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Next Generation Learner Interactions with Personal Assistants for Learning

Elaine M. Raybourn, Ph.D.
Sandia National Laboratories* / ADL
Orlando, FL
emraybo@sandia.gov, elaine.raybourn@adlnet.gov

Jeffrey Mills, Kent Weeks
Katmai / ADL, Tolliver Group / ADL
Orlando, FL
jeffrey.mills.ctr@adlnet.gov, kent.weeks.ctr@adlnet.gov

ABSTRACT

Next generation learners engage in self-paced individual and collaborative learning with digital tools, games, intelligent systems, and virtual environments more than ever before. The focus of this paper is on understanding how problem-solving is distributed and negotiated among high school learners and simulated Personal Assistants for Learning (PALs). In our research we envision a PAL as a coach that guides and supports the user's learning experiences, e.g., an early instantiation could be an intelligent tutor that can function across domains.

The OpenSimulator virtual environment (Imaginarium) we use in our study utilizes a factual complex problem scenario that takes place in the Pacific Northwest. Learners virtually explore how culture and the environment together act as a system that impacts sustainability science while interacting with a simulated PAL. Their actions are monitored by the virtual environment, ADL experience API (xAPI), Learning Record Store, and the hybrid chat bot/human PAL.

This paper is relevant to the I/ITSEC community because it explores the design and use of an open source virtual environment to 1) understand the future implications of a personal assistant for learning and 2) begin to formulate human-computer interaction (HCI) guidelines for next generation learning systems. This paper describes our study, reports preliminary findings, and addresses the following research questions: How is problem-solving negotiated between high school learners and a simulated PAL? Can rapid prototyping in virtual environments expose assumptions about instructional best practices and improve the design of technology-mediated learning experiences? While human interactions with future PALs cannot be accurately predicted, simulating these phenomena in an immersive environment allows for exploration of the effects of technology on human behavior.

ABOUT THE AUTHORS

Dr. Elaine Raybourn has a Ph.D. in Intercultural Communication with an emphasis in Human-Computer Interaction. She is a Principal Member of the Technical Staff in Cognitive Systems at Sandia National Laboratories. Elaine has worked on transmedia learning since 2010 and led the development of an award-winning Government game identified by the Defense Science Board Summer Study on 21st Century Strategic Technology Vectors as "critical capabilities and enabling technologies for the 21st century that show promise." She is an ERCIM (European Research Consortium in Informatics and Mathematics) Fellow and has worked in research laboratories in Germany, England, and France. Elaine speaks regularly on the topics of games and transmedia learning and serves on several advisory and editorial boards including international journals *Interactive Technology and Smart Education*, *Journal of Game-based Learning*, and *Simulation & Gaming*. Elaine was on the advisory board for the Game Developers Conference (GDC) Serious Games Summit from 2004-2007, Defense GameTech Program Chair in 2011, GameTech Program Advisor 2012-13, and is an Integrated Project Team (IPT) member of the I/ITSEC Serious Games Showcase & Challenge and a member of the Training Subcommittee. She is on assignment to Advanced Distributed Learning Initiative, Office of the Deputy Assistant Secretary of Defense (Readiness), where she leads research on transmedia learning systems, ubiquitous computing, collaborative virtual environments, distributed cognition, learner adaptability, and next generation learners' interactions with personalized assistants for learning (PAL). Elaine is a recipient of the Department of the Army Award for Patriotic Civilian Service, awarded to her by the U.S. Army Special Forces.

Jeffrey Mills, a contractor with Katmai Government Services, serves as ADL's Project Coordinator for Virtual World Technologies, exploring all facets of virtual worlds and games for advanced distributed learning and capabilities of new and emerging technologies to better support our nation's Warfighters. Current areas of involvement include adaptive training research and the use of virtual spaces in support of training. Jeff's previous experiences include working for the U.S. Army Simulation & Training Technology Center. Jeff has developed content within 3D environments as well as virtual visualization research projects that explore human interaction and use of these platforms. Jeff's core career also includes serving as the Director of Visual Arts Development for the Program Executive Office for Simulation Training and Instrumentation where he supported the Army by developing animation and multimedia programs for modeling and simulation.

Kent Weeks, a contractor with the Tolliver Group, is a member of the Next Generation Learner Team, exploring various new and emerging technologies. Current areas of research involve working on the Imaginarium virtual world scenario and exploration of various types of games and media to promote transmedia learning. Kent's previous experiences include working with the Learning Technology Lab, Learning Registry, and other ADL research efforts. Kent is a founding member of the Defense Advanced Distributed Learning Working Group (DADL WG). Prior to joining ADL, Kent developed courseware and assessments for the Air Force Civil Engineer Support Agency (AFCESA) at Tyndall Air Force Base, Florida. While at Tyndall AFB, Kent also administered the learning management system for all civil engineering courseware. His focus currently is how next generation learners interact with a personalized assistant for learning, or PAL.

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INTRODUCTION

Next generation learners engage in self-paced individual and collaborative learning with digital tools, games, intelligent systems, and virtual environments more than ever before. The use of virtual environments in education and training has also enjoyed some popularity based on their potential to provide immersive, experiential learning. The notion of immersion is described as a psychological state resulting from a participant's intense feelings of "presence" in a virtual experience (Gerhard, Moore & Hobbs, 2004). Similar to immersion is the concept of "flow." Csikszentmihalyi (1990) describes flow as an experience where an individual becomes so engaged in an activity that time becomes distorted, self-consciousness is forgotten, and external rewards disappear.

The present paper describes research being conducted by the Advanced Distributed Learning (ADL) Initiative to understand how problem-solving is distributed and negotiated among learners and simulated Personalized Assistants for Learning (PALs). Our research simulates a PAL with human-like capability to better understand how to shape the future vision for a fully automated PAL. A future PAL is intended to enable learners to access personalized learning content and peer and mentor networks from multiple devices or platforms (Regan et al., 2013). It is assumed that a PAL will track one's learning process, whether formal or informal. It will have a nonintrusive user interface and will consume data from device and environmental sensors to support context awareness. A PAL will be knowledgeable about diverse domains and provide the appropriate level of guidance for the user's needs and goals. A PAL should help create a self-regulated learner with a thirst for knowledge, and not engender dependency on technology (Regan et al., 2013). Our research attempts to recreate the essence of the future capability by leveraging a hybrid chatbot / human PAL.

The OpenSimulator virtual environment (Imaginarium) presents a scenario based on factual data that takes place in the Pacific Northwest. In this research the PAL is embodied in a virtual environment and communicates with learners via text. The PAL is represented by a sphere in-world and consists of a hybrid chatbot / human. Learners interact with the simulated PAL and each other to explore how culture and the environment together act as a system impacted by sustainability science. Learners' actions are tracked by the virtual environment, the ADL Experience API (xAPI) / Learning Record Store, and through communication with the hybrid chatbot / human PAL and each other. We envision a PAL as a coach that guides and supports the user's learning experiences, e.g., an early instantiation could be an intelligent tutor that is able to function across domains. From an interaction perspective our research attempts to explore the gap where current intelligent tutoring capability ends and best practices in human tutoring begin. However a significant difference is that our research explores a context in which the learner may choose whether to interact with the digital assistant. Leveraging the concepts of flow and immersion, we use the virtual environment to simulate how, when, and why next generation learners might choose to interact with a digital, adaptive, and personal assistant with human-like capability. We focus on younger learners (ages 13 – 18) in this study since we envision a fully automated PAL capability to be most likely available for their future use.

The theoretical foundation for this research is based on experiential learning and immersion. Experiential learning (or learning through experience) has been cited as a fundamental human process (Kolb, 1984). Experiential Learning Theory defines learning as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984; p. 41). According to Kolb, knowledge results from the combination of grasping and transforming experience. The constructs for creating knowledge include 1) concrete experience and reflective observation for grasping the experience, and 2) abstract conceptualization, and active experimentation for transforming the experience (Kolb et. al., 2000). Learning is characterized as a cycle of creative tension expressed as: concrete experiences that form the basis for reflective observations. These observations form abstract concepts that provide a framework for new implications of actions that can be taken. These implications are then tested in active experimentation to guide the formation of new actions. The design of the Imaginarium virtual environment and its immersive experience was informed by the Simulation Experience Design Framework (Raybourn, 2007). The Simulation Experience Design Framework is based on human-computer interaction (HCI) experience design principles that have been adapted for the design of serious games and transmedia learning. The framework addresses designing experiential learning through an emphasis on user interactions, narrative, place, and emergent culture. To foster experiential learning in a typical learning situation such as a classroom often requires the use of some type of engaging scenario-based learning activity. Computer-based immersive technologies such as virtual environments and simulations can provide scenario-based learning. These applications provide learners the opportunity to have experiences that they might not be able to have otherwise for many reasons including expense, risk levels, or the infrequency of similar situations (Raybourn, 2007; 2011).

This paper is relevant to the I/ITSEC community because it explores the design and use of an open source virtual environment to 1) understand the future implications of a personal assistant for learning and 2) begin to formulate HCI guidelines for next generation learning systems. The present paper describes a research study currently underway, reports preliminary findings, and addresses the following questions: How is problem-solving negotiated between learners and a simulated PAL? How can rapid prototyping in virtual environments expose assumptions about instructional best practices and improve the design of technology-mediated learning experiences? In subsequent sections we describe the virtual environment's design, functionality, and scenario. We discuss research methods and report preliminary findings. Finally, we conclude with a discussion on limitations and future research.

VIRTUAL ENVIRONMENT DESIGN AND FUNCTIONALITY

Mechanics and Design

OpenSimulator (http://opensimulator.org/wiki/Main_Page) is an open source multi-user virtual platform. It is used to create a wide range of environmental settings and is accessed through a variety of third-party client viewers that are freely available. This platform is based on Linden Lab's Second Life online virtual environment. OpenSimulator relies on the same core implementation as Second Life's configuration. Due to it being a free resource, it provides high levels of development flexibility with no software cost or licensing. The benefits for using OpenSimulator include complete control over content creation and the distributed interaction by multiple users within the environment simultaneously. OpenSimulator allows for the rapid prototyping of various terrain, atmospheres and bodies of water. The platform also offers the ability to import assets created with third-party software and the use of built-in tools that allows for rapid visual adjustments and updates.

The Imaginarium virtual environment uses OpenSimulator version 0.7.3 and the Phoenix Firestorm client viewer for connection. Each user is represented as an individual avatar. The environment is a visual representation of the Pacific Northwest area off the coast of Canada. To replicate this environment, OpenSimulator allows for quick development of 3D assets such as trees, rocks, shrubs as well as custom representations of indigenous buildings, artifacts, and animals found in the real-world location of British Columbia. Built-in client tools for terrain generation give developers the ability to shape the world in real-time, creating varied terrain topology from sea level to high mountain peaks. A build interface provides a base set of geometrical shapes that can be modified to create various constructions. OpenSimulator utilizes a low polygonal tree system that will rapidly generate dense forests. These trees have a realistic look but do not affect the performance of the simulation. Most of the custom elements that represent the First Nations people of British Columbia were made in the commercial 3D applications Autodesk Softimage XSI and 3D Studio Max. These third-party 3D applications provide flexibility for creating highly detailed models that are imported into OpenSimulator. All of the surface textures were created using the Adobe Creative Suite. The Haida longhouse shown in Figure 1 is an example of surface textures.

Another advantage of OpenSimulator is the complete and robust avatar and communication system built directly into the environment. This provided the ability to customize prebuilt stock avatars that have full animation for navigation and body gestures for emotion and eliminated additional development time for creating player avatars from scratch. Each OpenSimulator client has a user interface for local chat and instant messaging. The chat dialogue shows a visual typing motion to denote who is speaking.

Figure 1. Haida longhouse.

For this study, participant avatars as well as the First Nations role player avatars were visually altered using various textures and 3D asset attachments designed to replicate the cultural experience (Figure 2).

Figure 2. Members of First Nations, Haida man and woman.

Functionality

The design of the environment was organized in a way that allows for PAL interaction by combining automated scripted proximity triggers in the form of a chatbot and representational PAL avatars driven by a human-in-the-loop. This dual approach simulates a hybrid version of the PAL (Figure 3). Participants are unaware that the PAL is being augmented by human controllers since the chatbot and human-generated text appear in the same location in the interface and as public chat (viewed by all in proximity). In addition, avatar interactions are monitored by the environment via the ADL Experience Application Programming Interface (xAPI) / Learning Record Store. This monitors and records what participants touch in the environment and when they touch it. We also use uniform resource locator (url) scripts that communicate interaction with a custom web browser. A virtual Imaginarium notebook depicted on the right side of Figure 3 contains information about the environment and collects data from the participant concerning their interactions with the Imaginarium elements, while a competitive scoring system (leaderboard) keeps track of the progress cumulatively. In conjunction with url data recording, the OpenSimulator chat module stores all communications among participants and PALs in a time stamped log file. With the flexibility of this type of virtual platform, human-computer interactions are tested and adjusted according to direct feedback and observation. This platform is well-suited for interpersonal role-play exploration (Jaeger, 2009).

Figure 3. Research Ranger with PAL (sphere). Notebook on right.

NEXT GENERATION LEARNER IMAGINARIUM SCENARIO

The Imaginarium is an environment where participants 1) interact with a PAL and 2) can demonstrate adaptive performance when faced with shifting objectives. We define adaptive performance as solving problems creatively (use of imagination or original ideas), coping with ambiguity or unpredictability, and using effective interpersonal communication skills when dealing with shifting objectives in the scenario (Raybourn, 2007, 2011). Solving problems creatively and dealing with unpredictable situations are dimensions of adaptive performance (Pulakos, 2000). There are three research goals. The first goal is to understand how, when, and why participants interact with the PAL. The second goal of the Imaginarium scenario is to capture data of participants' reactions when faced with a problem that changes the current goal and requires a decision to adapt to a new situation. The scenario presents a complex sustainability science problem that is based on facts. The intent of utilizing a scenario that takes place in the Pacific Northwest is to encourage learners to become interested in how culture and the environment together act as a system that impacts sustainability. The third goal is to provide young learners with an opportunity to better understand how they react and cope when faced with an ethical dilemma, or a "common good" problem. *Common good* is a term used to describe "the greatest good for the greatest possible number of individuals." There are no wrong answers in the Imaginarium. Utilizing a common good dilemma we hope to understand how the Imaginarium can help young learners think more about why they make decisions and the implications of their decision-making on others. A key component of this interaction strategy is to stimulate self-reflection and metacognition, both of which have been shown to increase problem-solving skill (Flavell, 1976).

METHOD

The Imaginarium research team was led by a social scientist and included a scenario writer, 3D modeler and virtual world developer, instructional designer, software developers, and two seventh grade subject matter experts (next generation learners). The following research questions were addressed:

RQ1: How is problem-solving negotiated between learners and a simulated PAL?

RQ2: Can rapid prototyping in virtual environments expose assumptions about instructional best practices and improve the design of technology-mediated learning experiences?

Procedure

Participants completed pretest and demographic questionnaires. At the beginning of the Imaginarium session, each participant was told that s/he has been selected to go to an island off the coast of British Columbia, called Haida Gwaii, to help an international group of scientists nominate newly discovered species for a top 10 list. The introduction to the scenario involved training the participants (Research Rangers) on avatar navigation, use of chat functionality, notebook, and interaction with a personalized assistant for learning (PAL). Participants were told that the island has been outfitted with PALs and that they would assist each participant with any questions or requests s/he may have. The three PALs were instantiated in the environment as colored spheres, or orbs. The PALs functioned as Socratic guides, but also provided direct answers as appropriate.

Initially the participants were told that their challenge was to locate ten newly discovered animals and plants. Each Research Ranger selected a role: anthropologist, botanist, ecologist, entomologist, or marine biologist. The five rangers then set out to identify the animals and plants in the environment. The competitive scavenger hunt was a loosely-timed event allowing the participants approximately 30 minutes to locate these species. Participants recorded their findings in their interactive notebook. The notebook contained information about the animals and plants. A leaderboard tracked progress and awarded points. It was suggested that Research Rangers use the PALs as a resource but it was not mandatory. Additionally, Research Rangers were able to collaborate with each other, but it was not mandatory.

At a relevant point in the scenario, a confederate role player introduced the individual participants to a common good dilemma involving the Haida, members of the First Nations living on the island. The Haida Wat (woman) character asked each Research Ranger to determine why a large number of western red cedars were dying and why there were fewer salmon in the area. The participants decided whether they would like to find a solution or continue with the hunt for new species. The purpose of this activity was to determine how, and if, the participants adapted to a change in objectives.

The session ended after approximately 30 minutes. Since there were no prescribed interaction outcomes, the session ended when each of the participants 1) identified all plants and animals, 2) successfully identified the reasons for the decline in trees and salmon and provided a solution to help the Haida, or 3) both. Participants completed post-test questionnaires and participated in a focus group.

Participants

More than thirty next generation learners between the ages of 10-18 have participated in Imaginarium sessions. Since their participation led to significant changes in the scenario design, the present data analysis is focused on the most recent data collected using the procedure discussed above. Nine members of a local Florida high school volunteered to participate in an Imaginarium session conducted in May, 2013. Most participants (6 out of 9) were novices with little to no experience with virtual worlds, however all but one had experience playing video games. The age of the participants ranged between 14-17 years. Only two females participated in the study. Five of the participants were 11th graders, three were 9th graders, and one was a 10th grader. Participants from different grade levels were from the same class. Only two of the participants had visited British Columbia and five had studied British Columbia before the session with the Imaginarium. The participants interacted in the Imaginarium in two groups: the first group had five participants, and the second group had four. Participation in the study was randomized so that grade levels were represented in each group.

DISCUSSION OF PRELIMINARY FINDINGS

Since the study is exploratory, we used a data-driven, interpretive approach to understand learner adaptability and PAL interactions in the Imaginarium (Lindlof, 1995). The data we collected was interpreted both quantitatively and qualitatively. Since we are interested in adaptive performance, we used a mixed-method approach to identify and count observable behaviors such as use of speech acts (e.g., requesting, answering) and reaction to a shift in objectives. First we employed a pre / post-test design to capture learners' responses to a PAL interaction questionnaire. The use of the questionnaire allowed us to determine if their experience in the Imaginarium had shifted perceptions regarding the PAL. Second, we captured the chat log and notebook entries to conduct discourse analysis to identify decision points and actions taken during the session. Third, the PAL interviewed learners in world without them realizing they were being interviewed as they worked through the sustainability science problem together. Fourth, we captured user actions in-world that illuminated order of events, decision-making priorities, and frequency of learner patterns. Finally, we debriefed learners out-of-world in focus groups or interviews to capture final comments, thoughts, etc. on the scenario, common good dilemma, and PAL interactions. Given the qualitative data analysis and the tentative nature of the results, a brief discussion (narrative) of preliminary findings from nine participants is provided below.

PAL Interactions

Each participant completed a pre- and posttest questionnaire aimed at understanding PAL interaction preferences. The participants were asked whether they preferred a digital PAL that was like a teacher, mentor, guide, or friend. Each label has an implied interaction style. Three participants indicated no change in their PAL interaction preference from pre- to post-test, while five changed their preferences in the direction of "friend," and only one person changed their preferences in the direction of "teacher." These responses tentatively indicate that one's perceptions or expectations of interactions with a digital PAL could change after initial use. Therefore a take-away from these responses might be to provide distinct PAL personalities that users can customize or relate to on several levels (Raybourn, 2004). Participants also indicated that they wanted to be able to turn off their assistant, and call it when needed. Research has shown that context-aware, virtual assistants can be leverage personalities and interaction strategies to increase users' attention (Morel, 2004; Morel & Ach, 2011).

RQ1: How is problem-solving negotiated between learners and a simulated PAL?

Regarding problem-solving with a simulated PAL, we found that participants largely were reluctant to ask the PAL for assistance with solving the Haida's problem—therefore exposing an assumption we had made about how participants would use a PAL to problem-solve. In fact, most participants only asked the PAL for help when they had exhausted all measures to find animals or plants. We had expected there might be more interplay and collaborative negotiation among participants and the PAL, but instead the participants did not share the act of problem-solving. When reviewing chat log data we determined that most of the questions were asked by the PAL (e.g., Think about where eagles nest, where else would you look? and What is your hypothesis?). In this open-ended scenario, the PAL's questions seemed necessary to focus the participants on noticing the subtext of the scenario even though clues and hints were revealed quite explicitly throughout the environment. Participants indicated in the focus group that they wanted to "do as much as possible on their own" and wanted to use the PAL "as a last resort." They also did not want to interact with the PAL because the information provided by the PAL was public (visible to all in proximity). The participants "didn't want others to know the answers, and didn't want it [the PAL] telling others where things were." Participants did not want others to know they were "using" a PAL. A possible explanation for these findings could be the participants' ages and that they were encouraged to compete to find as many plants and animals as possible for potential inclusion in a Top 10 List. It is possible that since the teens did not want to give others an "edge" that they continued to behave competitively even after the objectives in the scenario had shifted. Another explanation could be that the nature of the insight problem itself may have engendered their desire to "discover" the solution on ones' own. (Metcalfe & Wiege, 1987). More research is warranted to more deeply answer RQ1.

RQ2: Can rapid prototyping in virtual environments expose assumptions about instructional best practices and improve the design of technology-mediated learning experiences?

Much of the reason for conducting this line of research is to gather data on how young people interact with a simulated PAL early in the design process. Another goal is to expose any assumptions about perceived best practices made by the research team that would impact the ultimate design of a PAL as discussed above regarding RQ1. We had expected that participants might let the digital PAL take on a more collaborative, peer-based role, but instead the participants only utilized the PAL to have it ask questions and provide feedback, much like current instantiations of intelligent tutors. The participants did not seem comfortable with letting a digital PAL take on a more substantial role in the generation of knowledge associated with learning. So while we had envisioned that natural language, feedback, and cross-domain expertise would result in the PAL being a more prominently utilized learning device, it would tentatively appear that these conditions are necessary but not sufficient. More research is warranted.

Adaptive Performance

Recall that adaptive performance is defined as solving problems creatively (use of imagination or original ideas), coping with ambiguity or unpredictability, and using effective interpersonal communication skills when dealing with shifting objectives in the scenario. Regarding adaptive performance we found that only 4 out of 9 participants shifted objectives willingly as soon as they were asked by Haida Wat to help during the scenario. They were able to determine the root cause for the sustainability science problem and propose what the Haida could do to mitigate the issue by engaging in interpersonal communication with Haida Wat, and synthesizing textual clues from the PAL and their interaction with the virtual environment. However, perhaps more interesting, five participants did not choose to help the Haida when asked and therefore did not shift objectives. These participants either ignored the direct request, or flatly refused. They cited the following reasons for not shifting objectives: not being emotionally invested, already having a goal (find animals and plants), and no perceived reward (nothing in it for them). One participant indicated that had he realized that the scenario was factual, he might have helped, and "felt bad" that he had chosen to ignore Haida Wat's request for assistance. Another participant indicated that he did not help since the Imaginarium was a "game." He said, "In real life I might have helped. I hope this doesn't affect my ethics" (it was later discovered that the school gives students a grade for ethical behavior). Following a debriefing, it seemed that participants were more aware of the implications of their decision-making on others.

LIMITATIONS AND FUTURE RESEARCH

A clear limitation of this research is the small number of participants assembled by the time of publication. Since the participants are largely middle and high school students it is anticipated that more data will be collected in the fall with university-level, adult learners. Nevertheless, these qualitative data illuminated assumptions regarding pedagogy and interface design as described above. In the spirit of sharing our exploration process, we have reported preliminary findings that will inform our next steps and future research. We intend to continue data collection to better understand expectations for PAL interactions and determine how the design of the virtual environment and scenario may impact one's perception of a common good dilemma. In other words, we intend to better understand whether participants perceive their actions in experiential learning activities presented in a "game" as valuable endeavors that they can put to practice in real life. Future research will explore implications for DoD learners.

CONCLUSION

The concepts outlined in the present paper are relevant to the I/ITSEC community because they explore the design and use of an open source virtual environment to 1) understand the future implications of personal assistants for learning and 2) begin to formulate human-computer interaction (HCI) guidelines for next generation learning systems. The reader may agree that some of the findings are intuitive. The strength of this exploratory approach is that the information garnered is data driven and utilizes grounded theory. Therefore even though the research is exploratory and the findings preliminary and tentative, feedback received on usability, interface design, and the contextual fidelity of the narrative (Lakhmani et al., 2012) has proven useful and will be folded into design considerations for future research and potential future data collection with members of the military. This research has provided the research team with valuable insights into future system development and has helped expose assumptions or biases about instructional best practices and learner preferences. This exploratory research will improve our design of future technology-mediated learning experiences.

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