

AWARD NUMBER: W81XWH-18-1-0400

TITLE: Dense Urban Environment Dosimetry for Actionable
Information and Recording Exposure (DUE DARE)

PRINCIPAL INVESTIGATOR: Prof. David J. Lary

CONTRACTING ORGANIZATION: University of Texas at Dallas

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13. SUPPLEMENTARY NOTES**14. ABSTRACT**

In dense urban environments there is currently a lack of accurate actionable information on atmospheric composition (gaseous and particulate) on fine spatial and temporal scales. By simultaneously measuring both the environmental state and the human biometric response we propose a holistic sensing environment and methodology for providing accurate actionable information. A state of the art sensor network involving fixed and mobile sensors using machine learning calibration and uncertainty estimation. Comprehensive wearable biometric sensors are used to characterize the real-time human response to the composition of the air, making the human response an integral part of the sensor network. The holistic sensor network incorporates embedded real time machine learning to increase functionality in providing actionable insights for active human participants.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON USAMRMC
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TABLE OF CONTENTS

Page

1. Introduction
2. Keywords
3. Accomplishments
4. Impact
5. Changes/Problems
6. Products
7. Participants & Other Collaborating Organizations
8. Special Reporting Requirements
9. Appendices

1. **INTRODUCTION:** *Narrative that briefly (one paragraph) describes the subject, purpose and scope of the research.*

Our goal is a holistic methodology for providing accurate actionable information on environmental dosimetry for atmospheric composition on fine spatial and temporal scales. The approach uses a state of the art sensor network involving fixed and mobile sensors with real-time cross calibration and uncertainty estimation. Comprehensive wearable biometric sensors are used to characterize the real-time human response to the composition of the air, making the human response an integral part of the sensor network. The holistic sensor network incorporates embedded real time machine learning to increase functionality in providing actionable insights for the active human participants.

2. **KEYWORDS:** *Provide a brief list of keywords (limit to 20 words).*

Dense Urban Environment, Dosimetry, Exposure, Biometrics, Machine Learning

3. **ACCOMPLISHMENTS:** *The PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction.*

What were the major goals of the project?

List the major goals of the project as stated in the approved SOW. If the application listed milestones/target dates for important activities or phases of the project, identify these dates and show actual completion dates or the percentage of completion.

- Sensor Acquisition & Calibration: 100% Complete
- Electric Vehicle Environmental Sensor Integration: 100% Complete
- Environmental Measurement Campaigns: 50% Complete
- Low-cost sensor calibration and deployment: 95% Complete
- Publication/Conference Presentation. 1 publication appeared, 3 presentations
- Machine Learning Analysis: 25% Complete
- Survey with participants: 25% Complete
- Machine learning analysis linking biometric responses to environmental triggers: 25% Complete

What was accomplished under these goals?

For this reporting period describe: 1) major activities; 2) specific objectives; 3) significant results or key outcomes, including major findings, developments, or conclusions (both positive and negative); and/or 4) other achievements. Include a discussion of stated goals not met. Description shall include pertinent data and graphs in sufficient detail to explain any significant results achieved. A succinct description of the methodology used shall be provided. As the project progresses to completion, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.

- Our first publication using biometrics and machine learning has appeared. The human body exhibits a variety of autonomic responses. For example, changing light intensity provokes a change in the pupil dilation. In the past, formulae for pupil size based on luminance have been derived using traditional empirical approaches. In this paper, we present a different approach to a similar task by using machine learning to examine the multivariate non-linear autonomic response of pupil dilation as a function of a comprehensive suite of more than four hundred environmental parameters leading to the provision of quantitative empirical models. The objectively optimized empirical machine learning models use a multivariate non-linear non-parametric supervised regression algorithm employing an ensemble of regression trees which receive input data from both spectral and biometric data. The models for predicting the participant's pupil diameters from the input data had a fidelity of at least 96.9% for both the training and independent validation data sets. The most important inputs were the light levels (irradiance) of the wavelengths near 562 nm. This coincides with the peak sensitivity of the long-wave photosensitive cones in the retina, which exhibit a maximum absorbance around $\lambda_{\text{max}} = 562.8 \pm 4.7$ nm.
- Our environmental surveys of the dense urban environment of the Dallas Fort Worth Metroplex is well underway. We have partnered with local government including Dallas County and the City of Plano.
- Some additional publications are in preparation on various aspects of the biometric analysis. The next publication is likely to be on automated accurate blink detection employing a suite of different machine learning approaches and topological data analysis. We believe it will be the most comprehensive analysis to date.

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

If the project was not intended to provide training and professional development opportunities or there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe opportunities for training and professional development provided to anyone who worked on the project or anyone who was involved in the activities supported by the project. "Training" activities are those in which individuals with advanced professional skills and experience assist others in attaining greater proficiency. Training activities may include, for example, courses or one-on-one work with a mentor. "Professional development" activities result in increased knowledge or skill in one's area of expertise and may include workshops, conferences, seminars, study groups, and individual study. Include participation in conferences, workshops, and seminars not listed under major activities.

There have been substantial opportunities for training and professional development of the many students involved in this project. This has included 5 high school students, 28 undergraduate students and 5 graduate students. They have been involved in sensor construction, sensor calibration using machine learning, research and analysis, writing research papers, presentations at meetings and to community groups, and significant community outreach. The biometric analysis has been the subject of 3 semesters of senior design projects for engineering students, each semester involving a different team of 4-5 students. Likewise the live map displaying the data from sensors cross the DFW area has been the subject of 3 semesters of senior design projects for engineering students, each semester involving a different team of 4-5 students. Last semester our air quality mapping team won first place in the end of semester completion among all the senior design teams. Graduate and undergraduate students were the key senior design team mentors and gained valuable leadership experience in the process.

How were the results disseminated to communities of interest?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how the results were disseminated to communities of interest. Include any outreach activities that were undertaken to reach members of communities who are not usually aware of these project activities, for the purpose of enhancing public understanding and increasing interest in learning and careers in science, technology, and the humanities.

1. Extended visit to US SOCOM and SOFWERX in Tampa, FL. Presentations to various SOCOM groups. Appointed United States Special Operations Command Fellow, SOFWERX, J5 Futures Missions Directorate. Awarded a numbered acknowledgement coin.
2. Presentation to General Koeniger Commander of the 711th Human Performance Wing. Awarded an acknowledgement coin.
3. Presentation at the Warrior Human Performance Research Center. Awarded an acknowledgement coin.
4. There is regular community group interaction, our live map displaying the real-time air quality data (<https://www.sharedairdfw.com>) is developed with community involvement involving weekly developer meetings, and quarterly partner meetings with the partner community groups, municipalities, counties, school districts and area community colleges involved.

What do you plan to do during the next reporting period to accomplish the goals?

If this is the final report, state “Nothing to Report.”

Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

- Conduct more street level surveys of the dense urban environment.
- Conduct joint comprehensive biometric and environmental measurement campaigns with cyclists.
- Complete deployment 24/7 street level sensors.
- Machine learning analysis of data from comprehensive biometric and environmental measurement campaigns with cyclists.

4. **IMPACT:** *Describe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to:*

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

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how findings, results, techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and

research in the principal disciplinary field(s) of the project. Summarize using language that an intelligent lay audience can understand (Scientific American style).

- We have been told by many people in the Human Performance space that this is the first time that such comprehensive environmental and biometric information has been brought together.
- Based on a literature survey, our calibration study of the pupillary response to light provides the most accurate model to date, and the most comprehensive in terms of wavelength resolution.
- Aspects of this study have led to a follow on robotic sentinel team study for SOFWERX answering the question “is the area safe” that uses the same mass spectrometer on a robotic boat.
- Local government in the Dallas area are now partnering with us thanks to the electric survey car that is part of this project.

What was the impact on other disciplines?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how the findings, results, or techniques that were developed or improved, or other products from the project made an impact or are likely to make an impact on other disciplines.

By definition, this project is multidisciplinary.

- The environmental sensing sentinels deployed as part of this project (electric environmental survey car & 24/7 street level sensors) are benefiting local communities in terms of environmental exposure surveys.
- Local law enforcement with the ability to “sniff” meth houses etc.
- Biometric sensing developed in this project is now being used in a SOCOM POTFF project for “live fire” training at Troysgate.

What was the impact on technology transfer?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use, including:

- *transfer of results to entities in government or industry;*
- *instances where the research has led to the initiation of a start-up company; or*
- *adoption of new practices.*

Nothing to report so far.

What was the impact on society beyond science and technology?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how results from the project made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world on areas such as:

- *improving public knowledge, attitudes, skills, and abilities;*
- *changing behavior, practices, decision making, policies (including regulatory policies), or social actions; or*
- *improving social, economic, civic, or environmental conditions.*

- Local government in the Dallas area are now partnering with us thanks to the electric survey car that is part of this project for environmental public health protection. This has led to the city of Plano, TX, requesting us to build them a network of 55 street level 24/7 air quality sentinels of the same kind used in this project to deploy across the city of Plano, TX.
- Dallas county is also now partnering with us and linking our live feed data and maps as part of their environmental health protection.
- Several other “preemptive human protection” projects have been spawned thanks to this study. We greatly appreciate your support, thank you, it is making a difference.
- The community group “Downwinders at Risk,” the oldest environmental group in Texas, raised funds and have commissioned us to provide a 11 node network (utilizing the same type of 24/7 sensors as in this study) for one of the most polluted communities in south Dallas.
- Five high school kids have been building the sensors with us, as have 4 undergraduates. A further 28 undergraduate computer science senior design students have been doing a project for a visualization mapping portal, winning First Prize for best senior design project. The undergraduate student who’s was involved in designing the long range wireless communication for the street level sentinels won an undergraduate research scholar award for this work. The graduate student who did the work on building the pupil dilation models won a Dean’s award for his poster on this work.

5. **CHANGES/PROBLEMS:** *The PD/PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction. If not previously reported in writing, provide the following additional information or state, “Nothing to Report,” if applicable:*

COVID-19 has put on temporary hold the participation of human subjects.

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

Describe problems or delays encountered during the reporting period and actions or plans to resolve them.

A one year no-cost extension was granted so that there is more time to complete the participation of human subjects once COVID-19 has passed.

Changes that had a significant impact on expenditures

Describe changes during the reporting period that may have had a significant impact on expenditures, for example, delays in hiring staff or favorable developments that enable meeting objectives at less cost than anticipated.

Nothing to Report

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

Describe significant deviations, unexpected outcomes, or changes in approved protocols for the use or care of human subjects, vertebrate animals, biohazards, and/or select agents during the reporting period. If required, were these changes approved by the applicable institution committee (or equivalent) and reported to the agency? Also specify the applicable Institutional Review Board/ Institutional Animal Care and Use Committee approval dates.

Nothing to Report

Significant changes in use or care of human subjects

Nothing to Report

Significant changes in use or care of vertebrate animals

Not applicable

Significant changes in use of biohazards and/or select agents

Not applicable

6. **PRODUCTS:** *List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state “Nothing to Report.”*

- **Publications, conference papers, and presentations**

Report only the major publication(s) resulting from the work under this award.

Journal publications. *List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

Shawhin Talebi, David J Lary, Lakitha OH Wijerante, Tatiana Lary, Modeling Autonomic Pupillary Responses from External Stimuli using Machine Learning, Biomedical Journal of Scientific & Technical Research, 20 (3), 14,999-15,009, (2019)

This award was acknowledged. Thank you!

Books or other non-periodical, one-time publications. *Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: author(s); title; editor; title of collection, if applicable; bibliographic*

information; year; type of publication (e.g., book, thesis or dissertation); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

Other publications, conference papers and presentations. *Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above. List presentations made during the last year (international, national, local societies, military meetings, etc.). Use an asterisk (*) if presentation produced a manuscript.*

- **Website(s) or other Internet site(s)**

List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site should be provided. It is not necessary to include the publications already specified above in this section.

<https://www.sharedairdfw.com> is the live map for the air quality data collected by the 24/7 sentinels.

- **Technologies or techniques**

Identify technologies or techniques that resulted from the research activities. Describe the technologies or techniques were shared.

- **Inventions, patent applications, and/or licenses**

Identify inventions, patent applications with date, and/or licenses that have resulted from the research. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.

- **Other Products**

Identify any other reportable outcomes that were developed under this project. Reportable outcomes are defined as a research result that is or relates to a product, scientific advance, or research tool that makes a meaningful contribution toward the understanding, prevention, diagnosis, prognosis, treatment and /or rehabilitation of a disease, injury or condition, or to improve the quality of life. Examples include:

- *data or databases;*
- *physical collections;*
- *audio or video products;*
- *software;*
- *models;*
- *educational aids or curricula;*
- *instruments or equipment;*
- *research material (e.g., Germplasm; cell lines, DNA probes, animal models);*
- *clinical interventions;*
- *new business creation; and*
- *other.*

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate “no change”.

Example:

Name: Mary Smith
Project Role: Graduate Student
Researcher Identifier (e.g. ORCID ID): 1234567
Nearest person month worked: 5

Contribution to Project: Ms. Smith has performed work in the area of combined error-control and constrained coding.

Funding Support:

The Ford Foundation (Complete only if the funding support is provided from other than this award.)

Shawhin Talebi
Graduate Student

His machine learning research project (part of his graduate study in Physics) led to the publication:

Shawhin Talebi, David J Lary, Lakitha OH Wijerante, Tatiana Lary, Modeling Autonomic Pupillary Responses from External Stimuli using Machine Learning, Biomedical Journal of Scientific & Technical Research, 20 (3), 14,999-15,009, (2019)

Which also won a Dean's award when it was presented as a poster.

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

If there is nothing significant to report during this reporting period, state "Nothing to Report."

If the active support has changed for the PD/PI(s) or senior/key personnel, then describe what the change has been. Changes may occur, for example, if a previously active grant has closed and/or if a previously pending grant is now active. Annotate this information so it is clear what has changed from the previous submission. Submission of other support information is not necessary for pending changes or for changes in the level of effort for active support reported previously. The awarding agency may require prior written approval if a change in active other support significantly impacts the effort on the project that is the subject of the project report.

Nothing to Report

What other organizations were involved as partners?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe partner organizations – academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other organizations (foreign or domestic) – that were involved with the project. Partner organizations may have provided financial or in-kind support, supplied facilities or equipment, collaborated in the research, exchanged personnel, or otherwise contributed.

Provide the following information for each partnership:

Organization Name:

Location of Organization: (if foreign location list country)

Partner’s contribution to the project (identify one or more)

- Financial support;*
- In-kind support (e.g., partner makes software, computers, equipment, etc., available to project staff);*
- Facilities (e.g., project staff use the partner’s facilities for project activities);*
- Collaboration (e.g., partner’s staff work with project staff on the project);*
- Personnel exchanges (e.g., project staff and/or partner’s staff use each other’s facilities, work at each other’s site); and*

Prof. Guido Verbeck’s group at the University of North Texas built for us the mass spectrometer. One of only ten of its kind in the world which has performed better than the reference instruments at the Army proving ground trials in 2019. We gratefully acknowledge and appreciate their partnership.

We have partnered with the community group “Downwinders at Risk” and the City of Plano, TX, to provide additional sensors.

We have partnered with the Dallas College Community College District (14 locations) as sensor hosts as well as various school districts and the City of Fort Worth, TX.

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS: *For collaborative awards, independent reports are required from BOTH the Initiating Principal Investigator (PI) and the Collaborating/Partnering PI. A duplicative report is acceptable; however, tasks shall be clearly marked with the responsible PI and research site. A report shall be submitted to <https://ers.amedd.army.mil> for each unique award.*

QUAD CHARTS: *If applicable, the Quad Chart (available on <https://www.usamraa.army.mil>) should be updated and submitted with attachments.*

Dense Urban Environment Dosimetry for Actionable Information and Recording Exposure (DUE DARE)

BA170483



PI: Prof. David J. Lary

Org: University of Texas at Dallas

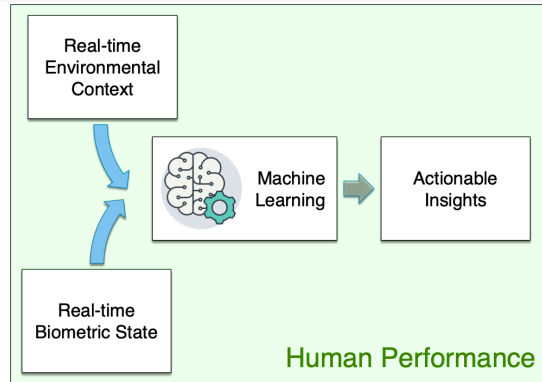
Award Amount: \$558,235

Study Aims

In dense urban environments there is currently a lack of accurate actionable information on atmospheric composition (gaseous and particulate) on fine spatial and temporal scales. By simultaneously measuring both the environmental state and the human biometric response we propose a holistic sensing environment and methodology for providing accurate actionable information.

Approach

A state of the art sensor network involving fixed and mobile sensors using machine learning calibration and uncertainty estimation. Comprehensive wearable biometric sensors are used to characterize the real-time human response to the composition of the air, making the human response an integral part of the sensor network. The holistic sensor network incorporates embedded real time machine learning to increase functionality in providing actionable insights for active human participants.



Timeline and Cost

Activities	CY	2018	2019	2020
Sensor Acquisition & Calibration – Milestones: Low cost sensor calibration/Publication/IRB/HRPO				
Electric Vehicle Integration Milestones: Test Survey				
Measurement Campaigns – Milestones: Deployment of low cost sensors & Surveys				
Machine Learning Analysis – Milestones: Publication/Final Report/Fort Detrick presentation				
Estimated Budget		\$200k	\$300k	balance

Updated: UT Dallas, September 11, 2020

Goals/Milestones

CY18 Goals – Sensor Acquisition & Calibration

- ▶ Sensor acquisition

CY19 Goals – Electric Vehicle Integration & Measurement Campaigns

- ▶ Low-cost sensor calibration and deployment
- ▶ Vehicle sensor suite training
- ▶ Vehicle sensor suite testing
- ▶ Publication/Conference Presentation
- ▶ Integration of vehicle sensors into sensor pod
- ▶ Integration of sensor pod into car

CY20 Goals – Machine Learning Analysis

- ▶ Survey with participants
- ▶ Machine learning analysis linking biometric responses to environmental triggers

CY21 Goals – Machine Learning Analysis

- ▶ Survey with participants
- ▶ Machine learning analysis linking biometric responses to environmental triggers

9. **APPENDICES:** Attach all appendices that contain information that supplements, clarifies or supports the text. Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.