STOIC BEHAVIOR HYPOTHESIS IN HINT SEEKING AND DEVELOPMENT OF REVERSI LEARNING ENVIRONMENT AS WORK BENCH FOR INVESTIGATION

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ABSTRACT

Tutoring systems provide students with various types of on-demand and context-sensitive hints. Students are required to consciously adapt their help-seeking behavior, proactively seek help in some situations, and solve problems independently without supports in other situations. We define the latter behavior as stoic behavior in hint seeking. In this paper, we propose the "Stoic Behavior Hypothesis," which posits that withholding hints achieves large learning outcomes. We consider this hypothesis from four perspectives: assistance dilemma, cognitive disuse atrophy, cognitive load theory, and goal achievement theory. In the latter part, we propose an experimental environment for investigating the stoic behavior hypothesis.

KEYWORDS

Hint seeking, Stoic behavior, Assistance dilemma, Disuse atrophy, Cognitive load theory, Goal achievement theory.

1. INTRODUCTION

Interactivity has become a crucial element of intelligent tutoring systems (Shute, 2008). Tutoring systems provide students with various types of on-demand and context-sensitive hints. At any stage of their learning, students can request computer-based assistance or tackle the problem independently. The nature of students' help seeking is crucial in understanding their rational learning behavior. In deciding whether to accept or decline help, students must monitor their own cognitive states and regulate their own behavior. In this sense, help seeking is related to meta-cognitive activities.

Help seeking is generally considered to maximize learning gains, but rational help-seeking behavior might also promote the acquisition of meta-cognitive skills. Several researchers have already constructed learning environments that teach meta-cognitive activities through help-seeking behavior (Roll, et al., 2011). In the initial decade of cognitive tutor development, it was optimistically proposed that students recognize their assistance needs more accurately than tutoring systems. However, according to empirical studies on students' meta-cognitive capabilities, students are less sophisticated at evaluating their learning needs than originally thought. Indeed, numerous studies have shown that students frequently adopt irrational behaviors such as "hint abuse," in which they request more help than required (Aleven, et al., 2000). They often demanded maximum hints, that is, requested direct answers to solvable questions. The opposite case is "hint avoidance" in which students refuse help when genuinely needed (Aleven, et al., 2004).

In the early history of computer supported learning, rich and thorough assistance appeared to benefit learning progress. More recently, however, students have been required to control their help-seeking behavior, proactively seeking help when required, but declining help and solving problems independently when not required. We define the latter behavior as stoic behavior in hint seeking.

In this paper, we propose the "Stoic Behavior Hypothesis," which posits that withholding of hints greatly facilitates learning in certain cases. We view the hypothesis from four perspectives: assistance dilemma, cognitive disuse atrophy, cognitive load theory, and goal achievement theory. The latter part of the paper proposes an experimental environment for investigating the stoic behavior hypothesis.

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2. FOUR PERSPECTIVES

2.1 Assistance Dilemma Perspective

The assistance dilemma issue is a critical consideration in computer learning support. Koedinger and Aleven (2007) posed a crucial question: how should learning environments balance assistance and withholding in order to optimize the learning process? While high assistance provides useful scaffolding that sometimes facilitates learning, it also elicits superficial responses without consideration. On the other hand, low assistance encourages self-learning in students, but may introduce enormous errors and sometimes impedes effective learning. To solve this dilemma, the support levels in tutoring systems must be adaptively controlled. The assistance dilemma is regarded as a primary problem in recent intelligent tutoring systems with high interactivity.

Much of help information promotes students' problem solving in the learning phase by reducing errors and preventing time-consuming trial and error behavior. However, such high assistance does not necessarily correlate with high learning gains. This discrepancy may result from the duality of cognitive processing, i.e., task performance and learning require different cognitive activities (Sweller, 1988). According to the assistance dilemma perspective, reduced assistance promotes learning under certain circumstances. Stoic behavior is expected to increase learning effects, even while incurring a partial loss of problem solving performance.

2.2 Cognitive Disuse Atrophy Perspective

The stoic behavior hypothesis was also motivated by human factor studies on automated systems. Automated systems are valuable supplements that greatly enhance human abilities in a range of working environments (Parasuraman & Riley, 1997). However, the convenience of such systems has negatively impacted some aspects of human society. A majority of people may already be experiencing the effects of these technologies. For example, daily usage of car navigation systems and word processers with spell check software remove the need to memorize maps and word spellings, respectively. Consequently, these everyday skills may be lost. Human factor studies have reported that the continuous use of automated systems decreases users' manipulation abilities (Sarter & Woods, 200). More seriously, complacency induced by automated device use has caused aircraft accidents (Wiener & Curry, 1980).

Miwa and Terai have proposed a concept called cognitive disuse atrophy to describe the loss of cognitive ability by lack of use (Miwa & Terai, 2014). The term "disuse atrophy" is generally applied to physical body atrophy, such as muscle wasting. Muscles that are no longer used slowly weaken. The body can also become weakened by continuous physical support that minimizes its use. We extend the bodily concept of disuse atrophy to cognitive abilities. Automated systems provide extremely high levels of support during problem solving tasks. Cognitive disuse atrophy occurs when performance skills and knowledge are diminished or lost under such assistance, even when a task is performed well. Maintaining control and providing less excessive help may be important for skill acquisition and learning knowledge, implying the validity of stoic behavior in hint seeking.

2.3 Cognitive Load Theory Perspective

Cognitive load theory has provided informative perspectives for designing learning environments constrained by cognitive architecture (Sweller, 1988). The cognitive load theory distinguishes three types of cognitive loads: intrinsic, extraneous, and germane (Sweller, van Merrienboer, & Paas, 1998). The intrinsic load is the basic cognitive load required to perform a task. The intrinsic load increases with increasing difficulty of a task and decreasing expertise of the performer. The extraneous load is the wasted cognitive load that is unrelated to learning activities, and is reluctantly processed. One source of extraneous load is inappropriately designed learning material. Extraneous load can also be increased by lack of related knowledge and problem solving skills. Finally, the germane load is the cognitive load for learning, such as constructing schemata.

Large assistance decreases the extraneous load by presenting related information for problem solving. Many design principles for reducing the extraneous load have been proposed. However, it should be noted that decreasing the extraneous load by providing high-level assistance does not necessarily increase the germane load, because the learning is reduced with superficial problem solving without deliberate thinking. The germane load is presumably increased by the so-called variability effect, a principle by which learners investigate a single topic with multiple representations and under various contexts. The low assistance imposed by stoic behavior may guide students toward reflective thinking and deeper consideration, activating their cognitive efforts in generalizing knowledge and developing schema, thereby increasing their germane load (Paas & van Gog, 2006; Ayres & van Gog, 2009).

2.4 Goal Achievement Theory Perspective

Another theory relevant to the stoic behavior hypothesis is the goal achievement theory (Elliot & Dweck, 1988). This theory has provided theoretical perspectives on the relationships between students' goals and their learning activities. It has also accumulated a vast amount of empirical findings. In goal achievement theory, student goals are divided into mastery and performance goals. The former motivates students to develop their own abilities, whereas the latter motivates them to seek higher social evaluation rather than their own development. In the early stages of goal achievement theory, the mastery goal was found to be superior to the performance goal (Utman, 1997). When learners set up the mastery goal, they become challenged and exhibit higher independence in task performance. Meanwhile, if learners set up the performance goal, they tend not to challenge them to new missions, and abandon tasks when faced with difficult requirements despite being relatively proactive when receiving high evaluation.

The relationship between students' goals and their help-seeking behavior was investigated in a recent study. According to this study, mastery-goal-oriented students tend to seek abstract (i.e., low level) hints first, and then move to more specific (i.e., high level) hints, whereas performance-goal-oriented students consult quick and direct help during the initial stage (Vaessen, Prins, & Jeuring, 2014). This implies that mastery-oriented-students who prefer learning to performing adopt a stoic approach to help seeking, again supporting the stoic behavior hypothesis.

3. REVERSI LEARNING ENVIRONMENT AS WORK BENCH

We are developing a Reversi-based learning environment as a workbench for investigating the stoic behavior hypothesis.

In our learning environment, a participant plays 8 by 8 Reversi games against an opponent computer agent. A partner agent assists the participant in selecting winning moves. Both agents are equipped with a Reversi engine, Edax, that suggests the best move by assessing future states in the game. The partner agent recommends candidate moves among valid squares before the participant makes a move. The competence of each agent is controllable by setting the maximum depth to which Edax searches the future game states. The Edax-incorporated agents are exceptionally competent Reversi players that cannot be defeated by human participants. To lower the strength of the opponent agent to a level compatible with human participants, the agents are set to randomly miss the best move four times in each of the initial, middle, and final stages. Support levels from the partner agent were controlled by presenting the candidate with the best, two, three, or four moves.

To predict the degree of winning by human participants in this environment, we conducted preliminary simulations. The simulated participant randomly selected one of the candidate moves. In the no-support condition, it randomly selected one of the possible moves.

Figure 1 shows the ratio of wins of the simulated participant against the opponent agent in 20 simulated games. The figure implies that the winning ratio of human novices increases as the support level increases. However, the stoic behavior hypothesis predicts that consistently presenting the best move to participants would inhibit their skill mastery compared to mid-range support such as the best two or three moves.

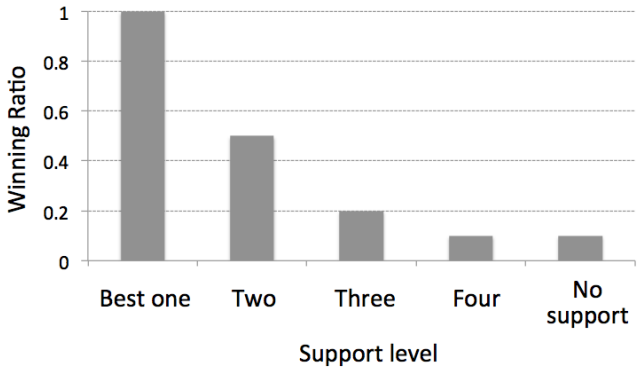

Figure 1. The winning ratio of the simulated participant as a function of support level in 20 preliminary simulations of a Reversi game.

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