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A Qualitative Analysis of Using a Virtual Mentoring Program on Black Computer Science Students

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Abstract

It has been a major goal of the United States government to increase the participation of Americans in the fields of Science & Engineering (S&E), especially in under-represented groups. This research examines the use of an embodied conversational agent (ECA) as a virtual mentor to African American undergraduates who are interested in pursuing a graduate degree in computing. Mentoring advice was collected from a group of experts and programed within the ECA. A between-group, mixed method experiment was conducted with 37 African American male undergraduate computer science majors where one group used the ECA mentor while the other group pursued mentoring advice from a human mentor. Results showed no significant difference between the ECA and human mentor when dealing with career mentoring functions. However, the human mentor was significantly better than the ECA mentor when addressing psychosocial mentoring functions.

Keywords: agent, conversational, embodied, graduate, mentoring, virtual

1. Introduction

In a 2007 report by the National Academy of Science (Rising, 2007), the case is made if the United States wants to maintain its global competitiveness it must continue to research and innovate in the areas of science and engineering (S&E). To achieve this goal, a 2011 report by the National Academies of Science (Expanding, 2011) highlights the importance of increasing the participation of under-represented minorities due to their increasing make up of the United States population.

One under represented group is African Americans in computer science. According to the 2011 Taulbee Survey (Taulbee, 2011), representing 184 PhD granting universities, African Americans represent 1.4% of all computer science faculty even though they make up 12.6 percent of the total population (Humes, Jones, & Ramirez, 2011). The small percentage of African American faculty can be attributed to the small percentage of African American students in computing. These students also have disproportionate numbers with 3.6% of computer science bachelor degrees awarded, 1.6% of master's degrees awarded and 1.2% of doctoral degrees awarded in 2011.

Several interventions increase participation for under represented minorities were discussed in the 2011 National Academies (Expanding, 2011) report including mentoring.

In this research, a virtual human, otherwise known as an embodied conversational agent (ECA), was used to mentor African American undergraduate computer science majors who are interested in pursuing graduate degrees in computing. It is hypothesized by the authors that this “virtual mentor” could provide mentorship comparable to a human mentor.

2. Literature Review

2.1 Mentoring Functions

Mentoring can be defined as a dynamic, reciprocal relationship in a work environment between an advanced career incumbent (mentor) and a beginner (protégé) aimed at promoting the career development of the mentee (Healy & Welchert, 1990). Mentoring has traditionally been divided into two primary functions, career and psychological (Kram, 1983). The career-related functions include “nominating the protégé for desirable projects, lateral moves, and promotions (sponsorship); providing the protégé with assignments that increased visibility to organizational decision makers and exposure to future opportunities (exposure and visibility); sharing ideas, providing feedback, and suggesting strategies for accomplishing work objectives (coaching); reducing unnecessary risks that might threaten the protégé’s reputation (protection); and providing challenging work assignments (challenging assignments)” (Noe, 1988). Psychosocial functions identified by Kram (1985) include “serving as a role model of appropriate attitudes, values, and behaviors for the protégé (role model); conveying unconditional positive regard (acceptance and confirmation); providing a forum in which the protégé is encouraged to talk openly about anxieties and fears (counseling); and interacting informally with the protégé at work (friendship)” (Noe, 1988). In this research, both career and psychosocial mentoring functions are measured.

2.2 Mentoring Constellations

Mentoring research has typically been conducted within traditional organizational settings with traditional, dyadic mentor-protégé relationships (Kram, 1985). In more recent mentoring manuscripts, a new model of mentoring has been emerging that encourages a broader, more flexible network of support, in which no single person is expected to possess the expertise required to help students exclusively (Sorcinelli & Yun, 2007). In this model, junior faculty-to-senior faculty relationships as well as doctoral student-to-faculty rely on “mentoring partners” in non-hierarchical, collaborative, cross-cultural partnerships known as multi-mentor networks or mentoring constellations (Sorcinelli & Yun, 2007). In a 2003 article (Mathews, 2003), Mathews provides a framework for mentoring that suggest that given the varied components of academic work, mentoring is best undertaken by a number of faculty members, rather than by one individual. Other studies have confirmed the relationship of having a network of mentors compared to just a single mentor will enhance career success and personal well-being (de Janasz, 2004; Girves, 2005; Johnson, 2007). In a study by van Emmerik (van Emmerik, 2004), it was found that having multiple mentors is not a substitute for a single mentor but should be held in addition to a core relationship. In a 2002 study of formal mentoring programs (Cawyer, Simonds, & Davis, 2002), the authors concluded that the most important feature of mentoring constellations might be accessibility to the mentors in that particular constellation. In studies conducted by Eby (Eby, 1997) and McManus and Russell (McManus & Russell, 1997) it was deduced that, depending on the research perspective, a mentor may not be from within the same organization as the protégé and it is actually optimal if the network of mentors come from different organizations due to a reduction in information redundancy (Higgins & Kram, 2001). In a 2000 study (Peluchette & Jeanquart, 2000), it was found that multiple mentors were used by early career professionals to seek emotional support. That same study also found that mentoring constellation patterns changed according to the career stage of the protégé (Peluchette & Jeanquart, 2000). Based on the research in mentoring constellations, an ECA mentor could possibly co-exist with other human mentors rather than replace them.

3. Methods

3.1 Participants

A total of 41 junior and senior Computer Science majors were enrolled at the college at the time of the study. Results from the power analysis recommended a minimum of 36 of the 41 students participate in the study assuming a 5% margin of error, 90% confidence level and a 50% confidence distribution. Of the participants who participated, 19 used the virtual mentor and 18 interacted with a human mentor.

Participants used in the study were selected using convenience sampling since the sampling frame had over 150 elements. Since the content of the relational agent was customized for African American male computer science majors, it was a requirement that each participant be an African American male computer science major.

Additionally, every participant had to be somewhat interested in graduate school, be at least 18 years old and enrolled in good standings at the institution where the study was conducted.

Of those who met the criteria above, participants were selected using purposeful sampling, rather than probabilistic or any other sampling method, ensuring that feedback was collected from students who had various experiences from their mentoring experience. Potential participants were informed about the study using a flyer as well as email.

3.2 Materials and Measures

The research variables in this experiment were divided into two groups – independent and dependent variables. The independent variables addressed in this research primarily came from user demographics that included the following: age, major, minor, classification (i.e. freshman, sophomore, etc.), school, grade point average and ethnicity. Other independent variables included the following:

1. The interest in pursuing a graduate degree in computing
2. Confidence in getting accepted into a graduate program
3. Knowledge about the graduate school application process
4. Knowledge of graduate school funding options
5. Knowledge of career options with a graduate degree in computing
6. Knowledge of graduate school terminology
7. The relationship they had with the agent

The primary dependent variables that were addressed in this research consist of the knowledge learned about graduate school in computing and interest in pursuing a graduate degree in computing.

The virtual mentor concept consists of an ECA programed with mentoring content made accessible by a web browser. The ECA was developed using the SitePal avatar creation tool at SitePal.com. The tool allowed for the selection of the avatar, the language spoken, the background image and facial expression of the persona.

Many steps were taken to construct the graduate school mentoring agent. First, the subject areas for the content that would be utilized by the mentor had to be selected. Second, questions from the selected area had to be created and asked to a series of experts. Third, an analysis was done of the answers provided by the experts, and generic responses were created for the list of questions. Fourth, a framework had to be selected or built from scratch to handle the input from the user of the system. Since the decision was made to create the agent from scratch, the code had to be written to process the users' input, compare the processed text with the content stored to the agent, and respond to the user. Fifth, the design and construction of the humanoid appearance of the agent was done using the SitePal avatar creation tool on the SitePal website. Sixth, a database was constructed to collect data provided by the participants. Lastly, a website was created to host the agent and the system software. The sections below describe each step in more detail.

Due to the vast amount of data that would have to be compiled and verified for every STEM degree and every single conversational topic, a sample of two topics related to graduate school study for one major, computer science, was collected. In order to identify two areas of interest by the initial users of the system, a survey instrument was constructed and distributed to a group of students from the computer science majors at the institution where the study was conducted. Once the survey instrument was constructed, it was submitted and approved by the Institutional Review Board (IRB) at both the institution where the study was conducted and the home institution of the author. A total of 60 students were surveyed. One survey was incomplete and discarded leaving a total of 59. The 59 students included 6 freshmen, 16 sophomores, 18 juniors and 19 seniors. Students were solicited using a flyer and given a box of movie-style candy as an incentive. Each student was instructed to rate their interest using a five point Likert scale when answering the following questions:

1. How do I obtain funding to attend graduate school?
2. How should I select a graduate school?
3. How do I select a graduate research advisor?
4. How do I apply for graduate school?
5. Why should I attend graduate school?
6. What are the duties as a graduate student?
7. How do I obtain letters of recommendations?
8. How do I complete an admission essay?

9. What are the differences between a Masters and a PhD?
10. What are the career options with a PhD?
11. What are the salary ranges for PhD graduates?
12. What are graduate courses like?
13. What can I do to start preparing for graduate school now?

Of the 13 questions above, the two highest rated were the questions about funding graduate school (Mean = 4.64, SD = 0.8) and career options with a PhD (Mean = 4.54, SD = 0.7). Due to the popularity of these topics, questions were asked that fit into these two categories.

The participants using the virtual mentor interacted with the agent using an Apple 21.5-inch iMac computer with a 2.5GHz Quad-Core Intel Core i5 processor and an NVIDIA GeForce GT 640M graphics processor with 512MB of GDDR5 memory. Each participant was given Sony MDR NC40 noise cancelling headphones to hear the virtual mentor and remove noise from the room. Users navigated the website with the agents using a full-size Apple wireless keyboard and a multi-touch magic mouse.

3.3 Procedure

The group that used the virtual mentor started by completing the pre survey. After the survey they sat at a desktop computer that already had the website loaded with the conversational agent. The virtual mentor, Lamar, told participants that he only knew about graduate school funding options and career options. However, participants were still able to ask questions that did not fit into these categories. Unfortunately, Lamar told the participants that he did not know an answer to their questions. This is the script that Lamar told participants upon accessing the website: “Welcome to the Virtual Mentorship System. My name is Lamar. I am here to mentor you about your possible decision to attend graduate school. I currently know mostly about funding options for graduate school and career options if you obtain a graduate degree in computing. Please fill out the information on the left and submit to begin.”

Participants were not given a time limit or maximum number of questions that they could ask the virtual mentor. After the single session, each participant immediately completed the post survey.

Students who participated in the study were randomly assigned to one of two groups. One group of participants was mentored by the virtual mentoring agent. The other group was asked to get mentoring advice from a qualified human mentor. Minimum qualifications for the mentor included the following:

1. An African American who had completed, or was in the process of completing a terminal degree in a STEM field.
2. Anyone who had worked in a job where a component of the job was to advise African American STEM students on graduate school opportunities.

Students were given the names of five individuals who met the above qualifications and worked at the school where the participants were enrolled. Three of those individuals worked in the same building where the participants currently took courses. Students were not restricted on which mentors to select.

The participants chosen for the human mentorship were provided names of three individuals on campus that they could interact with to learn more about graduate school. All three individuals were told about the experiment in advance. The individuals consisted of two faculty members in the computer science department with terminal degrees and the Director of the Office for Research Careers for the Division of Science and Mathematics. Participants were directed to meet with one of the individuals above or anyone else they feel that could provide quality advice about going to graduate school. In addition, participants were instructed to have only a single graduate school advisement session with this person until they completed their post survey and interview (if selected). There were no time constraints or question limitations between the participant and the mentor. Question topics asked by the participant were not restricted as well. Once the session was complete, the participant was to contact the principal investigator to set up the completion of the post survey.

The survey instruments were distributed in a quiet classroom at the home institution of the study participants. The surveys were distributed and collected based on the preference of the participant and availability of the author, Monday through Friday of the fall semester of 2012, and between the hours of 10:00 AM and 5:00 PM. Two surveys were given and collected for every participant in the study.

The first survey was given and collected before participants began their mentoring interaction and the second survey was given and collected no more than five days after their mentorship experience. A five-day window was used in hopes of limiting any memory loss about the experience. Both survey instruments were distributed and collected solely by the author. Questions on the survey instrument incorporated open-ended as well as closed-ended questions. Additionally, both instruments contained a combination of questionnaire type questions, attitudinal scale questions and achievement questions.

A pool of participants from both groups (those that used the virtual mentor and those who used a human mentor) were interviewed after completing their post study. These participants were selected using a convenience sampling method. Participants were contacted in person, at random and asked if they wanted to participate in a brief interview. Before conducting the interview, each participant was given introductory remarks about the study and was asked again for an informed consent. Each interview was audio recorded and transcribed with an online voice transcription service called Fox Transcribe. In addition to asking for an overview of their experience with their mentor, the following five questions were asked:

1. What did you learn from your experience with your mentor?
2. What could have made your mentorship experience better?
3. What impactful things did you learn from your mentorship experience?
4. What changes will you make after your mentorship experience?
5. How will you describe the relationship between you and your mentor?

Additional questions were then asked depending on the responses of the participant. After the conclusion of the interview, the participants were thanked for their cooperation.

4. Results

Qualitative data was collected in the study using semi-structured, retrospective interviews. Individual interviews were used instead of focus groups to eliminate any bias amongst participants. A total of 17 participants participated in the interviews. The total time spent conducting the interviews was 100 minutes and 26 seconds. Nine participants that interacted with a human mentor and eight participants that interacted with the virtual mentor were selected. The interviewees who interacted with the virtual mentor spent an average of 5:07 in their interviews with a minimum of 3:13 and a maximum of 6:07. In addition, the interviewees who interacted with the human mentors spent an average of 6:36 in their interviews with a minimum of 3:17 and a maximum of 9:27. Every participant in the study was asked verbally to be interviewed and all of those who agreed to be interviewed were interviewed.

Questions asked fell into the categories of experience questions, opinion questions or feelings questions. Interviews with the participants that used either a human mentor or the virtual mentor started with the following initial questions:

- How was your interaction with your selected mentor?
- What did you learn from your experience with your mentor?
- What could have made your mentoring experience better?
- What impactful things did you learn from your mentoring experience?
- What changes will you make as a result of your mentorship experience?

Additionally, participants who had a human mentor were asked to describe the relationship they had with their mentor. Since all participants, with the exception of two, selected mentors outside of the department, the following questions were added to the interviews of these participants:

- What is the background of the mentors selected?
- What is the relationship between the participants and their mentors?
- Why the participants chose mentors from outside of the school and department?
- Overall, how accessible were members of the department?
- What is the relationship between the participant and members of the department overall?
- What questions were asked to the mentor?
- What future interactions do you see between you and your mentor?

Additional questions were added based on the direction of the conversation between the author and the participant.

Of those students who did make contact with a mentor, a wide range of topics were discussed. All the topics fit under the categories of either career advice, funding opportunities and application assistance. Of the seven students who met with mentors, two of the students were in funded, undergraduate research programs.

Both of those students asked all the questions concerning application assistance, but did not ask about career options or funding opportunities.

Several items were consistent in the interviews. All the participants stated that their faculty, overall, were accessible if they needed them (even though one faculty member was mentioned for being inaccessible). Every mentorship experience was done in person. All participants stated they had a positive mentorship experience. Both students in the undergraduate research programs stated the learning in their mentorship meeting was limited. One of the nine selected mentors was a female. Lastly, not a single participant was told about a specific funding opportunity.

As indicated in the list below, several of the interviews had intriguing statements.

- Participant A had scheduling conflicts with his selected mentor; however, he stated that his work schedule, not the mentor's, was the problem.
- Participant B said he had no mentor overall.
- Participant C stated he met his grad school mentor from his normal mentor who was the faculty advisor for his fraternity.
- Participant D had a mentor who worked on campus, who was also his uncle. He also stated he was somewhat uncomfortable talking to faculty about things that would expose his "faults".
- Participant E selected his mentor based on the network of people she knew, rather than what she knew. Also, he received information about undergraduate funding opportunities rather than graduate opportunities.
- Participant F chose his long-time and graduate school mentor based on his professional demeanor as an undergraduate student.
- Participant G is a member of the NROTC and chose his mentor based on his experience with opportunities with the US Navy.
- Participant H is a member of an undergraduate research program and although he has complete trust that his mentor had his best interest in mind, the information given to him may not be completely accurate.

Participant I, another student in an undergraduate research program, stated his mentor (a member of the faculty) gave him encouragement in addition to advice. Unfortunately, this participant stated they did not learn anything novel from the interaction.

A total of eight participants who interacted with the virtual mentor were interviewed. Participants mentioned how the agent answered basic questions, but struggled to answer questions dealing with specific funding options, school rankings, specific graduate programs and personal experiences. There were eight positive and three negative references to the accuracy of the virtual mentor in answering questions that were asked. There were six positive references to trust they had with the content given by the agent and four of the participants indicated they would want to use it again. One of the participants preferred the virtual mentor to a human mentor, another participant preferred a human mentor to the virtual mentor and four participants mentioned they would prefer the virtual mentor depending on the situation or question asked.

Open-ended attitudinal questions were included in both the pre and post survey instruments. The pre survey asked participants what questions they had about pursuing a graduate degree in a computing field. The post survey included the following three questions:

1. What additional things would you like to know about graduate school?
2. How did you benefit the most from your mentoring session?
3. How could your mentoring session be better?

When asked about the items they wanted to know about the three most popular responses included those about funding, potential research areas and quality of particular graduate programs. Outside of funding questions, school rankings and research areas were popular topics that Lamar was not able to answer. When asked how the participant benefited the most from the mentoring experience, most mentioned more information about funding or they provided a generic response such as "motivation", "knowledge" or "much more opportunities than I believed".

In the post survey, participants were asked about ways to improve their mentoring sessions. For the participants using the virtual mentor, answers given by the participants were suggested improvements to the virtual agent, while answers given by those participants utilizing the human mentor were more abstract. Overwhelmingly, most individuals who used the virtual mentor suggested the mentor should have more responses to different questions or that the virtual mentor was sufficient and did not need improvements.

5. Discussion

The study set out to explore the use of embodied conversational agents as virtual mentors compared to current human-to-human mentoring. The population of the study was African American computer science majors at a historically Black college. The agent's purpose was to mentor the students on the pursuit of a graduate degree in computing. Success of this study could call for the need of additional studies that are longer in term, at different institutions on students with different majors, genders and ethnicities. The study sought to answer three primary questions:

1. How effective is organic, short-term, human-to-human mentoring in this environment?
2. How effective is short-term mentoring using an embodied conversational agent in this environment?
3. How effective was the virtual mentoring interaction compared to the human-to-human interaction in this environment?

All of the interviewees recorded a positive mentoring experience. Seven of the nine selected mentors were African American and only two out of nine of the selected mentors were women. The following conclusions were deducted from using enumeration and network diagrams on the interview transcription data:

1. **Students' schedules can become a barrier to gaining human mentoring in addition to the schedule of the prospective mentor.** Students may be overwhelmed with classes, coursework, on and off-campus jobs, involvement in student organizations and other responsibilities.
2. **Knowledge sought by students may differ when students are involved in sponsored graduate research programs.** The two students involved in undergraduate research programs asked questions that were less general than those participants that do not participate in a sponsored graduate school preparation program.
3. **Student grade point average and/or participation in an undergraduate research program could affect the choice of mentors.** The two students that chose a computing faculty member as their mentor were involved in an undergraduate research program. Additionally, those two students had the highest grade point average of all participants that sought human mentoring.
4. **Mentors come from a variety of sources.** Of the nine participants interviewed, their selected mentors included an officer in the school NROTC program, two current graduate students that attended the participants' university while the participant was enrolled, a real estate agent and an admissions director in addition to current computing faculty in the participants' department.
5. **Selected mentors typically have ties to the protégé or the protégé's school.** In the study, most of the mentors' knew the protégé from interactions on or off campus. Participants indicated they had a level of trust (their opinions were genuine as well as accurate) with these individuals and these individuals could give them "custom" information and guidance.
6. **Brokers can be used to find human mentorship.** Two of the interviewees went to a trusted person whom they already had a relationship with, but was unknowledgeable about graduate studies in computing to find a mentor with the traits they desired.
7. **Student aspirations affected their choice of mentor.** This was consistent in almost every case. Many of the student's lack of interest in becoming a faculty member was given as the primary reason students sought mentoring from others outside of their department. These students instead sought mentors whose professions were more closely aligned with their career goals or those that they had more intimate, long-term relationships with.
8. **Having non-faculty mentors available in dedicated time periods increases the likelihood for mentoring to occur.** After students in the human mentoring group completed their pre-surveys, they were given the names of faculty and staff members on their campus who they could seek mentoring from. Unknowingly, when asked for an update of their status after two weeks, seven of the students had completed their interviews with mentors off-campus yet only two students chose to connect with faculty or staff for their mentoring.

Many participants had trouble connecting with their selected mentors even though they had access to faculty and staff members. In order to finish the data collection another mentor was made available for the students to interact with. This mentor was an African American male PhD student in Human Centered Computing and a graduate of a historically Black university. Once available, the remaining students conducted their mentoring session with him over a two-day period. It is hypothesized that his availability attributed to the throughput of interactions in that time period.

Before analyzing the effects of the agent, it had to be confirmed that the knowledge base of the agent was sufficient to give an accurate critique of the system. Of the over 400 questions asked to the virtual agent, none were asked that fit into the two subject areas that did not receive a response. The quality of the responses provided was an obvious issue; however, feedback from the interviews and survey instruments justified the overall quality of the responses.

Eight participants who used the virtual mentor were interviewed. There were some suggestions and feedback given about the agent, but no negative reactions to the agent overall. Below is a list of conclusions based on the comments made during the interviews:

1. **Students liked the concept of using a virtual mentor in addition to having human mentors.** Only one participant mentioned having a negative experience with the virtual mentor; however, that was due to the detail of the responses provided rather than the concept of the virtual mentor itself.
2. **Virtual mentoring can be beneficial when questions are not asked with human mentoring.** Two of the participants stated that they sometimes forget to ask people questions when they meet with them in person, and the virtual mentor can assist in answering those types of questions.
3. **Virtual mentors can introduce basic concepts and terminology.** Many of the participants stated how they learned about funding opportunities and the terminology to go with it.
4. **Virtual mentoring may give detailed responses to some and broad responses to others.** Participants stated the level of in-depth answers was strength of the system while another participant stated the agent should have more in-depth answers.
5. **Virtual mentoring can appear to be non-biased compared to human mentoring.** Two of the participants mentioned that they felt no pressure from the virtual agent to go a particular graduate school or graduate school in general. It simply gave them unbiased answers to questions they had. The two students indicated exposure to graduate school and industry recruiters who come to their institution.
6. **Virtual mentoring can assist students at different usage levels.** The virtual mentor had positive feedback from students that were in sponsored undergraduate research programs as well as those who weren't exposed to prospects of graduate school at all.

The findings of this research provide multiple directions to expand. The following goals contain the primary targets for future studies into mentorship using embodied conversational agents:

1. The content stored in the virtual mentor should be expanded to include other areas of expertise other than career options and funding opportunities.
2. Information about particular graduate schools such as diversity, ranking, size, location, minimum GPA, minimum GRE scores, and application deadlines should be added to the agent.
3. A database of graduate school fellowships, description of current research areas and graduate school rankings can be merged with the virtual agent.
4. Custom responses from the agent should be delivered to the user based on user preferences and attributes such as GPA, REU experience, major,
5. Functionality of the agent should be expanded to enhance the delivery of psychosocial mentoring functions to users.
6. The study should be expanded to include other colleges and universities.
7. The long-term effects of using the agent should be measured in addition to the short-term effects.
8. The accuracy of VM1 should continue to be measure as the corpus of mentorship content and the number of interactions with the system increases.
9. More data should be collected on the current career interest of the participants to see how to adapt the system to provide more beneficial career advice.

Funding from various funding agencies including the National Science Foundation and the United Negro College Fund will be proposed to fund this work.

There were several limitations to this research that should be noted. First, the knowledge utilized by the virtual mentor only consisted of two areas, career options and funding opportunities. Second, the study was conducted at one school. Third, that school was an all-male institution and the study didn't show how effective virtual mentorship would be with African American females. Lastly, the school chosen for the study only offers bachelor's degrees and no graduate degrees.

This research was successful in justifying the need for more research being conducted on the option of offering virtual mentoring in addition to human mentorship for African American computer science students. In addition, the impact of human mentorship was confirmed as well. Findings from the study suggest the expansion of this research to include other ethnicities as well as other STEM disciplines. It is the opinion of the author that this manuscript adds virtual mentorship as an effective tool when used independent of or in collaboration with human mentoring in the effort to broaden participation in STEM fields. Thus, the mentoring constellation of the user will include virtual mentors in addition to human mentors.

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