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DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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AWARD INFORMATION	
1. Federal Agency: Department of Commerce / NOAA	2. Federal Award Number: NA20NWS4680047
3. Project Title: Mobilizing a Collaborative Community for Probabilistic Hazard Information	
4. Award Period of Performance Start Date: 05/01/2020	5. Award Period of Performance End Date: 10/31/2022
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
6. Last Name and Suffix: Bean , null	7. First and Middle Name: Hamilton ,
8. Title:	
9. Email:	10. Phone Number:
AUTHORIZING OFFICIAL	
11. Last Name and Suffix: Moore , null	12. First and Middle Name: Michael ,
13. Title: Manager, PreAward	
14. Email: xenia@ucdenver.edu	15. Phone Number: 3037240080
REPORTING INFORMATION	
Signature of Submitting Official: Stephanie Chandler-Thompson	
16. Submission Date and Time Stamp: 03/08/2023	17. Reporting Period End Date: 10/31/2022
18. Reporting Frequency: ○ Annual ◉ Semi-Annual ○ Quarterly	19. Report Type: ○ Not Final ◉ Final
RECIPIENT ORGANIZATION	
20. Recipient Name: REGENTS OF THE UNIVERSITY OF COLORADO, THE	
21. Recipient Address: 13001 E 17TH PLACE F428, AURORA, CO 80045-2571 USA	
22. Recipient UEI: MW8JHK6ZYEX8	23. Recipient EIN: 846000555

ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

The MCC-PHI project supports the CSTAR program's objectives by generating empirical evidence concerning how to: (a) strengthen decision-making guidelines for the issuance of PHI-enhanced weather warnings as a component of IDSS; (b) improve PHI-enhanced weather warning effectiveness between NWS Core Partners and publics, as well as among publics; (c) pinpoint inclusion criteria and formatting options for PHI-enhanced weather warnings within existing mobile public alert and warning platforms, especially Wireless Emergency Alerts (WEA); and (d) ascertain the value of rendering textual impact-based historical context alongside PHI content within mobile weather warning messages.

25. What was accomplished under these goals?

The PI generated a ~190-page final technical report that advances understanding related to IDSS (Impact-Based Decision Support Services), PHI (Probabilistic Hazard Information), mobile public alert and warning, and CCWI (Community Construction of Weather Information). The final technical report reflects the PI's efforts including: (a) attended the 2021 American Meteorological Society (AMS) annual conference (virtual) to ensure that the MCC-PHI project maintained the most up-to-date approach for investigating PHI-enhanced weather warning; (b) drafted mock PHI messages with guidance from the Denver/Boulder Weather Forecast Office; (c) sought input about the messages and MCC-PHI project from representatives of NOAA/OAR/Earth System Research Labs (ESRL), NOAA National Severe Storms Laboratory, CIMMS/NSSL Behavioral Insights Unit, and Denver OEM; (d) conducted workshop planning activities while on research leave at Kyoto University's Disaster Prevention Research Institute (DPRI) in the summer of 2021; (e) recruited 34 research participants for workshops scheduled for November 8, 9, 10, 2021; (f) conducted workshops with 31 community members; (g) conducted a collaborative workshop with NWS officials, Denver OEM, and community members on March 16, 2022; (h) conducted analysis and drafted findings; (i) honed findings via incorporation of new published research, as well as site tour and interface demonstration at the NWS Denver/Boulder field office; and (j) conducted additional analysis of workshop data to help contextualize the final technical report. Supporting prior experimental research results, the MCC-PHI project finds that inclusion of PHI forecast graphics within WEA messages improves participants' risk perception but may not necessarily improve protective action decision-making. Message-related uncertainties and non-message factors may erode the effectiveness of PHI-enhanced WEA messages for some recipients. Because warning response is a complex social phenomenon, NWS's emerging PHI paradigm may not produce significantly better protective action decision-making compared to the current dichotomous warning paradigm. Therefore, side-by-side comparison of warning messages in an operational environment—those that include PHI forecast graphics versus those that are dichotomous—would be warranted before widespread adoption of PHI-enhanced WEA messages for consumers.

ACCOMPLISHMENTS *(cont'd)*

26. What opportunities for training and professional development has the project provided?

The PI attended the 2021 American Meteorological Society (AMS) annual conference (virtual). The PI has benefited from interactions with NWS personnel along with representatives of NOAA/OAR/Earth System Research Labs (ESRL), NOAA National Severe Storms Laboratory, CIMMS/NSSL Behavioral Insights Unit, and Denver OEM. The PI presented the proposed study approach during the 47th Sogo Bosai Seminar at DPRI on August 6, 2021: https://www.dpri.kyoto-u.ac.jp/news_en/15180/ Additionally, the PI visited the NWS Denver/Boulder field office on May 6, 2022 for a site and WarnGen interface tour and demonstration.

27. How were the results disseminated to communities of interest?

The PI presented the proposed study approach during the 47th Sogo Bosai Seminar at DPRI on August 6, 2021: https://www.dpri.kyoto-u.ac.jp/news_en/15180/ Initial findings were presented during the collaborative workshop with NWS officials, Denver OEM, and community members on March 16, 2022. The PI is currently drafting a research article manuscript for submission to the journal Weather, Climate, and Society. Upon completion of the peer review process and acceptance of this manuscript, the PI will publicize the findings via a press release from the University of Colorado Denver. The final technical report will be posted for public access via the University of Colorado Denver's Department of Communication website following publication of the article in Weather, Climate, and Society.

ACCOMPLISHMENTS *(cont'd)*

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

This is the Final Report, so no further reporting, beyond the planned manuscript submission to Weather, Climate, and Society, will be conducted.

PRODUCTS

29. Publications, conference papers, and presentations

The PI presented the proposed study approach during the 47th Sogo Bosai Seminar at DPRI on August 6, 2021: https://www.dpri.kyoto-u.ac.jp/news_en/15180/ The PI is currently drafting a research article manuscript for submission to the journal Weather, Climate, and Society (by early 2023). Upon completion of the peer review process and acceptance of this manuscript, the PI will publicize the findings via a press release from the University of Colorado Denver. The final technical report will be posted for public access via the University of Colorado Denver's Department of Communication website following publication of the article in Weather, Climate, and Society.

PRODUCTS *(cont'd)*

30. Technologies or techniques

N/A

31. Inventions, patent applications, and/or licenses

N/A

Attach a separate document if more space is needed for #6-10, or #24-50.

PRODUCTS *(cont'd)*

32. Other products

N/A

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

The PI and occasionally the contacts mentioned in #36.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

No

35. What other organizations have been involved as partners?

Denver/Boulder Weather Forecast Office and Denver OEM are the formal partners.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

36. Have other collaborators or contacts been involved?

Based on recommendations from the Denver/Boulder Weather Forecast Office, the PI shared the draft mock messages with representatives of NOAA/OAR/Earth System Research Labs (ESRL), NOAA National Severe Storms Laboratory, and CIMMS/NSSL Behavioral Insights Unit.

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

The principal discipline of the project is risk communication. While publication of the study in Weather, Climate, and Society is planned/pending, it can be said that the impact of the project will be the following: The MCC-PHI project engaged the dual questions of how officials might include PHI forecast graphics within WEA360 messages and how those messages, in turn, might improve recipients' risk perception and protective action decision making. To do this, the MCC-PHI project analyzed qualitative data gathered from a combination of questionnaire, focus group interview, and think-out-loud methods conducted in collaboration with 31 community members in Denver, Colorado. Supporting prior experimental research results, the MCC-PHI project found that inclusion of PHI forecast graphics within WEA360 messages generally improved participants' risk perception but did not spur protective action for nearly half of the message recipients when the probability of impact was ~50%. As the risk of impact increased, so did participants' intention to take protective action. As the risk of impact decreased, so did participants' intention to take protective action. However, changes in intention to take protective action were not uniform among participants.

PHI-based weather warning may reduce over-alerting because a more narrowly defined warning area necessarily excludes people who are not at risk. Conversely, some people who might otherwise ignore a text-only WEA360 warning message might be more likely to take action in response to a message that includes a PHI forecast graphic. But because warning response is a complex, complicated, and social phenomenon, the emerging PHI paradigm may not produce better overall protective action decision-making for message recipients compared to NWS's current dichotomous warning messages. Both message-related uncertainties and non-message factors may erode the effectiveness of PHI-enhanced weather warning messages for some recipients. Private sector weather app developers might be able to pilot test PHI-enhanced weather warning messages as a first step toward eventual NOAA/NWS adoption. PHI-enhanced weather warning messages would also need to be adapted for people with visual challenges before their widespread use. Given these challenges, side-by-side comparison of warning messages in an operational environment—messages that include PHI forecast graphics adapted for access and functional needs populations and messages that are strictly dichotomous—would be warranted before adoption of PHI-enhanced WEA360 messages for consumers.

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

Nothing to Report

39. What was the impact on the development of human resources?

Nothing to Report

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

40. What was the impact on teaching and educational experiences?

Nothing to Report

41. What was the impact on physical, institutional, and information resources that form infrastructure?

Nothing to Report

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

42. What was the impact on technology transfer?

Nothing to Report

43. What was the impact on society beyond science and technology?

The MCC-PHI project benefits the general public because it is the first investigation, to our knowledge, that has engaged residents in the co-construction of PHI-enhanced weather warning messages in ways that directly account for milling behavior. As a result, the MCC-PHI project helps to account for the persistent disconnect between warning recipients' personal risk assessments and their chosen protective actions—phenomena that occasionally do not correspond in ways that officials and researchers expect and/or desire. The CCWI paradigm upon which the MCC-PHI project is based has also been shown to be meaningful to the stakeholders who have participated. The MCC-PHI project appeared to enhance mutual understanding among IDSS stakeholders and members of the general public in Denver and suggested the approach could be replicated in other communities.

IMPACT *(cont'd)*

44. What percentage of the award's budget was spent in foreign country(ies)?

0 , N/A

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

N/A

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

46. Actual or anticipated problems or delays and actions or plans to resolve them

N/A

47. Changes that had a significant impact on expenditures

As reported on the previous interim reports, Covid-19 related delays impacted planned workshop expenditures.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to Report

49. Change of primary performance site location from that originally proposed

Nothing to Report

Attach a separate document if more space is needed for #6-10, or #24-50.

PROJECT OUTCOMES

50. What were the outcomes of the award?

The underlying assumption of the PHI paradigm is that people who are presented forecast graphics depicting higher probabilities of impact will understand their increased personal risk and therefore be more likely to take appropriate protective action.People who are presented lower probabilities of impact will presumably understand their decreased personal risk and therefore avoid unnecessary protective action. To date, PHI-related research has mostly supported the reasonableness of these assumptions the evidence is mixed. While prior experimental studies have demonstrated that PHI can improve risk perception, tangible, consistent, and reproduceable improvements in protective action intention/compliance have remained elusive. The MCC-PHI project's qualitative research findings mirror the mixed outcomes of earlier experimental studies. The MCC-PHI project's findings suggest that presenting probabilities to people at risk will spur some people to act immediately especially those who are unfamiliar with weather hazards in the local area. However, the MCC-PHI project's findings also suggest that presenting probability swaths to at-risk communities will likely increase temptations for some people to engage in risky behavior that could undermine or negate NWS's instructional guidance—a finding that supports both Childs et al.'s (2021) conclusion and the findings of Walters et al. (2019). Childs et al. (2021) found that a traditional, deterministic polygon prompted more people to take immediate protective action than red-color probabilistic or textual warnings. Inclusion of numerical probabilities appeared to allow participants to "game" their personal risk in ways that were not possible with the deterministic warning. Our view is that presenting PHI-enhanced text and forecast graphics to the public via WEA360 tornado messages, in absence of a comprehensive, widespread, and effective public education campaign, could inadvertently lead to an increase in risky behavior among some people that might result in their injury or death. The benefits of reduced over-alerting and having fewer people disregard generalized WEA messages could be offset by increased risk-taking behavior among people who attempt to "game" their responses to warning messages that include forecast graphics with probabilistic swaths. NOAA/NWS should consider whether an information-rich, PHI-enhanced message that includes an audible tone, icon, text, map, radar image, PHI swaths, probability scales, personal locator, and (perhaps) a hyperlink could delay action as much as prompt it. The complexity of the message could pose problems for people who are driving. As Wood et al. (2018) argued, information seeking and confirmation "erodes the advantage provided by warnings for imminent threats" (p. 536). Some people who attempt to fully decipher a PHI-enhanced WEA360 message might delay acting and increase their risk. The MCC-PHI project findings therefore suggest that as FACETs develops in the near term, NWS forecasters should consider using PHI products to more precisely define a dichotomous tornado warning, moving from an unwieldy polygon to an oval-shaped geotargeted alerting area. This approach would be consistent with the findings of Shivers Williams and Klockow McClain's (2020) study, which showed slightly better outcomes for categorical warning compared to PHI. Out of an abundance of caution, the public alert and warning message instructing recipients to take protective action should not include embedded or linked visual tornado impact probability scales until more evidence is gathered concerning their safety and efficacy. The findings of the MCC-PHI project, coupled with divergent findings across recent experimental PHI studies, indicate that there is currently too much uncertainty to warrant the rapid, widespread diffusion of PHI-enhanced warning messages among consumers. The warning messages should provide specific and clear warning and instruction. (Mileti, 2018).

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- ◯ Male
- ◯ Female
- ◯ Do not wish to provide

Ethnicity:

- ◯ Hispanic or Latina/o Not
- ◯ Hispanic or Latina/o Do not
- ◯ wish to provide

Race:

- ◯ American Indian or Alaska Native Asian
- ◯ Black or African American
- ◯ Native Hawaiian or other Pacific Islander
- ◯ White
- ◯ Do not wish to provide

Disability Status:

- ◯ Yes
  - [ ] Deaf or serious difficulty hearing
  - [ ] Blind or serious difficulty seeing even when wearing glasses
  - [ ] Serious difficulty walking or climbing stairs
  - [ ] Other serious disability related to a physical, mental, or emotional condition
- ◯ No
- ◯ Do not wish to provide

Attach a separate document if more space is needed for #6-10, or #24-50.