Mind Wandering during Learning with an Intelligent Tutoring System

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Abstract. Mind wandering (zoning out) can be detrimental to learning outcomes in a host of educational activities, from reading to watching video lectures, yet it has received little attention in the field of intelligent tutoring systems (ITS). In the current study, participants self-reported mind wandering during a learning session with Guru, a dialogue-based ITS for biology. On average, participants interacted with Guru for 22 minutes and reported an average of 11.5 instances of mind wandering, or one instance every two minutes. The frequency of mind wandering was compared across five different phases of Guru (Common-Ground-Building Instruction, Intermittent Summary, Concept Map, Scaffolded Dialogue, and Cloze task), each requiring different learning strategies. The rate of mind wandering per minute was highest during the Common-Ground-Building Instruction and Scaffolded Dialogue phases of Guru. Importantly, there was significant negative correlation between mind wandering and learning, highlighting the need to address this phenomena during learning with ITSs.

Keywords: mind wandering, intelligent tutoring, engagement, attention

1 Introduction

Students do not always pay attention during learning. To make matters worse, it can be quite difficult to distinguish students who are concentrating intently from those who have completely zoned out [1]. Indeed, the phenomenon of zoning out might go particularly unnoticed in intelligent tutoring systems (ITS) and other advanced learning technologies that do not monitor lapses in attention. To date, many ITSs have focused on modeling a host of motivational and affective states, including types of engagement and disengagement (e.g., gaming the system, off-task behaviors) [2–5]. However, very little research has been done to uncover students' moment-to-moment level of attention, or lack thereof, a proposition we address in the current study.

adfa, p. 1, 2011.

Mind wandering is defined as an *involuntary* lapse in attention from task-related thoughts to internal task-unrelated thoughts [6]. Mind wandering is related to other "off-task" states, such as boredom, behavioral disengagement, and distractions [2, 7, 8], but is inherently distinct in that it is largely involuntary and that attention is directed towards internal self-generated thoughts that are unrelated to learning. Thus, mind wandering can be considered to be a form of attentional disengagement.

Emerging research suggests mind wandering occurs frequently during learning activities (see [9] for a review). For example, mind wandering occurs anywhere from 20-40% during reading and about 40% while viewing online lectures [1, 9, 10]. Mind wandering can also have negative consequences on learning [9, 10]. For example, information missed during episodes of mind wandering is not properly integrated into students' overall mental representations of a concept. Gaps in mental representations thus hinder the ability to make inferences and understand subsequent information that builds on earlier facts/concepts. For example, if a student is mind wandering when learning concepts such as, "folded chains of amino acids are proteins" or "enzymes are proteins" they might not be able to make the inference that "enzymes are folded chains of amino acids." To date, much of the research on mind wandering during learning has focused on non-interactive learning contexts, such as reading or lecture viewing. An open question pertains to the frequency of mind wandering when learning from more engaging technologies (ITSs, educational games) and whether mind wandering correlates with learning in these contexts? In this paper, we study mind wandering during interactions with an ITS.

In addition to studying overall rates of mind wandering, we are also interested in comparing mind wandering across the different types of ITS interactions. Some ITSs combine multiple teaching strategies, including modeling problems, scaffolding, quizzing, and so on. These strategies are inherently different from each other, involving different levels of overt student behavior. It is therefore possible that mind wandering will vary across the different types of activities in a single ITS. According to the Interactive-Constructive-Active-Passive (ICAP) hypothesis [11, 12], task types can be rank-ordered in terms of interactivity and effectiveness for learning (Interactive ≥ Constructive ≥ Active ≥ Passive). Whereas *passive* learning does not involve any overt behaviors (e.g., listening), *active* learning includes activities such as taking verbatim notes or reading. *Constructive* activities include summarizing, adding, and organizing ideas, while *interactive* activities include co-constructive learning situations that include dialogue.

An expansion of the ICAP hypotheses (called the ICAP-A or ICAP-Attention) predicts that mind wandering will follow the same pattern ($I \leq C \leq A \leq P$) based on the type of learning activity [13]. The ICAP-A hypothesis is based on theories of mind wandering that suggest that mind wandering occurs when the executive control system fails to suppress off-task thoughts when the appropriate level of goal construal (e.g., relevance) is not maintained [14]. Goal construal is more likely to be maintained during interactive and constructive learning activities (versus passive), thus facilitating attentional focus. In their review and re-analysis of the literature, student mind wandering indeed shifted as a function of the ICAP category [13]. This analysis included an array of learning activities, such as note-taking, video lectures, reading, and self-explanations [1, 15–18]. Although the ICAP-A hypothesis would posit that mind wandering might be deterred while using intelligent learning technologies, their analyses did not include any learning technologies, a proposition we consider in the current research. Using ICAP-A as our model, we investigate overall rates of mind wandering, as well as mind wandering rates during different ICAP activity types within a single ITS.

In addition to activity type, ICAP-A posits mind wandering is also influenced by top down influences. Therefore, it is possible that students’ prior knowledge and topic interest might also affect attention during learning with an ITS [18, 19]. Low prior knowledge or low interest may be related to less concrete goal structures during learning, and likely more mind wandering since off-task thoughts have been linked to less concrete goals [14] However, it is also possible the increased level of interactivity afforded by an ITS will promote concrete goals, thus minimizing the importance of top down influences.

We attempt to address a gap in the literature by investigating mind wandering in the context of learning with an ITS for the first time. In the current study, students interacted with GuruTutor, a dialogue-based ITS that contains a broad range of ICAP task types at different phases of the system (discussed in detail below). Four research questions will be addressed based on student interactions with GuruTutor: (1) How often does mind wandering occur during learning? (2) How does mind wandering vary across different phases in the tutoring session that differ in interactivity? (3) How does mind wandering relate to learning in GuruTutor? (4) To what extent do trait level factors, such as interest and prior knowledge, relate to mind wandering?

2 Description of GuruTutor

Participants interacted with an ITS called GuruTutor in the current study. GuruTutor is modeled after expert-human tutors and is designed to teach students biology topics through collaborative conversations in natural language. In GuruTutor, an animated tutor agent engages the student in a natural-language conversation that references (with gestures) a multimedia workspace displaying and animating content that is relevant to the conversation (see Figure 1). GuruTutor analyzes student responses (which are typed into open dialog boxes) via natural language understanding techniques and maintains a student model used for tailoring the session to individual student’s knowledge. For a more detailed description of GuruTutor, see [20, 21].

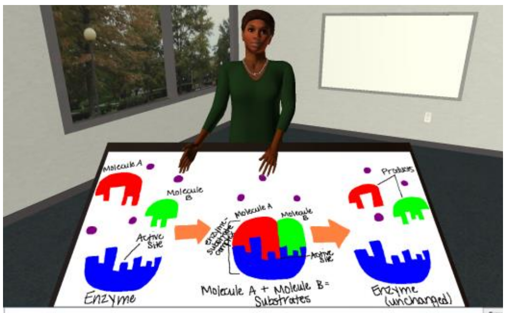

Figure 1. Example image from the *Common Ground Building* phase in GuruTutor

GuruTutor covers biology topics aligned with state curriculum standards, each taking 15 to 40 minutes to cover. Topics contain sets of interrelated concepts, e.g. *proteins help cells regulate functions*. GuruTutor attempts to get students to articulate each concept over a five phase session. GuruTutor begins with a brief preview making the topic concrete and relevant to the student before beginning the five phases. *Phase 1*: GuruTutor engages in a **Common-Ground-Building Instruction (CGB Instruction),** sometimes called collaborative lecture, where basic information and terminology is covered (this step is essential because biology involves considerable specialized terminology that needs to be discussed before more collaborative knowledge building activities can proceed). *Phase 2*: Students then generate natural-language **Intermittent Summaries (Summary)** of covered content, which are automatically analyzed to determine the concepts to target in the remainder of the session. *Phase 3*: For target concepts, students complete skeleton **Concept Maps** which are node-link structures that are automatically generated from concept text. *Phase 4*: Next students complete a **Scaffolded Dialogue**; GuruTutor uses a Prompt → Feedback → Verification Question → Feedback → Elaboration cycle to cover target concepts. A second Concept Mapping and Scaffolded Dialogue phase is initiated if students are having difficulty mastering particular concepts. *Phase 5*: A **Cloze** task requiring students to fill in an ideal summary by supplying key relations ends the tutorial session for a topic.

Importantly, GuruTutor is ideal for an investigation of mind wandering, as its five distinct phases vary in interactivity. In the context of GuruTutor, CGB Instruction is a combination of active and passive learning activity because it does not require constructive responses from the student other than responses to common ground questions (i.e., "do you understand") and forced-choice questions. Summary, Concept Map, and Cloze phases are all constructive activities, though perhaps not all equally constructive. For example, generating a summary is entirely constructive, whereas fill-in-blanks during the Cloze task are less constructive. Finally, Scaffolded Dialogue is only superficially interactive according to the requirements proposed by I-CAP. The tutor agent does not engage in co-construction by helping the student generate and revise answers, thus Scaffolded Dialogue is considered a combination of constructive, active, and passive (see [12] for an in-depth descriptions of the ICAP task types). The expected pattern of mind wandering in GuruTutor based on the ICAP-A hypothesis [13] is CGB Instruction > Scaffolded Dialogue > [Summary = Concept Map = Cloze Task].

3 Method

3.1 Participants and Design

Participants were 21 students from a Midwestern university in the U.S. Each participant received class credit for completing the study. The mean age was 20 years (*SD* = 1 year) and 85% were females. None of the participants were biology majors. Participants were randomly assigned to complete one of three biology topics in GuruTutor: biochemical catalysts, protein function, or carbohydrate function.

3.2 Materials and Procedure

Before interacting with GuruTutor, participants' interest in biology was measured with the following question: "How interested are you in learning about biology?" Participants responded by selecting a number on a 6-point scale between (1) *not at all interested* and (6) *very interested*.

Mind wandering was self-reported while students interacted with GuruTutor. Participants were given the following instructions regarding reporting mind wandering during GuruTutor: "Your primary task is to complete the learning session with GuruTutor in order to understand the biology topic." Participants were then explicitly instructed to report instances when they caught themselves mind wandering about anything unrelated to GuruTutor content. Thoughts generated from the content are not considered mind wandering. The following description of mind wandering, taken from previous studies [6, 22], was provided to the participants, "At some point during the tutoring session, you may realize that you have no idea what you just heard or saw. Not only were you not thinking about the topic, you were thinking about something else altogether." Participants indicated mind wandering by pressing a key labeled "ZONE OUT" on the keyboard. The instructions also emphasized that the participants should be as honest as possible when reporting mind wandering and that the results will have no influence on their performance or their progress in the study.

Participants completed a pretest in order to gauge prior knowledge on the assigned topic, followed by a self-paced learning session with GuruTutor, after which they answered a posttest. Pretest and posttest knowledge assessments were multiple choice tests consisting of at least 12 items, targeting shallow (factual knowledge) and deep knowledge (requiring inference). All questions were derived from either previously administered standardized tests or from the content of the CGB Instruction. Pre- and post-test questions were randomly selected by question type (shallow and deep) for each participant and the same question was never presented twice to the same student.

4 Results and Discussion

4.1 Overall Mind Wandering Rates

Mind wandering was reported a total of 363 times across the 21 participants while learning from GuruTutor. Analyses of mind wandering reports are limited to the five phases of GuruTutor where students are learning and do not include the time students spent on the pre and posttests. Two participants' volume of mind wandering reports as well as time spent in the learning session fell well outside the range of a normal distribution. The participants who reported 64 and 80 instances of mind wandering, greater than three standard deviations away from the mean, were removed from the analyses. Analyses proceeded with the remaining 19 participants who reported 219 instances of mind wandering.

On average, participants spent 22 minutes interacting with GuruTutor (not including the pre and posttests) and reported 11.5 (SD = 8.60) instances of mind wandering. We computed a mind wandering per minute (MW/Min) rate for each participant by dividing the total number of mind wandering reports by the number of minutes they interacted with GuruTutor. Participants reported mind wandering at a rate of .496 (*SD* = .310) reports per minute, or about one report every two minutes.

4.2 Mind Wandering Across Phases of GuruTutor

There were five phases of GuruTutor: lecture, summary, concept map, scaffolding, and cloze phase. A MW/Min rate was computed during each of the five phases for each participant. The CGB Instruction and Scaffolded Dialogue phases had the highest rates of mind wandering, while the cloze phase had the lowest (see Table 1 for descriptive statistics on mind wandering during each phase). In fact, over 90% of mind wandering reports occurred during the CGB Instruction and Scaffolded Dialogue phases combined.

A repeated measures ANOVA yielded significant differences in MW/Min rates based on phase, $F(4,68) = 7.67$, $p < .001$. The ANOVA included Phase was a within-subjects factor (5 levels) and biology topic was a between-subjects factor (3 levels) to address topic effects. There was no main effect of topic and no significant interaction between phase and topic so our discussion is limited to phase only.

Table 1. Means and standrad deviation (in parantheses) for mind wandering during each of the five phases in GuruTutor.

	MW Per Minute	**Avg. Prop. of MW Reports**	**Time Spent (Min)**
CGB Instruction	.748 (.512)	.494 (.277)	7.31 (2.34)
Summary	.123 (.318)	.017 (.045)	1.87 (.782)
Concept Map	.202 (.322)	.059 (.088)	4.34 (1.67)
Scaffolded Dialogue	.670 (.498)	.422 (.278)	6.26 (2.98)
Cloze	.039 (.119)	.008 (.024)	2.53 (1.24)
Overall	.496 (.310)	-	22.3 (6.71)

Notes. Avg. Prop. = average propotion of participants' mind wandering reports during each phase; MW = mind wandering

Pairwise comparisons were examined using a Bonferroni correction in order to account for multiple comparisons ($\alpha = .005$ or .05/10 since there were 10 comparisons). The pattern of results indicated that [Scaffolded Dialogue = CGB Instruction] > [Summary = Concept Map = Cloze]. This pattern partially confirmed predictions based on the ICAP-A hypothesis (predicted pattern: CGB Instruction > Scaffolded Dialogue > [Summary = Concept Map = Cloze Task]). Indeed, CBG Instruction, the most passive phase of GuruTutor, had significantly higher rates of mind wandering compared to each of the three constructive phases of GuruTutor (Concept Map, Cloze, Summary). The major inconsistency between the predicted pattern and observed results pertained to the rate of mind wandering during the Scaffolded Dialogue phase. Based on the ICAP-A hypothesis, Scaffolded Dialogue was predicted to have less mind wandering compared to CGB Instruction because of the constructive responses required by students and more evenly distributed dialogue turns between the tutor agent and student (6:1 dialogue turn ratio during the CBG and 3:1 during Scaffolded Dialogue) [12, 21]. However, rates of mind wandering in Scaffolded Dialogue were statistically equivalent to the rates during CGB Instruction phase of GuruTutor. This was unexpected based on the contrast in constructive elements between Scaffolded Dialogue and CGB Instruction phases. However, despite differences in the phases, Scaffolded Dialogue and CGB Instruction phases had similar rates of mind wandering, which were individually higher than all other phases combined.

4.3 Relationship between Mind Wandering and Learning

Participants' performance on the pretest and posttest were computed as the proportion of items answered correctly. A paired-samples t-test indicated that pretest (M = .651, SD = .147) and posttest scores (M = .826, SD = .147) were significantly different, $t(18) = 4.22$, $p < .001$, $d = 1.19$. Participants learned from interacting with GuruTutor, supporting findings from previous studies [21].

We correlated number of mind wandering reports with posttest scores. In order to account for prior knowledge and time, we computed partial correlations controlling for pretest performance and time spent in GuruTutor. Indeed, mind wandering was strongly and negatively related to learning, $r(15) = -.566$, $p = .018$. This finding replicates the negative relationship between mind wandering and performance across a range of learning activities [9, 10].

4.4 Individual Differences that Predict Mind Wandering

We also examined the relationship between mind wandering and two trait level factors: prior knowledge (pretest score) and interest. We correlated number of mind wandering reports with pretest score and participants' interest ratings taken before GuruTutor. Partial correlations were computed to control for time spent in GuruTutor. Although the correlations were not significant, mind wandering was correlated with both pretest ($r = -.233$, $p = .367$) as well as interest ($r = -.291$, $p = .257$) in the expected negative direction. It is also important to note that given this relatively small sample size, correlations with learning and trait level variables may be particularly sensitive to outliers and non-normal distributions. However, examinations of histograms and scatter plots alleviated these concerns.

5 General Discussion

Mind wandering is a ubiquitous phenomenon that is common during learning (e.g., during reading and online video lectures) and that is negatively related to learning outcomes [1, 9, 22, 23]. Given the paucity of research on mind wandering during interactive learning environments, the current study investigated mind wandering in the context of learning with an ITS for the first time.

Main Findings. In the present study, students reported mind wandering about once every two minutes while interacting with GuruTutor, a dialogue-based ITS modeled after expert human tutors [21]. This frequency of mind wandering, combined with the significant negative relationship with learning, highlights a concern for this phenomenon in the context of ITSs.

Results also suggest that mind wandering occurs at different rates depending on the type of learning activity (i.e. ICAP activity type). Based on the ICAP-A hypothesis, the following pattern was predicted for mind wandering in GuruTutor: CGB Instruction > Scaffolded Dialogue > [Summary = Concept Map = Cloze Task]. However, results indicated the Scaffolded Dialogue and CGB Instruction phases had similar rates of mind wandering, suggesting the constructive conversation in the Scaffolded Dialogue phase of GuruTutor did not deter mind wandering. One explanation for the deviation from the predicted pattern is that Scaffolded Dialogue and CGB Instruction were the longest phases in GuruTutor, and time on task has been correlated with mind wandering [24]. Additionally, participants were not exposed to Scaffolded Dialogue until about 9 minutes (SD = 3) into the session. The delayed onset in combination with the length of the phase (M = 6 min, SD = 3) may also have influenced participants' level of attention, as a previous study also found participants were more likely to report mind wandering during the second half of an online lecture [1].

Limitations. It is important to note the limitations of this study. For one, this was a lab study. Investigating mind wandering during learning with an ITS in more ecological settings, such as a classroom is an important next step. Second, this investigation was limited to a single ITS, so future work is needed to determine if mind wandering rates are comparable across ITSs. Another related limitation is that the order of phases in GuruTutor was constant across all participants. Therefore, differences in mind wandering based on phase should be interpreted with caution, due to issues such as carryover effects, time on task, and fatigue. Finally, analyses were limited to 19 participants, so replication with a larger sample is warranted.

Future Work. ITS research provides new ways of investigating levels of interactivity in relation to the ICAP/ICAP-A hypotheses, since we can precisely manipulate the qualities of the dialogue to bring it closer or further away from co-construction, while otherwise keeping it superficially interactive. For example, this could be done through modifications to GuruTutor through revising longer answers/summaries.

Additionally, future research may include other ways of measuring mind wandering. In the current study, mind wandering reports were collected using self-caught reports compared to responding to periodic thought probes during learning (e.g., Are you zoned out right now?). We chose the self-caught method of mind wandering for this initial investigation, as it is not limited by the placement of thought probes, thereby limiting the places and number of instances of mind wandering that can be recorded. However, this method only captures mind wandering reports that involved some level of metacognitive awareness. Thus future work should also investigate mind wandering in the context of learning with an ITS using other methods of to collect mind wandering reports, such as via thought-probes.

Future work should also consider behavioral/physiological indicators of mind wandering, via eye tracking or physiological measurements. Previous work has demonstrated success in predicting instances of mind wandering using eye tracking and peripheral physiology in the context of reading [25, 26]. Therefore, it is feasible that additional measures could aid in developing a more fine-grained models of mind wandering during learning with ITSs. Combining information about task factors (current phase) and trait-level factors (student interest) with physiological measures and eye tracking could be an initial step towards predicting when a learner begins to mind wander. Interventions may then be put into place to restore attentional focus to the learning task. This paper provides a foundation for this avenue of research by systematically studying mind wandering during learning with an ITS.

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