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The Relationships Between Sequences of Affective States and Learner Achievement

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Abstract. We study the relationships between affective states and sequences and learner achievement using sequential pattern mining techniques. We found, in accordance with prior research, that boredom is an undesirable state that is both persistent and detrimental to learning. We also found that confusion punctuated with periods of engaged concentration contributes to learning. However, confusion alone has a negative impact on student achievement, possibly indicating that students are stuck. These results shed light on past results finding inconsistent relationships between confusion and learning.

Keywords: boredom, confusion, engaged concentration, student affect, affect sequences, student achievement, Scatterplot tutor

Introduction

Past studies that examine relationships between affective states and achievement typically consider these states in isolation [cf. 4, 8]. However, learners experience affective states seamlessly and successively, implying that studies of affect in learning can be enriched by including time in the analysis. Affective dynamics are the study of natural shifts in learners' affective states over time [7]. Studies regarding affective dynamics determine which affective states tend to persist and which transitions, given a start state, are most likely or unlikely to occur. The combination of these analyses has led to the discovery of "virtuous cycles" where learning-positive behaviours (such as engaged concentration [3]) persist and "vicious cycles", where learners remain in learning-negative behaviours such as frustration [9] and boredom [3]. As of the time of this writing, though, published studies have not yet shown relationships between affective dynamics and student achievement. Our goal is to determine which combinations of states are associated with poorer and better learning.

1. Methods

We studied 127 students from a large public school in Quezon City (a part of Metro Manila – the 5th largest city in the world), the Philippines. Student ages ranged from approximately 12 to 14. Students used a short Cognitive Tutor unit on scatterplot generation and interpretation [2], for 80 minutes. Sixty nine of the participants (experimental group) were randomly assigned to use the tutor with an embodied conversational agent, "Scooter the Tutor" designed by Baker, et al. [2]. The remaining 58 participants (control group) used the Scatterplot Tutor without the conversational agent. The number of students assigned to the conditions was unbalanced because of data gathering schedule disruptions caused by inclement weather.

A quantitative field observation method similar to the method used in [3, 11] was used to collect the affective states of the students by a team lead by the first author. Each participant was observed 24 times, with an interval of 180 seconds between observations lasting 20 seconds. Two coders observed the participants such that the participant would not know that he/she is the one being observed, in order to reduce the degree to which affect is altered by the observation process. The coding scheme included seven categories: boredom, confusion, delight, engaged concentration (a subset of flow [5]), frustration, surprise and neutral (for more details on these affective states, see [3, 11]). The observers' inter-rater reliability was found to be acceptable at κ=0.54.

We then generated three sets of affect sequences. The first set consisted of single affective states. The second set consisted of sequences of two consecutive affective states (2-step affective sequences). The third and final set consisted of sequences of three consecutive affective states (3-step affective sequences). We counted the number of occurrences of each state or sequence within each set, across all students regardless of condition. We selected the 4 most frequently occurring single affective states from and the 10 most frequently occurring sequences from the 2-step and 3-step affective sequences, as highly rare affective states would be difficult to achieve statistical power for. The remaining sequences in each group were summed under a catchall "Other" category. We then split the generated the incidences of each state or sequence for both the control and experimental groups.

2. Results

In order to determine whether the relationship between a sequence's frequency and learning was significantly different between conditions, we set up a linear regression predicting post-test from pre-test and the interaction between the frequency of the sequence in each student and the condition, and examined the statistical significance and additional r^2 of the interaction term. Positive beta in this context means that the experimental condition has a more positive relationship between the frequency of the sequence and learning than the control condition; negative beta means the opposite.

Among the single affective states of Set 1 (Table 1), we found that confusion and delight have negative impacts on the achievement of students in the control condition. Engaged concentration, on the other hand, has a positive impact on learning for students of both the control and experimental groups (Table 4). However, the only single affective state that was significantly different (or marginally so) was boredom, which was marginally significant, two-tailed $p=0.09$, additional $r^2 = 0.022$, with negative beta (e.g. the relationship is more negative in the experimental condition). This may imply that some boredom was disrupted by the agent, but that the remaining boredom was the most intransigent, durable boredom, and that this "super-boredom" is more strongly associated with poorer learning; there is some evidence for particularly persistent boredom impacting learning differently than less stable boredom [3], potentially according with this hypothesis.

Table 1. Set 1 relationships between affective states and achievement.

States	Control Group			Experimental Group		
	Additional r^2	p	Beta	Additional r^2	p	Beta
CON	0.06	0.043	-0.265	0.012	0.384	-0.108
ENG	0.143	0.001	0.413	0.06	0.043	0.245
BOR	0.014	0.329	-0.121	0.032	0.147	-0.177
DEL	0.053	0.058	-0.238	0.011	0.403	-0.104

Among the 2-step affective sequences (Table 2), engaged concentration (ENG-ENG) among students in the control condition or confusion coupled with engaged concentration (CON-ENG or ENG-CON) among students in the experimental condition have a positive impact on learning. Confusion alone (CON-CON) has a negative effect on learning among students in the control group. Among students in the experimental group, boredom followed by engaged concentration (BOR-ENG) was found to harm learning. Two affective sequences were found to be significantly different between conditions: BOR-ENG and NULL-ENG. BOR-ENG were associated with significantly better learning in the control condition, two-tailed $p<0.01$, additional $r^2 = 0.06$, with negative beta. One possible hypothesis is that the agent induced BOR-ENG transitions that nonetheless did not emerge from the same processes as “natural” (non-induced) BOR-ENG transitions, and therefore did not impact learning in the same way. NULL-ENG (e.g. ENG in the first observation) was also associated with significantly better learning in the control condition, two-tailed $p=0.02$, additional $r^2 = 0.039$, with negative beta.

Table 2. Set 2 relationships between affect sequences and achievement.

Sequences	Control Group			Experimental Group		
	Additional r^2	p	Beta	Additional r^2	p	Beta
CON-CON	0.065	0.035	-0.270	0.016	0.305	-.0127
ENG-ENG	0.152	0.001	0.428	0.024	0.207	0.154
CON-ENG	0.015	0.316	0.124	0.065	0.035	0.256
ENG-CON	0.013	0.350	0.115	0.084	0.016	0.290
BOR-BOR	0.013	0.344	-0.118	0.024	0.213	-0.152
NULL-CON	0.003	0.664	-0.058	0.004	0.611	-0.063
NULL-ENG	0.027	0.174	-0.182	0.051	0.063	-0.229
CON-BOR	0.007	0.483	-0.087	0.003	0.684	-0.050
BOR-CON	0.00	0.844	-0.024	0.105	0.007	-0.324
BOR-ENG	0.004	0.592	0.066	0.105	0.007	-0.324

Set 3 findings (Table 3) were similar overall, but some interesting findings about the relationships between engaged concentration, confusion, and learning emerged. Confusion alone (CON-CON-CON) was detrimental to the learning of the control group. Engaged concentration (ENG-ENG-ENG) was positive. Among both groups, some combinations of confusion and engaged concentration—CON-ENG-ENG and ENG-CON-ENG in both groups, ENG-ENG-CON in the control group, and CON-ENG-CON in the experimental group—had positive effects on learning. In particular, the relationship between CON-ENG-CON and learning remained statistically significant in the experimental condition even when the frequency of engaged concentration itself was controlled for, $p=0.05$. This result suggests that confusion interspersed with occasional engaged concentration may be particularly felicitous for learning.

Table 3. Set 3 relationships between affect sequences and learning.

Sequences	Control Group			Experimental Group		
	Additional R^2	P	Beta	Additional R^2	p	Beta
CON-CON-CON	0.065	0.036	-0.265	0.018	0.277	-0.135
ENG-ENG-ENG	0.128	0.001	0.430	0.012	0.378	0.108
CON-CON-ENG	0.002	0.694	-0.050	0.024	0.212	0.153
ENG-CON-CON	0.001	0.799	-0.032	0.024	0.210	0.153
CON-ENG-ENG	0.078	0.020	0.280	0.066	0.034	0.256
ENG-ENG-CON	0.070	0.028	0.266	0.004	0.634	0.060
CON-ENG-CON	0.007	0.486	-0.087	0.112	0.005	0.334
ENG-CON-ENG	0.049	0.069	0.223	0.046	0.079	0.214
BOR-BOR-BOR	0.016	0.302	-0.128	0.015	0.320	-0.122
NULL-CON-CON	0.012	0.370	-0.117	0.00	0.957	-0.007

3. Discussion and Conclusion

Many of the findings of this study are consistent with findings from previous work. Boredom, for example, is a decidedly undesirable state. It tends to persist: A student who is bored will tend to remain bored [3]. It tends to co-occur and precede gaming the system [11], which is known to have a negative impact on student achievement [1]. This study's findings were not inconsistent with the prior finding that boredom has a detrimental effect on learning, but in this study this relationship was not significant.

Confusion, on the other hand, may affect learning positively or negatively. It occurs when a student encounters an anomaly or an impasse, at which time one of two things can occur: The student can think, deliberate, reflect and eventually resolve the problem, alleviating the confusion and returning to an engaged state (productive confusion) or the student can become stuck (hopeless confusion) [6]. Craig et al [4] found that productive confusion predicts achievement among students using AutoTutor. In our study, we found that confusion punctuated with periods of engaged concentration can contribute to learning. We equate this with D'Mello and Graesser's productive confusion. Persistent confusion, on the other hand, which may indicate "hopeless" or at least "unresolved" confusion, undercuts student achievement.

In previous work on the same dataset, we examined the likelihood that one affective state would succeed another [10]. We found that, of the 2-step affective sequences that have an effect on learning, CON-CON and ENG-ENG are likely to occur [11]. ENG-CON and CON-ENG are not likely to occur. These findings coupled with the results of this study imply that, although confusion is not inherently harmful for learning, the CON-CON transition is not desirable and should be disrupted. The ENG-ENG, ENG-CON, and CON-ENG transitions can help learning and should be fostered to the extent possible.

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