Attention in Educational Contexts: The Role of the Learning Task in Guiding Attention

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Abstract

Attention is crucial for effective learning. There is an emerging research trend that suggests attention can be improved by changing the structure of the learning task, leading to increased learning. This chapter reviews and reanalyzes studies of attention in educational settings with respect to the structure of the learning task. This analysis is then integrated with theoretical accounts of mind wandering, sequential action, and monitoring. The resulting elaborated theory of mind wandering explains how a learning task structure can enhance a student's level of attention within the learning task. Furthermore, it motivates a new hypothesis which could be used to suggest ways of changing task structure to optimize learning performance via improved attention.

1 Historical context

Attention is crucial for effective learning. Unfortunately, students do not always pay attention. Over the past century, educators and researchers have tried to maximize the time students pay attention, in various ways, in order to optimize learning (see Berliner, 1990 for a review). These efforts have largely focused on the construct *level of attention*. The level of a student's attention, sometimes referred

to as engagement[1], may be described as absent, passive, partial, or active (Currie, 1861). Efforts to measure student's level of attention in educational contexts has ranged from various types of probed self-report (e.g., mind wandering probes; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012), amount of note-taking (Scerbo et al., 1992), fidgeting (Farley, Risko & Kingstone, 2013), heart rate (Bligh, 2000), and more generally performance. Because a student's level of attention is not directly observable, direct observation can be misleading. For example, a student may have their gaze directed toward the teacher but in fact might be mind-wandering (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012).

Much work has demonstrated that level of attention is predictive of student achievement in authentic classroom environments (see Denham & Lieberman, 1980 for a review), and recent studies have confirmed these effects with increasing methodological precision. For example, inattention during reading and lectures in the form of mind wandering has been shown to be negatively associated with memory for the source material (Lindquist & McLean, 2011, Risko et al., 2012, Smallwood et al., 2008, Szpunar, Khan, & Schacter, 2013). One emerging finding in these more recent studies is that changing the task structure can improve student's level of attention, leading to increased learning (Szpunar et al., 2013). These results suggest that a deeper look at how task type might impact student attention is warranted. We attempt to provide such a perspective in the present chapter by unifying work on student attention with work on optimal learning activities (Chi, 2009; Menekse, Stump, Krause, & Chi, 2013).

Theories of optimal learning activities typically emphasize the role of task type and deemphasize the role of attention (Chi, 2009; Menekse, Stump, Krause, & Chi, 2013). For example, the Interactive-Constructive-Active-Passive (ICAP) hypothesis predicts that task type (as defined by overt behaviors) will largely determine learning outcomes and rank orders the effectiveness of these activities as $I \geq C \geq A \geq P$ (Chi, 2009). Examples of these activities include dialogue as part of a constructive activity (interactive), summarizing by adding new ideas or reorganizing old ideas (constructive), taking notes without adding new ideas or organization (active), and viewing a lecture or video with no other overt behavior (passive). In a reanalysis of 15 studies, Chi (2009) consistently found the $I \geq C \geq A \geq P$ pattern, and follow up studies in both controlled laboratory settings and classroom conditions provide additional evidence for ICAP (Menekse et al., 2013). Here we explore the idea that task structure can improve student's attention. Thus, the effect of task type on learning may be partially mediated by the influence of task type on attention.

The following sections review and reanalyze studies of attention in educational settings with respect to the task types in ICAP. This analysis is then integrated with theoretical accounts of mind wandering, sequential action, and monitoring. The resulting elaborated theory of mind wandering explains how a learning task structure can enhance a student's level of attention within the learning task. Furthermore, it motivates a new hypothesis we refer to as Interactive-Constructive-Active-Passive-Attention (ICAP-A), which predicts that attention level will follow the $I \geq C \geq A \geq P$ pattern. We also explore how ICAP-A could be used to suggest ways of changing task structure to optimize learning performance via improved attention.

2 State-of-the-art review

A growing body of work has investigated attention during lectures (Bunce et al., 2010; Lindquist & McLean, 2011; Risko et al., 2012; Szpunar et al., 2013; Young et al., 2009) and, critically for the present proposal, across different types of activities within lectures. These various studies provide an opportunity to investigate the relationship between the task structure, as defined by an ICAP learning activity, and student attention. In a recent classroom study of mind-wandering, Lindquist and McLean

1 Although attention and engagement are sometimes used synonymously, we consider engagement to be a multidimensional construct that includes both attention and affect (cf. D'Mello, 2013).

(2011) found evidence consistent with the idea that students who engaged in a more passive or active task during a lecture tend to mind wander more than students engaged in a more active or constructive task. At various times within a live, in-person lecture, students received a mind wandering probe. In addition, various measures of classroom activities and performance in the class was collected. Critically for the present purposes, the study found a significant negative association between mind-wandering and note-taking and between mind-wandering and exam grades. In other words, students who took more notes during the lecture mind wandered less than individuals who did not take notes. Within ICAP, the act of taking notes would have changed the task type from passive/active to active/constructive, depending on whether the notes were verbatim or elaborative in nature. Thus, the effect of note-taking can be interpreted as a shift in task type and the associated reduction in mind wandering evidence for the posited relation between the task type and student attention. While consistent with this hypothesis, it is important to note that the Lindquist and McLean (2011) research was correlational. Stronger evidence for a link between extent of note-taking and mind wandering would require an experimental design.

In a classroom study, Young et al. (2009) investigated student attention across four different lecture types/class activities using a measure of the vigilance decrement and found evidence consistent with the idea that more interactive activities could improve student attention. The vigilance decrement refers to performance costs in passive monitoring tasks (Mackworth, 1948) and are typically attributed to limits on human ability to attend for extended periods of time in those tasks. Risko et al. (2012) demonstrated the existence of a vigilance decrement in lectures using mind wandering as the measure. Young et al. (2009) used a measure of subjective workload (i.e., NASA-TLX) which previous research had demonstrated yields a "signature" pattern (i.e., relative high contribution of mental demand and frustration to overall perceived workload) associated with the vigilance decrement. Students, in an actual class, completed the NASA-TLX during four different types of lecture (1) standard lecture (2) guest lecture (3) lecture + small group discussion and (4) lecture + multimedia case studies. Critically, the "signature" of the vigilance decrement was (statistically) present only in the standard lecture. The absence of vigilance decrement in the guest lecture may be due to a novelty effect. In addition, while no formal statistical comparison was provided, Young et al.'s (2009) Table 1 suggests that the NASA-TLX pattern that least resembles the signature pattern occurred in the lecture + small group discussion condition – a condition that might be considered interactive in ICAP. Thus, Young et al.'s (2009) data support the hypothesized relation between task type and student attention.

Evidence that constructive activities included in lectures increases student attention was reported by Bunce et al. (2010) in a study investigating self-reported attention lapses across three chemistry classes over 6 weeks. Critically, Bunce et al. (2010) included both self-reported measures of attention lapses during the constructive activities and also during the non-constructive parts of lectures that were preceded by constructive activities, thus allowing an assessment of potential "carryover" of the attentional benefits of constructive activties. Using individual response devices ("clickers") to indicate when their attention had lapsed, the frequency of lapses was assessed during periods of standard lecturing and two other activities – questions answered by clicker (constructive) and demonstrations (passive/active). Bunce et al. (2010) found a reduced number of attention lapses during both clicker question periods and demonstrations relative to standard lecture periods. Thus, again, the constructive task was associated with greater attention than a more passive task. Interestingly, Bunce et al. (2010) also found evidence that attention, during the standard lectures, increased following constructive tasks suggesting some carryover.

Lastly, a recent laboratory study by Szpunar et al. (2013) provides further evidence for a link between task type and student attention. Szpunar et al. (2013) investigated lecture viewing with note-taking across three conditions of varying lecture related activities. Participants watched a video lecture on statistics in four segments of approximately 5.5 minutes each. After viewing a lecture segment, all participants solved unrelated math problems for approximately 1 minute. In addition, in a Test condition

participants received test questions on the material just covered whereas in a Study condition participants received the same test questions accompanied by answers, and participants were told to study and not solve them. Participants in a No-Test condition only did unrelated math problems (for the same amount of time as the other individual completed their tasks) after viewing each lecture segment. In response to mind wandering probes during the lecture, participants in the Test condition reported the lowest level of mind wandering (19%), followed by Study (39%), and No-Test (41%). In addition, the Test condition also scored higher on the final test (89%) than either the Study (65%) or No-Test conditions (70%). One interpretation of these results (similar to that offered in Bunce et al., 2010) is that interpolated testing shifted the participant's (spontaneously adopted) mode of interacting with the lecture (i.e., during the lecture segments). Consistent with this idea, and the Lindquist and McLean (2011) work above, Szpunar et al. (2013) reported that participants in the Test condition took more notes (24%), suggesting more active processing, than participants in the Study (9%) and No-Test (7%) conditions. Thus, not only did Test participants report half the level of mind wandering, but they also took approximately three times as many notes as the other conditions.

While lecture is certainly a common instructional format, most students spend an equal or greater amount of time reading instructional materials. Within ICAP, simple reading would likely be classified as active and certainly, on the whole, more active than a standard lecture. Accordingly, student attention should be greater during reading than listening to a lecture. A brief survey of mind wandering rates across studies involving lectures and reading seems to support this notion (see Varao Sousa, Carriere, & Smilek, 2013; p.2). Varao Sousa et al. (2013) also provided a direct test of this general idea by comparing mind wandering rates across three conditions – reading a text aloud, reading silently, and listening to the text being read to them. In each condition participants responded to mind wandering probes during the task. Critically, mind wandering was greatest in the listening condition, followed by silent reading, and the least amount of mind wandering was reported in the reading aloud condition. Thus, Varao Sousa et al. (2013) seems to follow the ICAP pattern closely. Specifically, as the task shifts from passive to more active (i.e., listening – silently reading – reading aloud), student inattention decreases. Critically, these results were mirrored by differences in performance across these conditions. In other words, participants memory for the material was greater in the two reading conditions than in the listening conditon.

A study by Moss et al. (2013) provides evidence that constructive activities improve student attention relative to active activities during reading. The study investigated three reading strategies: rereading (Active), paraphrasing (Active), and self-explanation (Constructive). After they were trained to perform these strategies, participants read texts aloud with instructions to use a particular strategy and rated their degree of mind wandering after each paragraph. Mind wandering ratings were lower for self-explanation than for paraphrasing or rereading, following the ICAP pattern. Moreover, the self-explanation strategy led to greater learning gains than the other conditions. These results complement and extend those of Varao Sousa et al. (2013) by showing how shifting the task type to constructive can further reduce mind wandering and increase learning during reading.

Educators have long suggested that the nature of standard lecture encourages a passive form of activity related to other pedagogical techniques (e.g., discussion, problem solving; Young et al., 2009). Consistent with this idea, in a study of a standard class lecture, Cameron and Giuntoli (1972) found that students reported not listening or superficially listening (Passive) 38% of the time, closely following (Active) 37% of the time, actively meeting the speaker's mind or engaging in episodic recall in response to what speaker is saying (Constructive) 21% of the time, and wanting to speak (Interactive) 5% of the time. Thus, a broad base of students were engaged in what would be considered passive and active activities and increasingly fewer were engaged in constructive or interactive activities. Presumably during any learning task, a group of students will naturally manifest a distribution of attention where the shape and center of the distribution depends on task type. Indeed a single student may shift in task type over a learning session and adopt a more or less demanding mode of processing.

In the studies reviewed above, overall pattern student attention shifted as a function of ICAP task type (see Table 1). It is important to note that the pairwise comparisons presented here should be taken with a grain of salt (e.g., a few rely on different measures of attention, and all use different types of content). For the most part, research comparing student attention across all the different ICAP task types is currently unavailable. We hope the theoretical framework offered here will inspire such efforts.

Table 1
Pairwise comparisons of attention according to ICAP task type

	Active	**Constructive**	**Interactive**
Passive	Lindquist & McLean (2011) Varao Sousa et al. (2013)	Bunce et al. (2010) Szpunar et al. (2013)	Young et al. (2009)
Active	-	Moss et al. (2013)	-
Constructive	**-**	**-**	**-**

3 Integration

The previous section reviewed and reanalyzed studies of attention in educational settings with respect to the task types in ICAP. The trend across these studies suggests an ICAP ordering of attention relative to task type. Specfically, student attention may be greatest in interactive tasks followed by constructive, active and lastly passive tasks. The current section offers a theoretical account of why an ICAP ordering of attention might be expected given a popular theoretical account of mind wandering (i.e., Control Failures x Concerns model; McVay & Kane, 2010, Kane & McVay, 2012), elaborated with novel conceptualizations of proactive and reactive control. The resulting elaborated theory licenses the hypothesis that learning task structure, such as ICAP, can enhance student attention within the learning task. We refer to this hypothesis as ICAP-A. Thus, the goal of the current section is to situate the reviewed work in a theoretical framework that can inform our basic understanding of task by attention interactions and provide guidance on how this knowledge could be translated into learning gains in the classroom.

A Model of Mind Wandering

Mind wandering arguably represents the quintessential representation of attentional disengagement in educational contexts, and as such provides a useful basis for an account of attention relative to task type in that context. A prominent theory of mind wandering presents it as an interaction between executive failure of control and current concerns, sometimes called the Control Failures x Concerns model (McVay & Kane, 2010, Kane & McVay, 2012). This theory integrates two theoretical frameworks (Watkins, 2008, Klinger, 2009) to argue that mind wandering results from automatically generated thoughts (current concerns, see Klinger, 2009) that the executive control system fails to suppress by not maintaining the appropriate level of construal (elaborated control theory, see Watkins, 2008). Klinger defines current concerns as the set of established, but unattained goals. Because neuroimaging studies have also tied mind wandering to the activity of the brain at “rest" via the brain’s so-called default network (Mason et al., 2007), there is reason to believe that current concerns reflect a kind of ever-present “background noise" in the brain. Thus, mind wandering about “what’s for dinner” (i.e., a current concern) in, for example, a one-on-one tutoring session, would represent a failure to suppress this “noise” and sustain attention on the educational goal.

To explain the relation between current concerns and executive control, the Control Failures x Concerns model relies on the elaborated control theory of Watkins (2008). The elaborated control theory is based upon the idea of construal. Watkins (2008) defines construal in terms of action identification theory (Vallacher & Wegner, 1987), which explains the connection between cognition and action as a cyclical process: intentions generate actions, and actions are interpreted to infer intentions. For example, one may decide that it would be nice to ride a bike around the neighborhood (intention generating action). On encountering a hill, progress becomes effortful, and may be interpreted as exercise (action interpreted to infer intention). In both cases the concrete action is the same, that of riding a bicycle. However this concrete action is consistent with the two more abstract goals of riding for pleasure and riding for exercise. Critically the new interpretation of getting exercise can trigger a shift in the higher-level goal away from riding for pleasure, even though the concrete behavior is unchanged.

Elaborated control theory applies this notion of cyclical feedback to repetitive thought and further specifies that construal may be either abstract or concrete. Abstract construal ("Why am I riding this bike?") promotes trait-based action interpretation ("I enjoy riding") and outcome-based goal intention ("Riding will be fun"). Concrete construal ("How do I ride this bike?") promotes state-based action interpretation ("I'm swerving to avoid a pothole") and means-based goal intention ("I need to brake and turn to avoid the pothole"). Elaborated control theory proposes that the level of construal depends on the difficulty of the current situation and follows a U-shaped curve. Specifically, low difficulty affords abstract construal, intermediate difficulty requires concrete construal, and high difficulty again affords abstract construal as goals are severely blocked.

The Control Failures x Concerns model holds that to prevent mind wandering, executive control must maintain appropriate construal relative to task difficulty (i.e., low difficulty = abstract; intermediate difficulty = concrete; high difficulty = abstract). For example, failure to maintain concrete construal on difficult tasks enables mind wandering because abstract construal activates current concerns, increasing the probability of mind-wandering. Control in the Control Failures x Concerns model can be either proactive or reactive and (as will be detailed below) tasks can vary in the extent to which they engage these mechanisms. Critically, it is this variation in proactive and reactive control across tasks that we suggest is helpful in explaining the variation in student attention across the ICAP task types. Specifically, the greater the engagement of proactive and reactive control in response to the task, the greater the student attention to the task. It will be argued that the ICAP ordering engages greater to less control as individuals shift from Interactive to Passive tasks. To support this argument, the Control Failures x Concerns model must be elaborated with mechanisms of proactive control and reactively initiated control. We briefly describe each in turn.

Proactive Control.

On way to think of proactive control is in terms of models of sequential action. Cooper, Ruh, and Mareschal (2014) have recently proposed the Goal Circuit model of sequential action, which shares a heritage of ideas with action identification theory (e.g. Norman and Shallice, 1986). The GC model explicitly models three kinds of influences on action, namely environmental affordances, task-specific ordering constraints, and top-down control. All three may be considered proactive in the sense that they exert an influence that is strictly forward in time, as opposed to a reactive system that implements feedback. Environmental affordances specify the preconditions of particular actions. Obviously, one cannot drive a car to the store if no car is present. Perhaps less obvious is the fact that simultaneously present environmental cues can facilitate or trigger particular actions. For example, seeing toast, butter, and a knife on a counter is sufficient to infer that someone is making toast. Task-specific ordering constraints operate at a more abstract level that might be thought of as a subtask level. For example, to make toast, bread must be obtained, placed into a heating device, and then the heating device must be activated. If the heating device is activated before the toast is placed there, the operation of making

toast will fail. Finally, top-down control, also known as the supervisory system, allows executive control during non-routine action sequences.

Each of these influences is represented by a path in a recurrent network, as shown in Figure 1. It should be noted that both input and output layers use a localist encoding, i.e. each node corresponds to a particular environmental affordance, action, or goal, represented below in italics. Environmental affordances are represented by input nodes that feed into a hidden layer and link to action nodes, e.g. *pencil is present*. Action nodes represent changes to the environment, and these changes are reflected in the environmental affordance nodes during the next time step, e.g. *pick up pencil*. Top-down control is likewise represented by input goal nodes that feed into a hidden layer and link to predicted goals, e.g. *write an answer*. These predicted goals become the goal inputs during the next time step. Task-specific ordering constraints are represented by recurrent connections on the hidden layer. The hidden layer receives both environmental affordance input and top-down control input and links to the analogous nodes in the output layer, so the task-specific ordering constraint pathway effectively merges environmental affordances and goals into a single context, e.g. *write next letter of a word*. In the case of goal nodes, all superordinate goals of the current goal are simultaneously active such that a hierarchy of goals are active at any given time. For example, the nodes for *write answer, write word, and write letter* might all be simultaneously active in a goal layer to represent the hierarchical goal structure of writing an answer.

With respect to the current discussion, the GC model illustrates how proactive control may stem from multiple sources: environmental affordances, task ordering constraints, and top-down control. Proactive control is strong when there are strong environmental affordances or a hierarchy of goals, which are both represented as multiple simultaneously active nodes in their respective layers. Proactive control is also strong when tasking ordering constraints are strongly predictive of future states. Trade-offs between these sources of proactive control may occur over time. For example, as action sequences become routinized they require less top-down control, especially if environmental affordances and task ordering constraints are relatively strong, e.g. *write the next letter of a word*. However, top-down control is needed for novel action sequences, especially if these sequences diverge from strongly routinized sequences, e.g. *write the next sentence*. When proactive control is strong, attention level is high, regardless of whether top-down control is strong or attention is consciously allocated – attention may be driven solely by environmental or contextual features (Dijksterhuis & Aarts, 2010).

A recent study may further illustrate the interactions between environmental affordances, task ordering constraints, and top-down control (Mueller & Oppenheimer, 2014). Participants in the study watched video lecture and took notes either by hand or by typing on a laptop. Notes taken by hand were significantly shorter and were significantly less verbatim with the lectures; moreover, hand note-takers performed significantly better on conceptual questions at post test. In terms of the GC model, we may consider both hand writing and typing to be highly automatized in the participants, who were college students. However, typing is faster than writing – so fast that it allows verbatim note taking that could not be accomplished by writing, due to working memory constraints. Instead, the task of writing forces a strategic top-down control with the goals of condensing the information (as seen in the shorter and less verbatim effects) and prioritizing important information (as may be evidenced by the improved performance on conceptual questions at post test).

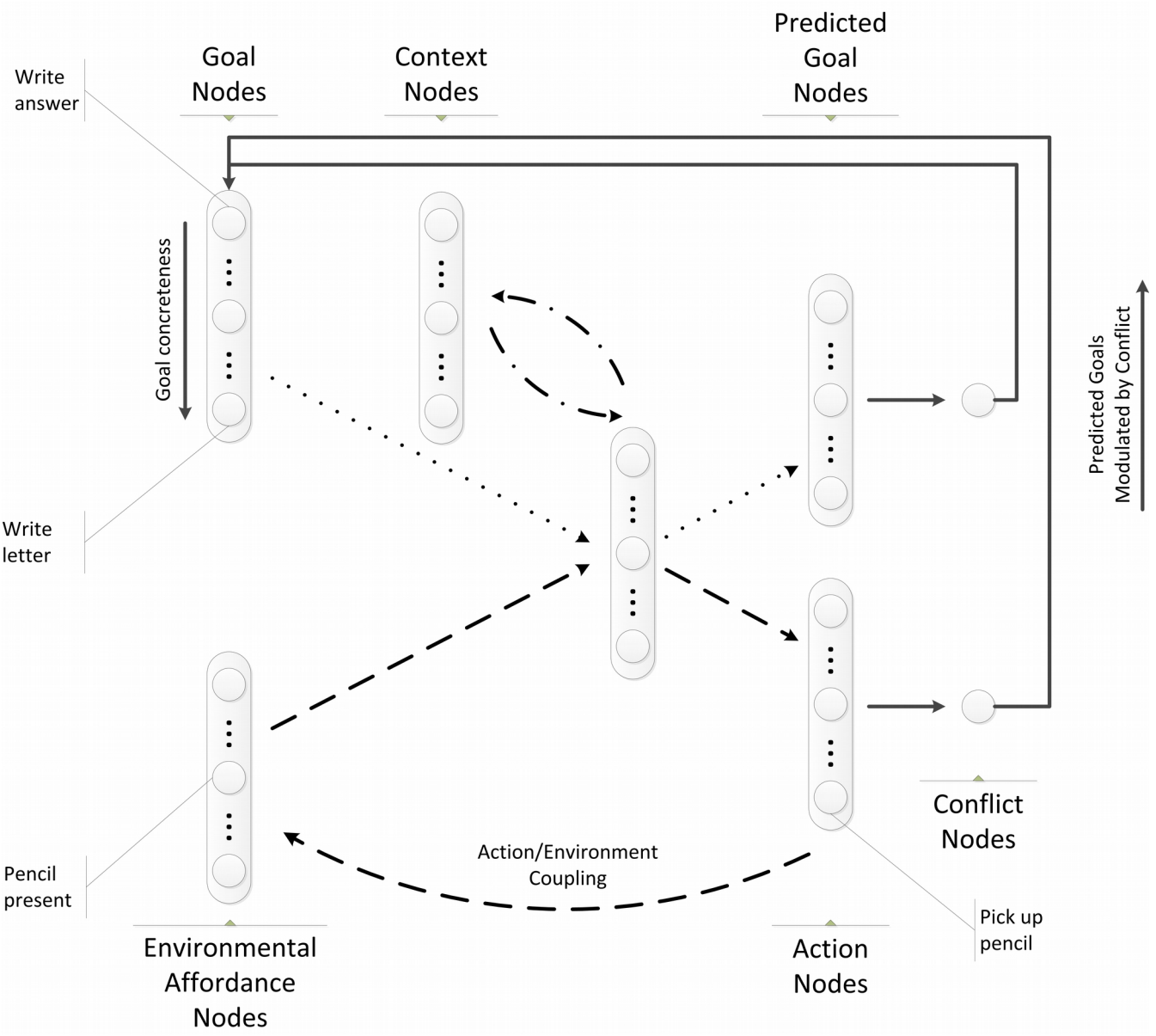

Figure 1: An elaborated version of the Goal Circuit Model with conflict nodes at the outputs. Layers are fully connected, with lines indicating the following mechanisms: the environmental affordance loop (dash), the goal circuit loop (dot), the task ordering loop (dash-dot), and the modulation of conflict nodes on top-down control (solid). Selected nodes are annotated according to the *writing* example given in the text.

Reactive Control.

The GC model provides a mechanistic explanation of proactively initiated control that is congruent with the Control Failures x Concerns model, but it does not explicitly model reactively initiated control. This is because the GC model specifies the top-down control at the goal node layer without specifying what drives the presence or absence of goals at those nodes. Botvinick, Braver, Barch, Carter, and Cohen (2001) describe a model of reactively initiated control that accounts for behavior and corresponding brain activation on a diverse set of tasks. The model consists of a single conflict monitoring node that is connected to multiple output nodes of a connectionist network, as shown in Figure 1. If multiple output nodes in the connectionist network are active, then the conflict node is active. In the GC model above, an active conflict node would mean that multiple goal output nodes or

action nodes were simultaneously active. It is important to note that given the nature of the GC model, multiple active output nodes are likely to occur either when the action sequence is being learned (so multiple actions are equally possible) or when the environmental affordances or task ordering are relatively weak (so multiple actions or goals are equally possible).

The conflict node, by itself, does not provide reactively initiated control. Reactively initiated control is provided by using the conflict node to influence top-down control nodes. Thus, periods of high conflict (e.g., a spelling error of *ghost* as *goast* where nodes for *h, o,* and *a* are highly active) lead to a greater amount of top-down control activation and periods of low conflict lead to a lower amount of top-down control activation (e.g., the production of each letter with no competing letters active). This feedback mechanism allows the model to account for a range of behavioral data where on-line control appears to adapt to error and trial-type frequency. In the GC model, such control would be applied proportionally more during the learning of novel action sequences, because in novel sequences various related and unrelated goals and actions will be active. However, control based on conflict monitoring would slowly fade if those sequences were routinized and task-irrelevant goals were suppressed.

In summary, reactively initiated control consistent with the Control Failures x Concerns model can be implemented by augmenting the GC connectionist model with conflict nodes at the action output and predicted goal output layers and using conflict node activation to modulate top-down control via the goal node input layer. This elaborated version of the Control Failures x Concerns model implies that novelty should increase attention because of the conflict and error generated in novel tasks. However, as the task is better learned, attention driven by this reactive mechanism should shift to proactive mechanisms as conflict diminishes and learning enhances proactive control.

Elaborating the Control Failures x Concerns model with the GC model and conflict nodes also provides an account of difficulty in terms of the need for control. As the GC model learns action sequences, it makes fewer errors: as the sequences become routinized they become less difficult. Learning is accelerated by top-down control, strong environmental affordances, and strong task ordering constraints. In general, conflict monitoring declines as action sequences are learned. However, monitoring is enhanced in novel situations or when the environmental affordances or task ordering contraints are relatively weak. For example, composing a new action sequence out of well known action subsequences will enhance conflict monitoring because ordering constraints between those subsequences will be weak “at the joints." Situations like this that require relatively more monitoring can be described as more difficult. This depiction of difficulty does not preclude additional considerations of difficulty like relational complexity (Halford, Wilson, & Phillips, 1998); however a more complete account of difficulty in educational contexts is outside the scope of the present discussion.

ICAP-A

The preceding discussion has placed the notions of control and difficulty in the the Control Failures x Concerns model into a more mechanistic framework. Specifically, the above accounts describe proactive control in terms of sequential action, reactively initiated control in terms of monitoring, and difficulty in terms of the need for control. Elaborated with these accounts, the Control Failures x Concerns model licenses the hypothesis that learning task structure, such as ICAP, can enhance student attention within the learning task. The ICAP-A hypothesis asserts that because proactive control and reactive control each increase as task type advances from passive to interactive, attention should likewise increase from passive to interactive. The remainder of this section describes how the three dimensions increase across the ICAP task types in order to motivate the ICAP-A hypothesis.

Passive tasks by definition involve no overt activity. Proactive control via sequential action is therefore non-existent in passive tasks. Likewise there can be no monitoring of actions because there is no sequential action. It should be noted that ICAP focuses on overt activities and that a student could be engaging in a constructive task covertly. In the description of other tasks types that follows this focus

on overt activities will be preserved; however, to the extent that the GC model could also apply to covert, or mental, action sequences, the same rationale for an ordering of attention can be applied to both overt and covert task types.

Active tasks involve actions that do not require the integration of new ideas with the learning materials. For example, underlining and verbatim repetition are examples of active tasks. As discussed previously, proactive control may stem from environmental affordances, task ordering constraints, and top-down control. In active tasks, the environmental affordances and task ordering constraints are relatively strong. Underlining, for example, provides continuous visual and motor feedback to guide the production of a straight line that stops at clause boundaries. Repetition similarly provides a tight coupling of perception and action. Presumably tasks like these are highly practiced and fairly well routinized, meaning they require less top-down control. Top-down control may be further weakened in these tasks by the relatively weak conflict detection produced by monitoring: these tasks have limited variation in action so little conflict is expected to occur. Accordingly in active tasks, student attention is limited by weaker top-down control and simpler task complexity.

Constructive tasks involve overt behaviors that integrate new ideas with the learning materials. Examples of constructive activities are problem solving and making analogies. Constructive tasks may involve routinized subsequences of action but would require combining these subsequences in novel ways. Therefore, unlike active tasks which are likely to have weak top-down control resulting from routinized action sequences, constructive tasks are likely to have relatively stronger top-down control while having comparable environmental affordances and task ordering constraints. For example, solving a math problem may involve basic operations like long division that are highly routinized, but the problem as a whole consists of a novel sequence of such operations. This novel sequence requires closer attention to the goal structure of the problem in order to correctly chain basic operations together. Likewise, the need for monitoring increases for constructive tasks because they are novel and multiple actions may seem appropriate at any given point. This increased need for monitoring should serve to increase top-down control in constructive tasks. Constructive tasks, as a result, have higher top-down control affordances than active tasks, which should result in a correspondingly higher level of student attention.

Interactive tasks are co-constructive. That is, in addition to individually being engaged in a constructive task, the participants are collaboratively assisting each other in a constructive task. Interactive tasks share proactive control and reactive control attributes with constructive tasks. However, in addition to these shared attributes, there are additional influences for control that come from the other partner in the interaction via redundant systems for proactive and reactive control. Both participants may reinforce their proactive control by observing each other's actions and inferring relevant goal structure from those actions. Likewise both participants reinforce reactive control by monitoring each other's actions and providing top-down control, i.e. correction, when needed. In other words, in interactive tasks, participants are not only monitoring their progress on the task but are also monitoring each other. Increased conflict from interpersonal monitoring would further serve to strengthen top-down control. Therefore interactive tasks should promote even greater levels of attention than constructive tasks, but only if redundancies in proactive and reactive control are exploited.

A summary of the ICAP-A hypothesis is presented in Table 2. Although the elaborated Control Failures X Concerns model makes more nuanced predictions including the novelty and variability of a task and the amount of previous practice on a task, Table 2 presents the ICAP-A hypothesis for the generic case of routinized action subsequences that may require novel recombination for certain problems. Under these conditions, students should manifest no action control for passive tasks, low control for active tasks, high control for constructive tasks, and redundant control for interactive tasks. As discussed earlier, the hypothesis is primarily concerned with overt student behaviors, and it is quite likely that even in a passive task like lecture viewing that some students are engaging in covert activities like self-explanation. Accordingly, the hypothesis does not assert that task type uniquely

determines student attention at an individual level but rather that task type shifts the distribution of attention at the group level. ICAP-A suggests that attention for a group of students may be improved by increasing the opportunities for top-down and reactive control.

Table 2
Pairwise comparisons of attention according to ICAP task type

	Passive	**Active**	**Constructive**	**Interactive**
Top-down Control	None	Low	High	Redundant
Reactive Control	None	Low	High	Redundant
Examples	**Lecture viewing Being read to**	Underlining Reading aloud	Problem solving Self-explaining aloud	Joint problem solving Tutoring

4 Future Directions

Emerging evidence from research on attention in education suggests that task structure can support attention. The hypothesis presented in this chapter, ICAP-A, proposes a framework for explaining how attention may be improved by changing task structure. These mechanisms, rooted in theoretical accounts of mind wandering, sequential action, and monitoring are well-known and have been individually validated. However, the ICAP-A hypothesis has not been directly tested, and much of the research reviewed here addresses pairwise contrasts (e.g. Active vs. Constructive); moreover, as shown in Table 1, several pairwise contrasts remain unaddressed empirically, particularly for interactive tasks. Direct experimental evidence is an important direction for future research. One possible approach for future research is to augment designs that have evaluated ICAP in a four-condition experiment (Menekse et al., 2013) with mind-wandering probes that query thought contents (Schoen, 1970).

An important implication of ICAP-A is that enhanced learning performance will be achieved in interactive learning tasks by virtue of improved attention. While this prediction is no different from ICAP, the mechanisms described in this chapter offer a more detailed explanation of the conditions under which this prediction will be true. ICAP-A predicts that redundant proactive control and reactive control each contribute to optimal attention. One avenue for future work is to ablate these mechanisms in an interactive task and compare to a constructive task control and measure whether attention decreases. For example, in a mathematics problem solving task, a worked example which makes the abstract problem solving structure clear (a strong goal hierarchy) could be contrasted with a worked example without this proactive support. Likewise feedback regarding errors made could be manipulated to provide or remove the error signal needed for reactive control.

The mechanisms behind ICAP-A also suggest future directions for the enhancement of instructional design for optimal learning performance. Both environmental affordances and task ordering constraints are frequently discussed in the learning sciences (Chandler & Sweller, 1991, Pavlik & Anderson, 2005); however, goal hierarchies may be an underutilized avenue for optimizing instructional design. Considerations of goal hierarchies have previously been proposed in the learning sciences (Farrell, Anderson, Reiser, & Boyle, 1987, Collins, Brown, & Holum, 1991, Anderson et al., 1995, Olney, in press), and the GC model provides an account whereby top-down control provided by a strong goal

hierarchy results in faster learning. However, the mechanisms behind ICAP-A provide an additional dimension to this account in terms of attention, namely that strong practice with weak goal hierarchies will actually be harmful to performance because it will increase mind wandering. Future work could pursue this avenue by training participants either with or without strong goal hierarchies on the same task. For example, teaching solutions to mathematics problems could be done completely procedurally (weak goal hierarchy) or by training participants to solve problems using the abstract problem solving structure of the task (strong goal hiearchy). If mind wandering does indeed occur more with weak hierarchies, even though the task in both cases is putatively constructive, then this provides yet another reason for instructional designers to strengthen goal hierarchies by making thinking visible (cf. Collins et al., 1991).

Finally, there are still many effects unaccounted for in the elaborated Control Failures X Concerns model. Perhaps the most prominent omissions are a model of deliberate decisions to go off-task and the modulating influence of affect (or emotion) on attention, and all of cognition for that matter (Clore & Huntainger, 2007; Dalgleish & Power, 1999; Fielder, 2001). The elaborated model provides an account for on-task behavior and a non-deliberate loss of control through weak proactive and reactive control. However, it does not model deliberate behavior by which a goal hierarchy is largely replaced in a top-down manner. Such action would occur outside the framework of the GC model and provide inputs to the goal node layer. The GC model assumes as given the initial values of the goal nodes and any later deliberate change. Likewise the model does not elaborate on the link between attention and affect. This omission may be significant given that negative moods appear to lead to an increase in mind wandering (Smallwood, Fitzgerald, Miles, & Phillips, 2009), presumably due to a shift towards current concerns and away from the task. Affect has also been shown to influence monitoring, such that enhanced negative affect in response to errors results in a more sustained response to conflict (Ichikawa et al., 2011). These studies suggest that affect may influence both proactive and reactive control and therefore be a non-trivial influence on attention in educational settings.

5 Box: Key Points and Outstanding Issues

Key Points

- Attention may be increased by changing the structure of the learning task, enhancing learning.
- An elaborated theory of mind wandering may explain how the learning task influences attention through mechanisms of proactive and reactive control.
- The ICAP-A hypothesis claims that Interactive, Constructive, Active, and Passive learning tasks differ in their needs and opportunities for proactive and reactive control, suggesting ways of changing task structure to optimize learning performance via improved attention.

Outstanding Issues

- Future research should study the stratification of attention across learning tasks types using methods that measure both the occurrence and contents of mind wandering.
- Attention researchers should investigate the contributions of proactive and reactive control, to attention, particularly for interactive tasks which are hypothesized to be the most beneficial for learning.
- Researchers in education, attention, and affect should consider the role of deliberate decisions to go off-task and affect on attention, as evidence suggests that these factors are inextricably linked to attention in real-world educational settings.

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