance across environments (but not in any system separately): the transition from Frustration to On-task Conversation, which was less likely than chance to occur (Z = -2.28). Note that the converse relationship was also marginally significant, suggesting that frustration neither follows nor precedes on-task conversation.

5 Conclusions

Several interesting patterns emerge from this study. Across environments, off-task behavior was found to more likely than chance to co-occur with Boredom, and less likely than chance to co-occur with the other affective states. This may suggest that off-task behavior plays some positive role in regulating negative affect during learning, disrupting “vicious cycles” where a student who becomes bored is highly likely to remain bored.

On-task solitary behavior was associated with a greater degree of future boredom and less engaged concentration. This might be explained by confusion and frustration co-occurring more than chance with on-task solitary behavior. By contrast, frustration neither preceded nor followed on-task conversation. On-task conversation was also found more likely to co-occur with confusion and less likely to co-occur with boredom. These relationships confirm reports that episodes of on-task conversation are a normal and beneficial part of “individual” use of educational software.

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