ARL-TR-8588 ● Nov 2018

US Army Research Laboratory

2018 Human Variability Workshop: Insights to Drive Scientific Innovations for Human State Detection and Prediction

by Jean M Vettel, Katherine R Gamble, Janice Booker, Evan C Carter, Sean M Fitzhugh, Joshua S Rubinstein, Derek P Spangler, Steven M Thurman, Arwen H DeCostanza, and Justin R Brooks

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
November 2018	Technical Report	October 2016–September 2018

4. TITLE AND SUBTITLE
2018 Human Variability Workshop: Insights to Drive Scientific Innovations for Human State Detection and Prediction

5a. CONTRACT NUMBER
W911NF-10-2-0022

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Jean M Vettel, Katherine R Gamble, Janice Booker, Evan C Carter, Sean M Fitzhugh, Joshua S Rubinstein, Derek P Spangler, Steven M Thurman, Arwen H DeCostanza, and Justin R Brooks

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Research Laboratory
ATTN: RDRL-HRF-B
Aberdeen Proving Ground, MD 21005

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-TR-8588

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The US Army Research Laboratory (ARL) executes a multidisciplinary research program to overcome existing limitations in technology that arise from brittle, hard-coded algorithms that cannot adapt to the dynamic demands of users. Under The Human Variability Project, researchers design novel approaches for noninvasive and unobtrusive longitudinal measurement of human performance while concurrently advancing analytic approaches that will enable real-time adaptive technology. ARL researchers hosted a Human Variability Workshop to ensure the employed approaches are both leveraging and advancing the current state of the art. In this two-day workshop, multidisciplinary experts, both internal and external to ARL, gathered to discuss a vision for future experimental and analytical approaches designed to achieve the project's high-risk and ambitious scientific goals. This report summarizes the core scientific vision of The Human Variability Project and how the workshop was designed to augment ongoing and future research plans. The first two sections summarize the scope of the program and execution plan for the workshop, while the bulk of the report summarizes the core scientific themes that emerged from the series of talks, panels, and breakout sessions at the workshop. Finally, the report discusses the core recommendations and future directions for the program, including appendices with output from the brainstorming sessions.

15. SUBJECT TERMS
human sciences, adaptive technology, physiology, behavior, performance, real-time analysis, multidisciplinary research, future Army, brainstorming, innovation, graphic recording, workshop design

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Jean Vettel
Unclassified	Unclassified	Unclassified	UU	184	19b. TELEPHONE NUMBER (Include area code) 410-278-7431

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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Acknowledgments

This research is aligned with the scientific aims of the Human Sciences campaign at the US Army Research Laboratory (ARL) and the vision for ARL's essential research programs, especially research identified for capabilities needs to support Human–Agent Teaming, Machine Learning and Artificial Intelligence, and Discovery. We want to acknowledge the intellectual contribution of the scientific community within the laboratory and its strong influence on the scientific approaches described in this technical report. This research was supported by mission funding to ARL, including work under Cooperative Agreements W911NF-10-2-0022 and W911NF-17-2.

Executive Summary

In October 2016, researchers at the US Army Research Laboratory (ARL) began a new multidisciplinary research program to overcome existing limitations in technology that arise from brittle, hard-coded algorithms that cannot adapt to the dynamic demands of users. Under the Continuous Multifaceted Soldier Characterization for Adaptive Technologies program, more commonly known as The Human Variability (HV) Project, researchers design novel approaches for noninvasive and unobtrusive longitudinal measurement of human performance while concurrently advancing analytic approaches that will enable real-time adaptive technology. ARL researchers designed and hosted a HV Workshop to ensure the employed approaches are both leveraging and advancing the current state of the art. This two-day workshop was hosted in Baltimore, Maryland, on 16–17 July 2018, and multidisciplinary experts, both internal and external to ARL, gathered to discuss a vision for future experimental and analytical approaches designed to achieve the project's high-risk and ambitious scientific goals.

This report summarizes the core scientific vision of The HV Project and how the workshop was designed to augment ongoing and future research plans. The first two sections summarize the scope of the program and execution plan for the workshop, motivating the interactive design intended to spawn innovative thinking and enhanced collaboration during the two-day workshop. Next, the bulk of the report summarizes the core scientific themes that emerged from the series of talks, panels, and breakout sessions during the workshop. The report also includes images created by a real-time graphic recording artist during the meeting that visualize the interconnections among the ideas discussed. Finally, the report discusses the core recommendations and future directions for the program following the invigorating discussion from the workshop, including a set of appendices that transcribe output from the brainstorming sessions as well as copies of the talk slides.

One core insight from the workshop highlighted the challenge for funding for this type of research from traditional sources given the high-risk nature of human variability research and the inability to provide pilot data based on the cost and implementation challenges of longitudinal collection. The funding challenges from traditional agencies also reflect how our HV approach intentionally departs from convention, including a systematic move away from the enduring reliance in human science on research using controlled behaviors in laboratory settings. The overarching viewpoint at the end of the workshop was that The HV Project at ARL was definitely high-risk, scoped for innovation, and connected tightly with the current state of the art in longitudinal study of real-world behaviors.

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1. Introduction: Origin and Aims of The Human Variability Project

As the Army's corporate laboratory, the US Army Research Laboratory (ARL) executes fundamental research to discover scientific innovations that deliver cutting-edge capabilities for the future Army. One component of successful execution involves the design of mission research programs that are vetted and incorporated in the Science and Technology (S&T) portfolio of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA[ALT]). Mission programs are scoped by existing scientific and/or technological gaps, and funded mission lines delineate targeted deliverables as metrics of success over the first several years of the program. Mission programs are then routinely evaluated and realigned, when necessary, to account for new technological advancements or burgeoning capability gaps. The intent is to constantly reinvigorate the questions and methods used in Army S&T to ensure technological and strategic overmatch for US Soldiers on the ever-evolving battlefield, including both physical and virtual/cyber domains.

The future Army systems envisioned in The Human Variability (HV) Project dynamically adapt to Soldier states, behaviors, and intentions in real-time across multiple domains to enhance individual, system, team, and human–agent team performance. The core intuition is that science must identify novel metrics that can detect and predict performance variability on moment-to-moment, day-to-day, month-to-month, and year-to-year timescales, and then incorporate these metrics in adaptive technologies using approaches that have been designed to mitigate performance decrements or enable performance enhancement.

The HV Project plans to achieve these game-changing, disruptive technological advancements by focusing on science that 1) measures and quantifies internal and external parameters of an individual's state and context, and 2) identifies or develops models and/or algorithms that can predict fluctuations in human performance. A promised metric of success for the program is the "HV Large Scale Experiment", which requires continuous collection of data from hundreds of participants across long time frames (>6 months) and in real-world settings (outside the laboratory). Thus, the essence of this program requires noninvasive and unobtrusive longitudinal measurement of comprehensive, high-resolution data across multiple subjects. In addition, these innovations in experimental design must be combined with novel approaches to analysis since the naturalistic data will necessarily (and intentionally) include less controlled, systematic experimental conditions characteristic of decades of human research in laboratory settings. In

short, The HV Project requires a paradigmatic shift in both the design and analysis of human data.

Given the high-risk, ambitious nature of the program, the execution of the research was conceived in three phases across the initial years of the program. In year one (FY17), the first phase facilitated the development of collaborative teams through a competitive research proposal process. The five funded proposals focused on theory development, pilot experimentation, methods and tool development, and/or critical analysis to build internal capability and expertise in the design and analysis of HV research. Thus, phase two encapsulates the execution of the five funded projects in years two and three of the program, plus the active growth of additional collaborators both internal and external to ARL. Collaborations are actively built through a number of programs, including ARL's Open Campus concept with shared personnel and data collection efforts, collaborative research alliances that use a competitive process to award funding for joint work between an external organization (academic or industry) and ARL, and a variety of "Broad Area Announcements" in ARL's core research interests (for more details on these and other such opportunities, see https://www.arl.army.mil/www/default.cfm?page=6). In short, this build of expertise and enhanced collaboration during phase two has the explicit aim of enabling the formulation and successful execution of the HV Large Scale Experiment in phase three of The HV Project, set to begin in year four of the program (FY20 or October 2019). The promised objective for the HV program in FY25 is to provide foundational technologies required for future Army systems to generate high-resolution, moment-to-moment predictions of individual Soldier's relevant state information for teaming with other human and nonhuman agents.

Another core element of phase two was the design and execution of the HV Workshop. This two-day gathering was hosted by ARL on 16–17 July 2018 in Baltimore, Maryland. The workshop facilitated discussion among ARL researchers, who are geographically distributed across a number of ARL sites, as well as discussion with a diverse set of external scientists from various cities and organizations, including HV proposal mentors, potential HV collaborators, and researchers with expertise in longitudinal and/or naturalistic data collections. The workshop invitation that was sent to external researchers is provided in Appendix A.

In this report, we describe how our workshop agenda was designed to maximize collaborative exchanges and innovative thinking (Section 2), summarize the insights from the talks and discussion throughout the workshop (Section 3), and conclude with recommendations moving forward and preliminary outcomes in the

two months following the workshop (Section 4). The appendices contain a transcription of the ideas generated during the brainstorming and group feedback discussions as well as copies of the talk slides.

2. Design of the HV Workshop

We briefly characterize three features of the agenda that were designed to maximize collaborative exchanges and innovative thinking during the two-day workshop. The full agenda is provided in Table 1. In short, the two-day workshop was designed with a full agenda on Day 1, running from 0930 to 1700, and an organized dinner for informal discussions in the evening. Day 2 was designed as a half day, running from 0930 to 1300, allowing ample time to fly out for out-of-town attendees.

Table 1 Workshop agenda

Time Start	Time Stop	Speaker	Topic
Day 1	**16-Jul-18**		
9:30	9:35	Justin Brooks	Welcome, overview, agenda (facilitators introduce themselves)
9:35	9:50	Jim White and Justin Brooks	Mapping preliminary thoughts and expectations
9:50	10:30	Justin Brooks	Our vision for adaptive technology & need to quantify human variability
10:30	12:00	Open Discussion/Facilitation	Brainstorming "pie in the sky" science & tech ideas
12:00	12:15	Break - gallery walk	
12:15	13:00	Panel of ARL Human Variability PIs	Discussion of emerging 5-year research ideas
13:00	14:00	Lunch + ARL Collaboration	
12:45	*13:00*	*Arwen DeConstanza*	*Discussion of ARL's Open Campus, CRAs, and collaboration mechanisms*
14:00	15:00	Campbell, Sliwinski, Thayer questions from audience	Panel Discussion with Academic Guests (each panelist has 7 minute overview of core suggestion/idea/topic)
15:00	16:00	Ackerman, Contractor, Nahum-Shani	Panel Discussion with Academic Guests (each panelist has 7 minute overview of core suggestion/idea/topic)
16:00	16:15	Break	
16:15	16:45	Open Discussion/Facilitation	Build a vision graph the integrates diverse ideas for future 10+ years
16:45	16:50	Jim White	Lightning wrap up
16:50	17:00	Justin Brooks	Wrap Up
19:00	????	Cocktails/Dinner	
Day 2	**17-Jul-18**		
9:30	9:35	Justin Brooks	Welcome back
9:35	10:15	Open Discussion/Facilitation	Meeting reflections, discussion of pantry topics, review Day 1 graphic depictions
10:15	11:00	Jean Vettel	Army Context for Research Aims and Scientific Capabilities
11:00	11:15	Break	
11:15	12:30	Open Discussion/Facilitation	Build another vision graph with near-term targets for context 5+ years
12:30	13:00	Lunch + Wrap-up	
12:30	*12:45*	*Justin Brooks*	*Wrap up, thank you*
13:00		Depart	

An essential design feature for our HV Workshop involved hiring a facilitator and graphic recording artist. Critically, this allowed the discussion to be facilitated by a nonexpert, intended to minimize bias for certain methods or theories and foster the incorporation of an initial discussion of attendee expectations for the workshop (Section 2.1) as well as several brainstorming sessions (Section 2.3). Even more importantly, the graphic recording artist provided a real-time visual summary of the interconnections among the ideas as well as an explicit coding of the most frequent concepts or topics that a nonexpert heard throughout the discussion. These drawings were then hung on the wall in the meeting room to allow "gallery walks", where participants could revisit topics or themes during the breaks by viewing the graphic summary images. Each of these elements provided opportunities for

enhanced discussion among attendees based on the dynamic evolution of the discussion, but without requiring exhaustive notetaking by the participants. The large volume of brainstorming ideas (Appendix B) also remains a strong resource to revisit during future research discussions when searching for new approaches or inspiration as The HV Project unfolds. A more detailed description of these agenda items and the associated graphic recordings are provided in Section 2.

A second design feature emphasized the flow of ideas across the agenda items. After asking everyone to briefly state their expectations for the workshop to build group connection, Dr Justin Brooks provided an overview talk about the underlying science in HV and promise of adaptive technologies for future systems, but this talk was intentionally devoid of the programmatic overview of Big Army context, ARL's mission space, and similar organizational framing. On Day 1, the goal for the HV workshop was to focus on the core scientific gaps and then move to brainstorming out-of-the-box ideas for the six core themes of our ongoing HV science (Section 2.3). The Day 1 agenda then included panels of ARL researchers and invited academic researchers to dive more into the specifics of research interests, including existing visions for ongoing research for non-Army applications. It was only on Day 2 that Dr Jean Vettel gave a talk about the Army context that prioritizes some science questions over others based on capability gaps and identifying Army niche areas. This flow facilitated a focus on the science on Day 1, moving from big picture and vision down to the results from specific HV-related studies, and then on Day 2, provided information about organizational context and near-term constraints. Often, short workshops with cross-organization attendance inadvertently spend a large amount of time at the front end of the workshop understanding organizational foci and erroneously down-scoping the imagined possibilities, so our agenda design flipped the placement of the organizational perspective to Day 2. This allowed attendees to naturally build curiosity about the host organization's perspective (evidenced by questions at the informal dinner on Day 1), and then served to minimally constrain the innovative thinking about potential future applications of adaptive technology on Day 1.

The third feature that we wanted to highlight focused on assigning attendees to groups for the brainstorming session on Day 1. Based on the RSVPs, each attendee was placed in one of six groups to maximize the mixture of scientific expertise, organizational perspective, and amount of previous interaction. The aim was to have multidisciplinary groups of attendees who had largely never met or only had minimal interaction. Each group was assigned a color sticker that was placed on their nametag, and then each group was split out for the brainstorming discussion about the six core themes of our ongoing HV science (Section 2.3).

3. Summary of Talks, Panels, and Discussion at the 2018 HV Workshop

The two-day workshop was hosted by ARL and co-facilitated by Doodletoonz.com. The 33 attendees included ARL scientists, HV proposal mentors, and a diverse set of external scientists from various cities and organizations across the United States. Collectively, this multidisciplinary group had an inspiring discussion about the current state of the art in longitudinal data collection from participants in naturalistic settings, and the following subsections encapsulate some central themes from each element of the two-day agenda that led to suggested recommendations and follow-on outcomes described in Sections 4 and 5.

3.1 Day 1: Expectations

To build connection to the flow of the workshop, the first group discussion on Day 1 focused on attendee expectations. Our facilitator asked everyone to share a brief thought about why they came to the workshop and what they hoped to learn while the graphic recorder visualized the responses. As depicted in Fig. 1, the group articulated 25 core sentiments, including sharing knowledge from diverse perspectives, identifying relationships with other techniques or questions, and learning about new methods, models, and sensors.

Fig. 1 At the beginning of Day 1, attendees were asked to provide a short description about their reasons for attending and expectations for the two-day workshop

3.2 Day 1: HV Overview Talk

The first talk was given by Dr Justin Brooks (slides in Appendix C), and he described the interconnections among the scientific gaps connected to ARL's vision for human–agent teaming, The HV Project, and ongoing ARL research. The critical gap for human–agent teaming centers on the development of real-time algorithms that can estimate states, behaviors, and intentions of interest. As depicted in Fig. 2, most systems are not flexible, unable to adapt to an individual. Consequently, The HV Project was conceived to execute the fundamental science needed to discover these foundational algorithms and systems to provide individualized, adaptive technologies.

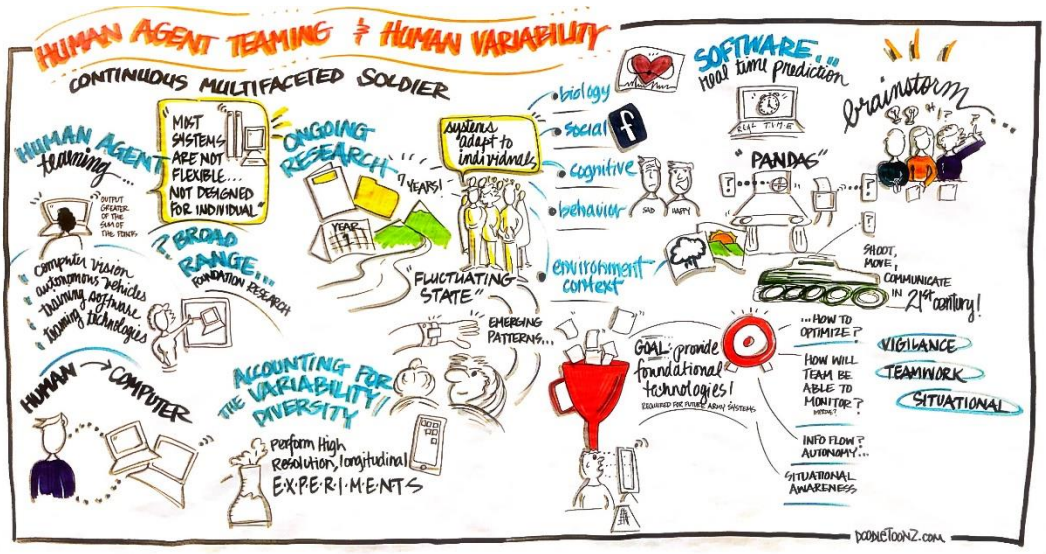

Fig. 2 On Day 1, Dr Brooks provided an overview of The HV Project and its relationship to human–agent teaming and ongoing ARL research

Dr Brooks' talk described the challenge of identifying the critical sources of human variability that are needed to optimize human–agent teaming, including biology, social context, cognitive state, behavioral performance, and environmental context (Fig. 2). His talk also described the interrelationships among the five funded HV projects, including a scenario that could highlight their intersection (see Appendix C, slides 14, and 17–18). Based on the core scientific gaps at the center of The HV Project, Dr Brooks then described the upcoming brainstorming session about six core topic areas for HV research.

3.3 Day 1: HV Brainstorming

For the brainstorming activity, attendees were divided into six predetermined groups to discuss six predetermined topics. Each predetermined group was

designed to maximize diversity in expertise and bring together researchers who had minimal or no previous interaction (Section 2). Each group was assigned a table, a big notepad on an easel, and a moderator. Each member of the group received a set of sticky notes and a pen to record their brainstorming ideas. After brainstorming potential technologies (unconstrained by logistics or current research capabilities), everyone in the group except the moderator moved to the next table to brainstorm about the next topic. Thus, at the end of the session, all attendees (except the six moderators) had generated ideas for each of the six topics.

For each of the six HV topic areas, the big themes across each of the groups were then summarized by the topic's moderator. In Fig. 3, the core themes plus the associated brainstorming stickies are illustrated. The six topics and their themes are briefly summarized here, but the full list of ideas (arbitrarily ordered) from the stickies have been transcribed and included as Appendix B:

1) For the topic on environmental context (including climate, seasonal effects, tasking, distractions, noise, etc.), the attendees brainstormed ideas that allowed the environment to adapt to individuals using information about task factors, physical factors, and cognitive interaction.

2) For the topic on biology/physiology (including genetics, sex, heart rate, microbiome, etc.), the attendees brainstormed ideas about novel sensors to assess both healthy and injury states, including adaptations for strengths and weaknesses.

3) For the topic on decision making (including decision fatigue, critical/life-and-death decisions, etc.), the attendees brainstormed ideas about ways to overcome the critical but nebulous concept of trust and the pervasive challenge of decision fatigue.

4) For the topic on information/data overload (including channels of communication, bandwidth for information, etc.), the attendees brainstormed ideas about what types of external channels and/or infrastructure can augment a human's ability to save information and/or internally process big data.

5) For the topic on social interaction (including new social environments, organizational hierarchy such as tenured faculty, supervisors, evaluation committees, and subordinates), the attendees brainstormed ideas about innovations to study multi-scale dynamics from the ion level up to nonverbal expressions, including the critical need to understand emergent group roles and influences on individual performance.

6) For the topic on rest/activity history (including running a marathon, sleep disruption, exercise/rest, stress/recovery, etc.), the attendees brainstormed ideas about how teams could capitalize on coordination among member rest/wake cycles or how technology aides for driving and other contexts could enhance performance.

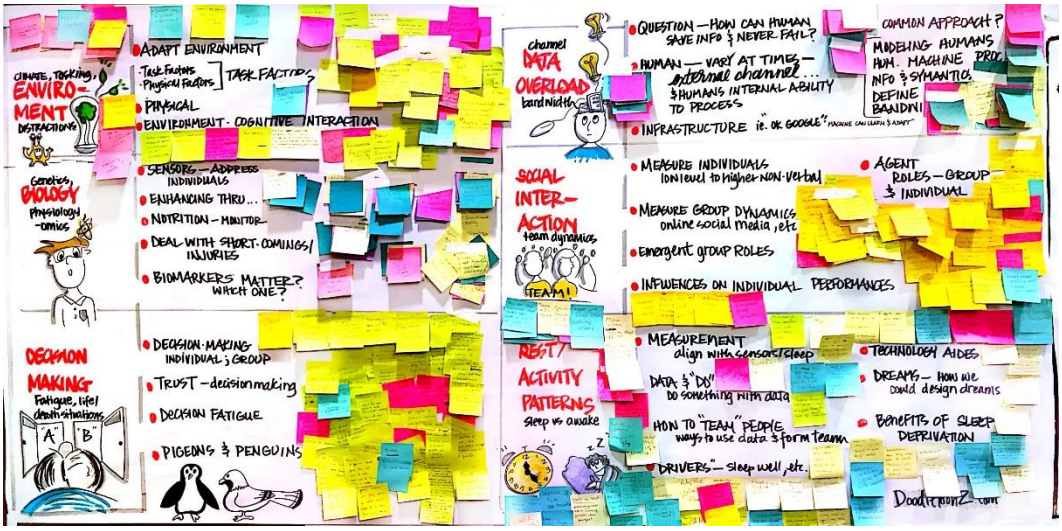

Fig. 3 After listening to the core vision of The HV Project, attendees were divided in six groups and asked to brainstorm future technologies that were unconstrained by current capabilities for each of six HV topic domains (recorded in red text). After each group rotated through each topic, the moderator for the topic summarized the core themes, recorded in the topic box, across the stickies of brainstorming ideas from each attendee, transcribed in Appendix B.

During the workshop, this brainstorming session facilitated a series of discussions about possibilities and targets for innovation; however, the large volume of brainstorming ideas that was the output of this session provides a valuable resource for future research discussions when searching for new approaches or inspiration as The HV Project unfolds (Appendix B).

3.4 Day 1: Panel of ARL HV Principal Investigators

The first panel of the workshop featured six ARL researchers who are executing projects related to the aims of The HV Project. These projects include the funded proposals from phase one of HV program execution or new collaborators on the project from phase two (Section 1). As reflected in their slides (Appendix D), each presenter was limited to 3–4 slides and 5 min to convey one of their core interests, synopsis of open gaps or desired innovation, and a terse description of their technical approach.

In Fig. 4, the core interests of the presenters are depicted on the left in red text, while the discussion during the question and answer (Q&A) period is shown on the right in green.

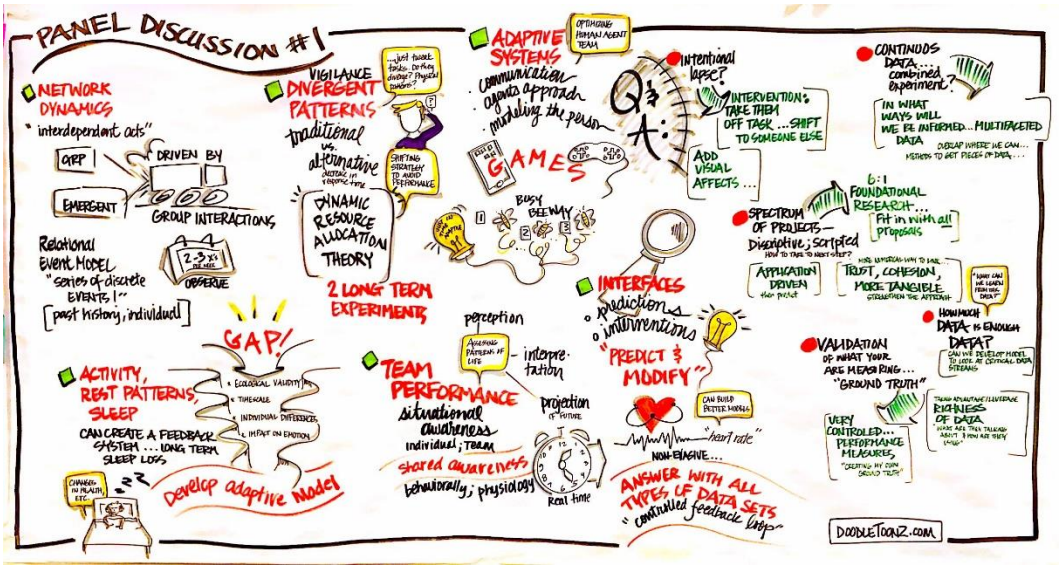

Fig. 4 A panel of six ARL researchers presented 5-min talks about one of their core interests for future HV research, including network dynamics by Dr Sean Fitzhugh; activity, rest, and sleep patterns by Dr Steven Thurman; variable vigilance by Dr Joshua Rubinstein; team performance by Dr Katherine Gamble; adaptive systems by Dr Evan Carter; and enhancing attention by Dr Derek Spangler. The talk themes are in red text on the left and Q&A themes in green on the right; their talks are included in Appendix D.

The following topics were presented:

1) In his talk, Dr Sean Fitzhugh discussed network dynamics for understanding group outcomes, where these outcomes stem from group processes, such as coordination or conflict management, and emergent states, such as trust or social cohesion. He described an approach that uses a relational event model to understand the timing and structure of interactions. A better understanding of interaction dynamics may help us to predict changes in group states and processes.

2) The next talk by Dr Steven Thurman described both immediate and long-term effects of sleep loss on health, performance, and relationships; however, there is a substantial gap in our current understanding about how naturalistic fluctuations in an individual's rest and activity patterns impact emotion, learning, and decision making. He described a modeling approach to predict individual performance from multi-timescale, multimodal data from noninvasive measurement devices.

3) The following talk by Dr Josh Rubinstein discussed the sources of variability during vigilance tasks. He proposed a new theory called Dynamic Resource Allocation Theory to account for traditional decrements in vigilance (characterized by a drop in sensitivity) and alternative decrements (characterized by a shift in criterion). He described designs for two long-term experiments.

4) In her talk, Dr Katherine Gamble proposed an experiment to operationalize the Army's nebulous concept of situational awareness to enhance team performance. Using an example to assess patterns of life, the experiment would examine the interaction among perception of the environment, interpretation of the information, and ability to project to future events.

5) The next talk by Dr Evan Carter included a description of research to develop adaptive systems through the use of mobile games. With their ability to allow high throughput of out-of-lab sampling, mobile games provide a rich opportunity to study more people in more diverse situations. He described developing a "Just in Time Adaptive Intervention (JiTAI)" in his first study to optimize human–agent teaming in a mobile game known as Busy Beeway.

6) In the final talk by Dr Derek Spangler, he discussed previous research that linked phasic heart rate and heart-rate variability (HRV) with fluctuations in attention. To capitalize on this relationship, he proposed minimizing attentional lapses by presenting stimuli earlier in the cardiac cycle. He was also interested in how this relationship would be influenced by between-subjects (ethnicity, sex) and within-subjects day-to-day (sleep, mood) factors.

3.5 Day 1: ARL Collaboration Mechanisms

During lunch, Dr Arwen DeCostanza led a discussion about ARL's collaboration mechanisms. They are actively built through a number of initiatives, summarized as follows, with details of these and other programs provided at https://www.arl.army.mil/www/default.cfm?page=6:

1) **Open Campus.** ARL's Open Campus initiative was designed to build a science and technology ecosystem that will encourage groundbreaking advances in basic and applied research areas of relevance to the Army through collaboration. Through the Open Campus framework, ARL scientists and engineers work collaboratively and side by side with visiting scientists in ARL's facilities as well as ARL researchers sitting at

collaborators' institutions. ARL's Open Campus is not a funding opportunity; instead, research collaborations are identified where there is a mutual scientific interest and investment by all partners.

2) **Collaborative Alliances.** Collaborative Technology Alliances and Collaborative Research Alliances are partnerships among Army laboratories and centers, private industry, and academia that are focused on the rapid transition of innovative technologies. Within these large-scale, funded programs, multidisciplinary research teams bring together world class research and focus it on Army-specific technology objectives for application to Army needs. ARL develops new topics for collaborative alliances on an ongoing basis, which are announced openly. After award, new collaborative partnerships can also be developed within the Alliance.

3) **Broad Agency Announcements (BAAs).** A BAA is a competitive solicitation procedure used to obtain proposals for basic and applied research. Solicited research under a BAA attempts to increase knowledge in science and/or advance the state of the art rather than the practical application of knowledge. ARL announces long-term BAAs in their core research areas that are open for several years, as well as short-term BAAs with specific solicitations and closing dates.

4) **Small Business Opportunities.** ARL participates in the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, designating topics and accepting proposals. The SBIR and STTR programs are a source of early stage/high-risk funding for start-ups and small business. To be eligible, the small business must be American-owned, organized as a for-profit entity, and have fewer than 500 employees.

3.6 Day 1: Two Panels of Invited Academic Researchers

The bulk of the afternoon on Day 1 was spent listening and discussing the expertise and experience of six academic researchers who have been involved in longitudinal and/or naturalistic experimentation. Similar to the ARL researchers, the academics were assigned to one of two panels. Unlike the ARL panelists, the academic researchers focused on previous research rather than future work. Each academic panelist was allotted 7 min to provide a short showcase about their core research expertise, and each panel of three presenters was followed by a Q&A period.

As depicted in Fig. 5 the first panel of academics consisted of Dr Andrew Campbell (Dartmouth University) who discussed the future of modeling from mobile devices

and wearable technology, Dr Martin Sliwinski (The Pennsylvania State University) who talked about measuring and predicting cognitive variability, and Dr Julian Thayer (The Ohio State University) who described a neurovisceral integration model of the stress response.

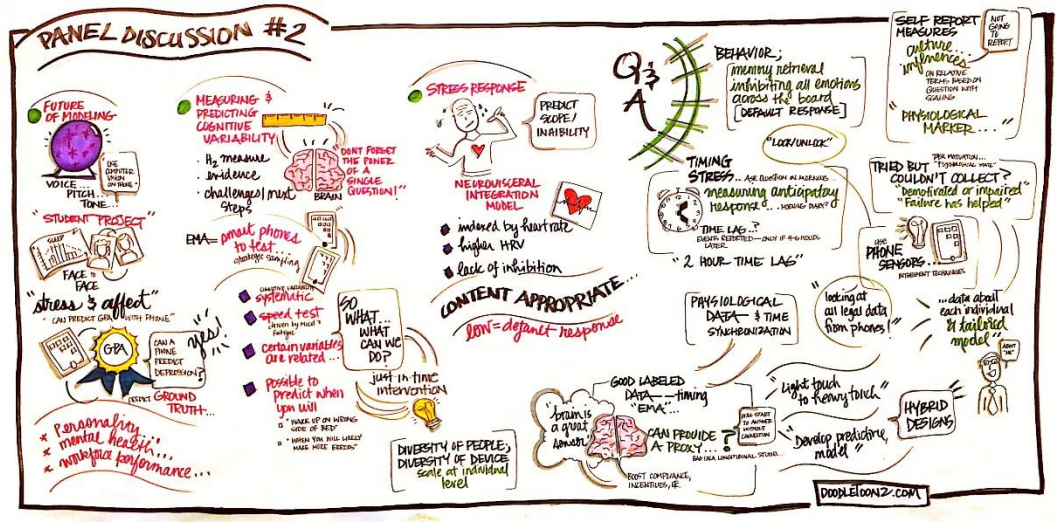

Fig. 5 The first panel of three external academics presented 7-min talks about their HV-related research expertise, including modeling from mobile devices by Dr Andrew Campbell; predicting cognitive variability by Dr Martin Sliwinski; and stress response by Dr Julian Thayer. The talk themes are in maroon text on the left and Q&A themes in green on the right, and their talks are included in Appendix E.

As depicted in Fig. 6, the second panel of academics consisted of Dr Phillip Ackerman (Georgia Institute of Technology) who discussed the interplay between task and context, Dr Inbal (Billie) Nahum-Shani (University of Michigan) who described adaptive interventions within the health domain, and Dr Noshir Contractor (Northwestern University) who presented interaction networks and influence of data, theory, and methods.

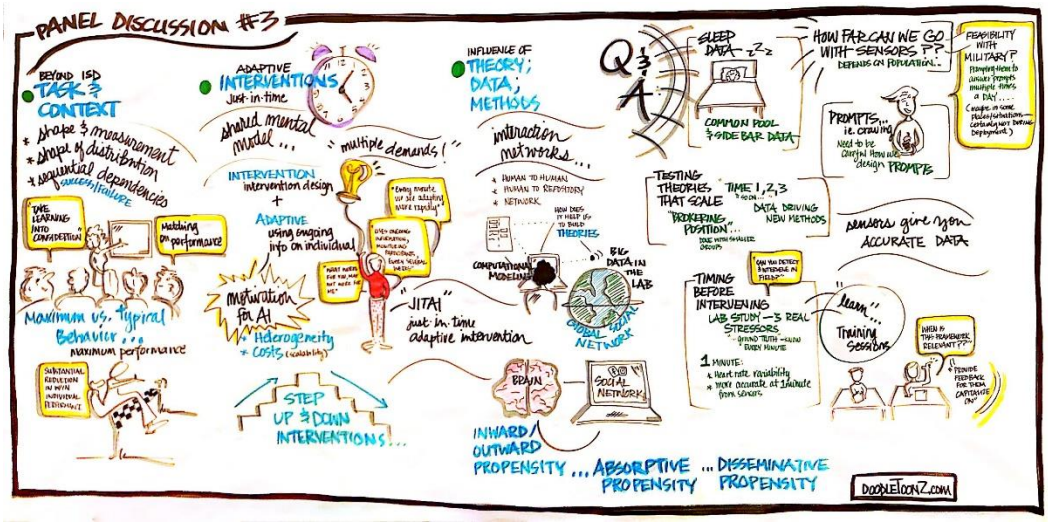

Fig. 6 The second panel of three external academics also presented 7-min talks about their HV-related research expertise, including interplay of task and context by Dr Phillip Ackerman; adaptive interventions by Dr Billie Nahum-Shani; and interaction networks by Dr Noshir Contractor. The talk themes are in blue text on the left and Q&A themes in green on the right, and their talks are included in Appendix E.

Each of these six talks is summarized in a subsection, and the associated slide decks are included in Appendix E.

3.6.1 Dr Campbell

Dr Andrew Campbell is professor at Dartmouth, and his research focuses on developing computational methods for mobile devices and wearables to understand and predict human behavior. Dr Campbell presented research on the StudentLife project that used passive and automatic sensing data from smartphones of 48 Dartmouth students to assess changes in mental health, academic performance, and behavioral trends across a 10-week academic term. The results revealed significant correlations between objective sensor data passively acquired from the phone and cumulative grade point average of the student body (r-squared=0.56).

Dr Campbell's research demonstrated the value of automatic continuous sensing of basic signals, including the phone's accelerometer, microphone, light sensor, and GPS signals. His proposed analytics system architecture combines these disparate signals into behavioral classifiers that characterize higher-order variables such as physical activity, social conversation, sleep, and physical location. Together with phone-based ecological momentary assessments (EMAs), these variables were statistically modeled and evaluated to explain outcome variables from life patterns in naturalistic settings. These results have spawned internal interest in employing the EMA method to augment ongoing efforts to assess naturalistic state estimates,

including a burgeoning collaboration to employ his "in the wild" technical approach in near-term HV studies.

3.6.2 Dr Sliwinski

Dr Martin Sliwinski is a professor at Penn State. He conducts research that examines physiological correlates of development and aging. Similar to Dr Campbell's research program, Dr Sliwinski uses EMA methods to assess behavior and psychological states in people's daily environment at points in time chosen by the experimenter. EMAs repeated daily, or even multiple times a day, can diminish nuisance sources of variability and allow the experimenter to sample the cognitive/physical constructs of interest.

Ongoing research in Dr Sliwinski's lab examines how to optimize human behavior by assessing people in their real, uninhibited environment. One of his core results revealed that participants' morning responses about how stressful they expect their day to be significantly impacts their working memory performance later in the day. This relationship is independent of the daily stressors actually experienced. More generally, his research on performance optimization approaches capitalize on 1) moments of risk, 2) risky situations, and 3) JiTAIs. Collectively, these results have reaffirmed the use of JiTAIs in ongoing HV research, and they augmented our interest in employing the EMA method for naturalistic state estimates.

3.6.3 Dr Thayer

Dr Julian Thayer is a professor at Ohio State, and his work focuses on autonomic nervous system function and the analysis of emotion and stress. Using a model of neurovisceral integration, his research has shown that high HRV is associated with improved regulation of negative emotion in a variety of experimental paradigms (e.g., affective imagery, mental arithmetic) and high HRV is linked to increased variability in behavioral (e.g., eye-blink startle magnitude) and physiological responding (e.g., cortisol and blood pressure responses) across environmental demands.

In threatening and uncertain situations, HRV is predictive: Soldiers with high HRV exhibit greater intra-individual variability in behavior and emotion, allowing them to adapt to ever changing conditions in complex environments. Harnessing HRV as a metric of dynamic variability may enable optimized training and adaptive systems. Using a dynamical systems approach, HRV and other HV metrics can be modeled across timescales and environmental complexity. These results support the decision in ongoing HV research to study HRV as a marker of state fluctuations, and the insightful conversation renewed internal interest in employing additional

analytic paradigms from a dynamical systems approach (i.e., trajectory estimates across the landscape).

3.6.4 Dr Ackerman

Dr Phillip Ackerman is a professor at Georgia Tech. His research program includes diverse topics, ranging from skill acquisition to student/employee selection to the physiological correlates of cognitive effort and fatigue. Dr Ackerman demonstrated results where various factors, such as prior success/failure or task resource-sensitivity, can influence the shape of the distribution of performance in an information processing system. Importantly, he also reported reduced within-individual performance variability during laboratory experiments compared to real-world tasks when close supervision is missing and performance occurs across long periods of time.

Dr Ackerman also emphasized that the choice of dependent measure produces different patterns of performance variability. For response-time measures, performance variability (measured as standard deviation) typically decreases with learning/skill acquisition. For skill attainment measures, on the other hand, variability can increase, decrease, or stay the same. In one vigilance study, Dr Ackerman described three different patterns of correlation between variability and performance for three different measures of performance produced by the same test subjects. These results support The HV Project's plan to manipulate features within two or more similar tasks and examine their influence on behavioral and physiological variability in real-world tasks.

3.6.5 Dr Nahum-Shani

Dr Inbal (Billie) Nahum-Shani is an associate professor at the University of Michigan. Her research develops interventions known as JiTAIs that actively adapt to the individual by combining detailed moment-to-moment information with well-developed behavioral theory. JiTAIs provide the correct amount and type of intervention for issues that can arise rapidly, unexpectedly, and in a person's natural environment. A JiTAI includes four components: *decision points* are moments in time when an intervention decision must be made; *intervention options* are the various interventions that could be administered at a decision point; *tailoring variables* are measured via active or passive sensing; and *decision rules* translate tailoring variables to a choice regarding which intervention to offer, to what degree, and when to offer it.

A JiTAI is optimized using a micro-randomized trial (MRT), a highly repeated, fully factorial experimental design in which each participant is randomly assigned

an intervention option at each decision point. As a result, each participant experiences a given intervention option hundreds or thousands of times, and by using the tailoring variables, researchers map the causal chain between intervention options and behavioral outcomes. Her results demonstrated the success of this approach in the behavioral health domain, bolstering our confidence to adopt this technical approach for understanding decision making in longitudinal, nonhealth behaviors.

3.6.6 Dr Contractor

Dr Noshir Contractor is a professor at Northwestern. His research examines social and knowledge networks in group contexts and investigates how the timing and structure of interactions shape outcomes at the group level. Dr Contractor discussed how big data provides an opportunity to observe behavior on timescales not previously feasible, leveraging the increasing availability of logged data from sensed environments that preserve traces of individual actions and interactions. Long-term projects, like NASA's Human Exploration Research Analog, allow us to observe dynamics of group states, like social cohesion, over many months, and networks of fitness tracker sensors allow us to examine contagion and social influence of networks of millions of individuals. In short, big data resources allow us to test and/or develop theories of behavior at novel scales.

The size and scope of big data resources compel the use of novel, machine-learning techniques to characterize data streams that may be too large to parse manually, such as communication logs spanning multiple weeks, months, or years. Behavioral logs enable the development of innovative representations of interaction behaviors, including temporal ordering of interactions within and across teams in multi-team systems. Such novel classifications reinforce the development of new theories of behavior. By harnessing big data approaches, The HV Project has the opportunity to make meaningful advancements in our characterization, interpretation, and prediction of large-scale, longitudinal group behaviors.

3.7 Day 2: Army Context Talk

While the emphasis on Day 1 focused on unconstrained brainstorming and big vision aims for HV science, the activities on Day 2 were meant to provide context and organizational priorities to focus the discussion of near-term target ideas. Dr Jean Vettel gave a talk (slides in Appendix F) in which she described three relevant contexts for understanding how research aims are identified and scientific capabilities are prioritized. In the first section of her talk, she described ARL's core identity as a future-focused organization for disruptive technologies, including

examples of the lab's recent accomplishments in new energy sources and new materials for helmet safety (Fig. 7). The second section described the strong influence that the ongoing Army "Modernization" process has on ARL scientific aims, including the relevance of the next generation combat vehicle scenario that Dr Brooks provided in his HV overview talk (Section 2.2). As depicted in Fig. 7, the development of the Army Futures Command as part of the Modernization effort also emphasizes the importance of ARL's Open Campus and the hub-and-spoke model of geographically distributed, collaborative research. Finally, the third section provided the core argument that Army-relevant research is inspired by a commitment to innovation and creativity that allows our nation to avoid technological surprise and maintain our sovereignty as a nation. Dr Vettel's example focused on the game-changing nature of understanding social context and its influence on communication and performance prediction.

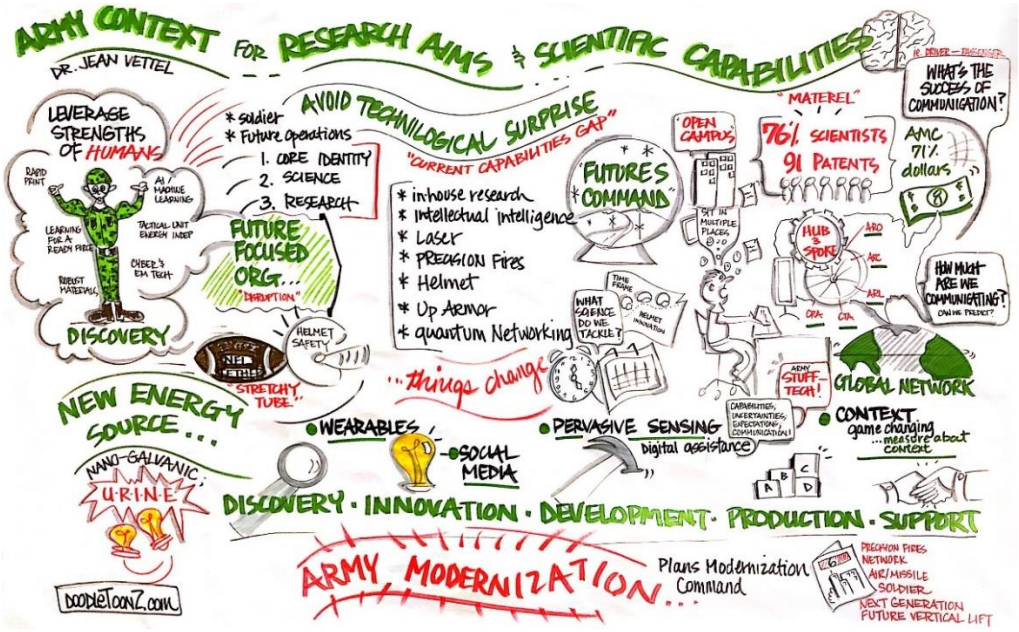

Fig. 7 On Day 2, Dr Jean Vettel contextualized The HV Project within ARL's research vision, the Army's Modernization effort, and the enduring S&T need for innovation

3.8 Day 2: Group Reflection

One of the final activities involved each attendee providing answers to three core questions:

1) How would you characterize the workshop?
2) How did the discussion at the workshop inform your work?
3) What personal actions will you take following the insights gained at the workshop?

In Fig. 8, some core themes that emerged from the ensuing discussion about the individual answers are recorded in the margins. The workshop was characterized as cutting edge, collaborative, interactive, informative, and multifaceted. Attendees felt that the workshop would inform their work by adding additional context, focusing their efforts, developing new techniques, and investigating trajectories to understand how individuals navigate a changing landscape. Many attendees also embraced follow-on personal actions after the discussion at the workshop, including more targeted networking to build strong collaborations, rereading some core theories to refresh ongoing technical approaches, and developing more concrete ideas to address the challenge of HV science. The full list of ideas (arbitrarily ordered) from the stickies have been transcribed and included as Appendix G.

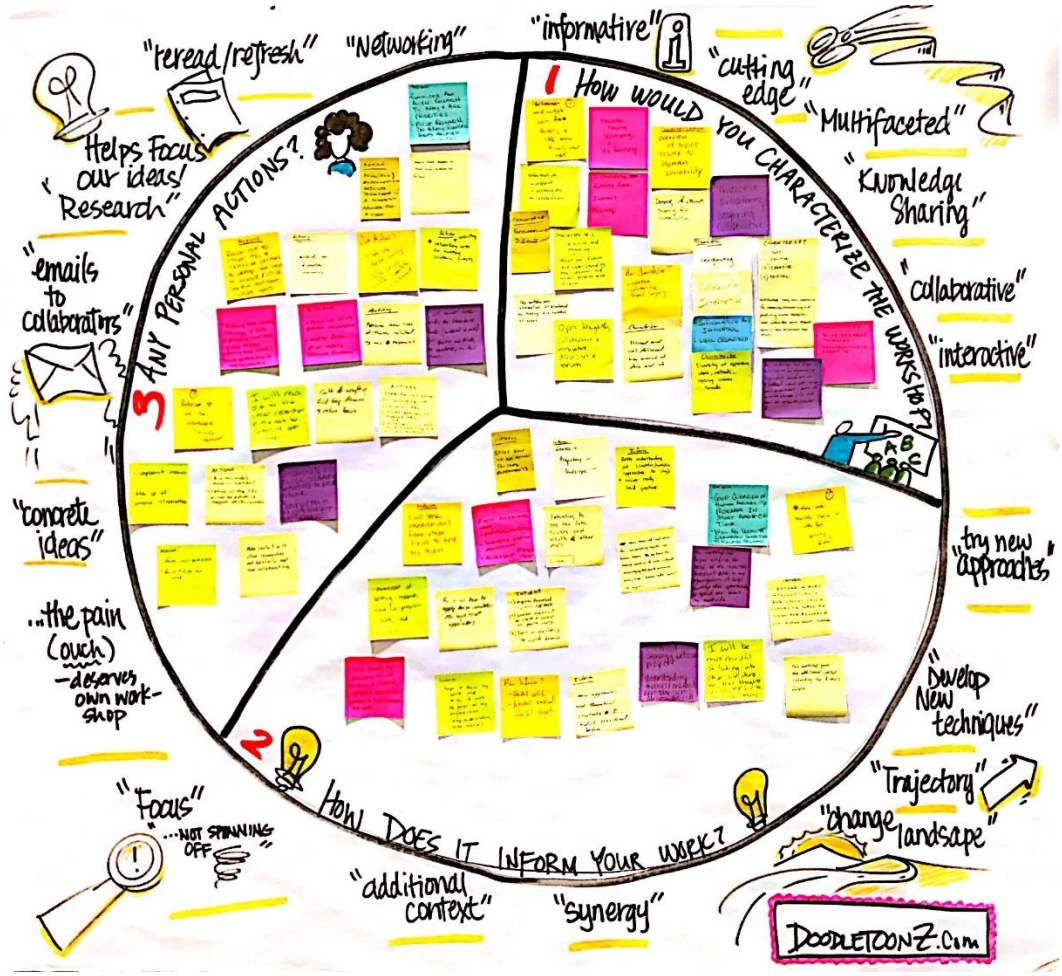

Fig. 8 At the end of the workshop, each attendee was asked to reflect on the workshop and answer the three questions illustrated here. The core themes are recorded in the margins, and a full transcription of the attendee responses is provided in Appendix G.

4. Summary of Workshop Insights and Future Plans

Across several metrics, the HV workshop succeeded in its primary goal: bringing together multidisciplinary researchers with invested interests and experience designing and analyzing longitudinal data to talk about a vision for understanding, predicting, and enhancing human performance in real-world settings. As one salient metric, the graphic recording of concepts revealed the synergy between the core science interests presented in the ARL-led presentations and the research presented by the invited academics. More specifically, the targeted recommendations from external researchers in their talks and the ensuing discussion nicely matched internal research foci, including the following:

- For the sake of generalizability, collecting data outside of the laboratory, in the real world, is imperative.
- When doing real-world data collection, interfere minimally with subjects and innovate to minimize data loss (from both participant compliance and compromised data fidelity).
- When measuring real-world behavior, one must assess both the context and the person's state.
- Continuous assessment offers the promise of optimizing performance.
- To be effective, interventions need to be dynamically adaptive and individualized, but an even more challenging constraint is that people need to be receptive.

Although well aligned topically across organizations, the workshop also identified several theoretical approaches and analytic methods that could be either strengthened or newly incorporated in existing ARL HV plans. As discussed in Section 2.5, several academic panelists presented results that bolstered ARL's interest in a number of active research areas and fostered adoption of new approaches into our research. A summary of these specific approaches and research areas discussed that are expected to impact future planning, include the following:

- Utilizing HRV as a metric of dynamic variability across varying timescales and levels of environmental complexity.
- Applying dynamical systems approaches to characterize performance and understand variability as fluctuations both in the system landscape and in the trajectory through the state space.

- Studying multiple variants of real-world tasks to capture different patterns of behavioral and physiological variability due to time-on-task and/or context effects.
- Extending JiTAI and MRT approaches from the health domain to decision-making in longitudinal nonhealth behaviors.
- Using the EMA method to augment ongoing efforts to assess naturalistic state estimates.
- Refining traditional construct assessment approaches to single items for experience and state sampling over time.
- Exploring methods to quantify and predict interaction behaviors about agents both within and between groups from big data.

5. Advancing the State of the Art

In addition to the synergy in research topics and scope, several external researchers commented during the meeting that ARL's scientific vision and ongoing science for HV was truly cutting edge, and one of the invited speakers started their talk by commenting that they would have changed some of their content had they known how sophisticated ARL's HV program already was.

Several external researchers commented how hard it was to secure funding for HV-related research questions from traditional sources like National Institutes of Health, National Science Foundation, and similar funding agencies, given the high-risk nature of HV research and the inability to provide pilot data based on the cost and implementation challenges of longitudinal collection. The funding challenges from traditional agencies also reflect how the HV approach intentionally departs from convention, including a systematic move away from the enduring reliance in human science to focus on controlled behaviors in laboratory settings.

As indicated from these highlighted examples, the overarching viewpoint at the end of the workshop was that The HV Project at ARL was definitely high-risk, scoped for innovation, and connected tightly with the current state of the art in longitudinal study of real-world behaviors.

6. Conclusion

Insights from the workshop have influenced ARL's immediate path forward by renewing our excitement about the scope and vision of The HV Project as well as augmenting our technical approaches employed. The workshop also resulted in two

specific future opportunities. First, the transcribed ideas from the brainstorming session on Day 1 (Appendix B) provides a resource for renewed inspiration as The HV Project unfolds in the years to come. Second, all of the attendees unanimously agreed about the critical value for a future workshop focused on the implementation challenges of HV research, such as data collection, storage, analysis, interpretation, and intervention. In short, for all of the innovation needed in just conceiving of the appropriate scope and future targets for The HV Project, equal if not more innovation will be needed to enable the successful execution of HV science.

In summary, the workshop provided an outstanding opportunity for scientists from multiple disciplines to come together, discuss The HV project, and provide reviews/recommendations. The response from this workshop was overwhelmingly positive, having spawned multiple collaborative threads and directly informing and improving the approach to execute HV science.

Appendix A. The Human Variability Project Workshop Invitation

Project Goal: To develop a better understanding and prediction of human variability to enable future Army systems to adapt to Soldier states, behaviors, and intentions in real-time across multiple domains to enhance individual, system, team, and human-agent team performance.

Workshop Goals: To further prepare for this large research endeavor, ARL is gathering an external advisory board, a body of experts with diverse expertise in applicable fields of research and experience with longitudinal and/or naturalistic data collections to discuss challenges and opportunities as we develop a path forward. In this two-day workshop, ARL will discuss a vision for future experimental and analytical approaches designed to achieve our project goal through longitudinal data collection from a large number of individuals in real-world settings. During the workshop, we are seeking collaborative exchanges and frank discussions to further develop this vision; with specific, written recommendations provided by the external advisory board after workshop completion.

Context: Integrated projects involving longitudinal data collection from a large number of individuals in real-world settings are expected to begin in October of 2019 and continue for 2–3 years pending continued funding. During the workshop, we desire a frank discussion about how to strike a balance between qualitative and quantitative research in naturalistic settings and constrained (but often unnatural) performance on specific, controlled tasks. Specifically, our focus is on predicting performance on daily tasks with nebulous objectives where performance is difficult to quantify at exact moments in time (e.g. communication, decision making, project planning). For more precise prediction, we anticipate a need to embed some controlled tasks (quantifiable by reaction time and accuracy, for example) into daily sampling of real-world behavior/performance (e.g. computer usage, strategy development/execution). In this workshop, we hope to brainstorm approaches to quantify "tasks of daily life" and useful mechanisms to gather data in naturalistic environments useful for performance characterization and prediction across multiple research domains. We seek to develop more integrated data collection methodologies and analytical approaches that address goals of multiple projects, with a unified vision to achieve the project goals.

Conceptual examples of the project aims include: 1) utilizing models of longitudinal data to improve how humans interact with autonomous agents, including unmanned aerial and ground vehicles, within the context of a surveillance or vigilance task and 2) improving and optimizing the efficiency of heterogeneous teams including human-human and human-agent teams to solve complex, dynamic problems.

Draft Agenda: This workshop will span two days. We request that the advisory board members fly in the night before so that Day 1 can involve a full day of workshop. In the first half of Day 1, ARL researchers will first share results and lessons learned from the past two years of longitudinal research and then detail our notional concepts for future research designs. After the lunch break, advisory board members will have the opportunity to provide presentations (how long? 15–30m?) on their work that relates to topics such as longitudinal experimentation, human variability, real-world behavior quantification, or other topics that might contribute to the project goal. These presentations are optional and will be developed in conjunction with ARL researchers.

On Day 2, we would like to hear initial recommendations from the advisory board, continue discussions from Day 1, and plan future workshops/other plans for continued collaboration. Interspersed throughout the agenda will be time for open, unstructured discussion among attendees. The workshop will end mid-afternoon to enable evening travel back home.

Audience: The primary audience for this workshop will be scientists from ARL, academia, and industry. Invitations for attendance may be sent more broadly to generate collaborative discussions amongst government, academia, and industry.

Example Research/Discussion Questions:

- Discuss the costs and benefits associated with different critical signals – whether derived from the environment or from people – and determine which signals would be the most robust and informational to meet project goals
- If someone is working in an office-type environment, how do we characterize their performance and behavior beyond simple laboratory tasks that measure variables like accuracy, reaction time, or time until task completion? Is there a need to combine laboratory-based experiments with real world experiments? If so, how?
- What types of measurements will volunteers be willing to do for extended periods of time? How do we ensure the highest level of compliance for a complex, long-term protocol that involves daily interaction with tasks and/or equipment for several months?
- What are the highest risk projects that could be pursued that investigate human–human and human–agent teams? Human–agent team game play? Augmented reality?

Appendix B. The Human Variability (HV) Project Workshop Brainstorming

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HV Workshop Brainstorming

	CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
	How Can Human Save Information and never fail?	**Measure Individuals Low level to high level, non-verbal**	**Measurement aligns with sensors/sleep**
	Human – Vary At Times External Channel . . . and Humans Internal Ability to process	**Measure Group Dynamics Online, Social Media, etc.**	**Data and Do: Do something with Data**
	Infrastructure i.e. "ok Google" Machine can learn and adapt	**Emergent Group Roles**	**How To Team People: Ways to use data and form team**
	Common Approach? Modeling Humans	**Influences on Individual Performance**	**"Drivers" Sleep well, etc.**
	Human Machine Proc./Info and Symantec's	**Agent Roles: Group and Individual**	**Technology Aides**
	Define Bandwidth		**Dreams: How can we design dreams**
			Benefits of sleep deprivation
RESPONSES			
	Clothing as note taker. Clothing displays topic keywords for conversation. Cliff notes, 3 bullets no themes	Leveraging experience and expertise of group member	Sleep training across your life. Night terrors Lucid dreaming Dream training
	Modeling how to bring information from multiple data streams together	Tension diffusing joke agents	Tasking forces high/low performers at a given time based on circadian rhythm to team up.
	Two challenges: Attending to what needs attention and tuning out what does not.	Robot shouts your mood	A team that sleeps well together works well together

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
See decision making chart (computers making decisions).	Agents who move people's meetings to optimize performance.	Models, factors predicting sleep and relationship to performance
Human in the loop for learning. Addresses the gap when human is not overloaded.	Friendly bot feedback, Bot screens out bad actors	Designing dreams/ counteractive nightmares = avoid PTSP
How to detect salience and downgrading the rest?	Context translators to force productive conversation	Benefits of sleep dep?
Google hot words	Identify need/availability for social support	Tech enabled hug pajamas assist with comfortable sleep
Machine good at dealing with information overload but humans are not. Deep learning	Learning to detect or infer convert group (alliance) formation and predict impact on team	Automatic feedback for destructive group behaviors
Adapting the feel to labels	Highly tuned social interface	Turning team behavior to ambient social and cultural context (e.g. a "social advisor" agent)
(Auto) clothing and goggles that selectively inform to enable comprehension	Dolphins who diffuse tension with rides in the sea	Computational nonverbal communication
Reduce information biases in human	Robots that tell people when to stop talking to avoid conflict	How body heat reads into conversation
Contextual or adaptive inform. display/interaction	AI dogs who can embody emotions to allow training to work with all personality types.	Social proximity (facilitation of performance).

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
Implications for types of signals	Clothing that can modify your mood based on sensing conflict.	Interpersonal interactions effectiveness
Present information in a personalized way (e.g. written vs. audio)	Intersubject correlation, signals or hormones/genes	Sleep scheduling and sleep quality. Linkages to use of tech to recognize long term drift in their relationship and thus need for change schedule
Personalized noise filter	Evidence of bottlenecks in the system (where info is getting stuck)	"5 and Dime" puts you out of alignment with 24-hour circadian rhythms, Navy changed it.
Internal/External channel Cognition/Performance measures makes you more or less capable of acting on information	Adaptable distractions	Sleep patterns affected by decision making or having an infant (context)
System – physical infrastructure/organization	Automatic movement of people to foster innovation, enable divergent thinking	Systemic inputs to sleep. Taco Bell at 10 pm+
Point human to important information	Contextually emotionally sensitive AI	Insomnia: Detection of potential causes Effects of mobile device usage Food, activity Stressors Tech to induce or prevent sleep

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
Technological level in vivo-reliance on technologies bandwidth/smart sampling	Classification of interaction (speech) throughout planned interactions. During a date? Practice presentation?	Changing dreaming patterns (night terrors) ESP soldiers with PTSD
Visualize information in new ways	Transparent and natural human agent interaction	Tech to design dreams to make better processing of day's activities
Extraction of high level information vs. discrete data	Blood enzyme/protein or epigenetic hormone and gene expression monitoring for affect during interactions.	Can a sleep rhythm be rapidly shifted while preserving performance?
Red warning sign for when individual is at low comprehension	Intelligent agents focused on systems based team's performance. Optimize team vs. agents focused on individual to help that person be a better team member	Improve performance during sleepy times
Incorporate meaning and semantics into analysis	Heart/popillometry measurements for affect/trust e.g. like someone/ an interaction or not	Identify health and wellbeing of employees (e.g. depression)
EEG overstimulation detection paired with white noise generator	Cultural crossover, hearts and minds. Identify experts and training. Algorithms developed to quantify expertise to facilitate interactions in real time for trained	Adjust work requirements to individual circadian rhythms

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
Information across modalities	Agents who can clarify cultural impressions	Need additional means of technology to measure and adapt technologies
Turn data into knowledge (improving faster/better)	Determine work relationships, group assignment, leadership roles	Understanding of all sleep benefits and negative effects
Human interpretation info overload individual action	Group formulation and diffusion	Sleep tracking rates memory reliability on given days and flash warning lights when your statement is unreliable
Speed adjustments of recording based on comprehension	Collective intelligence and emergent sentiment analysis	Mattresses that change based on your sleep state to move you between stages
Fill in missed data	Robots to disambiguate ambiguous nouns	Agent who tells when speaker is too tired to be believable
Human question, how to deal with large amounts of data: Certain integration of info that machines cannot do	Better understanding of language (nonhuman)	Agents move sleep deprived folks to noncritical vigilance tasks (or nonvigilant tasks)
How do indiv. physical bio aggregate to team level? Idea of bio/physio contagion	Improve understanding of tone of written communication	Gestures/body language

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
Are teams a solution?	Episodic communications	Training how much does preparation mitigate pert decrements? Can we cope?
Agent buckets that categorize speech to collect themes, later analysis	How to detect salience and downgrading the rest	Exoskeleton provides straight lane fast walking for tired/sleeping folks (annoying pedestrian prevention)
Learn and expand, nail it, scale it. One human's ability change over time day to day	Human in the loop for learning. Address the gap when human is not overlooked	Adaptive wake/sleep time
Truth/trust detector	Talk timer/prompter to make sure everyone participates	System real time monitoring individual factors influencing social interactions
Identify data amount preferences	Identification/prediction of possible coordination breakdowns	Exoskeleton that behave, as you would while you sleep, inside an avatar when you are asleep
Individual preferences for display of data	Feed forward control systems based on scout team (1st team). Interactions, what worked, didn't work	Robots that follow you around and when ready for nap, it rolls out to make a bed
Human preference ranking	Set of bees that all link to different teams and provide connections to their expertise	Identify when tasks are impacted by sleep?
Identify "lost" info b/w people, teams, agents	Present information in personalized way (e.g. written vs. audio)	Doppler technology

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
Overload as a weapon, benefits of overload	Voice modulation to "reset" established social relationships	Sleep/rest makes you more resilient to infor. oversleep decision making
Sources of information: internal/external, sensory/cognitive	Low-level characteristics of speech (tone, pitch, freq., content) and its relationship with state	How do you account for the individual variability in resting hours/active hours? Baseline Calibration Changes in same individual over time.
Why is there a limit?	Frequency of contact and type (tense/enjoyable)	Sleep styles, sleep technology
How to make large data more interpretable?	Emergence of rumors vs facts through social media	What future tech may measure, sleep quality.
How much information can a human process at a given time?	Information transfer how to measure display	How do individual factors affect the calibration of measures of sleep over time, when do they re-calibrate?
Agent distills messages to a sentence	How sleep physio explains pro-social vs anti-social tendencies that fluctuate over time, feeding social interaction	State vs. trait Morning person now, evening person when younger?
AI to prioritize information	Clothing that modifies to match another teammate to cause sync thinking	Improve team formation

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
Quantitative value of information (VOI)	Virtual agents that can join influence online group behavior	Fatigue impacting teaming
Adaptive modes of information	Countering social engineering in real time (also detecting and countering dis- and misinformation)	Besides sensors? Sleep with aging
Predict what infor human or machine need	Identify climates "Ethical" "Inclusive"	Multi-sensor diagnostics for ability to do task
Set of biases that all link to different teams and provide connections to their expertise	Socially informed control systems. External "motivation" as needed without user having to request	Future applications of sleep/rest what do you do with it? Team composition Mission selection duration of task
Eye tracking removes under viewed displays, gauges, etc	Understanding differences in developing social interactions in physical/virtual environment with limited connectivity	How to vary human machine tasks given sleep pattern
Emails auto fixed to 3 bullets	Detection on leader emergence	Resulting actions/Team composition/mission selection/intervention Individual tools vs leader tools
	Predict in group, out group identification	Technological aids, promote sleep reduce need

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
	Hierarchical vs vertical affiliations Impact on behavior Conflicting affiliations Complementary Impact on performance	Measurement
	Inter effect of group and possible areas of frustration or conflict	Culture of military How important is sleep How tractable/realistic is this? Recognition of problem
	Facial emotion ID	Identify job-person fit
	Communications patterns (especially in crisis situations)	Help heal sleep/urcad disturbances
	Relating individual dynamics to emergent group constructs. Characterizing group dynamics in deaf Questions of aggregation	Natural circadian cycles aligned with workplaces
	The emergence of informal networks that go around more formal hierarchies/networks	Exoskeletons that fully cover body to provide day/night info for optimal sleep patterns
	Predictive models to influence or estimate the likelihood of new online slang	Penguins that dance, sign, or animate to make things restful

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CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
	Adaptive translation engines to specific language and dialects to incur trust with in local population	Tuned workflow e.g. China's employment of EEG sensing in manufacturing
	Bridging cultural divides with real time systems.	Alarm when activity drops off
	Social interaction Online Recognize bots, propaganda manipulation online	Noisy data? Ground truth of sleep?
	Natural language processing and predict mood/emotion distress	Design ECR(?) to mitigate the need for sleep, more than caffeine
		Improve team human coordination over time
		How does sleep/rest/restless sleep/restful sleep matter or account for activity and sleep/rest
		Mission driven ability to disrupt (distract, deceive opposition)

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	CHANNEL DATA OVERLOAD BAND WIDTH	SOCIAL INTER ACTION TEAM DYNAMICS	REST/ACTIVITY PATTERNS SLEEP VS WAKE
			Suggest work breaks when activity lessens
			Work life balance
			Optimize sequence as function of sleep pattern
			Individual knowledge optimal performance vs. organizational changes – leader tools
			Stress injury affect sleep quality

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HV Workshop Brainstorming

	CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
	ADAPT ENVIRONMENT	**SENSORS ADDRESS INDIVIDUALS**	**DECISION MAKING INDIVIDUAL/GROUP**
	TASK FACTORS/PHYSICAL FACTORS	**ENHANCING THRU**	**TRUST DECISION MAKING**
	ENVIRONMENT	**NUTRITION MONITOR**	**DECISION FATIGUE**
	PHYSICAL	**BIOMARKERS MATTER, WHICH ONES?**	**PIGEONS VS. PENGUINS**
	Environment cognitive interaction	Predicting overload or boredom and adjusting assistance based on current level of attention	Team dynamics – with human-human and human-agent pairings
RESPONSES	Disparate vs. co-location for communication	Monitoring engagement/attention Driving Working Other tasks	Highly tuned satisficing
	Familiarity vs. novelty	Balance of intervening to alter physiology vs monitoring and responding to physiologic state of user	Experience with other team members
	Level of risk in task environment	Access to outside world	Change individual words in prompt and quantify divergence of responses to identify core decision factors

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CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
Safety to make mistakes learning environment	Real epigenetic monitoring e.g. cortisol, 5-HT, adrenaline encephalin	Products/visualization to make decision
Interdependence of task environment	Sensor to determine what and when to alter state	Political valve systems define decision value
Novelty of task environment	Genetically sensitive preference to convert objects	Modeling value
Uncertainty of task environment	Link states to performance (individualized)	Decision support systems that can communicate uncertainty in M.L. suggestions based on sensor error and user capability
Physical layout of environment (co – location vs. virtual/geographical separation)	Clothing that can optimize genetic mutations	How do similar decisions change over time (answer to similar question)
Situation awareness training	Physiology: Analyzing sweat/saliva to infer changes in readiness/availability	How to instantiate real risk for design of experiments on decision-making
Impact of climate change	Distraction adaptive presentation. People may be sensitive to different types or sources of distraction by knowing that methods to compensate for that can vary per person	Decision making for agent Intervention timing

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CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
Physical comfort	Sensing and responding to physical environment (dirt, hills, gravel, rain etc.) Seamlessly to the user	TIME
Urban vs. rural	Modeling – Sensing environment important to refining model. Factor necessary to interpret human data - covariates	Key elements environmental context
Garrison vs. operational environment	Measure in real time environmental factors et temp, noise, airflow	The influence of individual risk/reward Perception on decisions of different types (action vs. in action)
Amount of noise distraction in environment	Environmentally resilient passive biometrics footstep	High intensity moment to moment decision making Is technology helpful here? Cost/benefit analysis
Level of stability/productivity of task environment	Background noise mitigation (block only unwanted noise)	Technologies to enhance group states/processes critical for decision making Shared mental models Shared situation awareness
Training vs operational, would control systems be same in both? Intelligent systems to adapt to both as needed	To what extent is task performance a function of a familiar environmental context? What about unfamiliar contexts?	AI agents of different cultures who provide pro/con of decision based on their viewpoint

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CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
Adjust temperature based on environment and individual preference	Social mental model Integrate more members	Swarm of penguins that can dynamically adopt climate
Stimulate brain in circuits needed to execute task	Interactions with personality can affect decision making performance	Contextually optimal decision
Wearable light sensors (light sensing affective disorder)	Pigeon drones that carry information between people	Novice vs. experts
Robot to tell me what to wear	Understanding semantic context of dynamic environments	Culture/influences in decision making
Environment of augmentation technology changes more or less control. Controls systems physical contact or connection to user can longitudinal data provide insight on user responses to these changes	Customize presentation of visual information to user based on mission tasks and cognitive lead capability	Tailor task assignment based on individuals differences. This interest with: Fatigue level, Task difficulty, Teaming
Isolate domains of decision making that we could conceive of agents making decisions	Adaptive virtual environment	Shoulder penguins that give the AI view and the view and figure which is better

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	CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
	Environmental Context: Help predict/understand physical/psychological/social responses Who will perform will in different contexts Army Who is best matched at missions?	Penguins that carry away distracting objects	Modify the task parameters based on Internal state change Task performance Change in task difficulty
	Changing physical context due	Environmental context: Help predict/understand Physio/psychological Social responses Who will perform will in different contexts – Army – who is best matched to missions?	Policies that are based on the average of Alexa questions
	Biological context determines task performance	Environment of augmentation technology changes, more or less control, more control systems, physical contact/connection to user can longitudinal data provide insight on user responses to these changes	Detection of Bias, from social media context of physio response to question
	Tech to create context, then to recall context at point of need. E.g. sound/smell, Drugs, Internal states		Penguin avatar friendlies up counter-arguments when crowdsourcing

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CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
Distraction: Individualize how to manage distraction and different learning strategies How does content impact intervention temp	Stimulate brain circuits need to execute task	Army culture Cultural issues Reliance on technology a hurdle
Context sensitive acoustic filtering	Biological context determines task performance	Understanding the factors that influence long term drift in risk perception
Adaptive clothing – thicken layers based on temperature.	Adjust temperature based on environment and individual preference	"Rebuttal" robot (Devil's Advobot 3000) points out counter arguments to force more robust decisions
Adaptive deception of agents	Changing physical context due to something impacts performance	Physio signals eeg, fnirs, hrv, eye-trx immobile
Environment as cognitive load	Hormonal cycles to adaptive diet, performance etc	Two questions: How do you detect bad decision-making? How do you intervene?

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	CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
	Personal background and context being brought into situation	Reactions to environmental elements to predict issues	Realistic training to operational tools. Simulation systems
	Food from environment	Using biology as indicators for psychological constructs previously assessed with self-report	Change in trust with teammate or agent. Physiologic metrics that might indicate these changes and could provide adaptation
	Backups for disruptive environment	Soft tissue fatigue detection to shuffle physical labor and prevent injury	Crowdsourcing clustering divides individuals to prevent convergence
	Distraction: specifics of environment Can we train people to be tolerant to distractions? Mitigate distractions effects	Systems that predict and understand intent and desires	Google robots who play movies of what would happen x time from now for you to pick choice
	Assign tasks based on comfort (move tasks from folks who get too hot, too cold, over stimulating etc)	Detection system adaptation to internal state to produce corrective action/adaptation (for the human or the system)	Being able to compensate (or identify opportunities for how to) for poor decision making

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CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH
Mission driven ability to disrupt (distract, deceive) opposition	Do we understand the complexity of factors that might affect the physio/bio changes we see?	Air horn to induce alertness for better decisions
Environment- use of AI/Mi and other statistical tools to help infer context for better understanding what we see in physio (for instance)	Physiology/genetic based performance adaptation	Cirque du Soleil show where you have to visualize the risk level of the decision
Developmental environment	Anticipate and predict injury/illness in order to augment as needed to maintain performance	Empowering people to make decisions (more democratic process) using expertise
If (context) then (state behavior). How do we model with approp. data? Cognitive/affective Dynamical model based on context	How to physical better integrate women into combat	Tech not just to determine if a bad decision making state, but give human more accessible information to know in bad state
Change in level/type of automation	Health screening	Pebbles that dance at the frequency of uncertainty levels you pick the one that resonates

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	CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH
	Fan lights that are turned on based on circulation phase	Health and exercise recommendations based on family and behavior	Detecting stress levels and predicting, the risks to decision making
	Changes of automation with changes in age	Characterize user "prescribe" best augmentation based on that genetic/physiologic/biologic characterization	Integration and summarization of information to assist decision making based on the level of complexity the user needs and can handle
	Information diffusion without direct interaction (awareness)	Isolate domains of decision making that we could conceive of agents making decisions.	Knowing when a human vs when an agent is capable of make the best decisions
	Consider changes in job/task requirements	HIL feedback: Stress management Anxiety Ex: Fitbit breathing app	Behavior – outcome relationships
	Mission adaptive task planning based on the user group response to a given environmental situation	Identifying at risk performers, illness, stress and recruiting assistance	Predictable decision can lead to disaster – introduce random behavior
	Environment Cognitive Interaction	Machine calls for help for human in crisis	Detecting poor heuristics that will negatively impact decision making

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CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH
	Quantify stress (fatigue/stress)	Combat decisions must be fast reflexive not deliberative
	Bio markers of developmental charge to track fit/suitability of roles and team membership	High quality protocols
	Key elements of behavior and physiology (what are these elements for? Given decision)	Taking pigeons that discuss pros and cons and then you pick one to follow
	Medical: General life/ sense vulnerabilities and interventions to prevent illnesses. Lifetime/ identify genetic vulnerabilities Develop life plan for monitor/manage	How to visualize present information to make decision. Continuously vs. cross sectional
	Future ways to model what can't be now? Intuit? Workload?	Interpretive dance-off for decisions
	Caffeine adjustment and nootropics and neurosis	Decision support tools that can anticipate biases of decision makers to correct/push towards the ideal forgiven situation

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CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH
	True models	Optimal intelligence phase Right inform. Right amount Right time
	Get microbiome and cognition	How to detect? What to do about it?
	Physiological measures that predict future changes in Intent Strategy Engagement level	Determining when to switch task allocation between Human/auto Human/Human
	Dog smell indicators of mood, EEG interprets from dog	Real recommended system
	Better ability in sensors to classify states from pulse, etc.	Track your own decision making process over time: Based on previous decisions what might you like to do? Blind spots/cognitive blocks Track success of decisions Optimize your process
	Personality traits. States vs. traits	Learning while resting

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	CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH
		Intervene when HR gets too high (for any reason) and adapt what "high" is based on changes in environment and activity	How to detect? How to intervene? Human agent interaction to help address fatigue. When do you need to know that you are tired?
		Sensors that give you access to live streams	Tactile, visual, auditory alerts to influence decisions. Crowd sourcing – individualize "narrow or expend the crowd". People with similar backgrounds, education, personality, health etc
		MRE vs performance vs bathroom statistics to identify issues and allergens	Low latency transportation Tires adopt to weather Planes, no delays
		Army – Super soldiers and individualized training, monitoring, feedback for specific goals for soldier capabilities and skills	Developing and determining shared mental models in H-M teams to inform decision making

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	CLIMATE TASKING ENVIRONMENT DISTRACTIONS	GENETICS, BIOLOGY, PHYSIOLOGY OMICS	DECISION MAKING: FATIGUE, LIFE/DEATH SITUATIONS
		Determine "likeness" b/w individuals at a given moment in time	Able to help filter thru/prioritize information needed for decision making to avoid cognitive overload
		Mental health Integrate multisource info Biological/psychological Indicate, monitor, manage Facilitate intervention	
		Physiology: enhanced Fitbit for better health improvement Individualized feedback for workout/health plan Integrate nutrition, exercise and genetics	
		Sensors of blood levels that auto order food for nutrient deficiencies	

Appendix C. Continuous Multifaceted Soldier Characterization for Adaptive Technologies (The Human Variability Project)

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Continuous Multifaceted Soldier Characterization for Adaptive Technologies (The Human Variability Project)
HVP Workshop
16-17 July 2018
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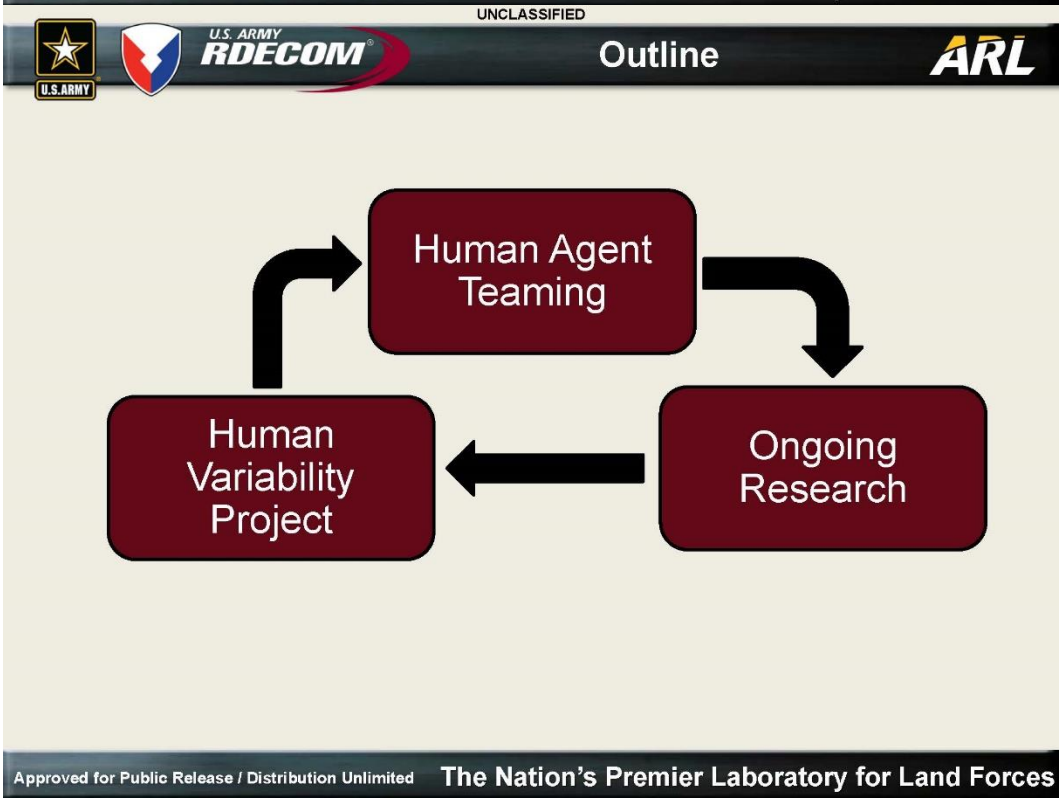
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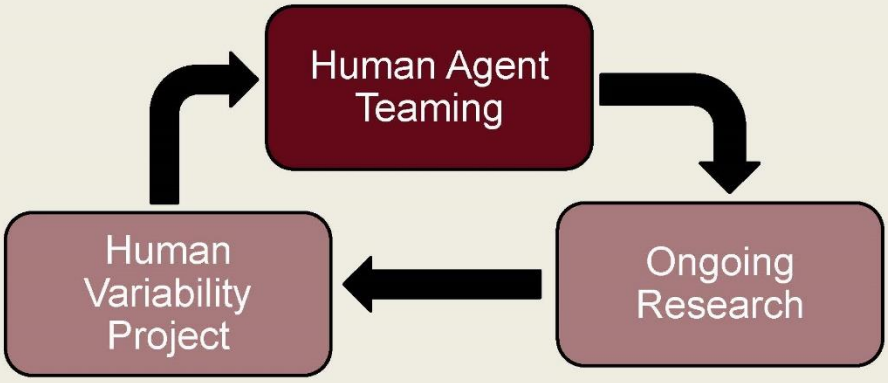

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Human Agent Teaming (HAT)

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J.C.R. Licklider (circa 1960)

"In not too many years, human brains and computing machines will be coupled together very tightly, and the resulting partnership will think as no human brain has ever thought."

Leverage the respective strengths of humans and agents to outperform either in isolation.

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HAT - Examples

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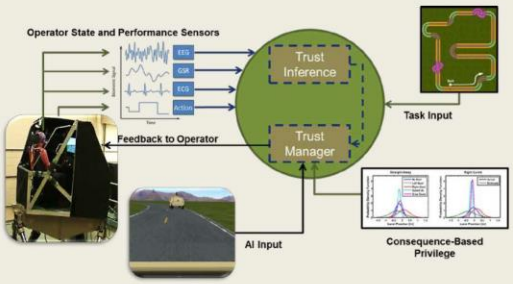
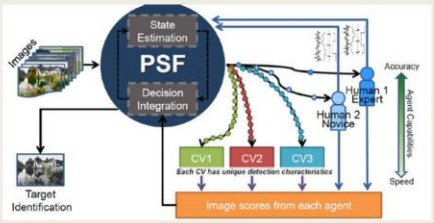
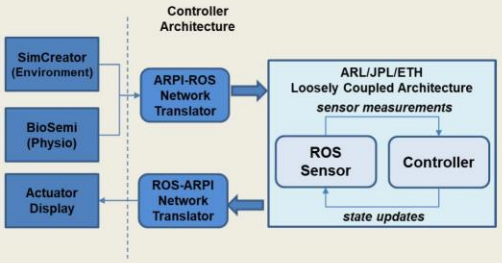
Examples
- computer vision
- autonomous vehicles*
- training software
- teaming technologies (information mediators)







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Critical Gap

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For Human Agent Teaming to be successful - critical, fundamental research is required to develop real-time algorithms that can estimate states, behaviors, intentions of interest

The Human Variability Project was conceived to perform the basic and early applied science to develop the foundational algorithms and systems to provide individualized, adaptive technologies.

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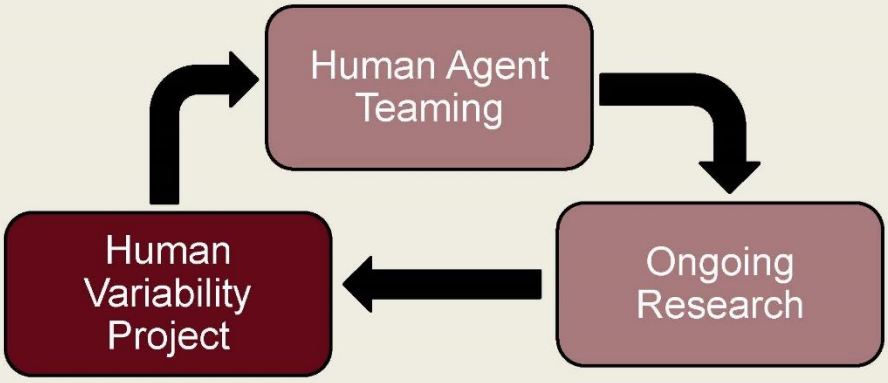

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Basic Science - Gap

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Needs to account for the variability/diversity of the human condition in order to tailor specific *adaptations for an individual* at a given moment in time, i.e. not one-size fits all solutions – analogous to the personalized, precision medicine initiatives

Perform high-resolution, longitudinal (>6mos) experiments across various laboratory and real-world settings to better understand/model human variability.

- Enables the understanding and modeling of human variability over time that become the foundation of algorithms used to adapt technologies

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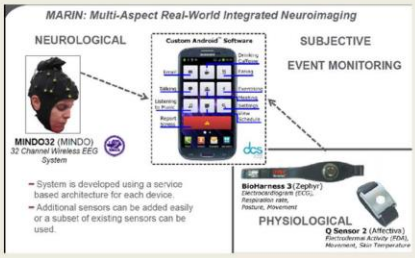
Early Applied Science - Gap

Operate in the real-world (outside of the laboratory), and therefore require contextual/environmental information, contend with low signal to noise ratio.

Develop systems capable of acquiring these data to permit real-time processing

- Data collation systems that are robust to connectivity issues, scalable, and receptive to heterogeneous sensors



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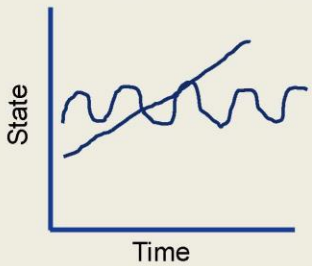
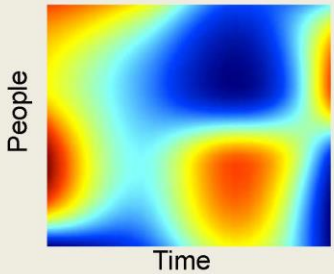
HVP - Variability

Variability is a broad concept – within subject, across subjects

For our purposes, we are interested in being able to contend with all of these sources such that systems adapt to individuals with minimal training/burden on the user





Requires LOTS of data!

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HVP - HAT

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Sources of Human Variability

Facet/Dimension	Example
Biological	Genetics, -omics, development, Cardiorespiratory timings, circadian rhythms
Social	Social networks, leadership profile
Cognitive	Bored, excited
Behavior	Learned patterns, performance
Environment/Context	Distractions, climate, tasking

Agent Interactions

Facet/Dimension	Example
Trust	Use of autonomy in uncertain conditions
Information routing	Information bandwidth control
Autonomous action	Tuning AI/ML to perform autonomous functions to augment HAT
Control Switching	Toggle control between human and agent

What are the critical sources of human variability to optimize Human Agent Teaming?

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Data Requirements

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In order to model and understand this variability, large amounts of data are needed:

- Continuous, longitudinal (multi-year), and high resolution (enables multi-temporal scale modeling)
- Collected on numerous (100s to 1000s) of individuals (enables intra vs inter individual difference analysis)
- Multidimensional (e.g. environmental, physiologic, behavioral) to enable modeling of the interdependence of these factors to variability

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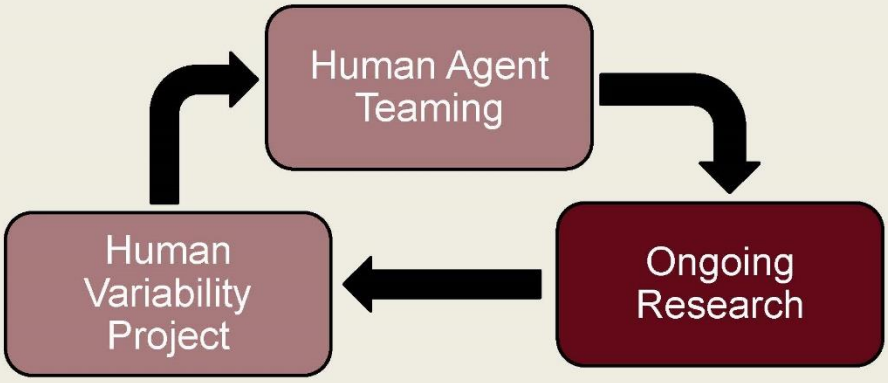

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Human Variability Project

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Executed as an internally competitive process with investigators that have diverse areas of interest and expertise

5 Projects (FY18-FY19):

1. Vigilance Decrement
2. Sleep/Performance Interaction
3. Social/Teaming Dynamics
4. Psychophysiology
5. Human Agent Teaming through gaming

Goal (FY25): Provide foundational technologies required for future Army systems to generate high-resolution, moment-to-moment predictions of individual Soldier's relevant state information for HAT

The purpose of this workshop is to brainstorm and develop recommendations for longitudinal experiments (months to years) to achieve the FY25 goal

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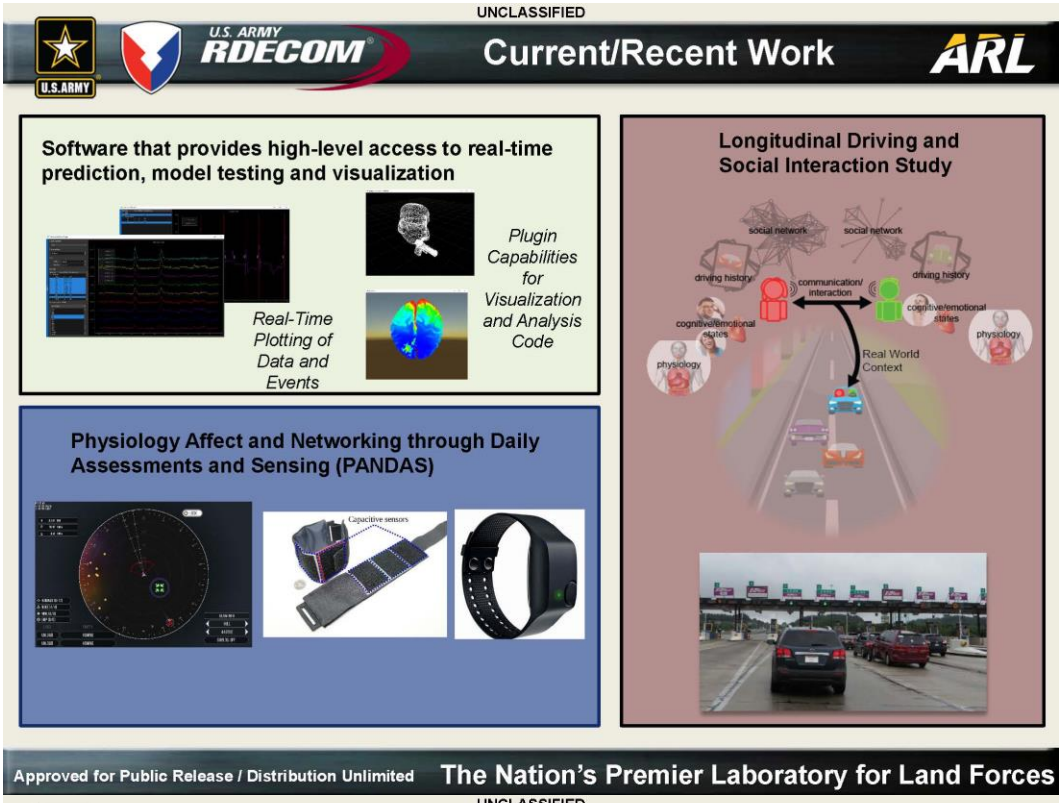
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Current/Recent Work
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Software that provides high-level access to real-time prediction, model testing and visualization
Real-Time Plotting of Data and Events
Plugin Capabilities for Visualization and Analysis Code
Physiology Affect and Networking through Daily Assessments and Sensing (PANDAS)
Capacitive sensors
Longitudinal Driving and Social Interaction Study
social network
social network
driving history
communication/ interaction
driving history
cognitive/emotional states
cognitive/emotional states
physiology
physiology
Real World Context
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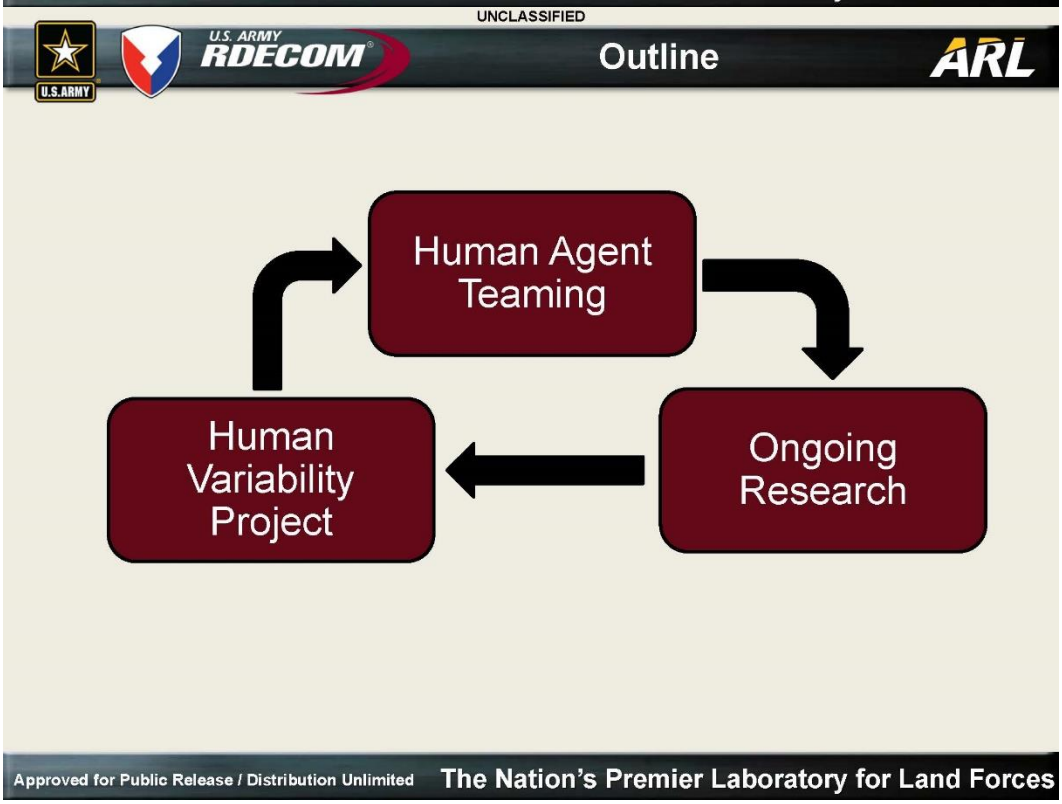
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Potential Application: Next Generation Combat Vehicle

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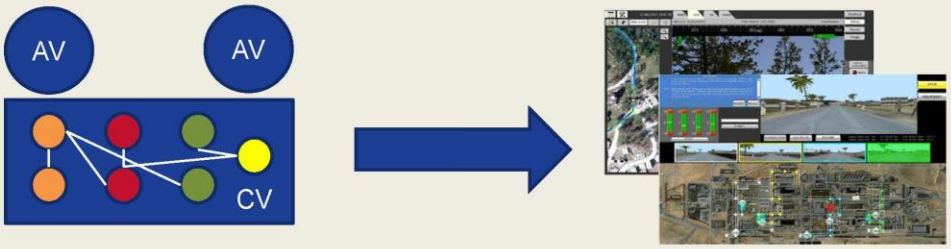
Core Functions: Shoot, Move, Communicate in the 21st Century



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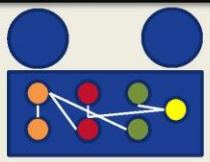

- **Vigilance** – the ability monitor, detect, report rare events
- **Teamwork** – ability to communicate with agents and team members
- **Human-Agent Interaction** – toggle control, trust, reciprocal behaviors/adaptions
- **Situational awareness** – observations, interpretation, prediction
  - **Rest/Sleep** – multiple effects
  - **Psychophysiology** – wearable sensor to state/performance

How can we optimize the NGCV's interaction with humans through these processes?

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Summary

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Goal: Develop models and algorithms to provide individualized, adaptive technologies to improve human-agent teaming.

Approach: Understand and model the influence of human (multifaceted) variability on state, intentions, and behaviors that will affect human agent interaction. Will require large volumes of data over years to sample the breadth and depth of variability.

Implementation: Perform preliminary experiments in vigilance, sleep, psychophysiology, situational awareness, team interaction, and human-AI interaction and coalesce them into a larger, multi-site experiment that executes over years.

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Workshop Goal

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BRAINSTORM!

- Discuss experiment ideas that span current to future goals
- Hear "lessons-learned" from similar longitudinal studies
- Think about what measures contribute to the greatest sources of variance that would be applicable to HAT
- ***Develop collaborative partnerships***

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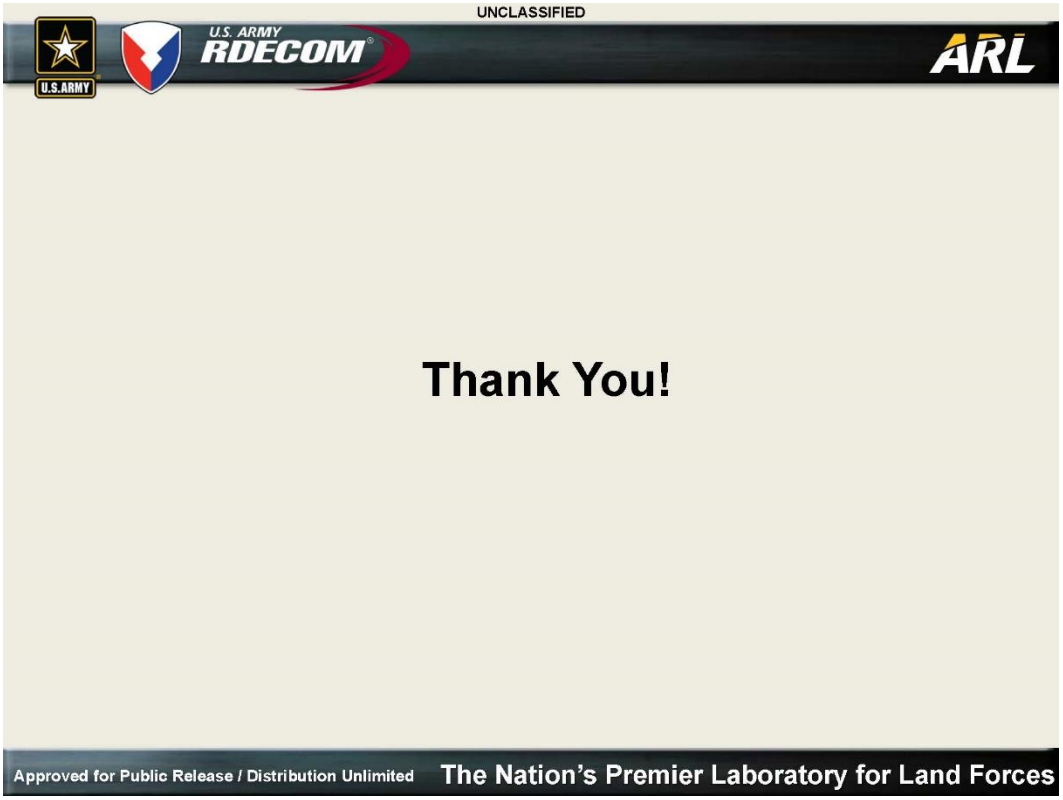
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Appendix D. Day 1: Panel of US Army Research Laboratory (ARL) Human Variability (HV) Principal Investigators

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Using Network Dynamics to Characterize Individual and Group Variability

Sean M. Fitzhugh

Human Variability Workshop
July 16-17th, 2018

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Background

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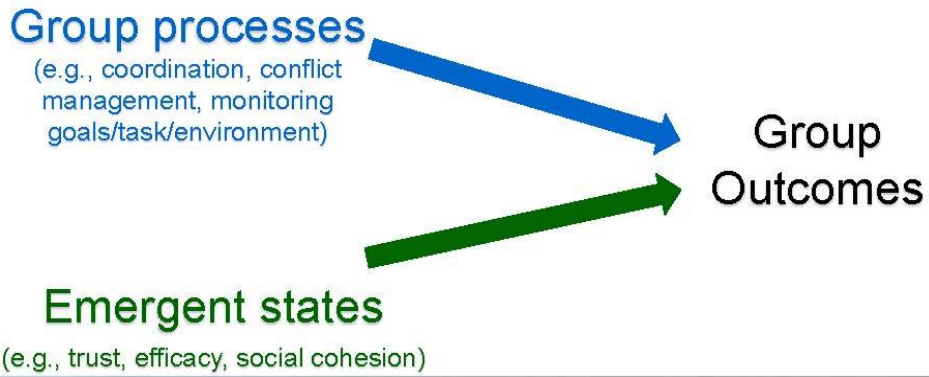
- Group outcomes stem from group processes and emergent states
  - Group process: "members' interdependent acts that convert inputs to outcomes…to achieve collective goals" (Marks et al., 2001, p. 357)
  - Emergent states: group-level phenomena that come about due to interactions among individuals



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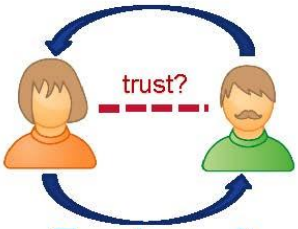
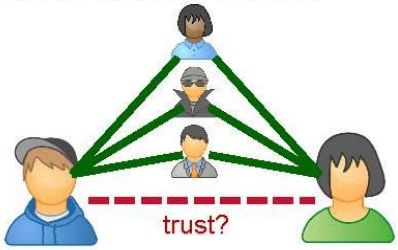
Background

- Group processes and emergent states are driven by interactions within the group
  - We know little about how temporal factors shape group processes and emergent states (Marks et al., 2001; Ilgen et al., 2005; Quintane et al., 2013; Leenders et al., 2016)
    - Time lags? Feedback loops? Path dependency?

Which interaction patterns build trust?



Reciprocity

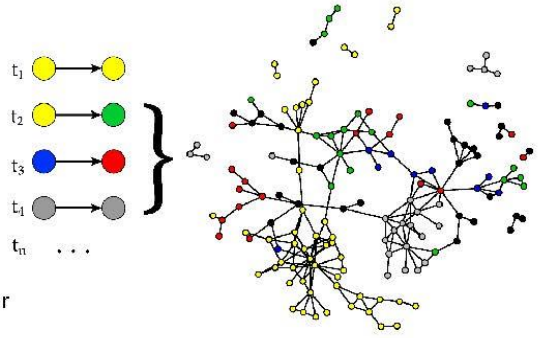


Friend of a friend

Relational Event Model

- *"holy grail for research on team dynamics is to be able to watch a 'movie' of team process as it unfolds, then pause the movie, and be able to answer the questions: what will likely happen next and with what implications for the outcomes?"* (Leenders et al., 2016, p. 97)

- **Solution:** relational event model (Butts, 2008)
  - Model posits likelihood of observing next event as a function of past event history, individual covariates, event covariates
  - "past history creates the context for present action" (Butts, 2008, p. 160)



- REM builds on event history models by accommodating complex dependence structures among actors

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Long-term Experiment

- High-resolution observation of team task 2-3 times per week
  - Do features of interaction (timing, structure, content, tone, affect, eye gaze, posture, mimicry) predict changes in group processes and emergent states?
    - Initially have to obtain processes/states from surveys, but we aim to be able to infer these unobtrusively through sensors and relational event models
- Army-relevant applications
  - Trust among members of Brigade staff, where members typically rotate in and out over the span of 18 months
  - Cohesion among teams of humans and autonomous agents

Further Suggestions?

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Modeling the influence of natural sleep history on behavioral states, cognition and social behavior

Stephen Thurman
& Jean Vettel

Human Variability Workshop
July 16-17th, 2018

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General Impact of Sleep Loss

ARL

Immediate Effects

- Less vigor & more **fatigue**
- **Impaired** decision making
- **Reduced** reaction times
- Mood **dysregulation**
- Attentional **instability**
- Increased **stress** response

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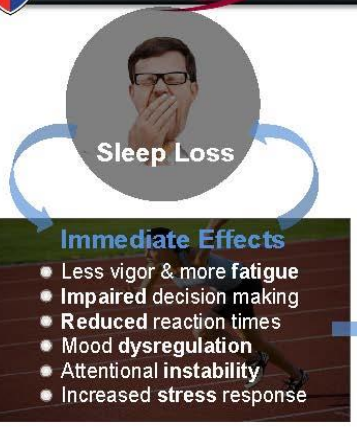
General Impact of Sleep Loss

ARL



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- Increased **stress** response

Longer-term Effects

- **Worse** overall health
- **Abnormal** endocrine function
- Risk for obesity & heart **disease**
- More **inflammatory** proteins
- Risk for **mental health** disorders
- **Shorter** life span

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- **Shorter** life span

Consequences

- Increased risk of **accidents**
- Higher incidence of **failure**
- **Strained** social relationships
- More **illness** and hospital visits
- **Suboptimal** performance
- Less **ability** to problem solve

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Limitations of Prior Work

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There are Gaps in our Understanding of Naturalistic Sleep and Performance Outcomes

Ecological Validity

Most sleep studies have assessed sleep-to-performance relationships in laboratory settings. Less is known about complex natural sleep patterns.

Timescale

What is the timescale over which natural sleep debt accumulates to impact performance in different task domains? Is it days? Weeks? Months?

Individual Differences

Only broad relationships can be learned at the group level. How do individual factors or traits determine susceptibility and resilience to sleep loss?

Impact on emotion, learning & decision making

Despite the largely shared neurobiology between chronic sleep loss and emotion and executive functions, this has been relatively unexplored.

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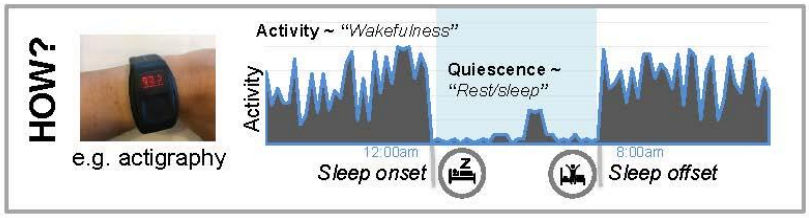
Approach: Measure long-term activity patterns while subjects perform variety of tasks daily/weekly



General Goals

1) Develop *adaptive models to predict individual performance from multi-timescale, multi-modal longitudinal time series data including wrist actigraphy (sleep) & physiology.*

2) Understand *how naturalistic sleep measures relate to intrinsic variability of physical fatigue, learning, emotion, social behavior, team performance and broad executive functions.*

Connection to existing proposals

Josh*: vigilance performance*
Sean*: team interaction dynamics*
Katherine*: situational awareness*
Derek*: psychophysiology*
Evan*: gaming, communication, HAT*

Potential Applications:

- *Smart sleep and/or team scheduling tools*
- *Better-targeted sleep countermeasures*
- *Momentary state assessment of soldiers*

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Sources of Variability During Vigilance

Joshua Rubinstein

Human Variability Workshop
July 16-17th, 2018

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Divergent Patterns

Traditional Vigilance Decrement

Examples:

PVT
Mackworth's Clock Test
Simple Detection
Change Detection

A drop in Sensitivity
Signal Detection Theory

Alternative Vigilance Decrement

Examples:

Industrial Inspection
X-ray Screening
Other search tasks

A Criterion shift
Signal Detection Theory

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Theoretical Issues

Current vigilance-decrement theories – Resource Depletion Theory and Under-stimulation Theory – do not predict these divergent performance patterns.

Testing a new theory called Dynamic Resource Allocation Theory: Changes in vigilance performance over time-on-task are caused by *strategic changes* in behavior designed to reduce the waste of cognitive resources during low-payoff tasks.

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Research Questions

Overarching questions to be answered:

1. How do specific task features determine these divergent patterns of vigilance decrement?
2. Will tasks producing the two different patterns of vigilance decrement react differently to repeated exposure across large time scales (6 months)?
3. Can physiological measures (e.g., HRV, respiration) explain performance/attention changes across large time scales?
   a. Do prefrontal processes inhibit HRV to change ones behavior in response to task conditions?
   b. Do physiological measures respond differently to the two tasks?
   c. Will physiological measures be able to predict future drops in attention/performance equally for both tasks?

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Technical Approach

1. Simulate army-relevant visual search tasks, for example:
   a. Searching for targets from an aerial view provided by UAV - applies to the TAC, Command and Control, and NGCV
   b. Searching for targets from a forward-looking view provided by video feed while driving – applies to NGCV

2. Identify two similar search tasks that differ in small ways that produce the divergent vigilance decrement patterns

3. Conduct 2 long-term experiments
   a. One for each task
   b. Subjects perform 1-hour visual search task, 3 times per week, for 6 months
   c. Record behavioral (RT, hit rates, false alarm rates) and physiological (HRV, respiration, others TBD) measures

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Further Suggestions?

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Long-term measurement to predict team performance

Katherine Gamble

The Human Variability Project Workshop
16 July 2018

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Army Priorities

- Enhanced situational awareness is one of the Army's top priorities
- A basic understanding of how situational awareness, behaviorally or physiologically, in individuals and teams, is critical to address the Army's needs

- Short-term Goal: Assess situational awareness (SA) through psychophysiology (e.g., phasic HR, eye-tracking, communication)
- Measurement at the individual and group levels

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Short-term: Individuals and Teams

Assessing Pattern of Life: 3 levels of SA on the below feed

Level of SA	Individuals	Teams
Perception	1. Eye-tracking: increased fixations on people (Ratwani, McCurry, & Trafton, 2010) 2. Phasic HR: decrease in HR (Somsen, Jennings, & Van der Molen, 2004)	1. Eye-tracking: complimentary gaze and fixations 2. Phasic HR: decrease in HR (Somsen, Jennings, & Van der Molen, 2004) 3. Communication: increased discussion about where to look
Interpretation	1. Eye-tracking: increased scanning back to people (Ratwani et al., 2010) 2. HRV: increased HRV (Saus, Thayer, & Johnsen, 2006)	1. Eye-tracking: complimentary gaze and fixations 2. HRV: increased HR coherence with time 3. Communication: increased discussion
Projection to the future		
	Over many trials, changes in psychophysiological measures will predict SA, and varying levels of SA will predict performance	Physiological coherence between team members will predict shared SA, which will inform team performance

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Long-term Goals

Long-term: Use real-time data and on-line intelligent learning to determine a point of need for individuals and/or teams for an intervention, assistance, or changed course of action

- Real-time psychophysiological (HR, eye-tracking, communication, behavior) measures will detect changes in SA and how these may affect performance
- Soldiers + AI will be able to detect minute changes in patterns of life, improving SA and thus performance

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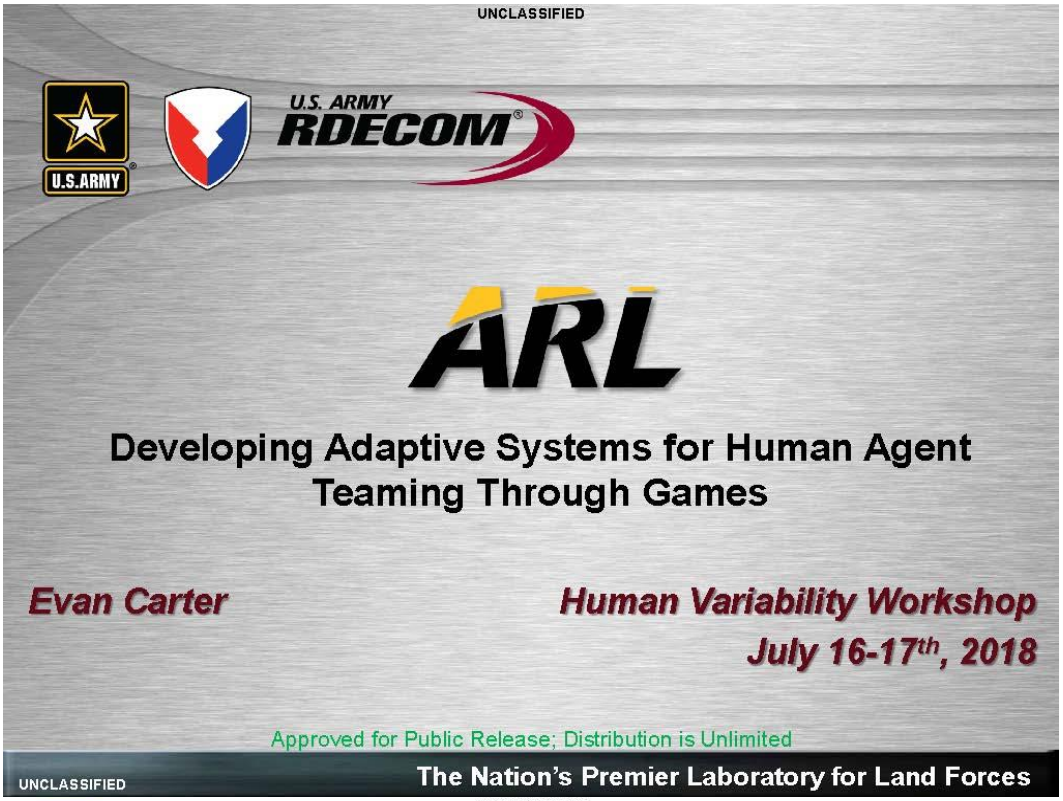

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The overarching goal of this program is to **develop adaptive systems for optimizing human-agent teaming.** We will move toward this by testing the following general hypotheses.

Communication from the agent

[H1.1.] **Different people will benefit differently** from agent communication. [H1.2.] Matching a person with **the right communication style at the right time** will improve performance.

Agents' approach

[H2.1.] **Different human-agent teams will perform differently** (e.g., a riskier person may perform less well with a riskier agent). [H2.2.] **Adapting the agents' approach** to the participants' will improve performance.

Modeling the person

[H3.1.] We can **predict human-agent interactions and team performance**. [H3.2.] Using transfer learning techniques, **prediction algorithms designed for one context will be useful in other contexts**.

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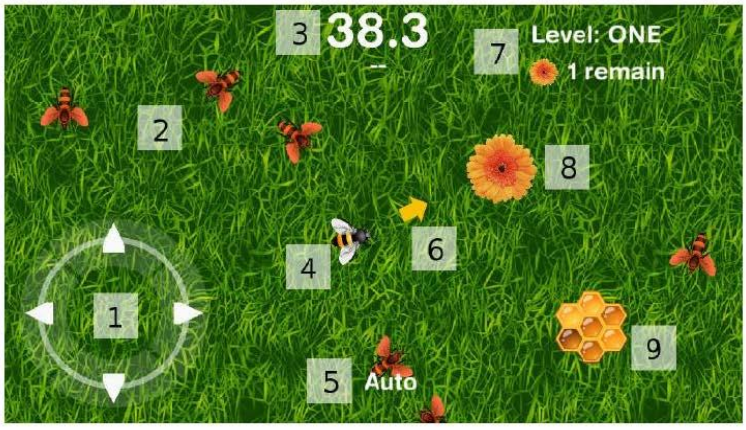
Our plan is to do this by **studying human-agent teaming within the context of games**.

Pros of games: Relatively cheap, allows for high throughput, out-of-lab sampling
Cons of games: Potentially limited generalizability

Why care about high throughput/cheapness/out-of-lab sampling? More data from more people in more situations means **a better account of human variability**.

Why does human variability matter? A better account of human variability means **a more generalizable model.** An adaptive system is only as good as the underlying model



Our initial focus will be on a previously developed game: **Busy Beeway** (Adamson et al., 2017)

To adapt the agent to the person, we will make use of research on **Just in Time Adaptive Interventions** (JiTAIs).

In an initial data collection effort, we will run a **Micro-Randomized Trial** (MRT).

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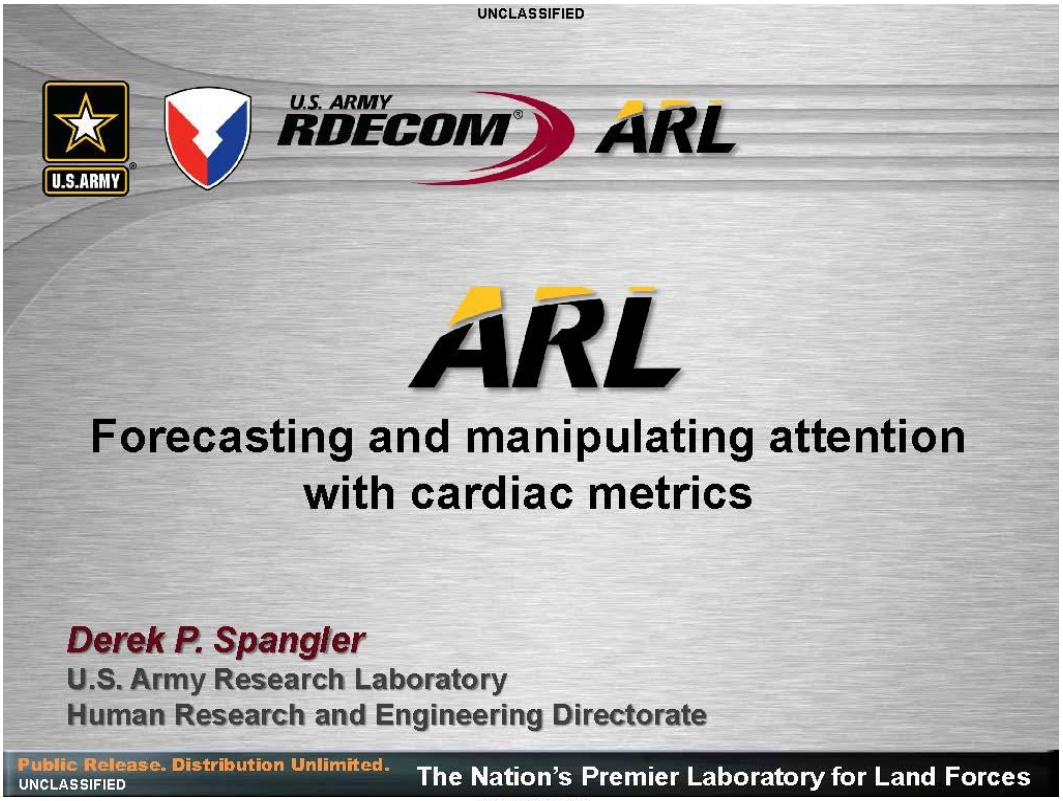

Optimizing human performance in adaptive systems requires:

1) **Prediction** of future lapses in attention
2) **Interventions** to prevent predicted lapses (e.g., modifications to augmented reality)

How can we forecast and alter intra-individual variability in attention?

Prediction of attention

- Phasic heart rate (HR) and heart rate variability (HRV)
  - Noninvasive
  - Autonomic aspects of attention (Porges, 1992)
  - Forecast attentional performance (Jennings et al., 1977)

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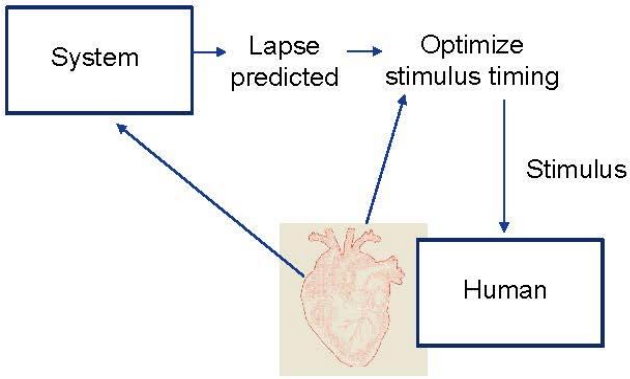
Problem & Solution

Intervention: Change how human variability unfolds over time:

- Presenting a stimulus earlier in *cardiac cycle* can enhance attention to that stimulus (Azevedo et al., 2017; Lacey & Lacey, 1974)



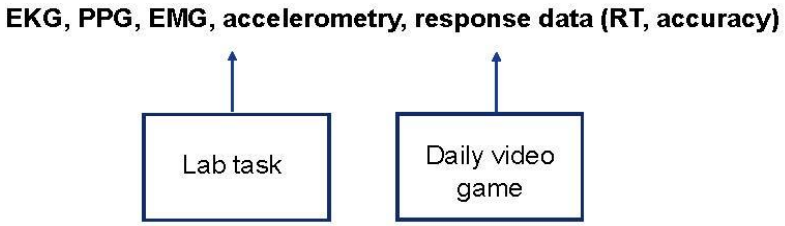
Research

Can we predict future lapses and prevent them with cardiac cycle timing intervention?

Do these attentional effects (prediction & intervention) **vary**:

(i) Between-subjects: ethnicity, Sex?

(ii) Day-to-day: sleep, mood, environmental conditions?



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Appendix E. Day 1: Two Panels of Invited Academic Researchers

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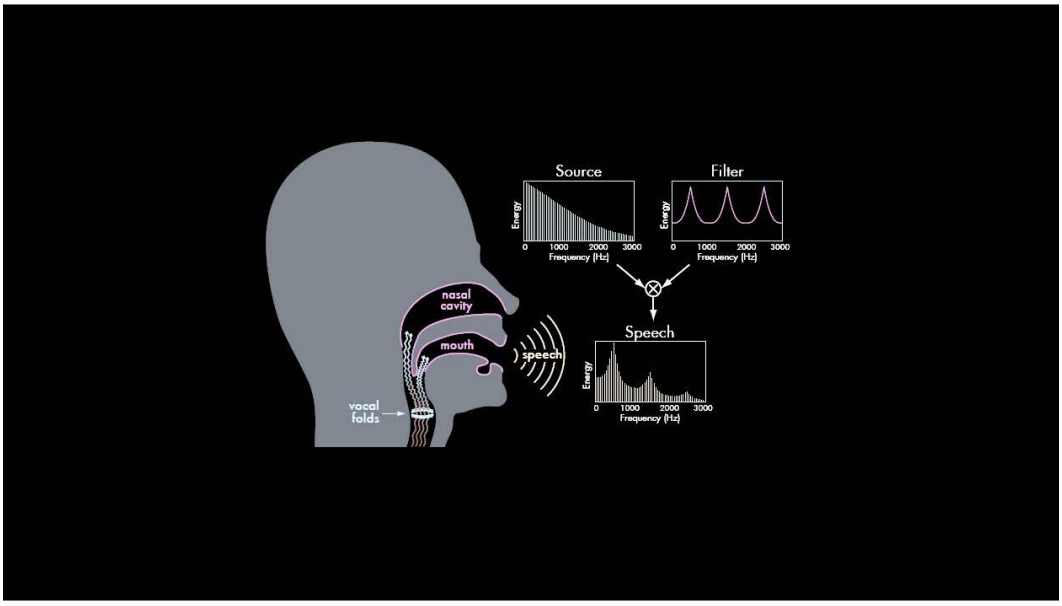

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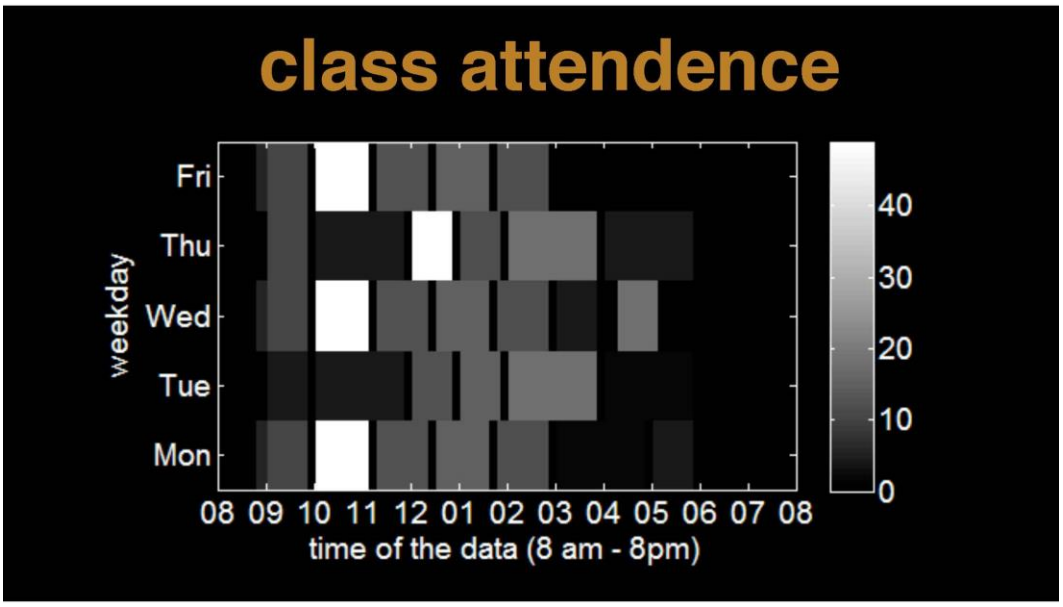

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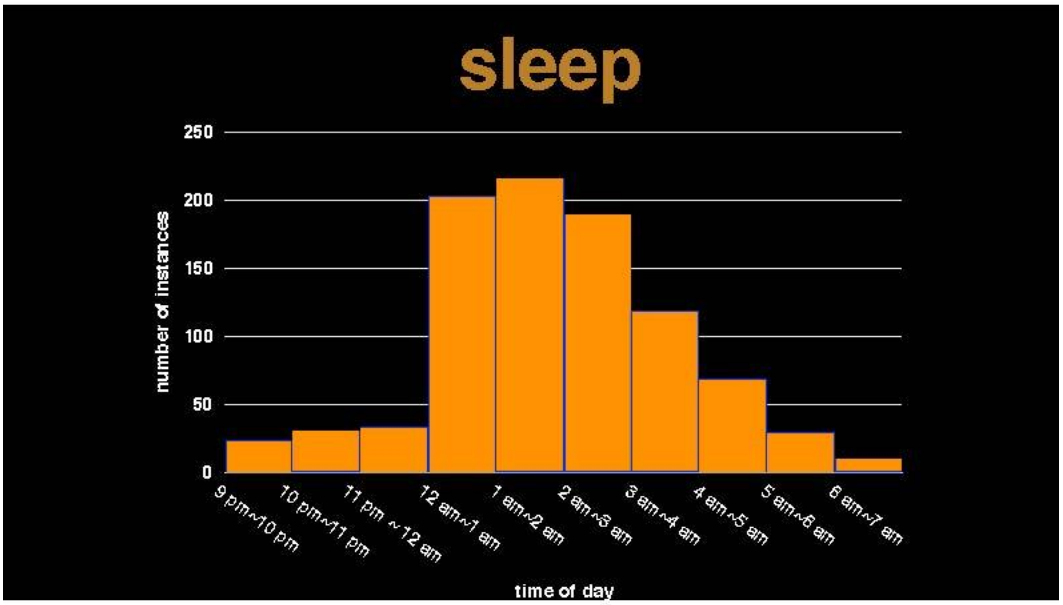

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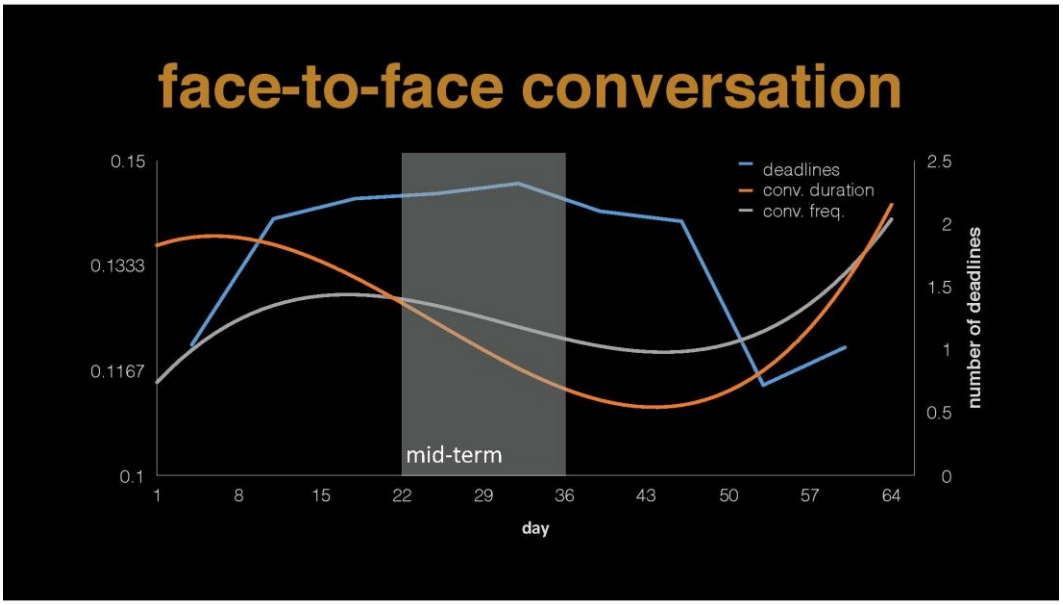

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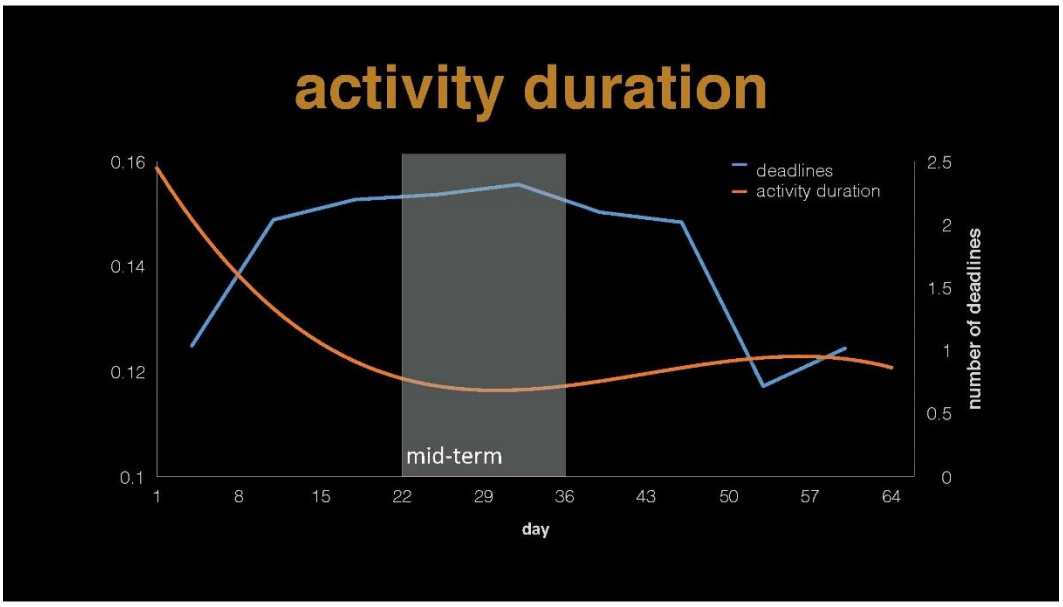

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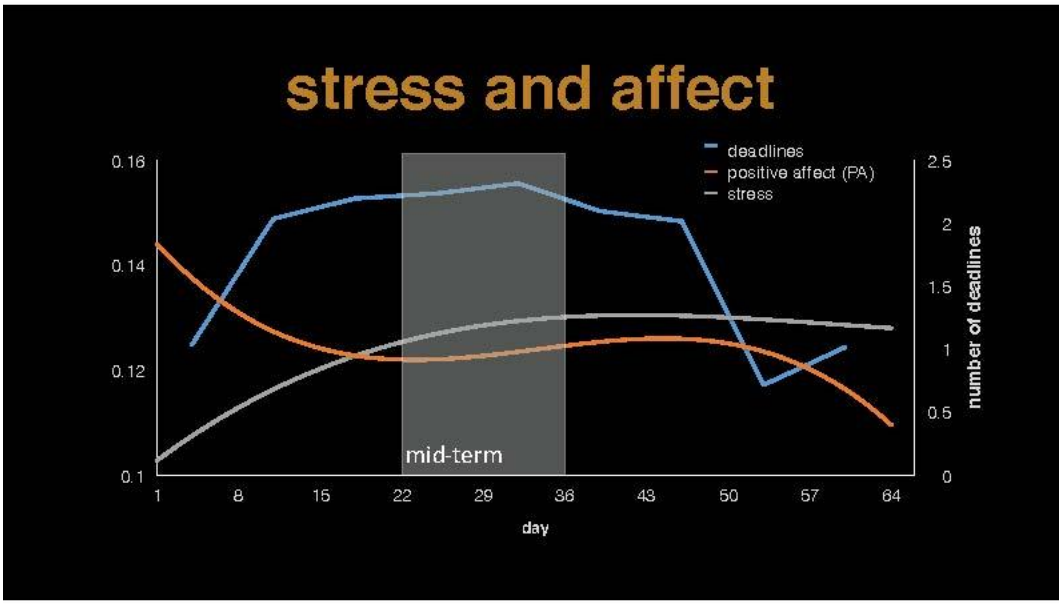

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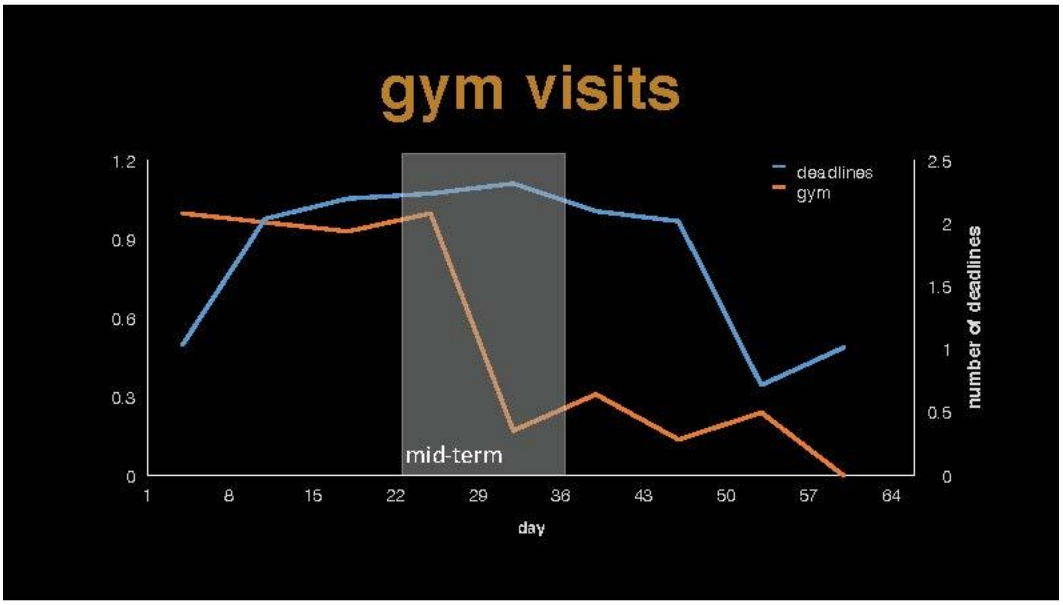

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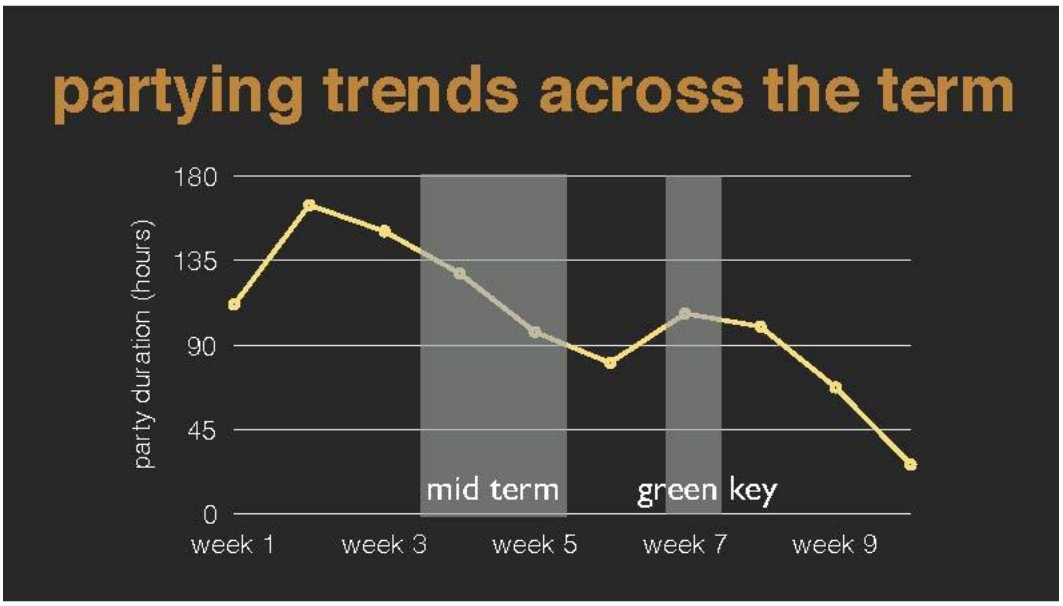

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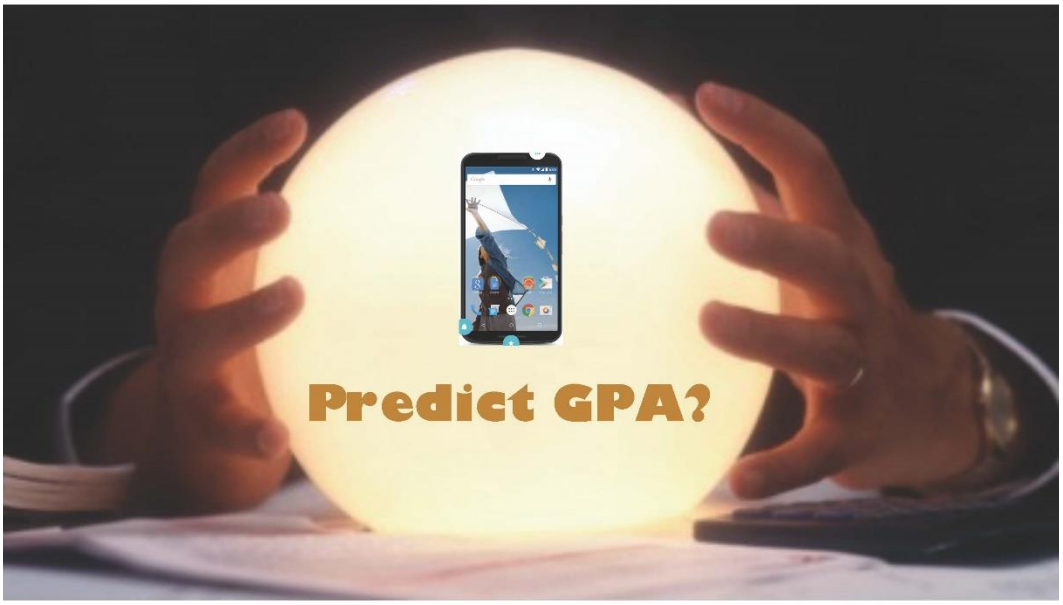

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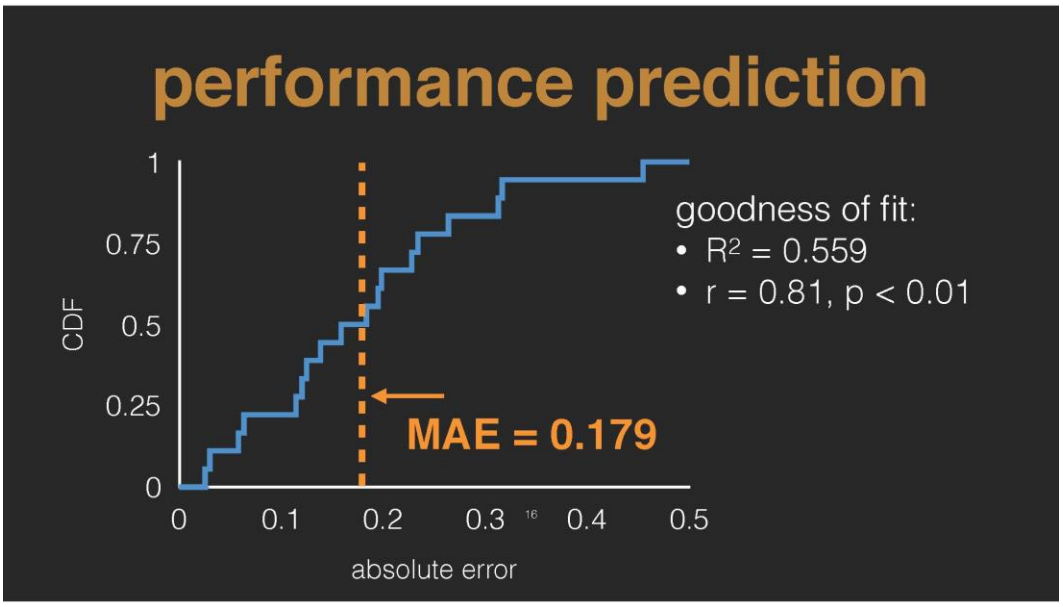

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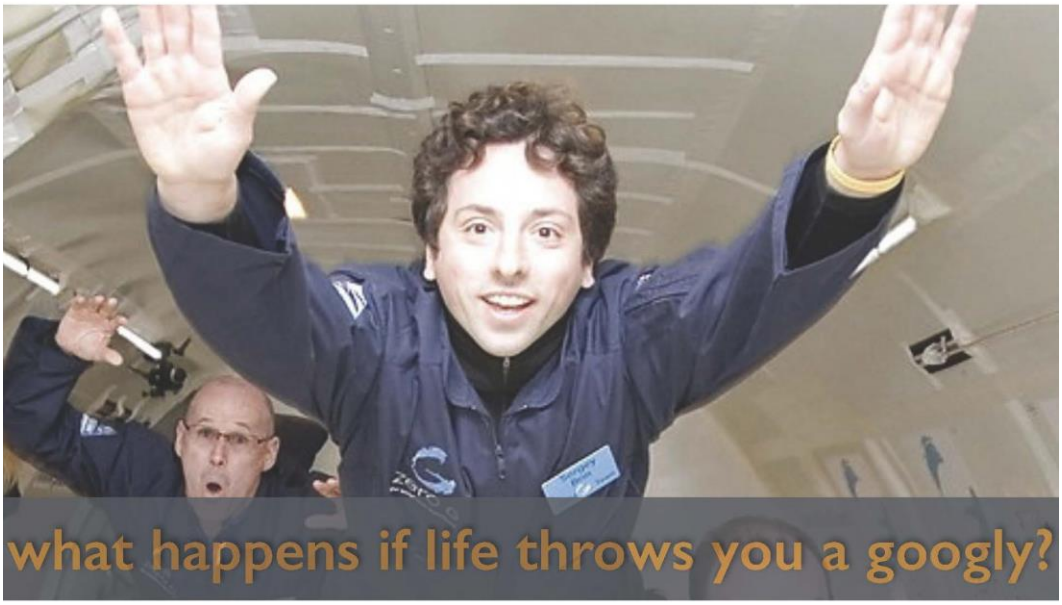

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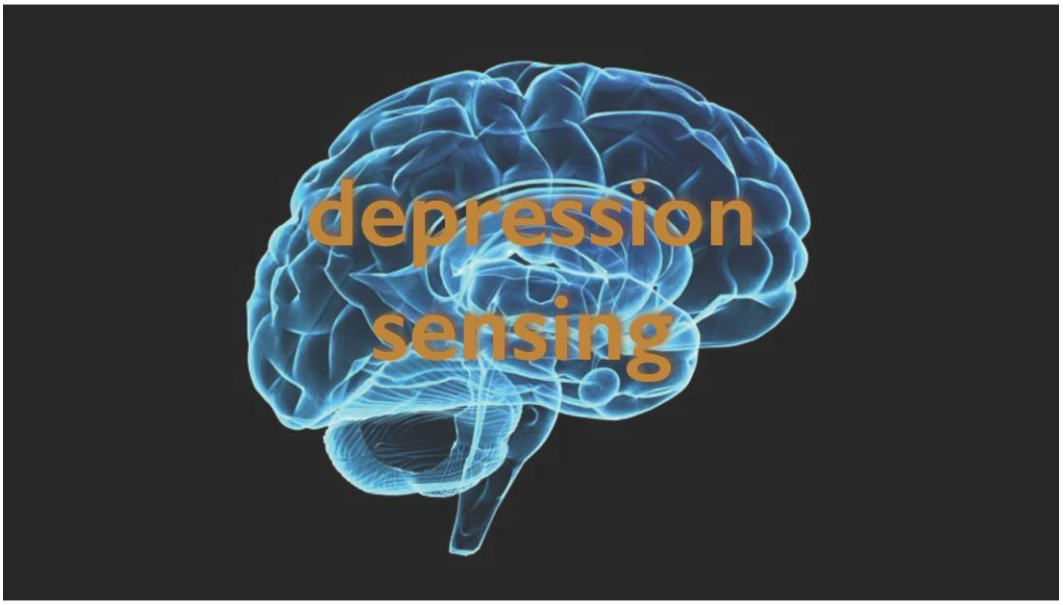

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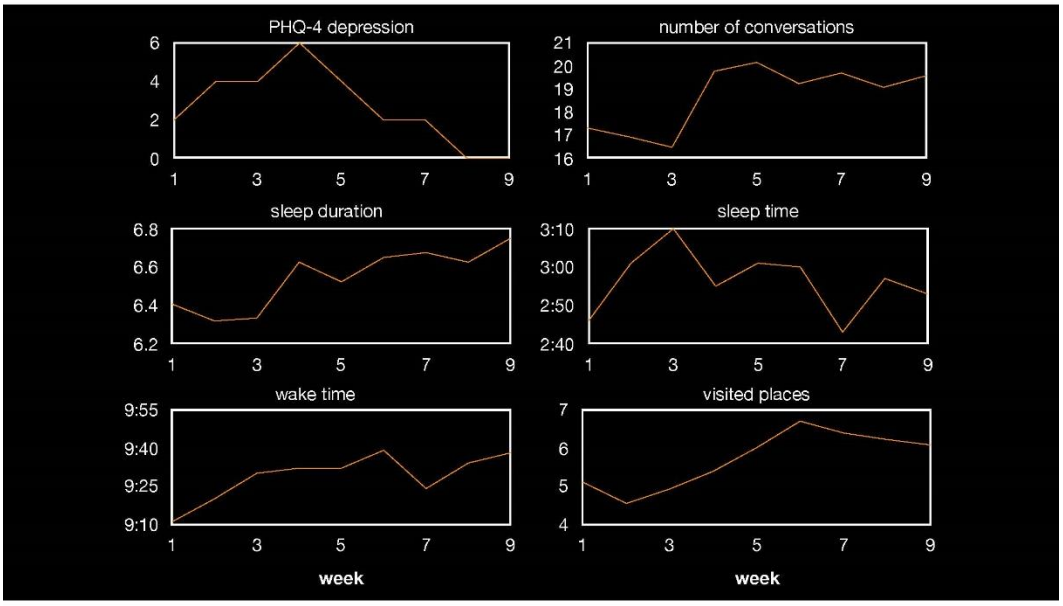

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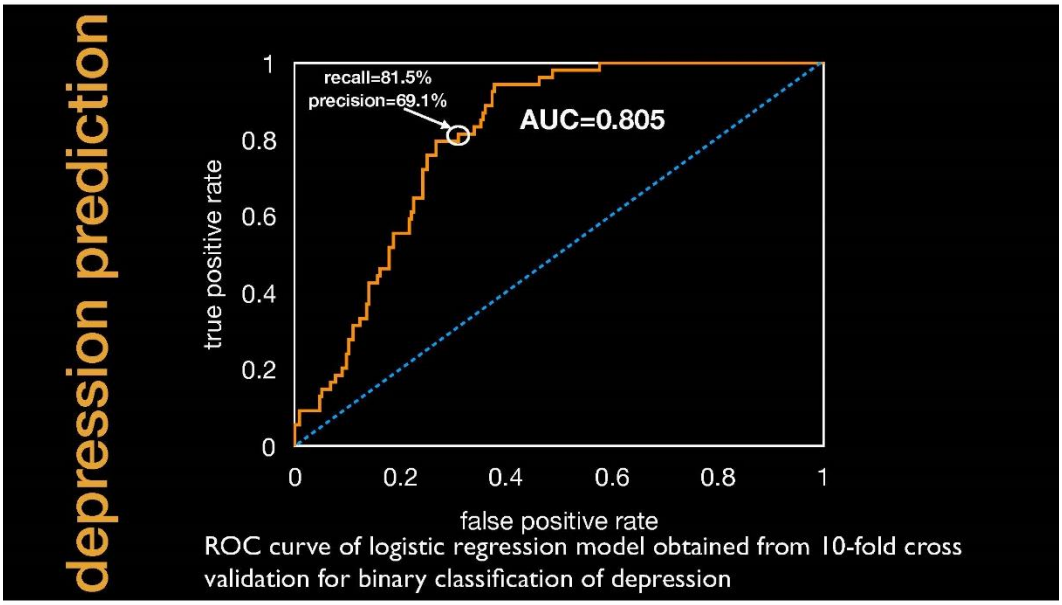

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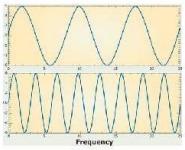
Measuring and Predicting Cognitive Variability Using Mobile Technology

Human Variability Project Workshop

Martin Sliwinski, PhD

Today's Objectives

Briefly and reliably measure cognitive variability



Cognitive variability is systematic and predictable

Challenges and next steps

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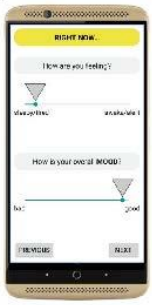
Ambulatory Cognitive Assessment

Real-time measurement of cognition in **naturalistic** settings

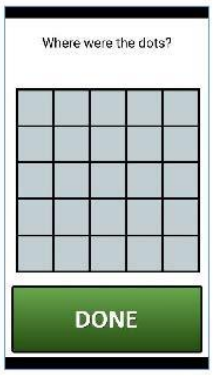
Ecological Momentary Assessment (EMA)

- Mobile technology (smartphones/tablets)
- Brief performance tests
- Real-time self-reports/passive sensing
- Strategic sampling of occasions
  (specify both *what* and ***when*** to measure)



Example Protocol

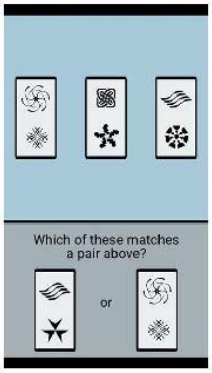
Working Memory
(2 trials)



Design Features

- 14 days of assessments (5/day)
- ~1 minute per assessment
- Valid and reliable (ICCs >.90)

Attention/Speed
(12 trials)



Study supported by NIA grants AG-03949 and AG-04295

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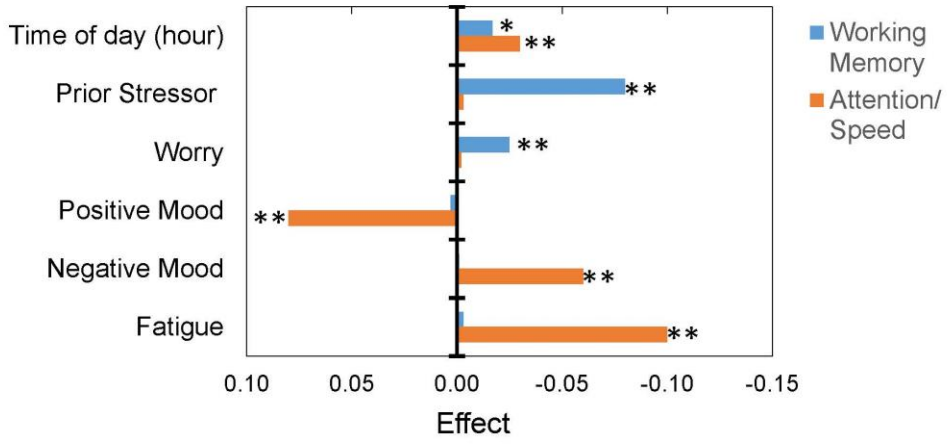
Predicting variability in cognitive performance

1. **Trends**: Time of day, practice
2. **Coupling**: stress, mood, worry

Cognitive Variability is systematic

Cognitive variability is systematically related to stress and mood



*<.05, **<.01

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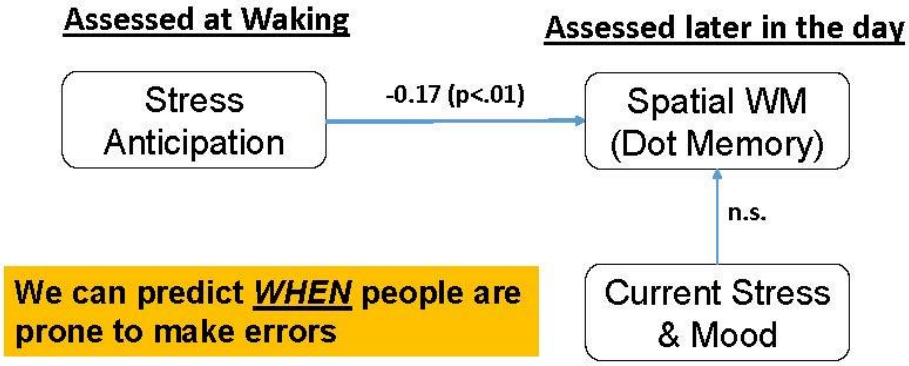
Example:
Predicting (sub)Optimal Cognitive Performance



Hyun, Sliwinski & Smyth (2018) Waking up on the wrong side of the bed: effects of stress anticipation on WM performance in daily life

Applications for optimizing human performance

Moments of risk (Stress, fatigue)

Just-in-time intervention (relaxation, stimulant)

Risky situations (location, poor sleep)

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Discussion Points

Design Challenges

- Brevity vs. precision
- Adaptations/learning effects
- Adherence to protocol

Next generation cognitive assessments

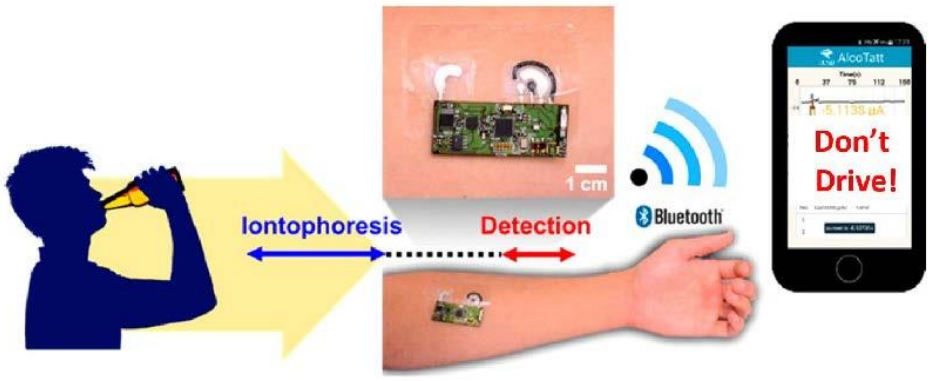
- Unobtrusive
- Embedded into structured tasks (e.g., driving)

Link to passively measured biometrics

- Stress/worry
- Sleep
- Fatigue

Thank you!

Example: “Just-in-time” intervention



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Prefrontal Regulation of the Stress Response: A Neurovisceral Integration Perspective

Julian F. Thayer
The Ohio State University

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Emotion Regulation

- The ability to generate an emotional response that is appropriate for the environmental demand
- Involves top-down regulation via inhibitory pathways between the prefrontal cortex and subcortical sympathoexcitatory circuits

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Neurovisceral Integration Model

- This neural network can be indexed by heart rate variability
- Higher HRV associated with greater prefrontal inhibitory tone
- Lack of inhibition leads to undifferentiated threat response to environmental challenges (less flexibility)

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BEHAVIOR THERAPY 26, 457–466, 1995

Vagal Tone in Generalized Anxiety Disorder and the Effects of Aversive Imagery and Worrisome Thinking

JAMES D. LYONFIELDS
T. D. BORKOVEC
JULIAN F. THAYER
The Pennsylvania State University

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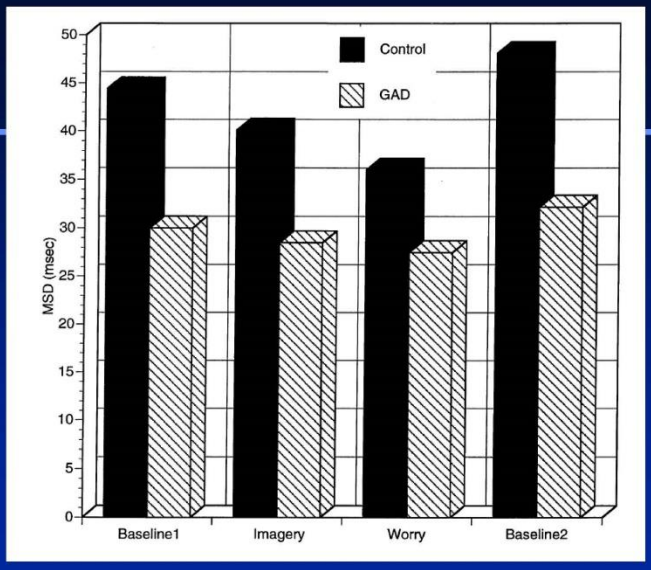

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Eur J Appl Physiol
DOI 10.1007/s00421-009-1341-x

ORIGINAL ARTICLE

Low vagal tone is associated with impaired post stress recovery of cardiovascular, endocrine, and immune markers

Cora Stefanie Weber · Julian F. Thayer · Miriam Rudat · Petra H. Wirtz · Frank Zimmermann-Viehoff · Alexander Thomas · Frank H. Perschel · Petra C. Arck · Hans C. Deter

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Vagal Regulation of Allostatic Systems

- Collaboration with Cora Weber and Hans-Christian Deter, Berlin
- 44 healthy males
- Median split on resting HRV
- Exposed to mental stress
- Examined recovery of cardiovascular, endocrine, and immune systems

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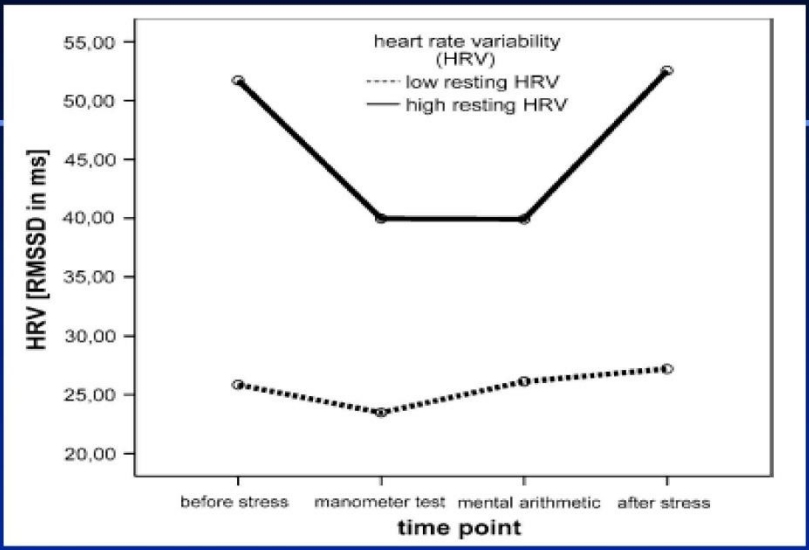

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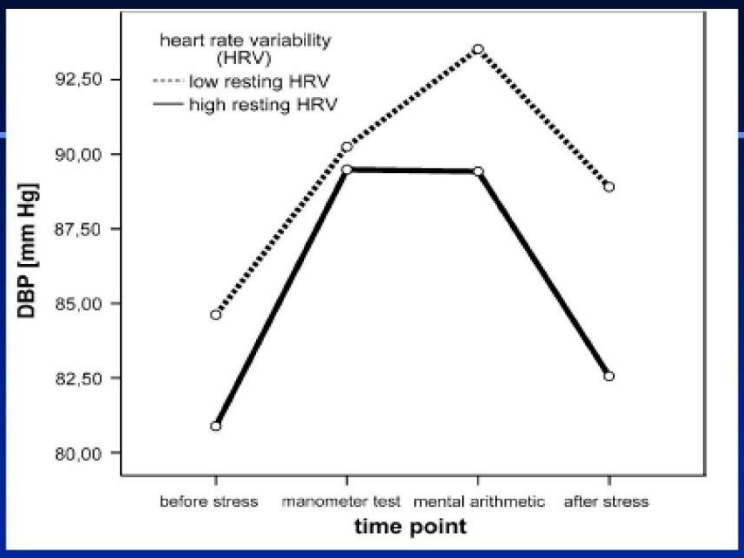

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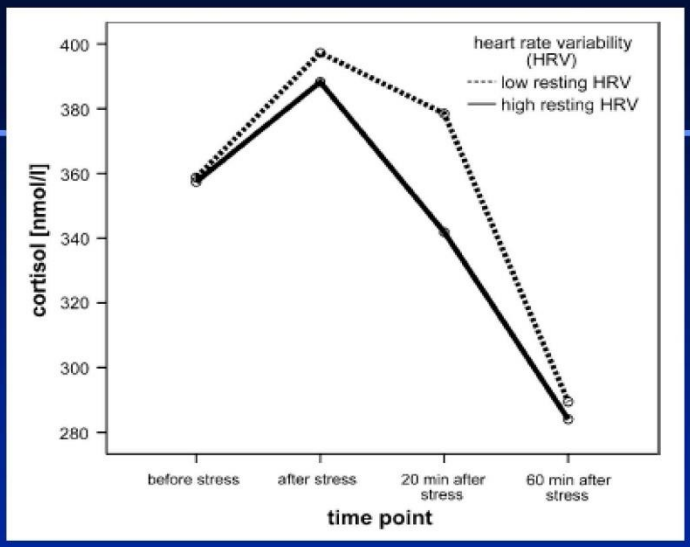

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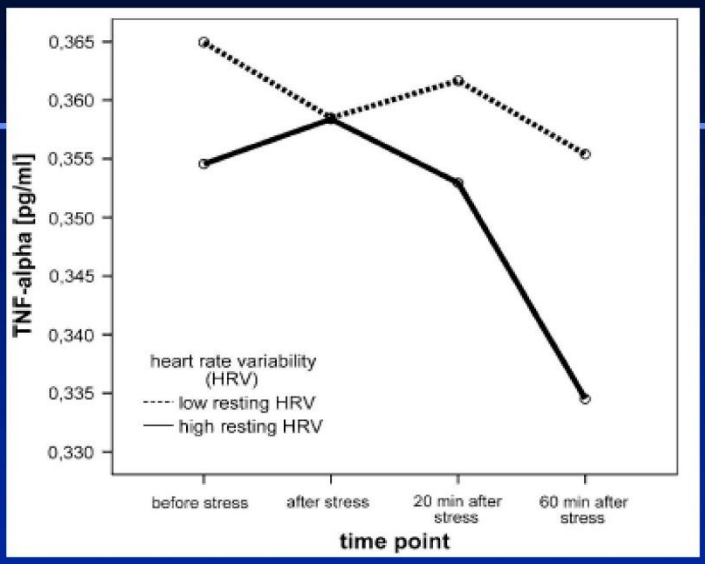

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Psychophysiology, 51 (2014), 419–426. Wiley Periodicals, Inc. Printed in the USA.
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DOI: 10.1111/psyp.12186

When tonic cardiac vagal tone predicts changes in phasic vagal tone: The role of fear and perceptual load

GEWNHI PARK,[a] MICHAEL W. VASEY,[b] JAY J. VAN BAVEL,[c] AND JULIAN F. THAYER[b]

[a]Department of Psychology, Azusa Pacific University, Azusa, California, USA
[b]Department of Psychology, The Ohio State University, Columbus, Ohio, USA
[c]Department of Psychology, New York University, New York, New York, USA

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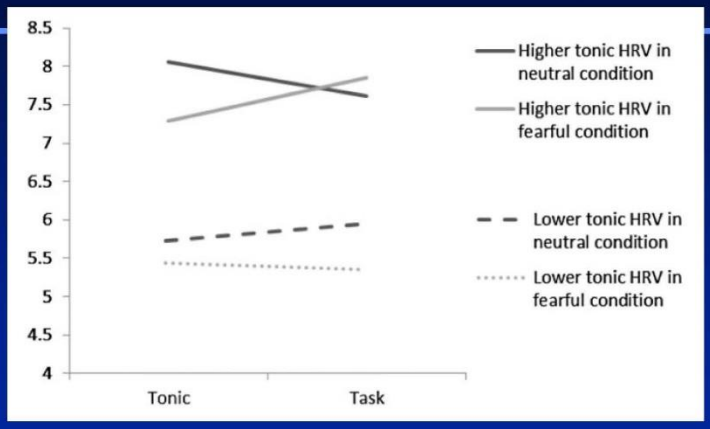

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Journal of Psychophysiology

Individual Differences in Attentional Capture by Pictures of Fear and Disgust as Indexed by Cardiac Responses

Elisabeth Ruiz-Padial, M.T. Mendoza Medialdea, G. Reyes del Paso, and J.F. Thayer

Online First Publication, July 13, 2017. http://dx.doi.org/10.1027/0269-8803/a000198

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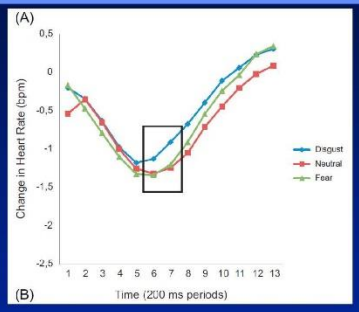

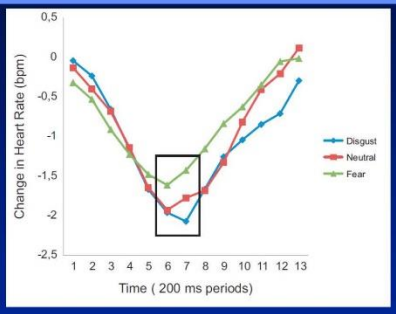

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Emotion Modulated Startle

- Foreground stimuli modulate magnitude of startle reflex via top-down modulation of central nucleus of the amygdala
- PFC modulates amygdala to produce context appropriate emotional response
- Prediction: High HRV associated with context appropriate responses whereas low HRV associated with threat responses to 'safe' stimuli

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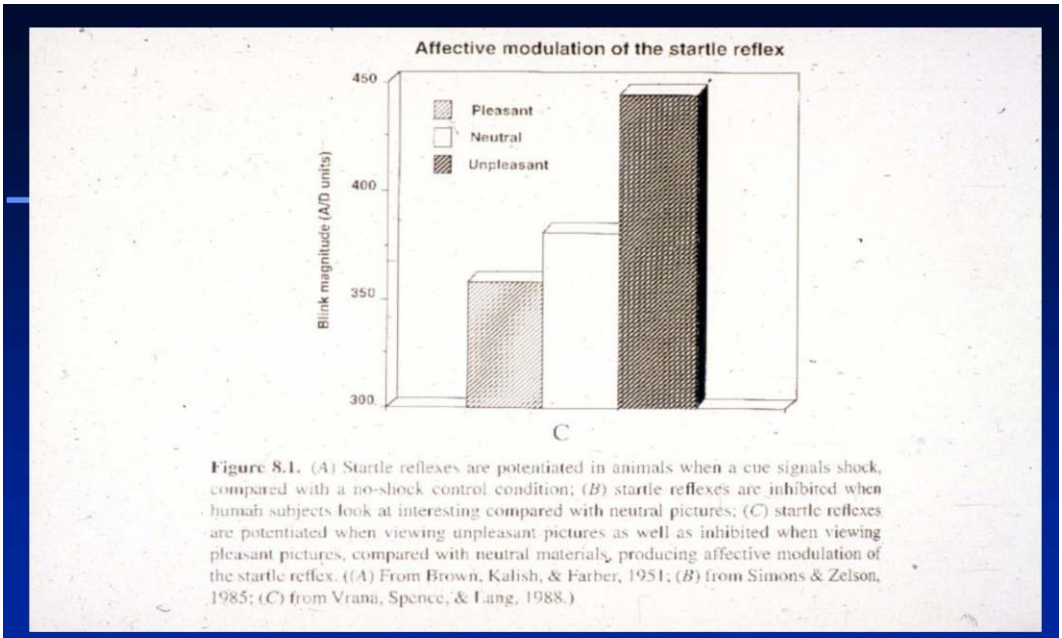

Figure 8.1. (*A*) Startle reflexes are potentiated in animals when a cue signals shock, compared with a no-shock control condition; (*B*) startle reflexes are inhibited when human subjects look at interesting compared with neutral pictures; (*C*) startle reflexes are potentiated when viewing unpleasant pictures as well as inhibited when viewing pleasant pictures, compared with neutral materials, producing affective modulation of the startle reflex. ((*A*) From Brown, Kalish, & Farber, 1951; (*B*) from Simons & Zelson, 1985; (*C*) from Vrana, Spence, & Lang, 1988.)

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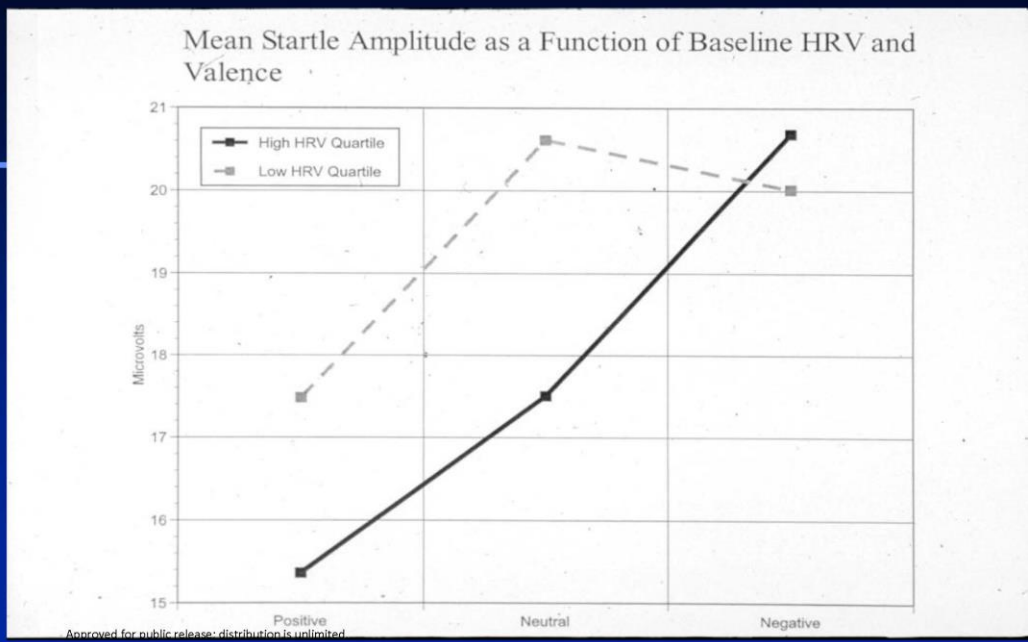

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Resting heart rate variability and the startle reflex to briefly presented affective pictures☆

Elisabeth Ruiz-Padial [a,*], Julian F. Thayer [b]

International Journal of Psychophysiology 94 (2014) 329–335

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Acute Stress Affects Heart Rate Variability During Sleep

Martica Hall, PhD, Raymond Vasko, PhD, Daniel Buysse, MD, Hernando Ombao, PhD, Qingxia Chen, MS, J. David Cashmere, BS, David Kupfer, MD, and Julian F. Thayer, PhD

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Why

SLEEP ?!

* Major restorative period (1/3 of life)

• If stress responses are prolonged during sleep, than sleep = major **mediator** stressors ⟶ organic disease

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Figure 1. **Mean and Std Dev of Parasympathetic Activity for Control vs. Experimental Group During NREM and REM**

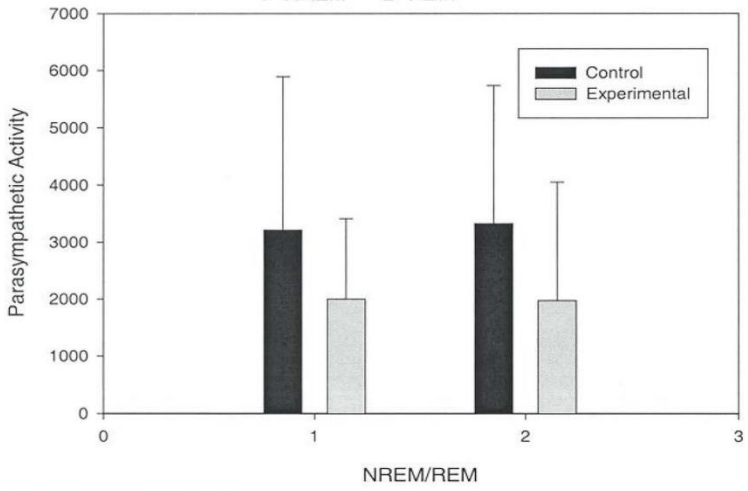

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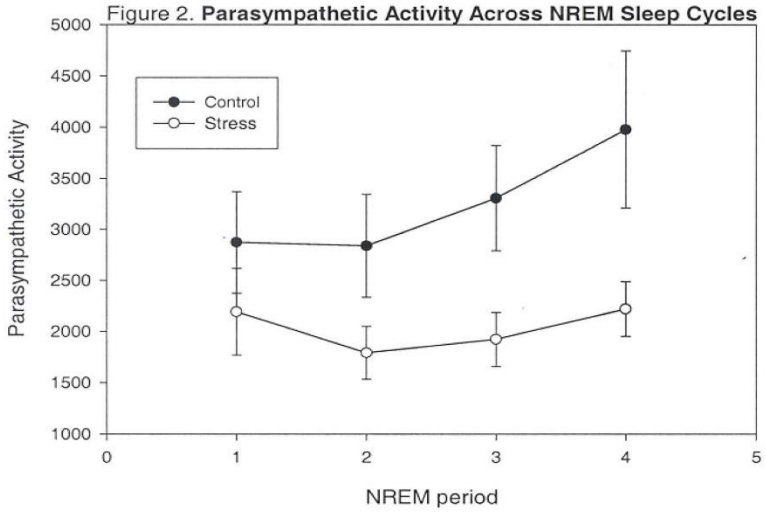
Figure 2. **Parasympathetic Activity Across NREM Sleep Cycles**



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Review article

Exposed to events that never happen: Generalized unsafety, the default stress response, and prolonged autonomic activity

Jos F. Brosschot[a,*], Bart Verkuil[b], Julian F. Thayer[c]

Neuroscience and Biobehavioral Reviews

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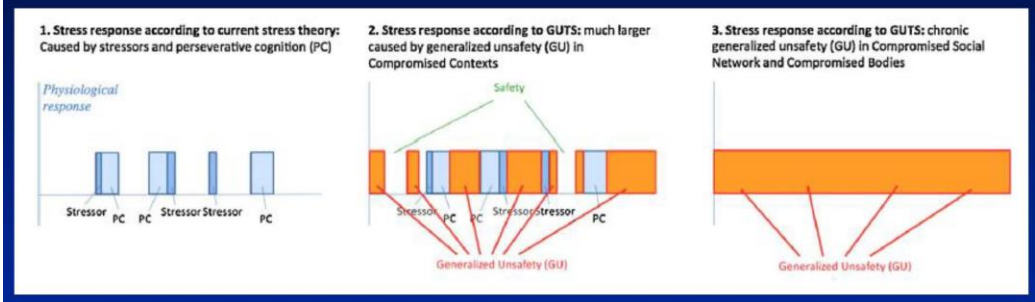

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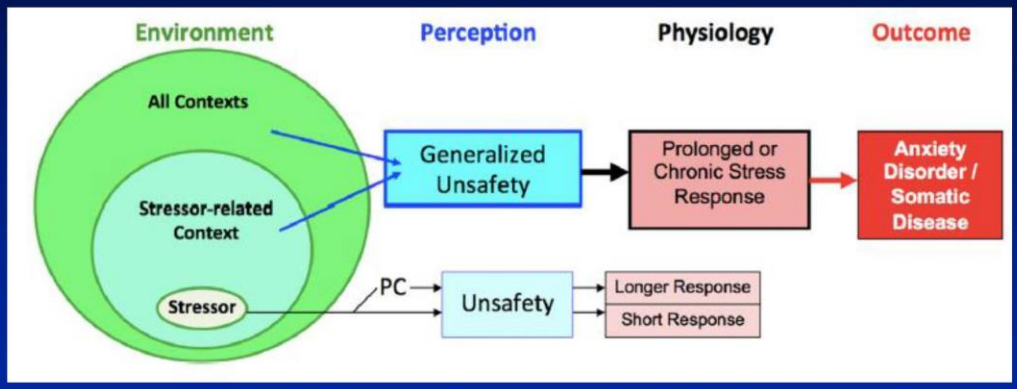

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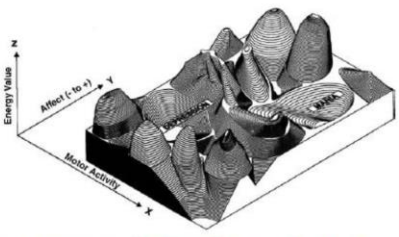

Fig. 1. State space representation of bipolar disorder, with large attractors for depression and mania (reprinted from Globus and Arpaia, 1994, with permission of the publisher and primary author).

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Variability in Human Performance
(A few brief remarks)

Phillip L. Ackerman
School of Psychology
Georgia Institute of Technology
Atlanta, Georgia, USA

July 16, 2018

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Georgia Institute of Technology

Overview

- Beyond intra-individual standard deviations (ISD)
- Resource-limited vs resource-insensitive tasks
- Maximal Performance vs. Typical Behavior
- Disorganization of behavior under stress and fatigue
- Measurement (RT vs. Attainment)
- Matching on performance, examining correlates of ISD

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Beyond ISD

- E.g., Slifkin & Newell (1998)
  - Shape of distribution of performance may be illustrative of something more than Gaussian noise in the human information processing system
  - Additionally, evidence exists for sequential dependencies in the stream of behavior (e.g., as a function of prior success/failure)

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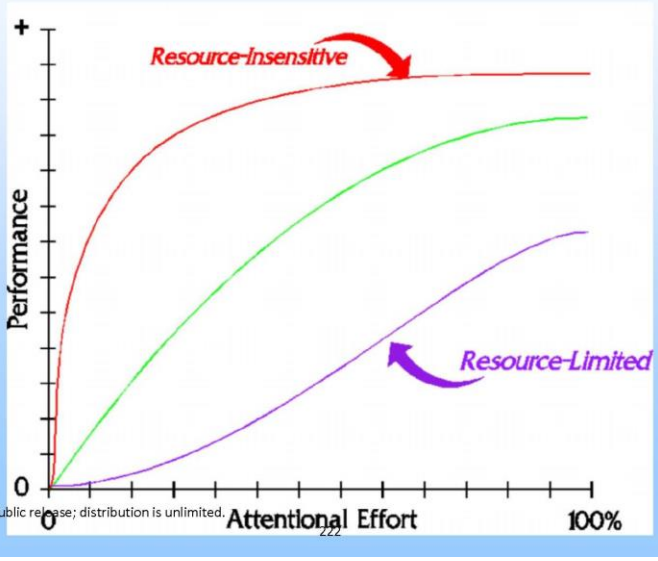
Resource-limited vs. resource-insensitive tasks

- After Norman & Bobrow (1975)



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Maximal Performance vs. Typical Behavior

- Historically, the focus of inter-individual assessments (especially in the ability domain), has been entirely on "maximal performance")
  - That is, expectation is that the individual exerts maximal attention and effort on task
  - Under these conditions, assumption is that there is a substantial reduction in within-individual variability
- However, in the real world, what one actually gets is "typical behaviors" – which may not align with maximal effort, especially:
  - When no close supervision is involved
  - Performance over long periods of time is involved

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Disorganization of behavior under stress or fatigue (Davis, 1945)

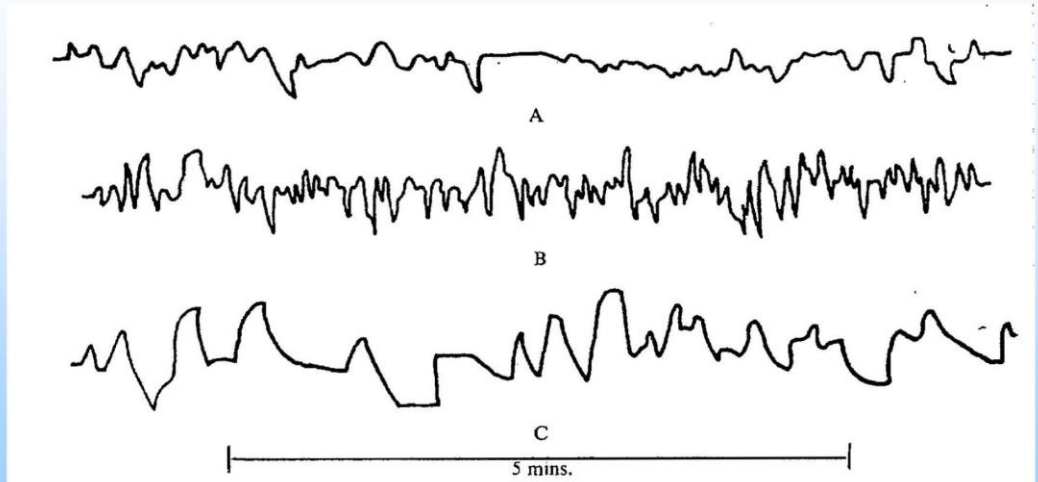

FIG. 4.—Extracts of the side-slip records of representatives of the three test classes.
A. " Normal " class.
B. " Overactivity " class.
C. " Withdrawal " class.

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Attainment vs. RT

- Choice of measure is highly related to changes in inter-individual variance during learning/skill acquisition (Ackerman, 1987)
  - For RT measures and consistent tasks, SDs typically decrease with learning/skill acquisition
  - For attainment measures, SDs may decrease, stay the same or increase; but typically increase as period of time considered increases

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Mental Multiplication Task Correlations with Math Ability Composite

Session	Mean Attainment (items)	ISD Attainment (items)	Mean RT (sec)	ISD RT (sec)
1	.740	**.077**	-.667	**-.393**
2	.650	**.294**	-.590	**-.448**
3	.641	**.371**	-.572	**-.368**

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Matching on performance, examining correlates of ISD

- Select groups at top and bottom of performance distribution. Match on performance, select based on highest/lowest ISD
- Example – study of Kanfer-Ackerman Air Traffic Control task (skill acquisition over 3 sessions)

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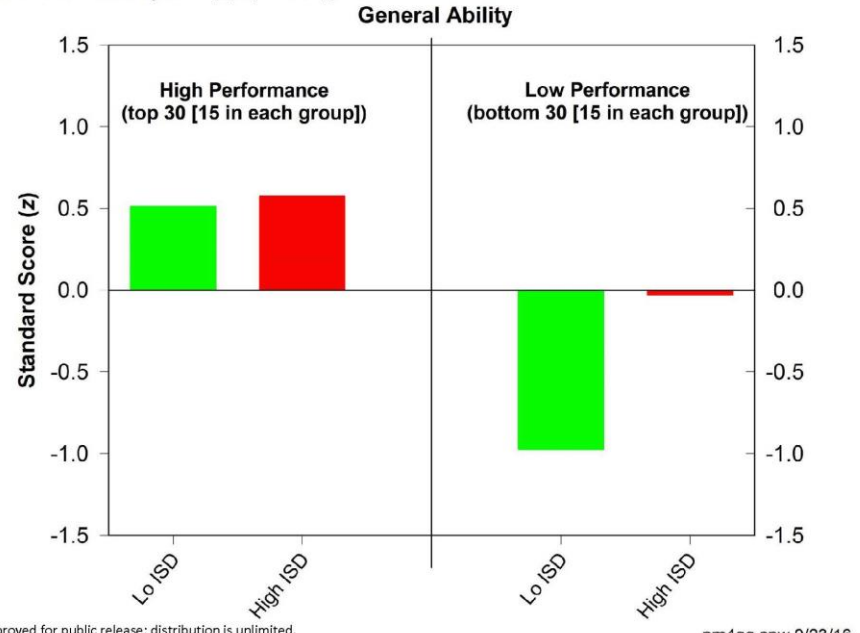
Main Effect of Performance $F(1,56) = 22.41$, $p < .01$
Main Effect of ISD $F(1,56) = 5.21$, $p = .03$
Interaction Performance by ISD $F(3,56) = 10.54$, $p < .01$



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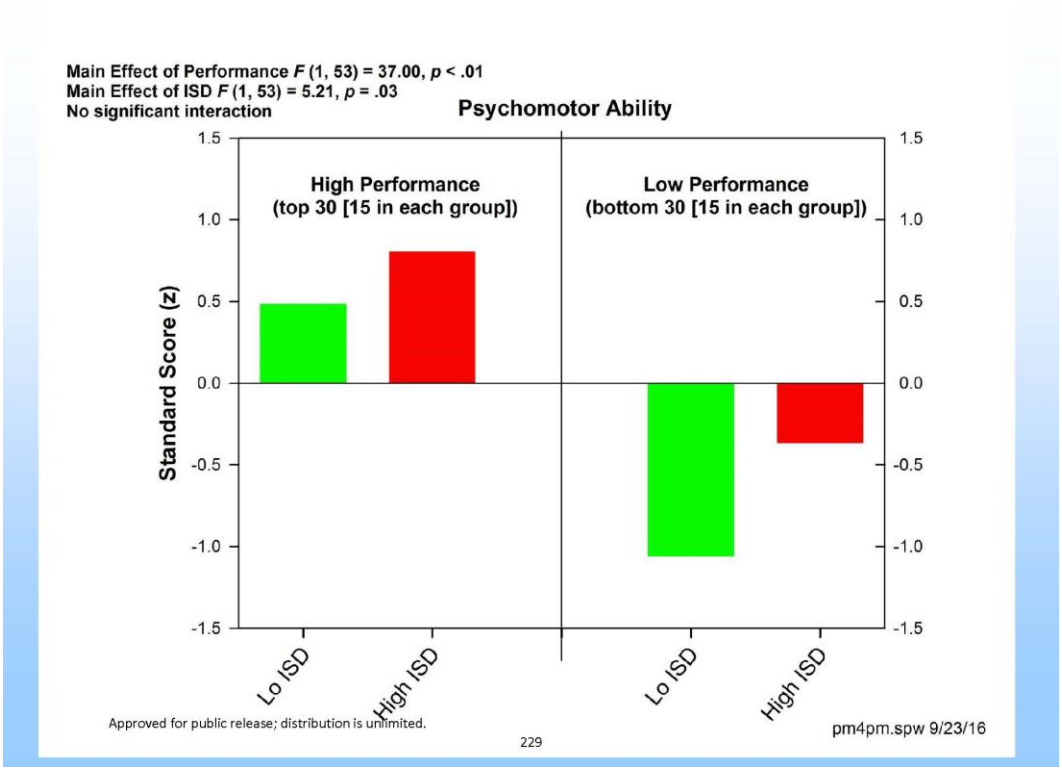
Main Effect of Performance F (1, 53) = 37.00, p < .01
Main Effect of ISD F (1, 53) = 5.21, p = .03
No significant interaction
Psychomotor Ability
High Performance
(top 30 [15 in each group])
Low Performance
(bottom 30 [15 in each group])
Standard Score (z)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
Lo ISD
High ISD
Lo ISD
High ISD
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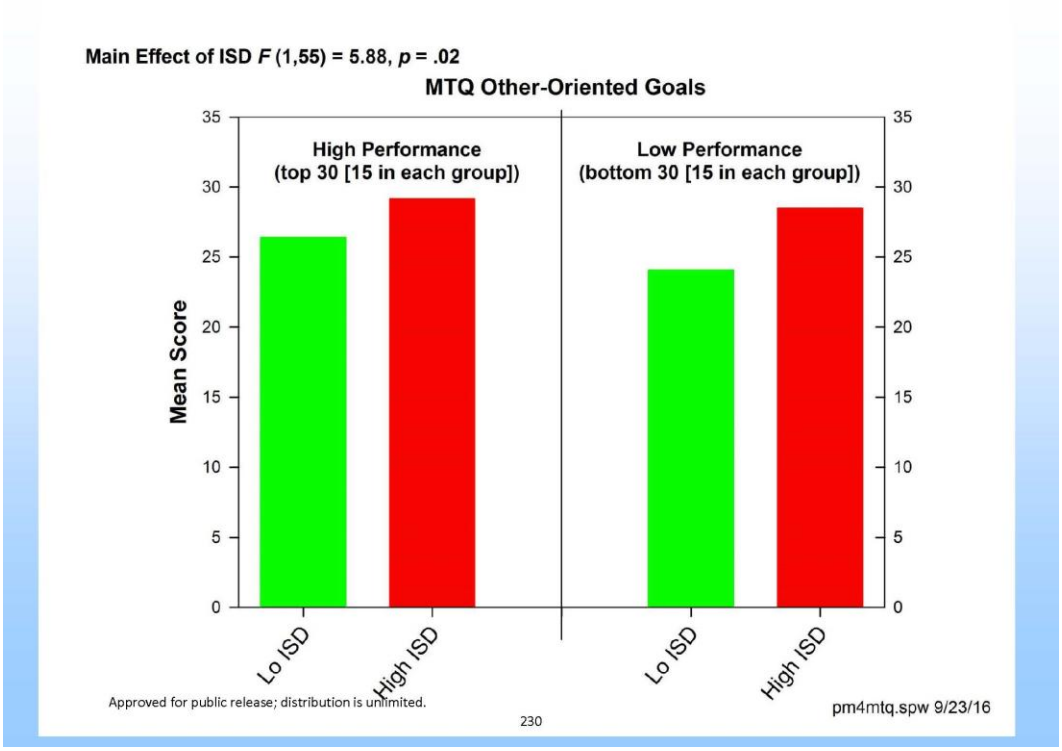
Main Effect of ISD F (1,55) = 5.88, p = .02
MTQ Other-Oriented Goals
High Performance
(top 30 [15 in each group])
Low Performance
(bottom 30 [15 in each group])
Mean Score
35
30
25
20
15
10
5
0
Lo ISD
High ISD
Lo ISD
High ISD
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pm4mtq.spw 9/23/16
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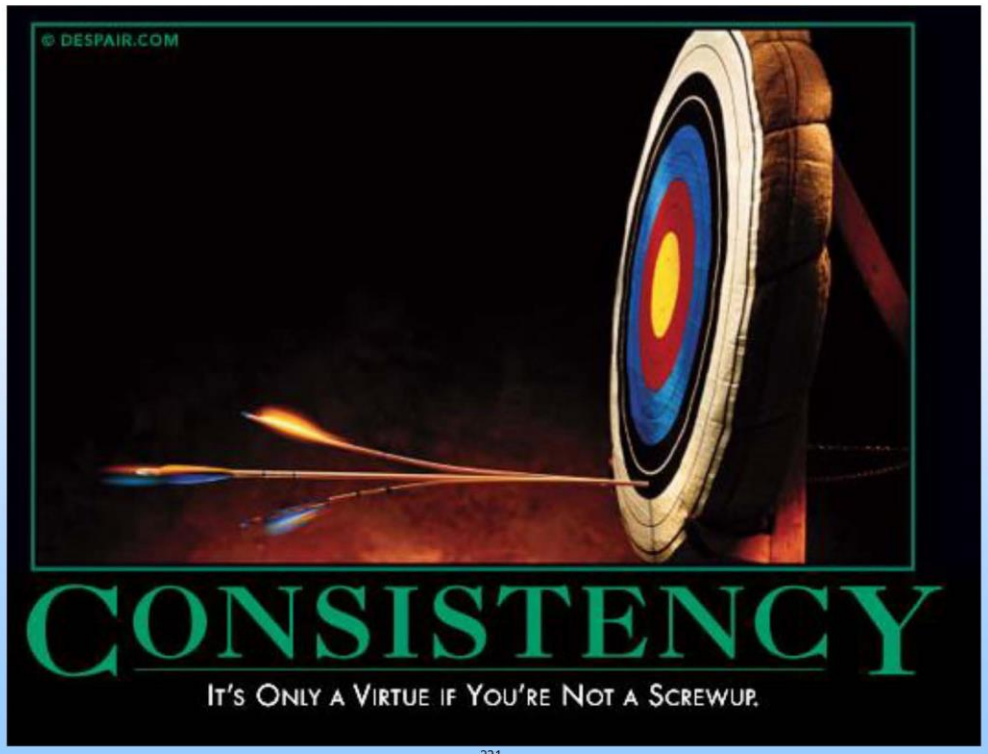

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Addressing Human Variability: Adaptive and Just-In-Time Adaptive Interventions

The Human Variability Project Workshop, July 2018

Inbal (Billie) Nahum-Shani
Institute for Social Research
University of Michigan

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Adaptive Interventions

Intervention + **Adaptive**

Intervention design;

uses ongoing information about the individual to decide how to modify type/timing/dose of treatment.

The goal:
Address the changing needs of individuals

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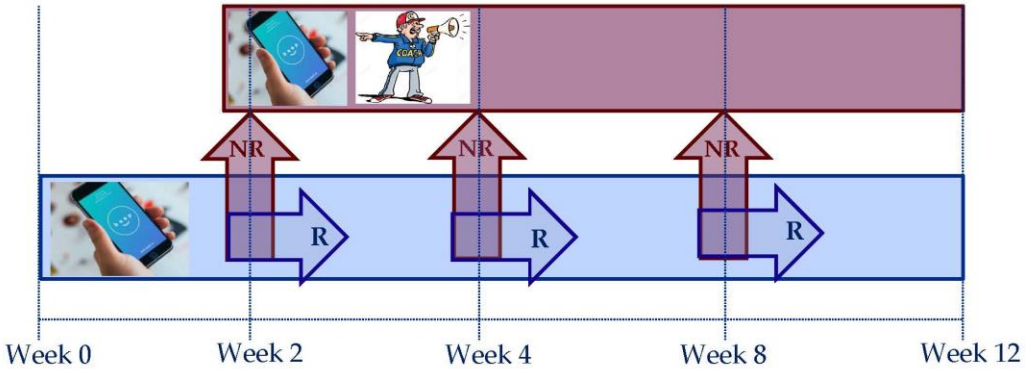
Adaptive Interventions

- *Example:* *NIH/NIDDK R01DK108678; Spring & Nahum-Shani*



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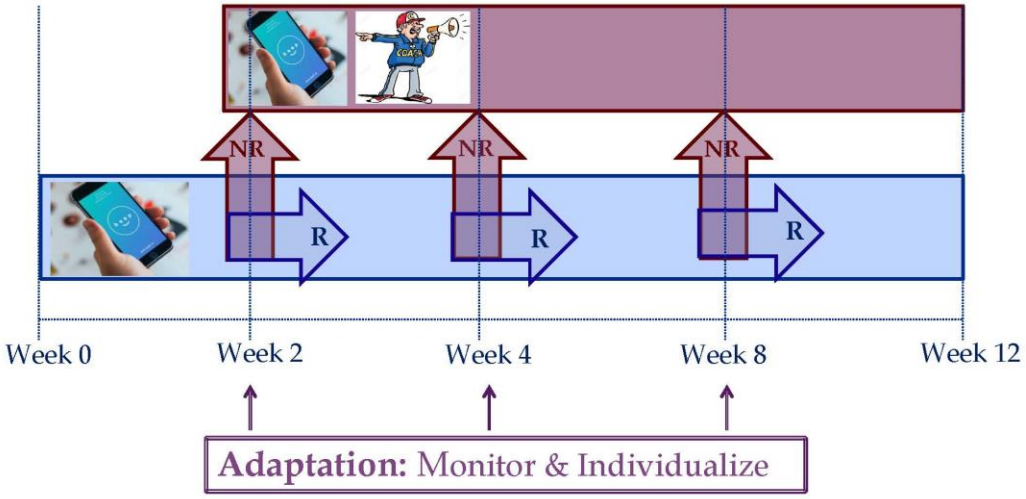
Adaptive Interventions

- *Example:* *NIH/NIDDK R01DK108678; Spring & Nahum-Shani*



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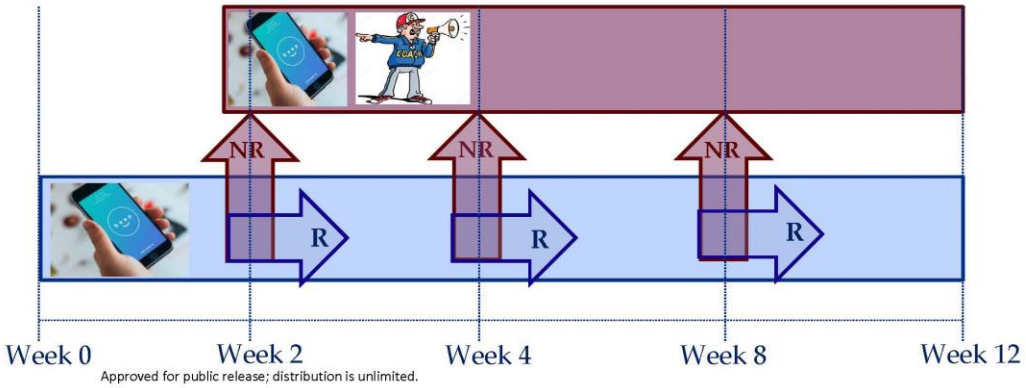
Motivation for AI

Heterogeneity: what works for one person might not work for another

Cost: Some mHealth components are costly; resources are often limited



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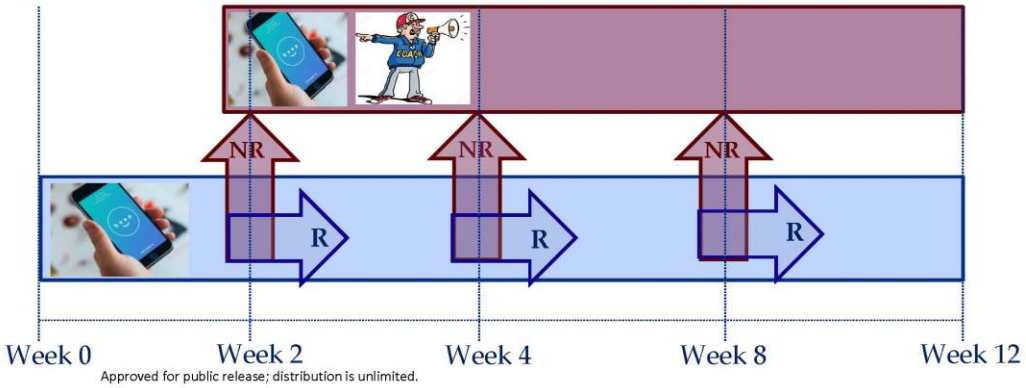
Open Scientific Question

- *What is the best initial intervention*
- *What is the best subsequent intervention for non-responders*



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SMART

- *SMARTs can help us build empirically-based adaptive interventions:*
  - *Randomized Trials*
  - *Multiple stages of randomization*
  - *Each stage corresponds to a critical question concerning the sequencing and adaptation of intervention options over time*

_ Nahum-Shani, I., Qian, M., Almirall, D., Pelham, W. E., Gnagy, B., Fabiano, G. A., ... & Murphy, S. A. (2012). Experimental design and primary data analysis methods for comparing adaptive interventions. *Psychological methods*, *17*(4), 457.

_ Lei, H., Nahum-Shani, I., Lynch, K., Oslin, D., & Murphy, S. A. (2011). A" SMART" design for building individualized treatment sequences. *Annual review of clinical psychology*, *8*, 21-48.

_Nahum-Shani, I., Ertefaie, A., Lu, X., Lynch, K. G., McKay, J. R., Oslin, D. W., & Almirall, D. (2017). A SMART data analysis method for constructing adaptive treatment strategies for substance use disorders. *Addiction*, *112*(5), 901-909.

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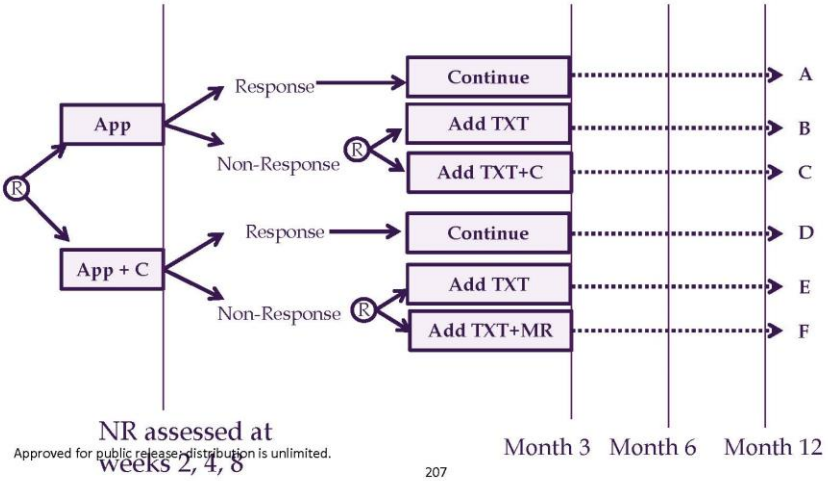
SMART Weight Loss

R01DK108678 (Spring & Nahum-Shani)



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Just-In-Time Adaptive Intervention

Intervention + **Adaptive**

Intervention design;

uses ongoing information about the individual to decide how to modify type/timing/dose of treatment.

The goal:

Address conditions that

- *Change rapidly*
- *Unexpectedly*
- *In the person's natural environment*

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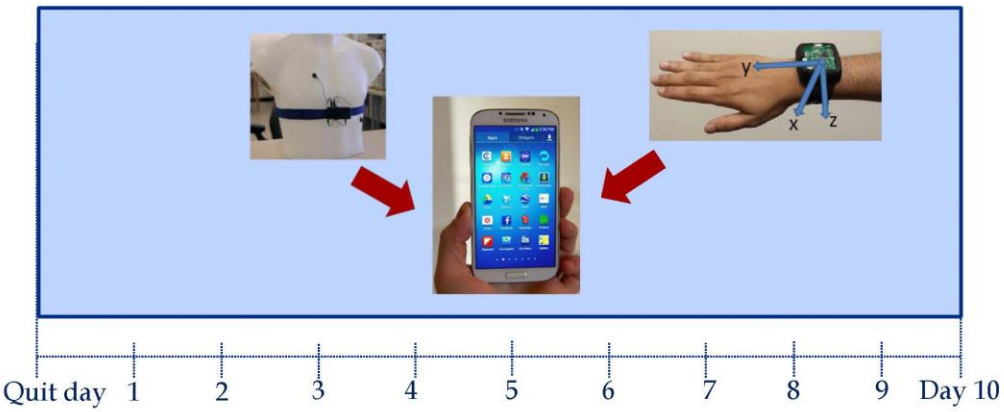
JITAI

- *Example: Sense2Stop*
  - Goal: smoking cessation support



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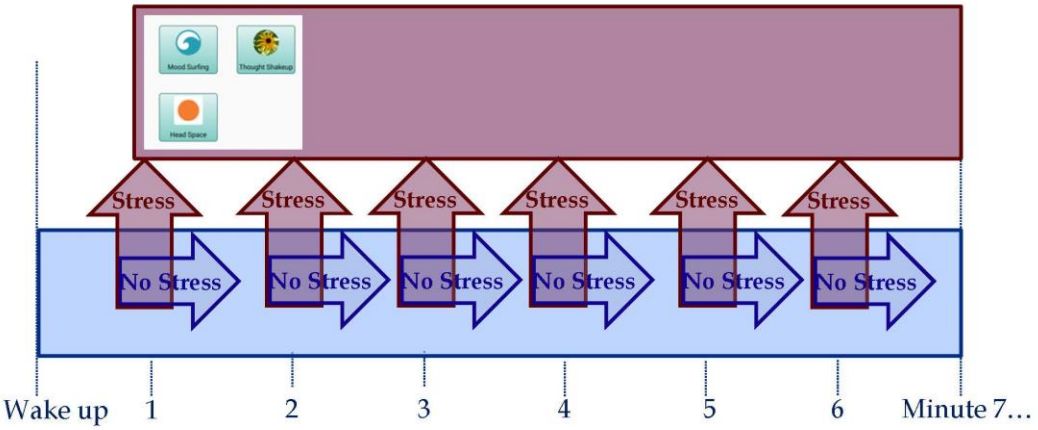
JITAI

- *Example: Sense2Stop*



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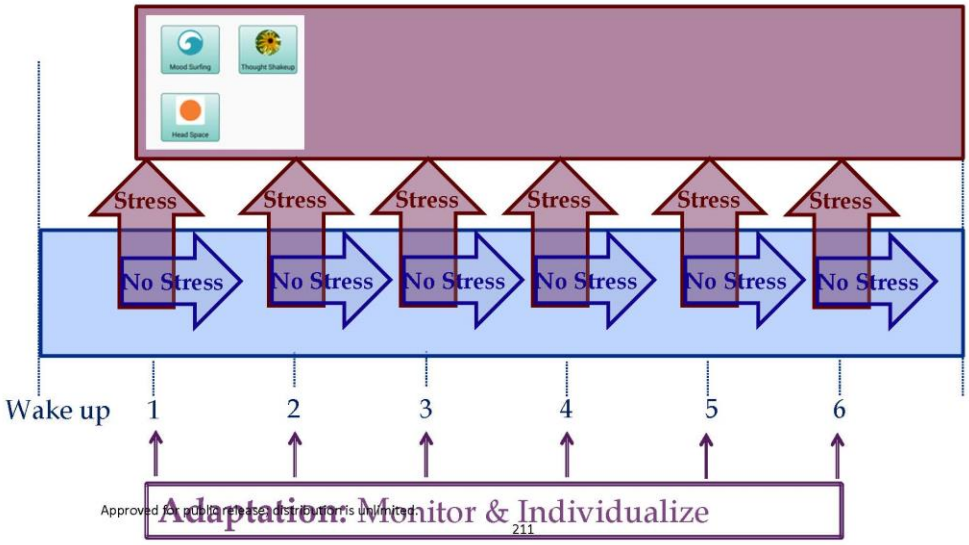
JITAI

- *Example:* *Sense2Stop*



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Motivation for JITAI

Adaptation process → **Just In Time Support**

Address conditions that likely occur

- *Rapidly*
- *Unexpectedly*
- *Vulnerability and/or Opportunity*
- *In the person's natural environment*

Nahum-Shani, I., Smith, S. N., Spring, B. J., … & Murphy, S. A. (2016). Just-in-Time Adaptive Interventions (JITAIs) in Mobile Health: Key Components and Design Principles for Ongoing Health Behavior Support. *Annals of Behavioral Medicine*, 1-17.

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In the Person's Natural Environment

Two implications:

Problem:
Outside of standard treatment settings

Solution:
Capitalize on mobile technology

Problem:
Multiple competing demands

Solution:
Minimize disruptions

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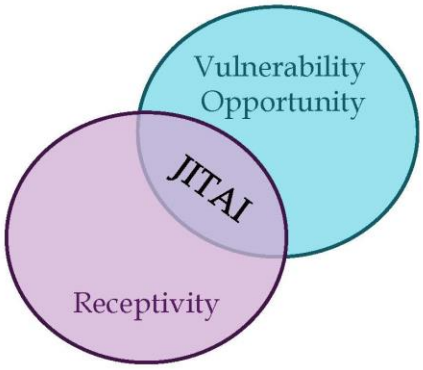
Motivation for JITAI



Nahum-Shani, I., Hekler, E. B., & Spruijt-Metz, D. (2015).
Building health behavior models to guide the development of
just-in-time adaptive interventions: A pragmatic framework. Health Psychology, 34(S), 1209.

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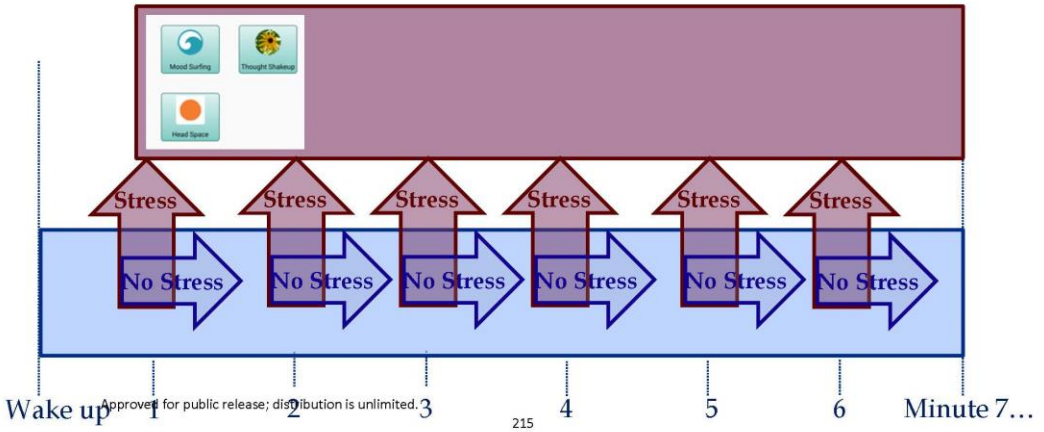
Open Scientific Question

- *Which intervention works best*
- *Under what conditions*
- *To influence the proximal outcome*



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Micro-Randomized Trials

- *Randomize each participant between intervention options at each decision point*
- *Each person may be randomized 100's or 1000's of times and multiple times per day.*
  - *These are sequential, "full factorial," designs.*
  - *Extension of A/B testing & Single Case Designs*

_Walton, A., Nahum-Shani, I., Crosby, L., Klasnja, P., & Murphy, S. (2018). Optimizing Digital Integrated Care via Micro-Randomized Trials. *Clinical Pharmacology & Therapeutics*.
_ Liao, P., Klasnja, P., Tewari, A., and Murphy, S. A. (2016) Sample size calculations for micro-randomized trials in mHealth. Statist. Med., 35: 1944–1971.
_ Dempsey, W., Liao, P., Klasnja, P., Nahum-Shani, I., & Murphy, S. A. (2015). Randomized trials for the Fitbit generation. *Significance*, *12*(6), 20-23.

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Thank you

Bonnie Spring

Susan Murphy

Danny Almirall

Emre Ertin

John Dziak

Santosh Kumar

Dave Wetter

Tim Hant

Mustafa Al'Absi

Moushumi Sharmin

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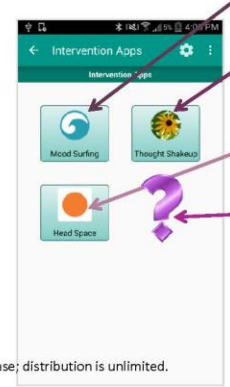
Intervention options

- *Multiple stress management apps*
  - *Evidence-based approaches*
  - *Take about 3-5 min for user to apply*
  - *Feasible to implement in mobile setting*
  - *Developed and refined based on input from experts and users*



Mood Surfing:
- *3 exercises*
- *Grounded in ACT*
- *Target cognitive defusion*
- *Experts: K. Witkiewitz, I. Yovel.*

Thought Shakeup
- *Grounded in CBT*
- *Target cognitive restructuring*
- *Expert: I. Yovel.*

Head Space
- *Grounded in ACT*
- *Mediation / Mindfulness*
- *Consistently rated as one of the best 5 commercial mediation apps*
- *Permission for free use in the trial*

Joy
- *Under development; story board*
- *Grounded in positive psychology*
- *Target relaxation + gratitude*
- *Deep breathing exercise with pictures of things one is grateful for as background.*

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How should theory, data, and methods influence, and be influenced by, research on *Human Agent Teaming* ?

Noshir Contractor

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Supported by following grants:

National Science Foundation: IIS-1514427, CMMI-1436658
Army Research Office: W911NF-14-10686, Army Research Laboratory : W911NF-09-2-0053
Bill & Melinda Gates Foundation: WU-16-197//OPP1135005
NASA: NNX15AM32G, NNX15AM26G, NNX15AK73G, NNX16AQ48G
National Institutes of Health: 5U01GM112623-02, U01DA036939, R01GM112938, 5R01DA042711

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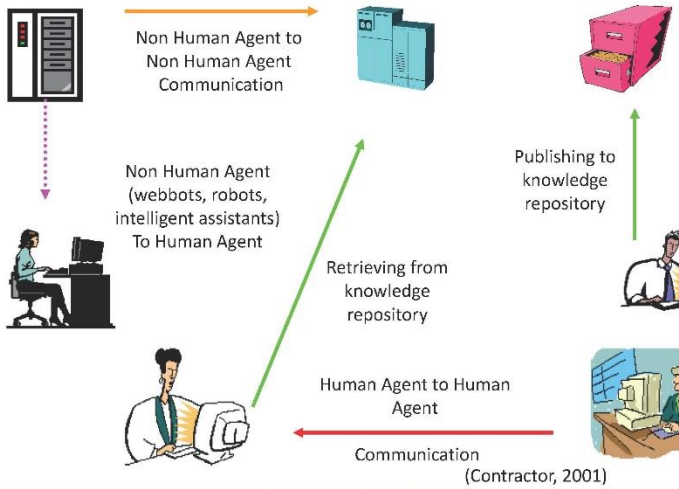
Interaction Networks



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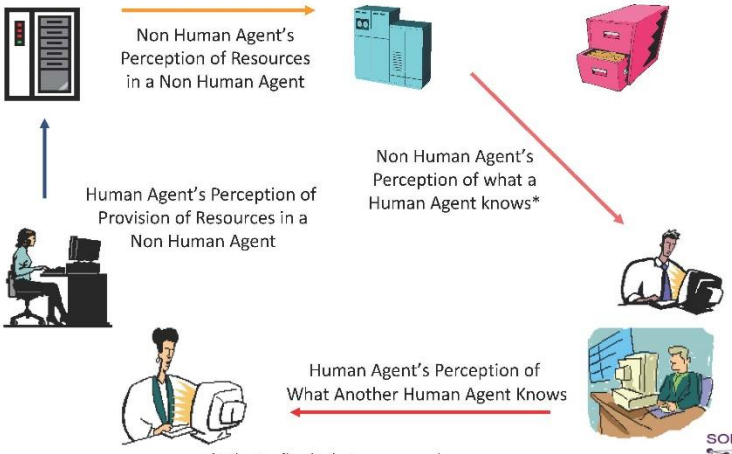
Cognitive Knowledge Networks



Why Netflix thinks I am gay and Amazon thinks I am pregnant .... (Contractor, 2001)

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Theory

- Theories we have not been able to test at scale (e.g. brokerage and mobility)

nature COMMUNICATIONS

ARTICLE

Received 19 Jul 2016 | Accepted 27 Jan 2017 | Published 18 Apr 2017 DOI: 10.1038/ncomms14753 OPEN

Exercise contagion in a global social network

Sinan Aral[1] & Christos Nicolaides[1]

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Theory

- Theories that focus attention on new – or at least increasingly prevalent – phenomena (e.g., collective intelligence, team assembly)

Optimal incentives for collective intelligence

Richard P. Mann[a,1] and Dirk Helbing[b]

[a]Department of Statistics, School of Mathematics, University of Leeds, Leeds LS2 9JT, United Kingdom; and [b]Computational Social Science, Department of Humanities, Social and Political Sciences, Eidgenossische Technische Hochschule (ETH) Zürich, 8092 Zurich, Switzerland

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Theory

- Theories that invite consideration of new combinations of variables

Brain connectivity dynamics during social interaction reflect social network structure

Ralf Schmälzle[a,b], Matthew Brook O'Donnell[b], Javier O. Garcia[c], Christopher N. Cascio[b], Joseph Bayer[d], Danielle S. Bassett[e,f], Jean M. Vettel[c,e,g], and Emily B. Falk[b,1]

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Data: Sources

- Large digital trace data repositories: actions, interactions, and transactions (e.g. in a virtual world)
- Large digital trace data repositories: Enterprise Social Media
- Big (and Broad) data from lab

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Virtual World Exploratorium

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Data: Sources

- Large digital trace data repositories: actions, interactions, and transactions (e.g. in a virtual world)
- Large digital trace data repositories: Enterprise Social Media
- Big (and Broad) data from lab

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Microsoft Teams

LinkedIn

Workplace

jive

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Data: Sources

- Large digital trace data repositories: actions, interactions, and transactions (e.g. in a virtual world)
- Large digital trace data repositories: Enterprise Social Media
- Big (and Broad) data from lab

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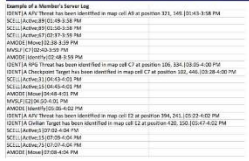
Big Data in the Lab

Self-Report– What people "feel"

Completely Disagree	Disagree	Neutral	Agree	Completely Agree

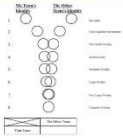
1. I believe that the member(s) of _____ have my best interests in mind.
2. The member(s) of _____ watch my back.
3. I can depend on the member(s) of _____.
4. I usually know how the member(s) of _____ are going to react.
5. The member(s) of _____ know what they are doing.
6. I have faith in the abilities of the member(s) of _____.

Server Log – What people "see" and "do"



Chat Log – What people "say"

Self-Report - What people "think"



Little Teams, Big Data: Big Data Provides New Opportunities for Teams *Theory*

Dorothy R. Carter, Raquel Asencio, Amy Wax, Leslie A. DeChurch and Noshir S. Contractor

Industrial and Organizational Psychology / Volume 8 / Issue 04 / December 2015, pp 550 - 555
DOI: 10.1017/iop.2015.82, Published online: 17 December 2015

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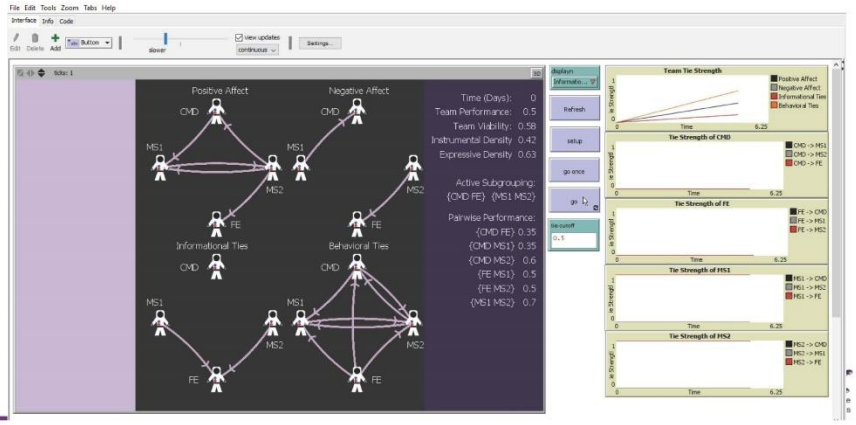
Methods

- Computational Modeling: Computer assisted theory building using empirical data (Behavior Search) to estimate computational model parameters.

Modeling positive and negative affect ties among crew members in NASA's Human Exploration Research Analog (HERA) at the Johnson Space Center, Houston TX



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Methods

- Combining theory-driven and data-driven: Data/text mining – from "Dustbowl empiricism" to the "Superbowl of novel insights"

Machine Translation: Mining Text for Social Theory

James A. Evans and Pedro Aceves

Department of Sociology, University of Chicago, Chicago, Illinois 60637; email: jevans@uchicago.edu

Evans, J. A., & Aceves, P. (2016). Machine Translation: Mining Text for Social Theory. Annual Review of Sociology, 42(1), 21–50. http://doi.org/10.1146/annurev-soc-081715-074206

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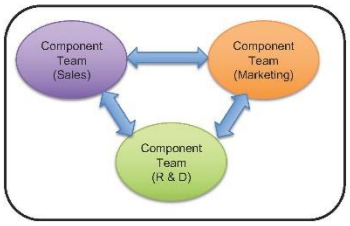
Structural signatures to understand Performance of Teams & Multiteam Systems

- Multiteam systems (MTS) are organizational forms that include several traditional teams in an interdependent system (Mathieu, Marks, & Zaccaro, 2001)
- Each team has at least one local goal, while all teams share at least one superordinate goal
- Between-team processes are crucial to MTS performance (Davison et al., 2012; Marks et al, 2005; Lanaj et al., 2013)



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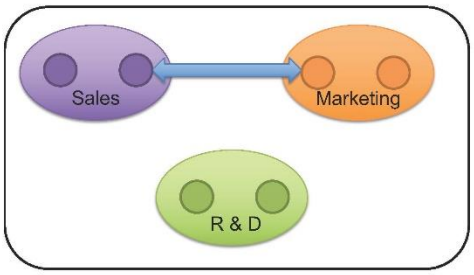
Team Boundary Behavior



Team boundary spanning *is defined as the team's actions to establish linkages and manage interactions with parties in the external environment*

(Ancona, 1990; Ancona & Caldwell, 1992; Marrone et al., 2007; Marrone, 2010).

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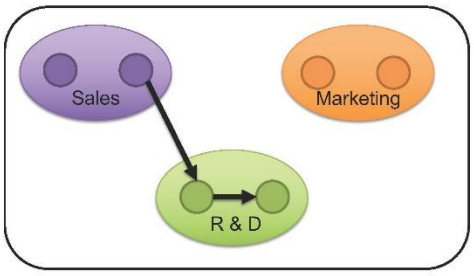
Illustrating External Activity



Filtering: Taking information from outsiders and delivering a smaller amount to the group

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Team Boundary Propensity

- ***Boundary Propensities*** *are the tendencies for team members to engage in boundary behavior*
- *Boundary propensities incorporate timing and sequencing*

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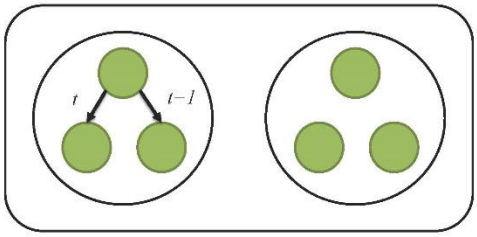
Inward Propensity

Inward Propensity: The tendency for team members to interact.



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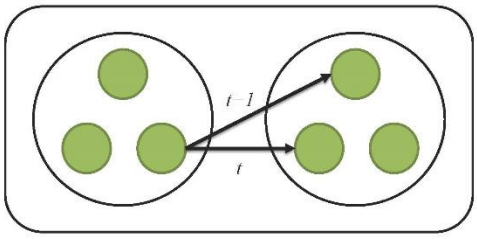
Outward Propensity

Outward Propensity: The tendency for team members to interact with those outside the team (e.g. scanning or scouting).



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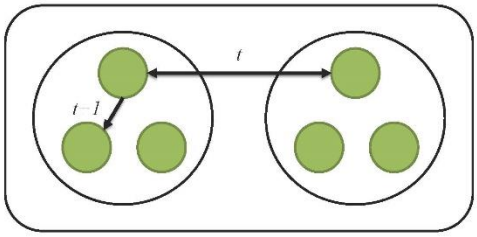
Absorptive Propensity

Absorptive Propensity: The tendency for a team's external interactions to prompt internal interactions (e.g. modeling or filtering).



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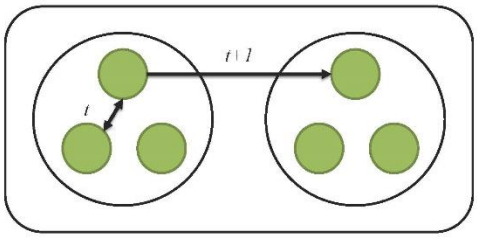
Disseminative Propensity

Disseminative Propensity: The tendency for a team's internal interactions to prompt external interactions (e.g. gathering information or coordinating & negotiating).



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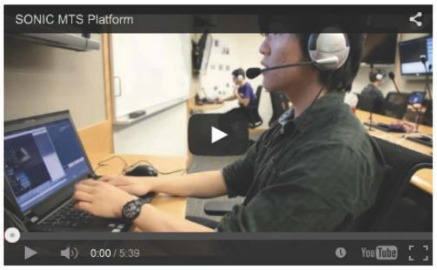
Method: Participants & Task

Sample:
37 MTSs

Each MTS:
20 people – 4 teams of 5
740 participants

Task:
Lead a humanitarian convoy through a hostile region



https://www.youtube.com/watch?feature=player_embedded&v=7bAo5-U__Xw

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Method:

Eliciting Communication to Determine Boundary Propensities

Data are directed communication ties when one member contacts another on Skype

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Summary of Findings

	Impact on the Team	Impact on the MTS
Inward Propensity	H1: Positive	H2: Negative
Outward Propensity	H3: Not Significant	H4: Positive
Absorptive Propensity	H5: Positive	H6: Negative
Disseminative Propensity	H7: Positive	H8: Positive

Acknowledgements

National Science Foundation WHERE DISCOVERIES BEGIN
NATIONAL INSTITUTES OF HEALTH
NETWORK SCIENCE CTA ARL
NASA
BILL & MELINDA GATES foundation

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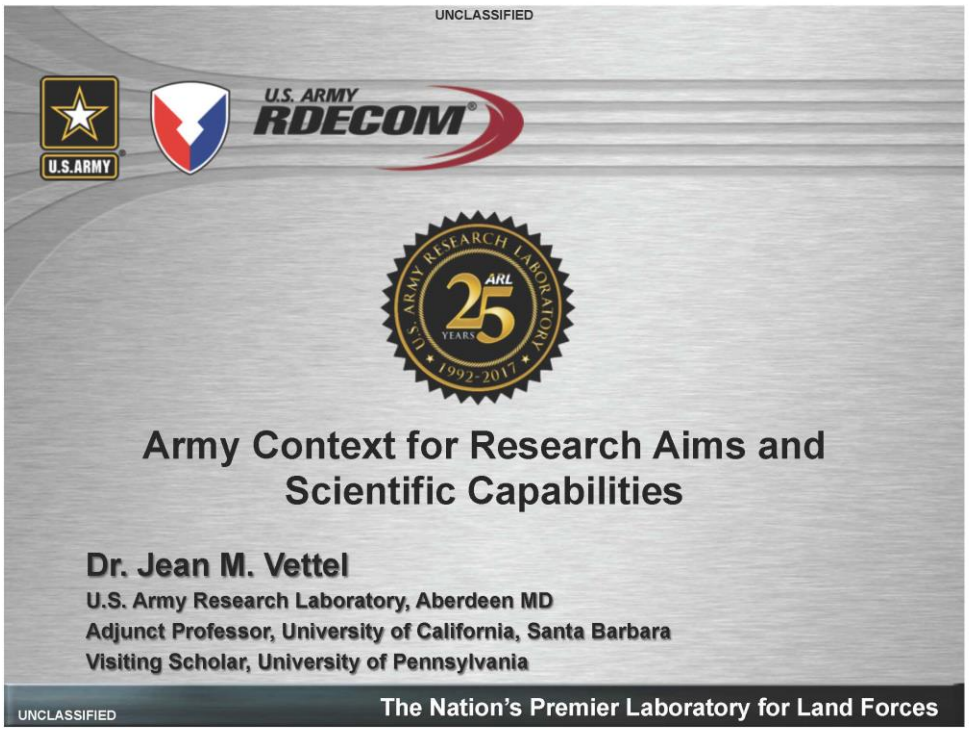
Appendix F. Day 2: Army Context for Research Aims and Scientific Capabilities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U.S. ARMY RESEARCH LABORATORY
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25
YEARS
1992-2017
Army Context for Research Aims and Scientific Capabilities
Dr. Jean M. Vettel
U.S. Army Research Laboratory, Aberdeen MD
Adjunct Professor, University of California, Santa Barbara
Visiting Scholar, University of Pennsylvania
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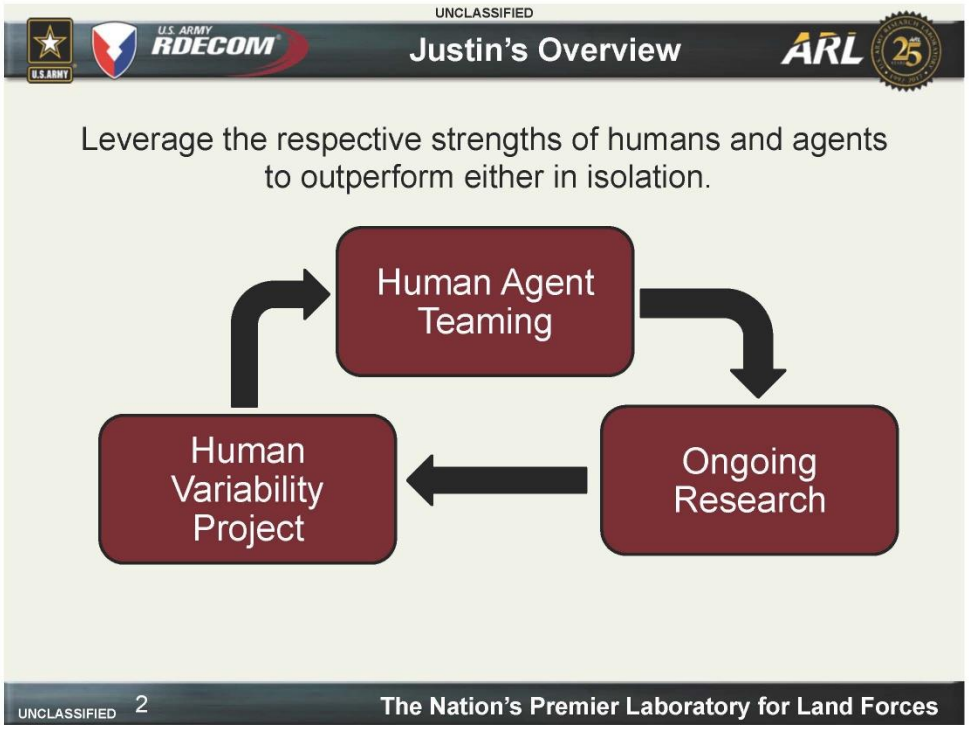
The Nation's Premier Laboratory for Land Forces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Justin's Overview
ARL
25
Leverage the respective strengths of humans and agents to outperform either in isolation.
Human Agent Teaming
Ongoing Research
Human Variability Project
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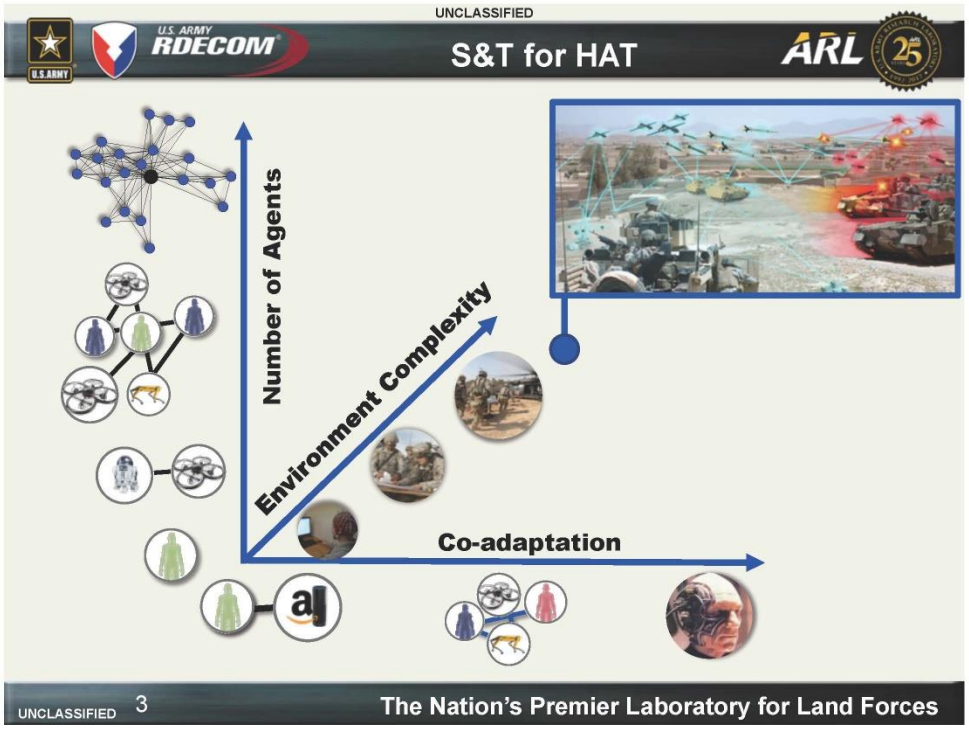
The Nation's Premier Laboratory for Land Forces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Number of Agents
Environment Complexity
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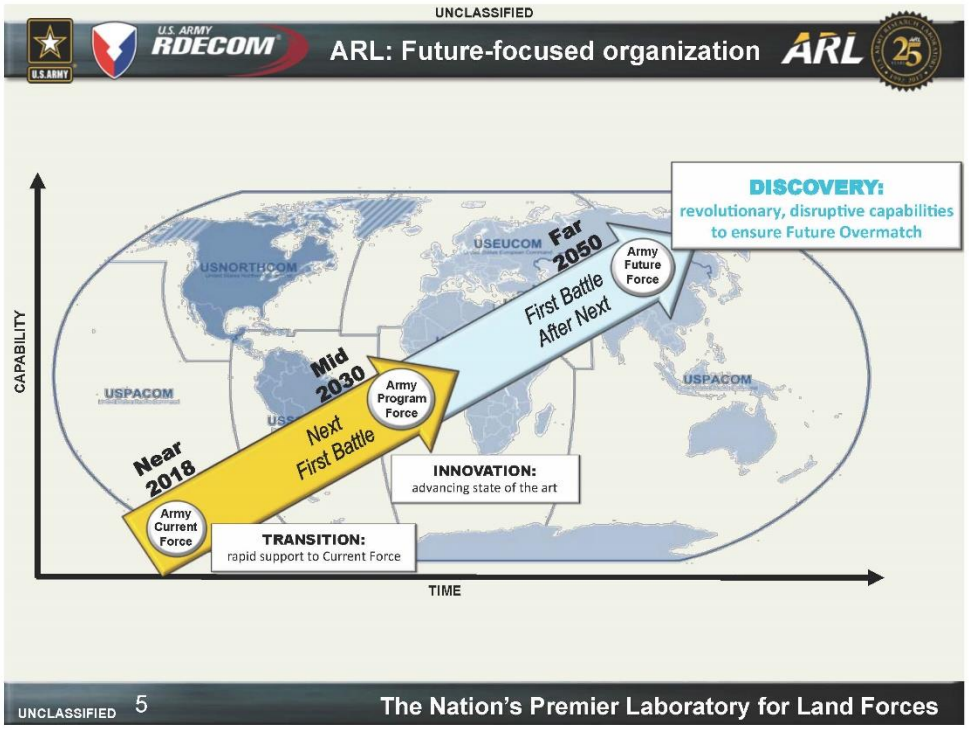
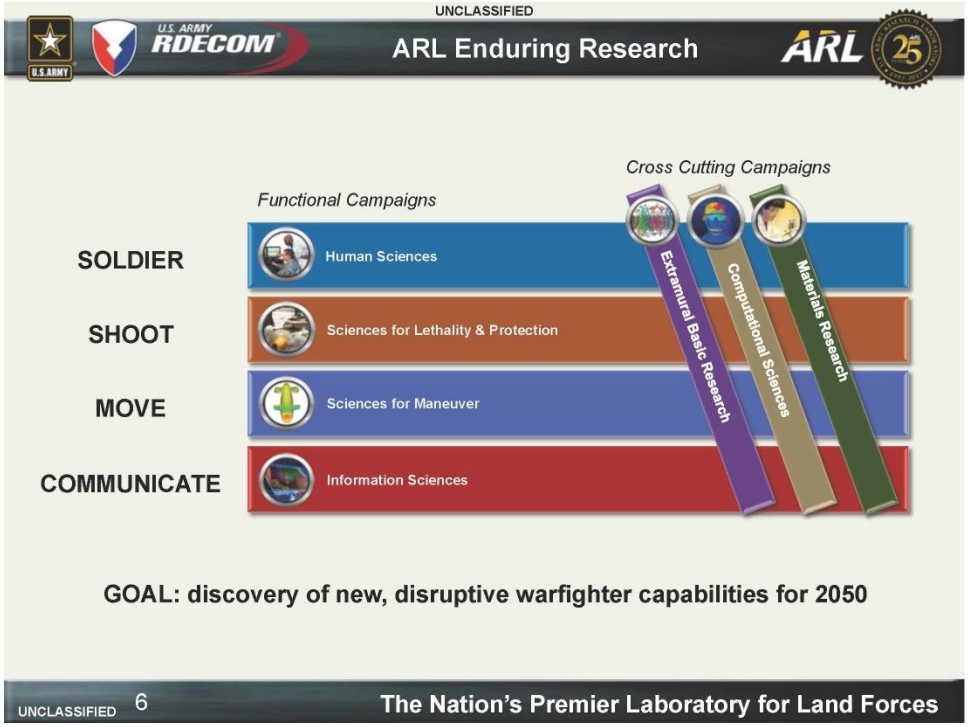
Essential Research Programs
ARL
Human-Agent Teaming
Cyber & EM Technologies for Complex Environments
Distributed / Cooperative Engagement in Contested Environments
Artificial Intelligence/ Machine Learning
Manipulate Failure Physics for Robust Materials
Tactical Unit Energy Independence
Manufacturing at the Point of Need
Accelerated Learning for a Ready Force
Discovery
UNCLASSIFIED 4
The Nation's Premier Laboratory for Land Forces





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Predictions of Futuristic Ops

UNCLASSIFIED

Three Contexts

- What is ARL's core identity? Examples of success from ARL HQ?
- How are ARL science aims influenced by "Modernization"?
- What inspires Army-relevant research?

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U.S. ARMY RDECOM The Army's Corporate Research Lab ARL 25

Operationalizing S&T for the Army

- ARL conducts foundational threat-based research to avoid technological surprise
- Provide Army Leadership with knowledge and understanding to inform decisions on options for disruptive warfighting capabilities with reduced uncertainty and calculated risk
- Align and synchronize research to address CSA's Modernization Priorities (capability gaps).

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U.S. ARMY RDECOM The Army's Corporate Research Lab ARL 25

ARL executes our mission by:

- Having world-leading in-house researchers in Army-unique areas (e.g., armor, EW, munitions, soldier power)
- Converging intellectual capital of research universities and industry towards Army needs

Discovery: Laser

Discovered with academic and industrial partners

Innovation: Precision fires using GPS

Integration of GPS and munitions

Transition: Improved Helmet

Manufacturing technology for ACH and ECH

Quick reaction: Up Armor

Armor Survivability Kits for OEF/OIF

Future: Quantum Networking

Completely secure communications

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New Energy Source

ARL

Army scientists and engineers found that a nano-galvanic aluminum-based powder they developed produces hydrogen when added to water or any liquid containing water.

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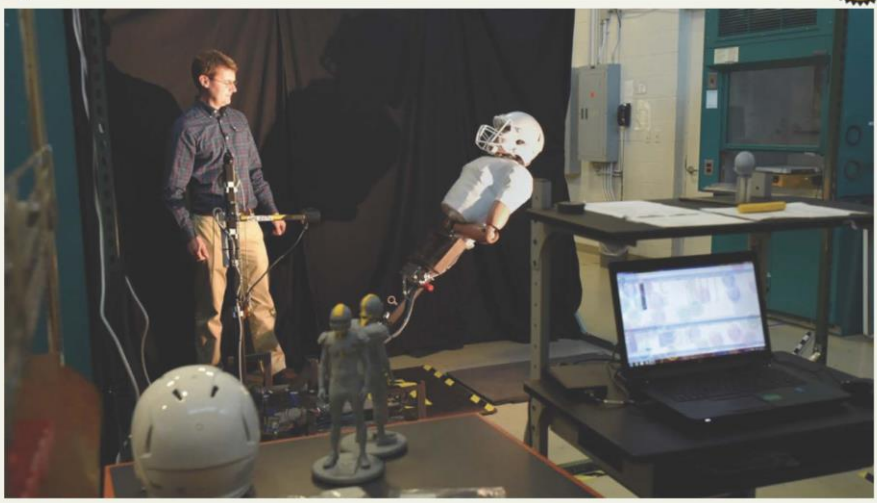
U.S. ARMY RDECOM

NFL Tether

ARL



The straps the Army lab developed are stretchy tubes containing an engineered liquid that changes consistency when stress is applied. "If you pull it slowly, it stretches and relaxes slowly," said Eric Wetzel, one of the lab's research scientists. "If you try to pull it quickly, it takes 100x more force."

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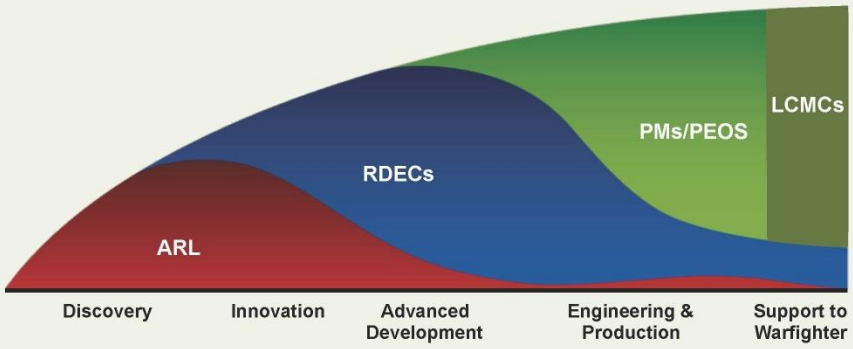
Challenge: Getting S&T to Soldier

Challenge: Getting S&T to Soldier



ARL depiction… but S&T more generally…

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Three Contexts

- What is ARL's core identity? Examples of success from ARL HQ?
- **How are ARL science aims influenced by "Modernization"?**
- What inspires Army-relevant research?

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Army Modernization

ACQUISITION, BUDGET, LAND, STRATEGY & POLICY

Army Shifts $1B In S&T, Plans Modernization Command: UnderSec McCarthy

By SYDNEY J. FREEDBERG JR.
on December 07, 2017 at 11:38 AM
8 comments

30 SHARES

Ryan McCarthy

PENTAGON: Merry Christmas, US Army. As you read this, the White House Office of Management and Budget is reviewing the service's draft spending plan for 2019-2023, which reshuffles more than a billion dollars in science and technology funds, undersecretary of the Army Ryan McCarthy told me in an exclusive interview. The goal: to better resource the Big Six modernization priorities he and Chief of Staff Mark Milley announced in October.

"I personally led those meetings. We had all the Army staff components, secretariat, all the directors of the labs, PEOs (Program Executive Officers), they all came in and we did a realignment of the entire S&T portfolio," McCarthy told me. "I picked this project over that project....winners and losers."

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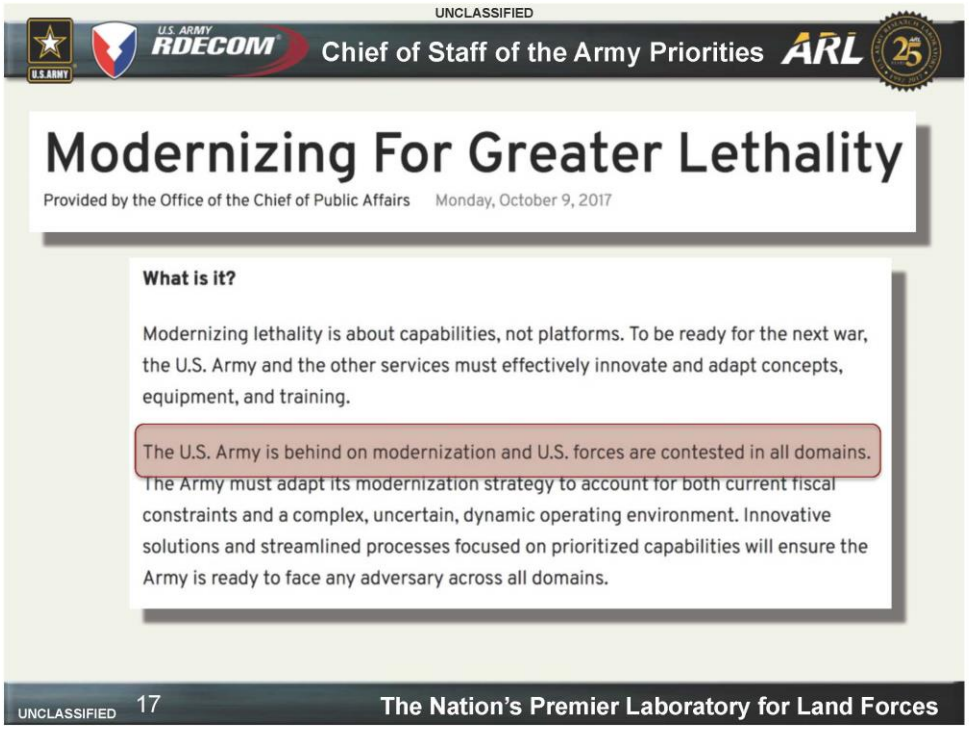
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U.S. ARMY RDECOM
Chief of Staff of the Army Priorities
ARL
Modernizing For Greater Lethality
Provided by the Office of the Chief of Public Affairs Monday, October 9, 2017
What is it?
Modernizing lethality is about capabilities, not platforms. To be ready for the next war, the U.S. Army and the other services must effectively innovate and adapt concepts, equipment, and training.
The U.S. Army is behind on modernization and U.S. forces are contested in all domains. The Army must adapt its modernization strategy to account for both current fiscal constraints and a complex, uncertain, dynamic operating environment. Innovative solutions and streamlined processes focused on prioritized capabilities will ensure the Army is ready to face any adversary across all domains.
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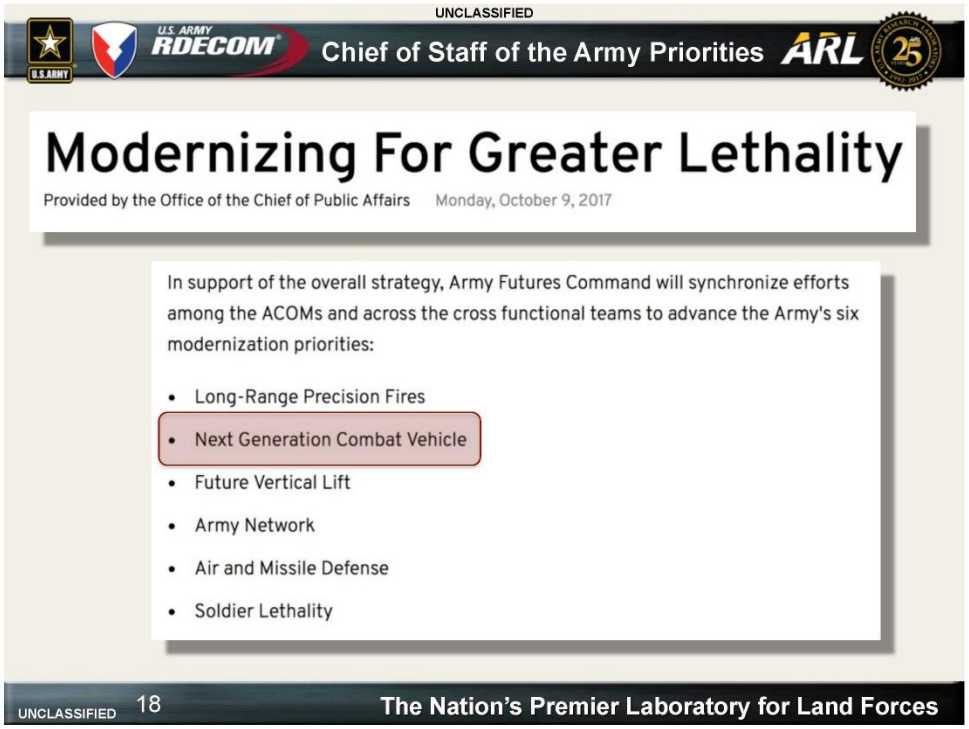
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U.S. ARMY RDECOM
Chief of Staff of the Army Priorities
ARL
Modernizing For Greater Lethality
Provided by the Office of the Chief of Public Affairs Monday, October 9, 2017
In support of the overall strategy, Army Futures Command will synchronize efforts among the ACOMs and across the cross functional teams to advance the Army's six modernization priorities:
• Long-Range Precision Fires
• Next Generation Combat Vehicle
• Future Vertical Lift
• Army Network
• Air and Missile Defense
• Soldier Lethality
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U.S. ARMY RDECOM
Essential Research Programs
ARL
Aligned to the Army's Modernizations Priorities
Human-Agent Teaming
2. Next Gen Combat Vehicle
Cyber & EM Technologies for Complex Environments
4. Network/C3I
Distributed / Cooperative Engagement in Contested Environments
1. Long Range Precision Fires
Artificial Intelligence/ Machine Learning
2. Next Gen Combat Vehicle
Manipulate Failure Physics for Robust Materials
6. Soldier Lethality
Tactical Unit Energy Independence
2. Next Gen Combat Vehicle
3. Future Vertical Lift
Manufacturing at the Point of Need
2. Next Gen Combat Vehicle
Accelerated Learning for a Ready Force
6. Soldier Lethality
Discovery
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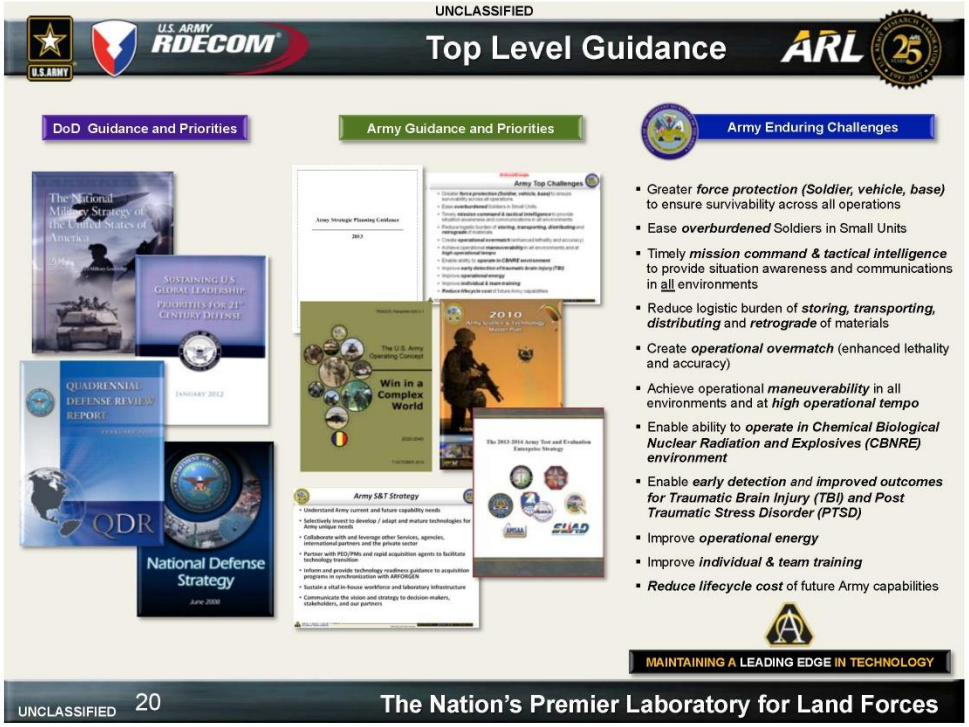
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U.S. ARMY RDECOM
Top Level Guidance
ARL
DoD Guidance and Priorities
Army Guidance and Priorities
Army Enduring Challenges
The National Military Strategy of the United States of America
Sustaining U.S. Global Leadership: Priorities for 21st Century Defense
Quadrennial Defense Review Report
QDR
National Defense Strategy
Army Strategic Planning Guidance
Army Top Challenges
The U.S. Army Operating Concept
Win in a Complex World
2010
Army S&T Strategy
ESLAD
Greater force protection (Soldier, vehicle, base) to ensure survivability across all operations
Ease overburdened Soldiers in Small Units
Timely mission command & tactical intelligence to provide situation awareness and communications in all environments
Reduce logistic burden of storing, transporting, distributing and retrograde of materials
Create operational overmatch (enhanced lethality and accuracy)
Achieve operational maneuverability in all environments and at high operational tempo
Enable ability to operate in Chemical Biological Nuclear Radiation and Explosives (CBNRE) environment
Enable early detection and improved outcomes for Traumatic Brain Injury (TBI) and Post Traumatic Stress Disorder (PTSD)
Improve operational energy
Improve individual & team training
Reduce lifecycle cost of future Army capabilities
MAINTAINING A LEADING EDGE IN TECHNOLOGY
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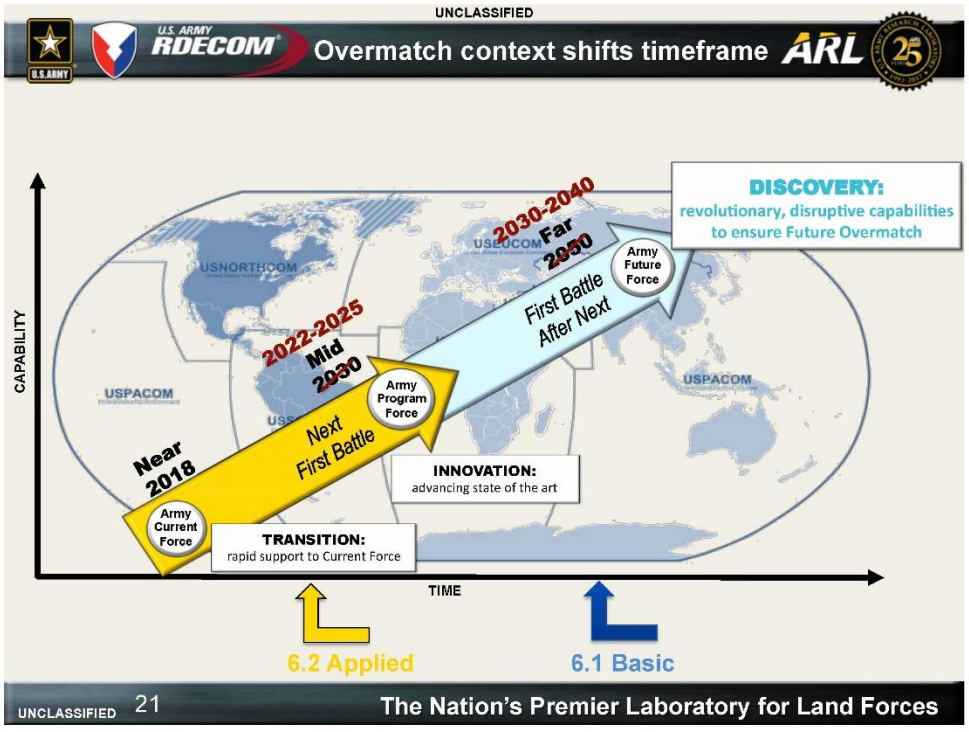
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U.S. ARMY RDECOM
Overmatch context shifts timeframe
ARL
DISCOVERY:
revolutionary, disruptive capabilities
to ensure Future Overmatch
2030-2040
Far
2050
Army
Future
Force
First Battle
After Next
2022-2025
Mid
2030
Army
Program
Force
Next
First Battle
Near
2018
Army
Current
Force
INNOVATION:
advancing state of the art
TRANSITION:
rapid support to Current Force
CAPABILITY
TIME
USNORTHCOM
USPACOM
6.2 Applied
6.1 Basic
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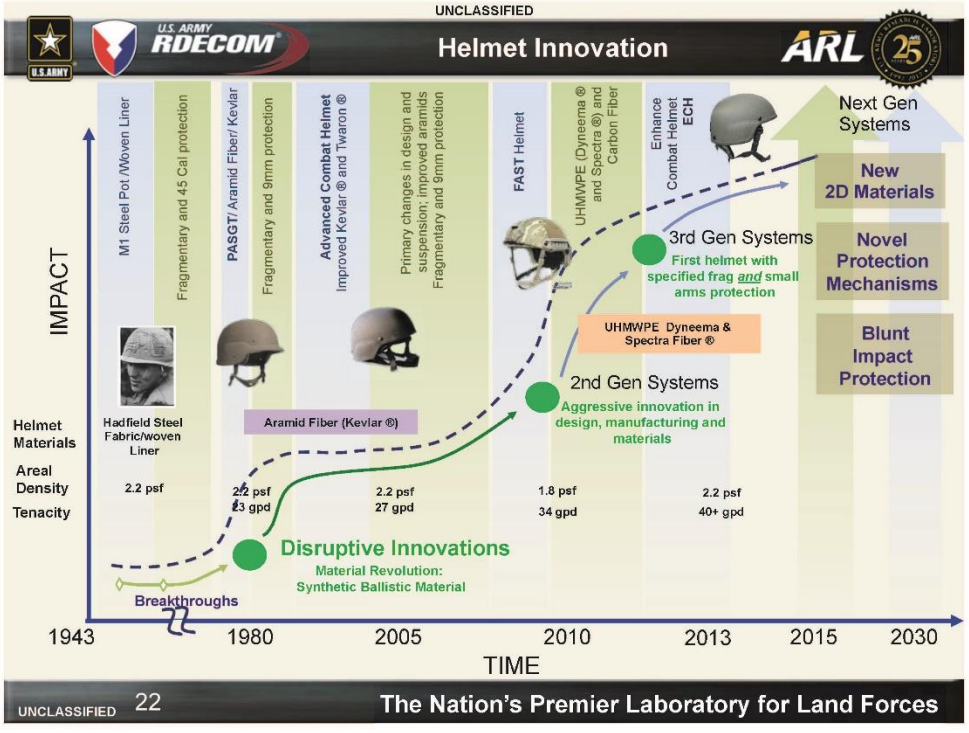
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Helmet Innovation
ARL
M1 Steel Pot /Woven Liner
Fragmentary and 45 Cal protection
PASGT/ Aramid Fiber/ Kevlar
Fragmentary and 9mm protection
Advanced Combat Helmet
Improved Kevlar ® and Twaron ®
Primary changes in design and suspension; improved aramids
Fragmentary and 9mm protection
FAST Helmet
UHMWPE (Dyneema ® and Spectra ®) and Carbon Fiber
Enhance Combat Helmet ECH
Next Gen Systems
New 2D Materials
Novel Protection Mechanisms
Blunt Impact Protection
3rd Gen Systems
First helmet with specified frag and small arms protection
UHMWPE Dyneema & Spectra Fiber ®
2nd Gen Systems
Aggressive innovation in design, manufacturing and materials
Aramid Fiber (Kevlar ®)
Disruptive Innovations
Material Revolution:
Synthetic Ballistic Material
Breakthroughs
IMPACT
Helmet Materials
Areal Density
Tenacity
Hadfield Steel Fabric/woven Liner
2.2 psf
2.2 psf
23 gpd
2.2 psf
27 gpd
1.8 psf
34 gpd
2.2 psf
40+ gpd
1943
1980
2005
2010
2013
2015
2030
TIME
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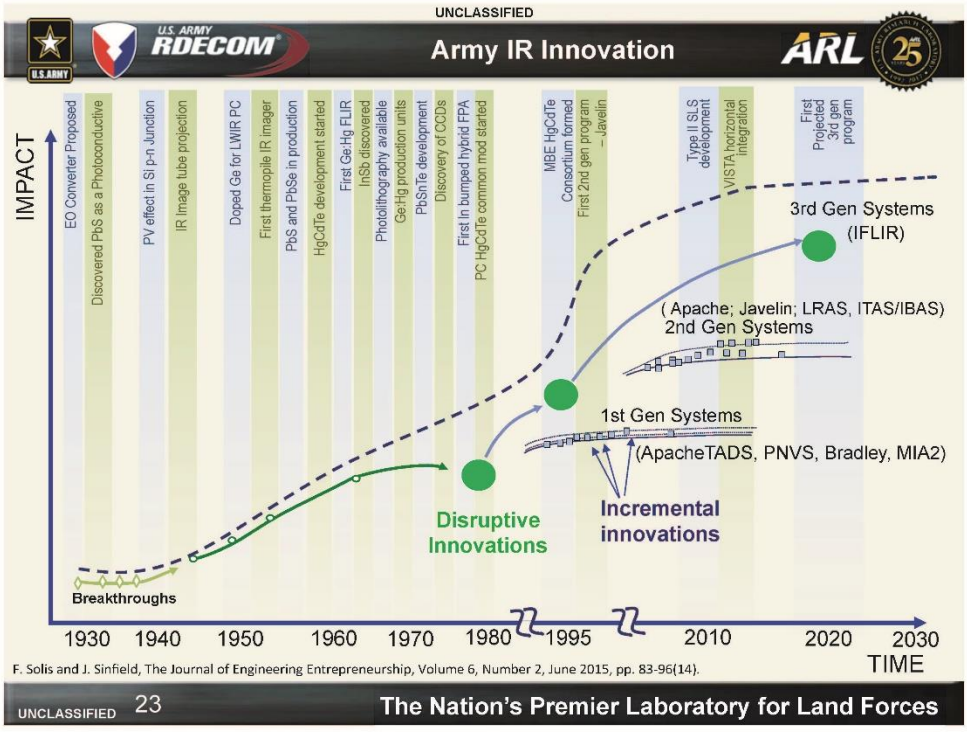
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U.S. ARMY RDECOM
Army IR Innovation
ARL
IMPACT
EO Converter Proposed
Discovered PbS as a Photoconductive
PV effect in Si p-n Junction
IR Image tube projection
Doped Ge for LWIR PC
First thermopile IR imager
PbS and PbSe in production
HgCdTe development started
First Ge:Hg FLIR
InSb discovered
Photolithography available
Ge:Hg production units
PbSnTe development
Discovery of CCDs
First In bumped hybrid FPA
PC HgCdTe common mod started
MBE HgCdTe Consortium formed
First 2nd gen program – Javelin
Type II SLS development
VISTA horizontal integration
First Projected 3rd gen program
3rd Gen Systems (IFLIR)
(Apache; Javelin; LRAS, ITAS/IBAS) 2nd Gen Systems
1st Gen Systems
(ApacheTADS, PNVS, Bradley, MIA2)
Disruptive Innovations
Incremental innovations
Breakthroughs
1930 1940 1950 1960 1970 1980 1995 2010 2020 2030
TIME
F. Solis and J. Sinfield, The Journal of Engineering Entrepreneurship, Volume 6, Number 2, June 2015, pp. 83-96(14).
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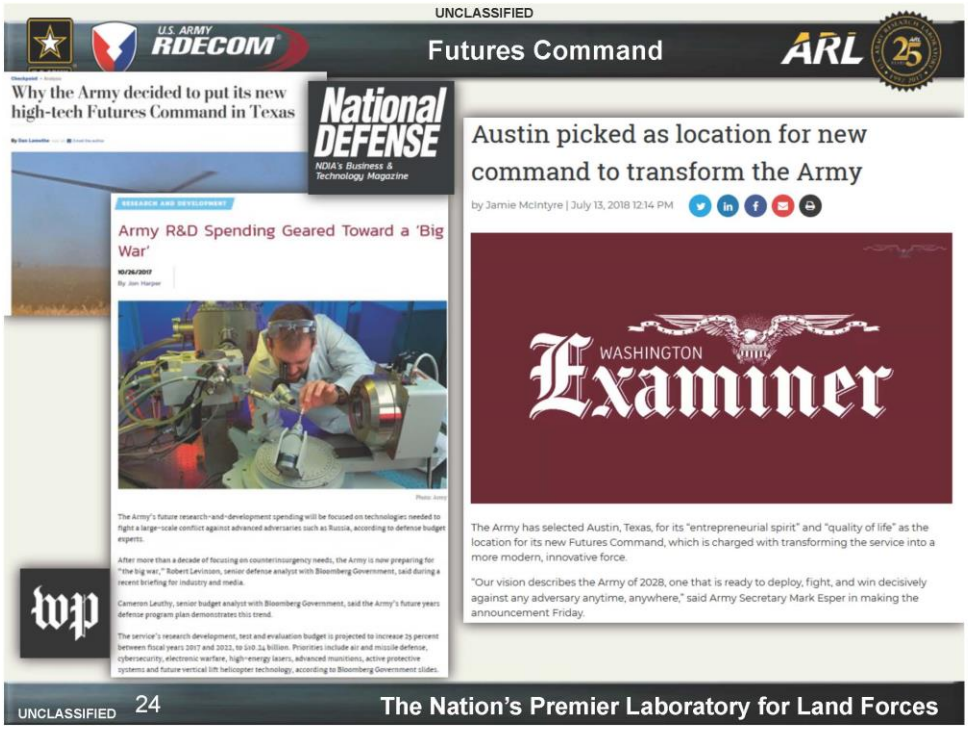
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U.S. ARMY RDECOM
Futures Command
ARL
Why the Army decided to put its new high-tech Futures Command in Texas
National DEFENSE
NDIA's Business & Technology Magazine
Army R&D Spending Geared Toward a 'Big War'
Austin picked as location for new command to transform the Army
by Jamie McIntyre | July 13, 2018 12:14 PM
WASHINGTON Examiner
The Army has selected Austin, Texas, for its "entrepreneurial spirit" and "quality of life" as the location for its new Futures Command, which is charged with transforming the service into a more modern, innovative force.
"Our vision describes the Army of 2028, one that is ready to deploy, fight, and win decisively against any adversary anytime, anywhere," said Army Secretary Mark Esper in making the announcement Friday.
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U.S. ARMY RDECOM The Army's Corporate Research Lab ARL 25

ARL executes the mission by:

- Having world-leading in-house researchers in Army-unique areas (e.g., armor, EW, munitions, soldier power)
- Converging intellectual capital of research universities and industry towards Army needs

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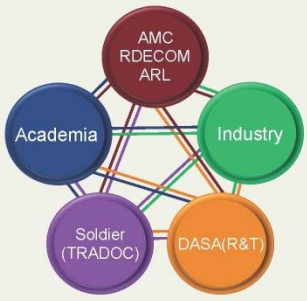
U.S. ARMY RDECOM Open Campus Initiative ARL 25



Collaborations focused on Army-specific challenges of mutual importance to all partners

Partners from Army, Industry and Academia engage in research with shared access to people, infrastructure and resources

Expanded S&T Research Ecosystem

ARL Open Campus is "a role model to the broader defense research enterprise"
- Defense Science Board (DSB) Task Force on Defense Research Enterprise Assessment, January 2017

Army Benefits as of March 2018:

$39M in-kind research

$83M in-kind research since Open Campus start

140 Active CRADAs

61 CRADAs with Academia

79 CRADAs with Industry

353 CRADA projects

147 CRADA projects in Negotiation

700 visiting researchers

80 visiting researchers from

22 different nations

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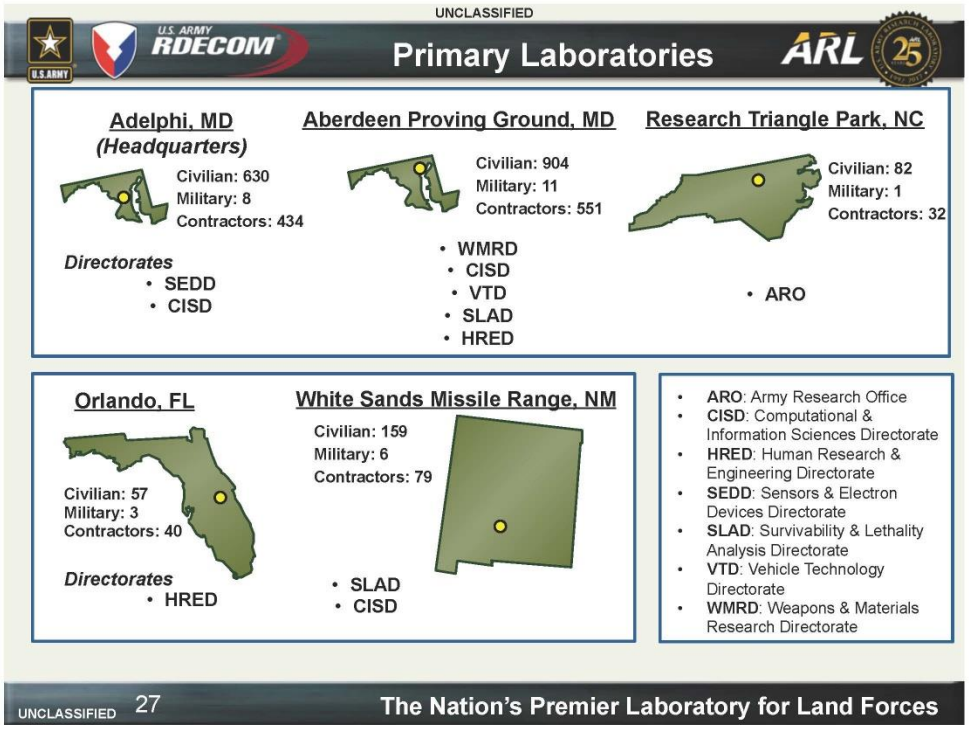
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U.S. ARMY RDECOM
Primary Laboratories
ARL
Adelphi, MD
(Headquarters)
Civilian: 630
Military: 8
Contractors: 434
Directorates
• SEDD
• CISD
Aberdeen Proving Ground, MD
Civilian: 904
Military: 11
Contractors: 551
• WMRD
• CISD
• VTD
• SLAD
• HRED
Research Triangle Park, NC
Civilian: 82
Military: 1
Contractors: 32
• ARO
Orlando, FL
Civilian: 57
Military: 3
Contractors: 40
Directorates
• HRED
White Sands Missile Range, NM
Civilian: 159
Military: 6
Contractors: 79
• SLAD
• CISD
• ARO: Army Research Office
• CISD: Computational & Information Sciences Directorate
• HRED: Human Research & Engineering Directorate
• SEDD: Sensors & Electron Devices Directorate
• SLAD: Survivability & Lethality Analysis Directorate
• VTD: Vehicle Technology Directorate
• WMRD: Weapons & Materials Research Directorate
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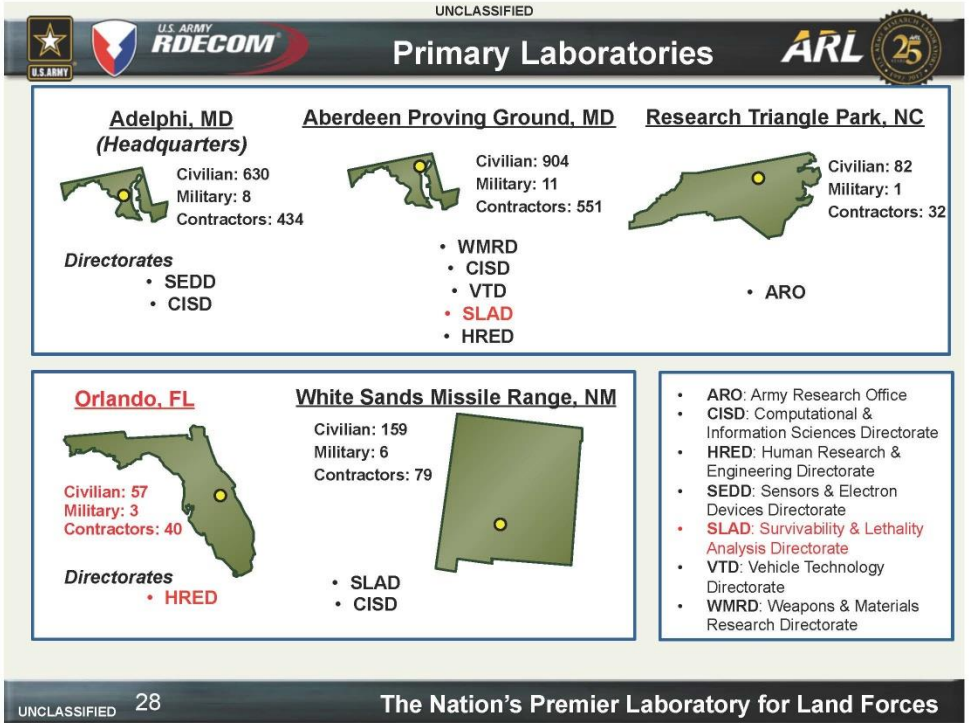
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• VTD: Vehicle Technology Directorate
• WMRD: Weapons & Materials Research Directorate
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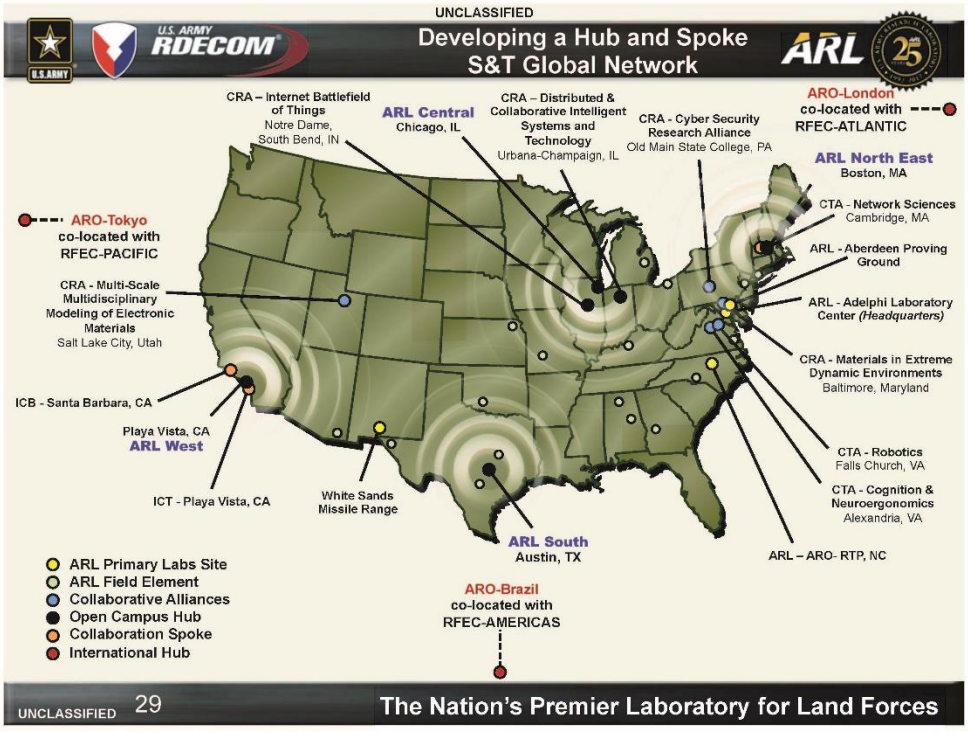
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Developing a Hub and Spoke S&T Global Network
ARL
CRA – Internet Battlefield of Things
Notre Dame, South Bend, IN
ARL Central
Chicago, IL
CRA – Distributed & Collaborative Intelligent Systems and Technology
Urbana-Champaign, IL
CRA - Cyber Security Research Alliance
Old Main State College, PA
ARO-London co-located with RFEC-ATLANTIC
ARL North East
Boston, MA
CTA - Network Sciences
Cambridge, MA
ARL - Aberdeen Proving Ground
ARL - Adelphi Laboratory Center (Headquarters)
CRA - Materials in Extreme Dynamic Environments
Baltimore, Maryland
CTA - Robotics
Falls Church, VA
CTA - Cognition & Neuroergonomics
Alexandria, VA
ARL – ARO- RTP, NC
ARO-Tokyo co-located with RFEC-PACIFIC
CRA - Multi-Scale Multidisciplinary Modeling of Electronic Materials
Salt Lake City, Utah
ICB - Santa Barbara, CA
Playa Vista, CA
ARL West
ICT - Playa Vista, CA
White Sands Missile Range
ARL South
Austin, TX
ARO-Brazil co-located with RFEC-AMERICAS
ARL Primary Labs Site
ARL Field Element
Collaborative Alliances
Open Campus Hub
Collaboration Spoke
International Hub
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U.S. ARMY RDECOM
ARL Leadership
ARL
Director
Dr. Philip Perconti
Director Plans & Programs
Mr. Todd Rosenberger
Director Laboratory Operations
Ms. Teresa Kines
Associate Director Executive Staff
Ms. Kelly Foster
Chief Scientist
Dr. Alexander Kott
Associate Director Strategy Management
Mr. Karl Kappra
Military Deputy
COL Kevin Ellison
Sergeant Major
Keith Taylor
Army Research Office
Dr. David Stepp (A)
Computational & Information Sciences
Ms. Cynthia Bedell
Human Research & Engineering
Dr. Corde Lane (A)
Sensors & Electron Devices
Dr. Keith Krapels
Vehicle Technology
Dr. Jaret Riddick
Weapons & Materials Research
Dr. Jeffrey Zabinski
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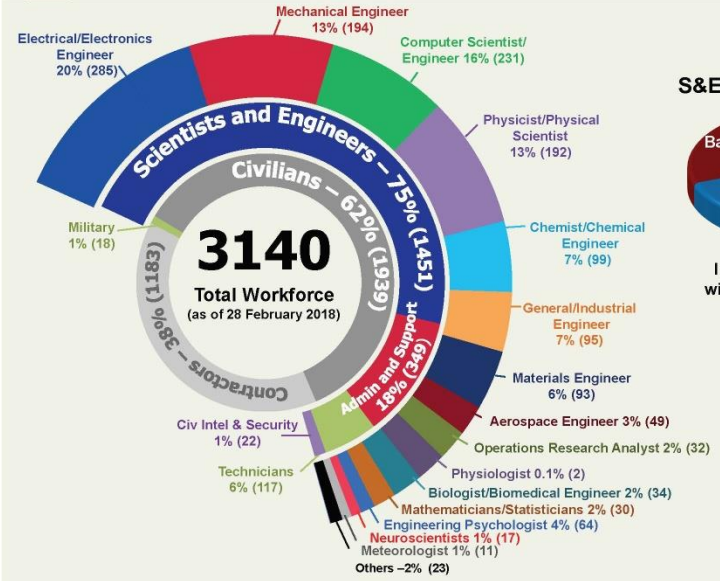
Talented Workforce



S&E Degree Distribution

Increased civilian S&Es with PhDs from 434 to 675 (FY06- FY18-2nd Qtr)

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Knowledge Products (2016-2017)

1569 peer-review journals and 3,336 Citations

91 Patents (FY16 - FY17)

Organization Awards

2016 invention of the year award by University of Maryland for Dr. Xu, Wang, Suo, Borodin, von Cresce

NFL, Under Armour and GE's Head Health Challenge Winner

Joint Army-DCS Team Wins International Machine Learning Research Competition
10 OSD Laboratory University Collaboration Initiative (LUCI) program winners (FY16 and FY17)

Excellence in Fed. Career Awards (FY16) 17, (FY17) 26

ASM Silver Medal: Excellence in Research (FY16)

OSD Laboratory Scientist of the Quarter (2nd and 4th quarters, FY17)

European Physics Letters Editor's Choice Award (FY16)

Ralph P.I. Adler Award for Lifetime Achievement (FY16)

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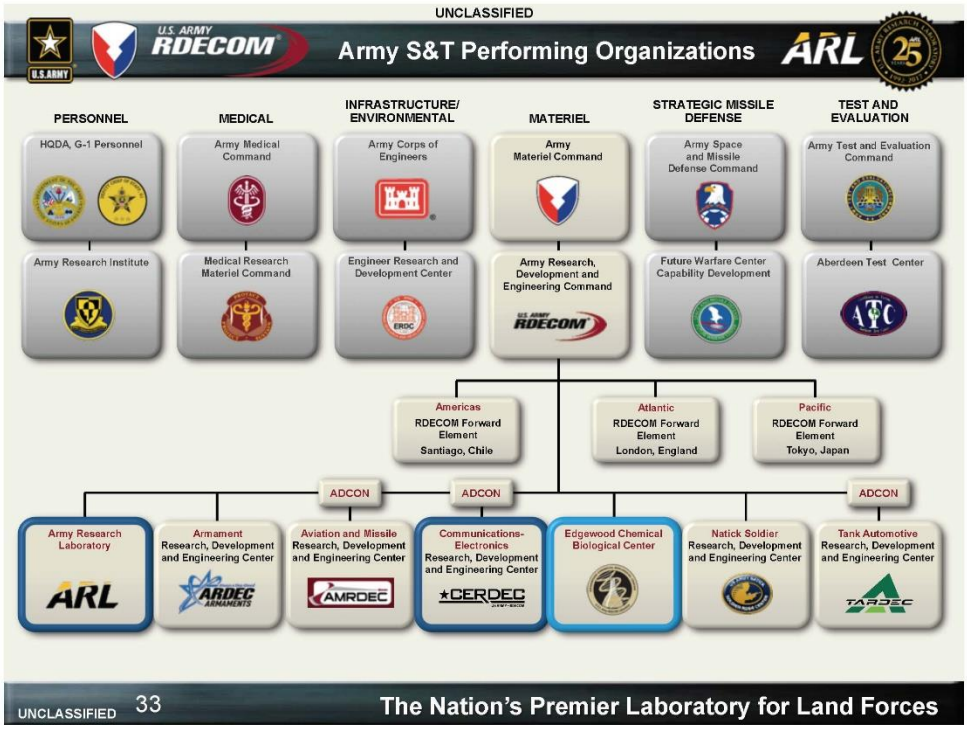
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U.S. ARMY RDECOM
Army S&T Performing Organizations
ARL
PERSONNEL
MEDICAL
INFRASTRUCTURE/ ENVIRONMENTAL
MATERIEL
STRATEGIC MISSILE DEFENSE
TEST AND EVALUATION
HQDA, G-1 Personnel
Army Medical Command
Army Corps of Engineers
Army Materiel Command
Army Space and Missile Defense Command
Army Test and Evaluation Command
Army Research Institute
Medical Research Materiel Command
Engineer Research and Development Center
Army Research, Development and Engineering Command
Future Warfare Center Capability Development
Aberdeen Test Center
Americas
RDECOM Forward Element
Santiago, Chile
Atlantic
RDECOM Forward Element
London, England
Pacific
RDECOM Forward Element
Tokyo, Japan
ADCON
ADCON
ADCON
Army Research Laboratory
Armament Research, Development and Engineering Center
Aviation and Missile Research, Development and Engineering Center
Communications-Electronics Research, Development and Engineering Center
Edgewood Chemical Biological Center
Natick Soldier Research, Development and Engineering Center
Tank Automotive Research, Development and Engineering Center
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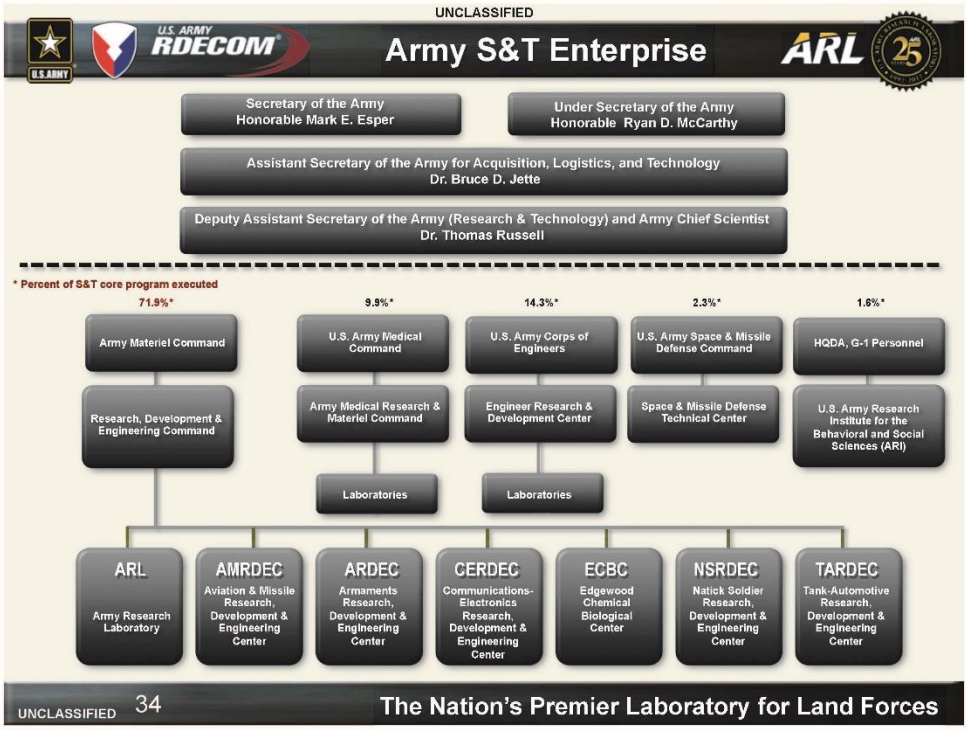
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U.S. ARMY RDECOM
Army S&T Enterprise
ARL
Secretary of the Army
Honorable Mark E. Esper
Under Secretary of the Army
Honorable Ryan D. McCarthy
Assistant Secretary of the Army for Acquisition, Logistics, and Technology
Dr. Bruce D. Jette
Deputy Assistant Secretary of the Army (Research & Technology) and Army Chief Scientist
Dr. Thomas Russell
* Percent of S&T core program executed
71.9%*
9.9%*
14.3%*
2.3%*
1.6%*
Army Materiel Command
U.S. Army Medical Command
U.S. Army Corps of Engineers
U.S. Army Space & Missile Defense Command
HQDA, G-1 Personnel
Research, Development & Engineering Command
Army Medical Research & Materiel Command
Engineer Research & Development Center
Space & Missile Defense Technical Center
U.S. Army Research Institute for the Behavioral and Social Sciences (ARI)
Laboratories
Laboratories
ARL
Army Research Laboratory
AMRDEC
Aviation & Missile Research, Development & Engineering Center
ARDEC
Armaments Research, Development & Engineering Center
CERDEC
Communications-Electronics Research, Development & Engineering Center
ECBC
Edgewood Chemical Biological Center
NSRDEC
Natick Soldier Research, Development & Engineering Center
TARDEC
Tank-Automotive Research, Development & Engineering Center
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U.S. ARMY RDECOM

Futures Command

ARL

Why the Army decided to put its new high-tech Futures Command in Texas

National DEFENSE
NDIA's Business & Technology Magazine

RESEARCH AND DEVELOPMENT

Army R&D Spending Geared Toward a 'Big War'

10/26/2017

By Jon Harper

The Army's future research-and-development spending will be focused on technologies needed to fight a large-scale conflict against advanced adversaries such as Russia, according to defense budget experts.

After more than a decade of focusing on counterinsurgency needs, the Army is now preparing for "the big war," Robert Levinson, senior defense analyst with Bloomberg Government, said during a recent briefing for industry and media.

Cameron Leuthy, senior budget analyst with Bloomberg Government, said the Army's future years defense program plan demonstrates this trend.

The service's research development, test and evaluation budget is projected to increase 25 percent between fiscal years 2017 and 2022, to $10.24 billion. Priorities include air and missile defense, cybersecurity, electronic warfare, high-energy lasers, advanced munitions, active protective systems and future vertical lift helicopter technology, according to Bloomberg Government slides.

wp

Austin picked as location for new command to transform the Army

by Jamie McIntyre | July 13, 2018 12:14 PM

WASHINGTON Examiner

The Army has selected Austin, Texas, for its "entrepreneurial spirit" and "quality of life" as the location for its new Futures Command, which is charged with transforming the service into a more modern, innovative force.

"Our vision describes the Army of 2028, one that is ready to deploy, fight, and win decisively against any adversary anytime, anywhere," said Army Secretary Mark Esper in making the announcement Friday.

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Three Contexts

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- What is ARL's core identity? Examples of success from ARL HQ?
- How are ARL science aims influenced by "Modernization"?
- **What inspires Army-relevant research?**

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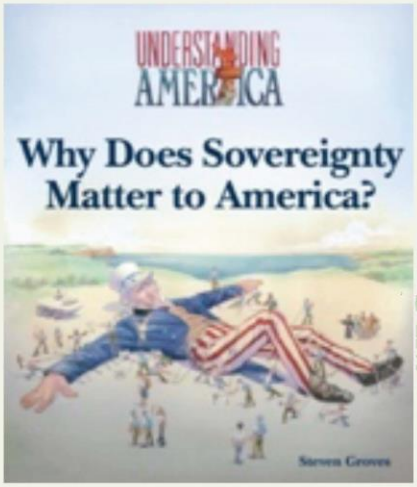
Heart of S&T

ARL



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Pervasive Sensing

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Wearables

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Social Media

Cambridge Analytica: Facebook data-harvest firm to shut

2 May 2018 Share

Facebook-Cambridge Analytica data scandal

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Digital Assistants

DIGITAL TRENDS Menu

SMART HOME

OK, Google: What can Home do? The speaker's most useful skills

AMERICA

Amazon Echo Recorded And Sent Couple's Conversation — All Without Their Knowledge

May 25, 2018 3:16 PM ET

LAUREL WAMSLEY

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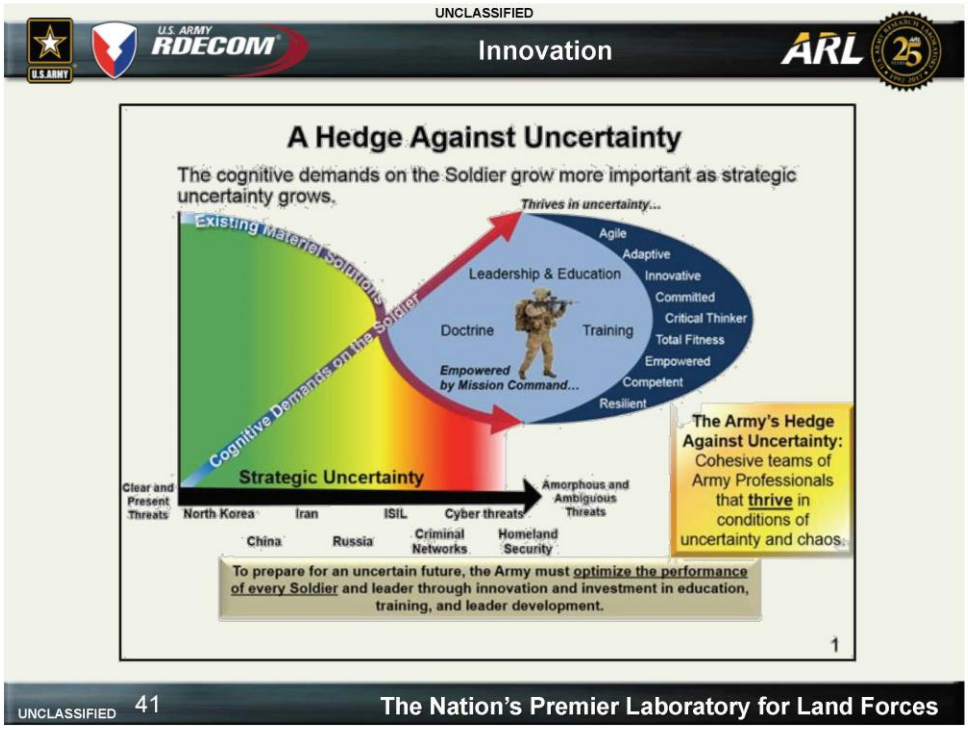
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Innovation
ARL
A Hedge Against Uncertainty
The cognitive demands on the Soldier grow more important as strategic uncertainty grows.
Existing Material Solutions
Cognitive Demands on the Soldier
Thrives in uncertainty...
Agile
Adaptive
Innovative
Committed
Critical Thinker
Total Fitness
Empowered
Competent
Resilient
Leadership & Education
Doctrine
Training
Empowered by Mission Command...
Strategic Uncertainty
Clear and Present Threats
North Korea
Iran
ISIL
Cyber threats
Amorphous and Ambiguous Threats
China
Russia
Criminal Networks
Homeland Security
The Army's Hedge Against Uncertainty: Cohesive teams of Army Professionals that thrive in conditions of uncertainty and chaos.
To prepare for an uncertain future, the Army must optimize the performance of every Soldier and leader through innovation and investment in education, training, and leader development.
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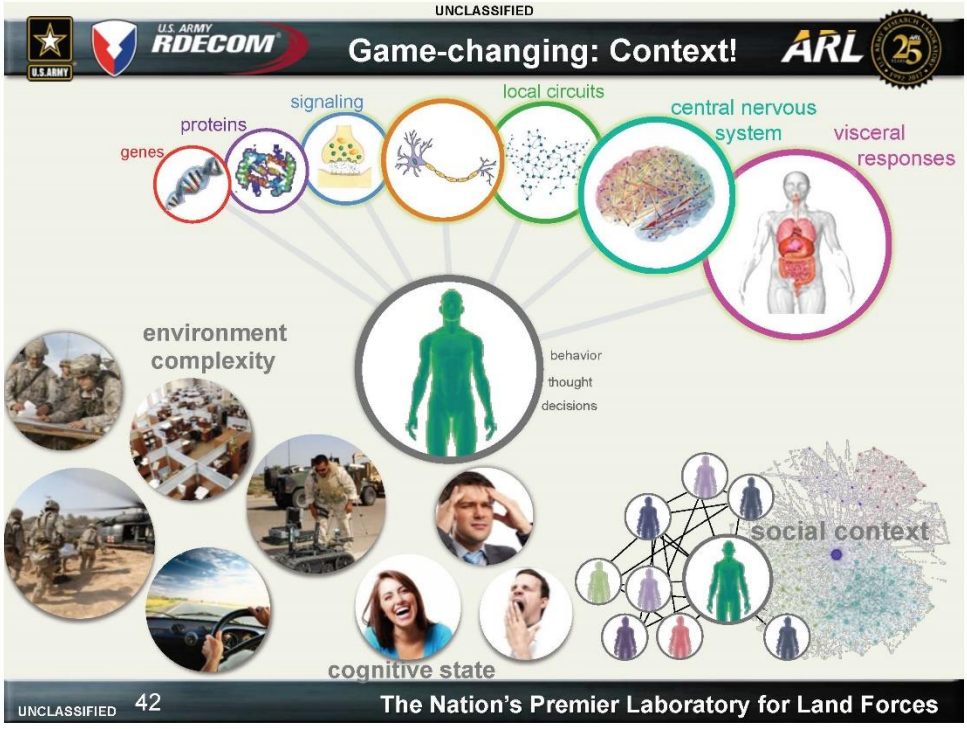
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Game-changing: Context!
ARL
genes
proteins
signaling
local circuits
central nervous system
visceral responses
environment complexity
behavior
thought
decisions
social context
cognitive state
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Communication
ARL
Did you hear the news about…
No! Was this yesterday?
heart rate
physiology
heart rate
physiology
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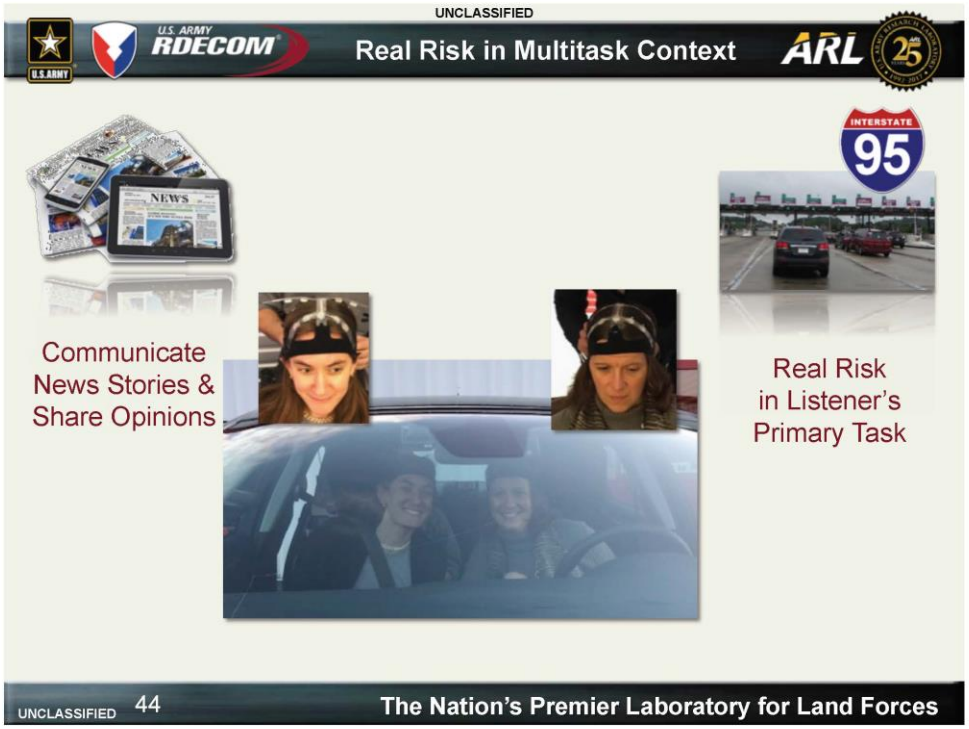
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Real Risk in Multitask Context
ARL
NEWS
INTERSTATE 95
Communicate News Stories & Share Opinions
Real Risk in Listener's Primary Task
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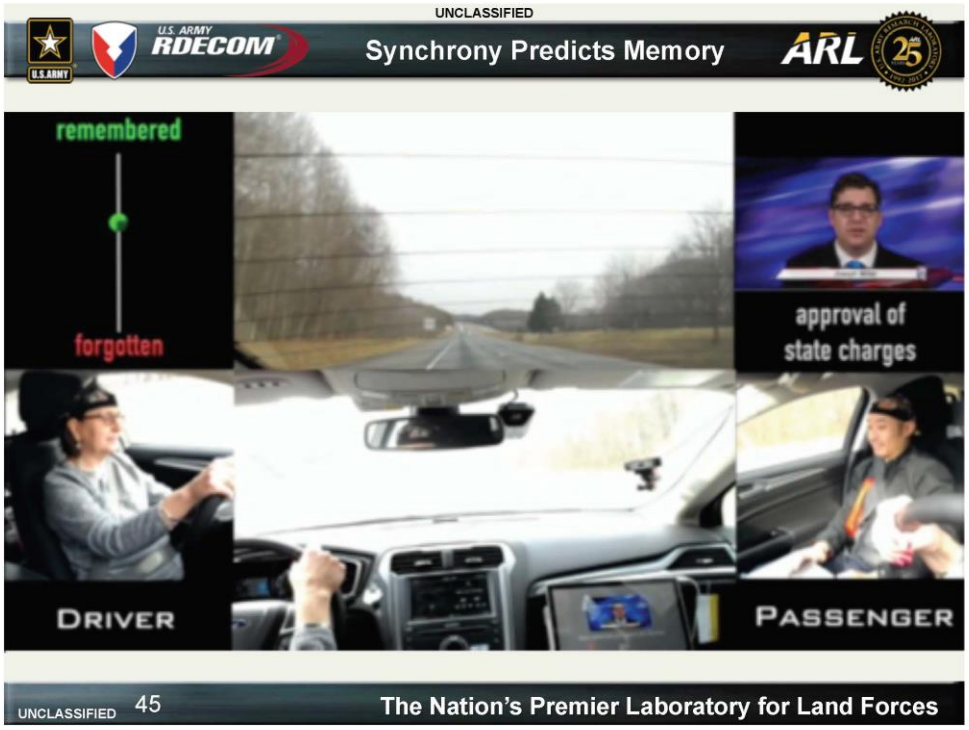
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Synchrony Predicts Memory
ARL
remembered
forgotten
approval of state charges
DRIVER
PASSENGER
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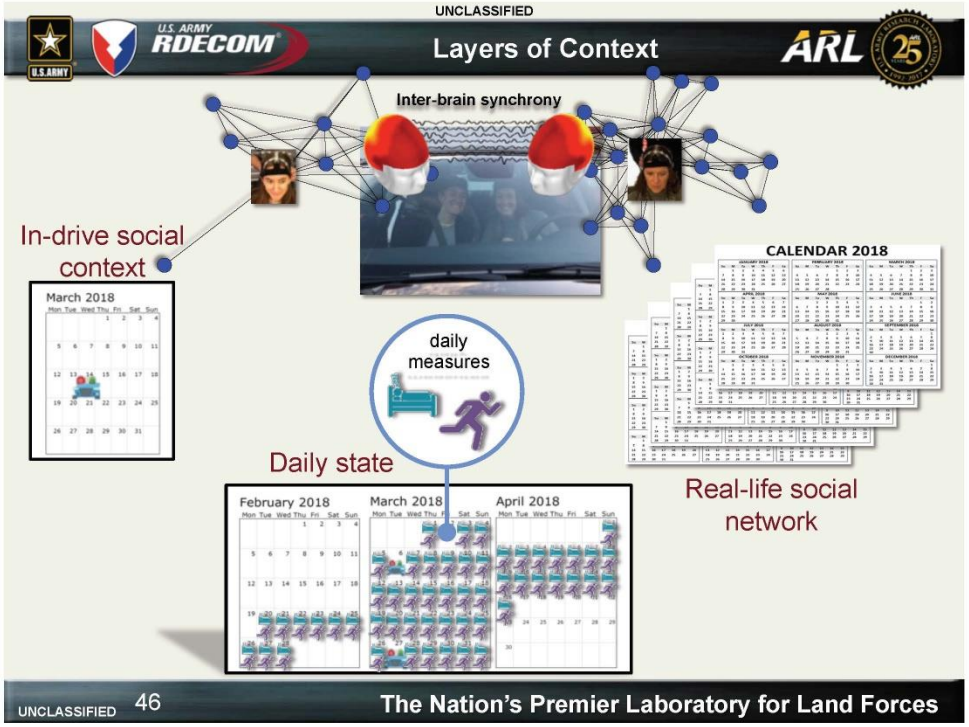
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Layers of Context
ARL
Inter-brain synchrony
In-drive social context
March 2018
daily measures
Daily state
February 2018
March 2018
April 2018
CALENDAR 2018
Real-life social network
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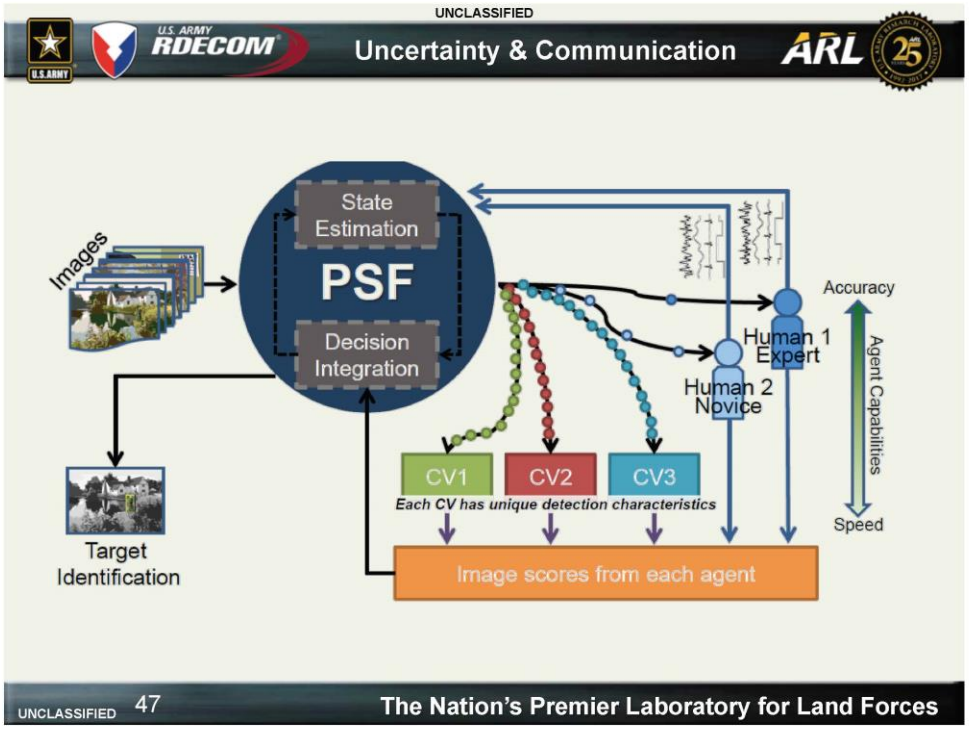
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Uncertainty & Communication
ARL
State Estimation
PSF
Decision Integration
Images
Target Identification
Accuracy
Human 1 Expert
Human 2 Novice
Agent Capabilities
Speed
CV1
CV2
CV3
Each CV has unique detection characteristics
Image scores from each agent
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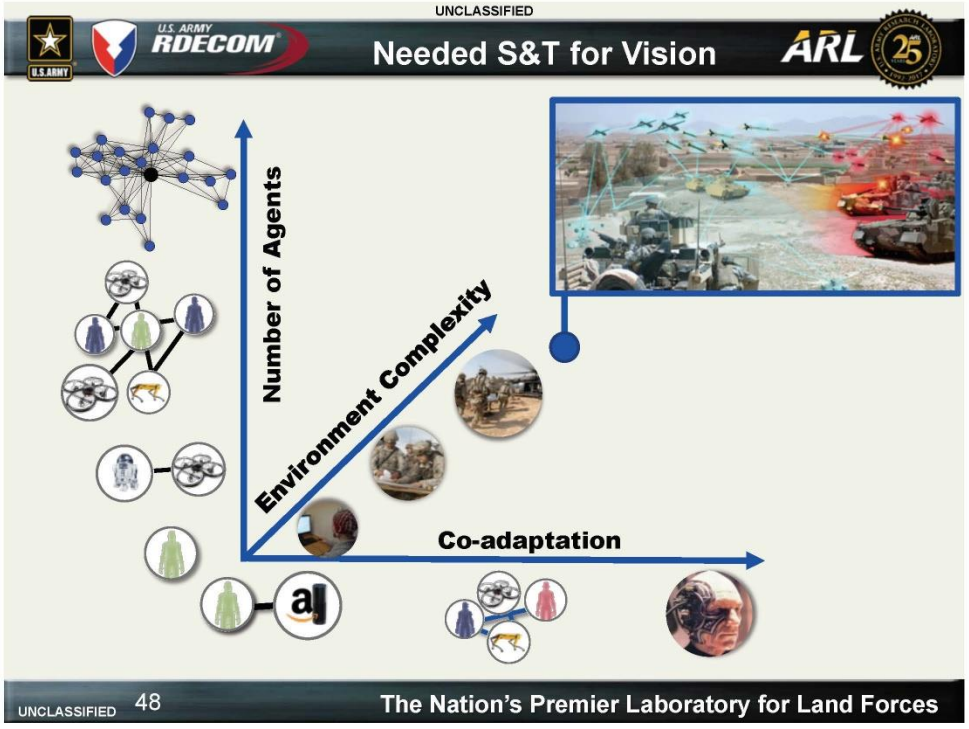
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Needed S&T for Vision
ARL
Number of Agents
Environment Complexity
Co-adaptation
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Three Contexts

- What is ARL's core identity? Examples of success from ARL HQ?
  - Army's corporate laboratory
  - Collaborative engagements for future capabilities
- How are ARL science aims influenced by "Modernization"?
  - Timeframe of innovation influenced by overmatch assessment
  - Hierarchy influences mission space
- What inspires Army-relevant research?
  - Ensuring an eco-system of innovation for sovereignty that reflects culture shifts
  - Uncertainty and communication – human/human, human/agent, agent/agent

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Thanks

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Appendix G. Day 2: Group Reflection Ideas

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How Would I Characterize The Workshop?	How Does It Inform Your Work?	Any Personal Actions?
I heard multiple theories, thinking a little more broadly about that.	Study how to do human factors experiments	Implement research
Informative Research Techniques Collaborations	States, trajectory, landscape	Follow up with potential collaborators
Freewheeling discussion	Better understanding of scientific/analytic approaches to (try) to answer really hard questions	Run new models based on individual
This workshop was informative. It boarded my thinking in a number of areas	Good overview of Human Variability Program in short amount of time. Will be useful to draw new connections to related programs	Discuss with other PIs on how to optimally integrate design/procedure
Open, thoughtful, collaborative and innovative discussion and forum	Makes one think here is use for survey data	Make contact with other researchers and hopefully start new collaborations
Creative Collaborative Board Ranging	Extend in more intellectually and logistically concrete ways my vision for research on human agent teaming	Follow up on the collaborative, development
Focused and well delivered. Huge amount of ideas and information	This workshop gave me additional context regarding the Army's future	Disseminate information on new collaborative initiatives to broad network
Diversity of experience, ideas, methods; exploring common threads	I will be more mindful of looking into other literatures for their thoughts on solutions to our same problems	Work with PIs to integrate workshop brainstorming into future plans
Informative and insightful Well organized	This workshop has helped reinforce the value of the research directions taken in my organization. It helps identify other opportunities to expand our focus and methods	I will reach out to the other researchers in the room for continued open dialogue

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How / I Would Characterize The Workshop?	How Does It Inform Your Work?	Any 3 Personal Actions?
Collaborative /Interactive	New approaches and theoretical constructs that I had not considered before	Read to get down to specifics of 1. Designing RQs 2. Study Designs to answer RQs 3. Data Collection and instrumentation for study design
Productive Enlightening Inspiring Collaborative	Potential collaborations, Potential methods, Potential targets	Pursue new lines of theory related to my research
Open Positive Creative Critical	Cutting edge and innovative	Follow up with potential collaborators Modify design of our mobile software platform
Multifaceted: Many, many approaches for measuring, characterizing and predicting human variability, even within the same research domains (team performance, sleep, activity)	I will think more about predictive modeling, leveraging passive measurements, participant engagement	Methods on sample time series
Blue-sky free thinking Constructively creative	Focus on how to apply micro orientation into large-scale applications	Follow up both internally and externally with folks to determine next steps on how to begin addressing these issues. Provide guidance back to company leadership
Diversity of interest searching for commonalities	Help identify key focus areas for our research and identify potential collaborative partners to help accomplish that work	I will connect better with the literature base (current and past) on theory, methods and evidence in this area

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How / I Would Characterize The Workshop?	How Does It Inform Your Work?	Any 3 Personal Actions?
Cutting Edge Important Exciting	Awareness of existing research, future/in progress research, and techniques	Reach out to other ARL and external partners to develop new ways to analyze and utilize long-term multidimensional human data
Interactive and engaging Focus on future and understandings how individuals and teams perform across context	I will seek researchers from other fields to help my studies	Pull (all) experimental results together in a coherent manner for a start
	Interesting to see the data sources and results of other people	Many more papers to read and authors to follow
	1. Inspires dynamical systems approach 2. Smarter assessment of state in context of passive sensing 3. Focus on translations to applies domains	Network and consulting with our amazing attendees
	Newly recognized implications for incorporating agents into human teams: e.g. how to balance shifting of roles without encouraging the same outcome every time (human cedes control to agent)	Consolidate and align research to Army and ARL priorities Focus research on Army scientific gaps related to priorities

List of Symbols, Abbreviations, and Acronyms

ARL	US Army Research Laboratory
ASA[ALT]	Assistant Secretary of the Army for Acquisition, Logistics, and Technology
BAA	Broad Agency Announcement
EMA	ecological momentary assessment
FY	fiscal year
HRV	heart-rate variability
HV	human variability
JiTAI	Just in Time Adaptive Intervention
MRT	micro-randomized trial
Q&A	question and answer
S&T	science and technology
SBIR	Small Business Innovation Research
STTR	Small Business Technology Transfer

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2698 G ST BLDG 190
WRIGHT PATTERSON AFB OH
45433-7604

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ALEXANDRIA VA 22350

ABERDEEN PROVING GROUND

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J LOCKETT
P FRANASZCZUK
K MCDOWELL
K OIE
RDRL HRB
D HEADLEY
RDRL HRB C
J GRYNOVICKI
RDRL HRB D
C PAULILLO
RDRL HRF A
A DECOSTANZA
RDRL HRF B
A EVANS
J VETTEL
RDRL HRF C
J GASTON
RDRL HRF D
A MARATHE