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State and Trait Influences on Variability in Human Performance: Final Report

by Stephen R. Mitroff, Dwight J. Kravitz, Chloe Callahan-Flintoft, Sean M. Fitzhugh, and Kelvin S. Oie

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State and Trait Influences on Variability in Human Performance: Final Report

Stephen R. Mitroff

The George Washington University

Dwight J. Kravitz

The George Washington University and The National Science Foundation

Chloe Callahan-Flintoft, Sean M. Fitzhugh, and Kelvin S. Oie

DEVCOM Army Research Laboratory

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14. ABSTRACT Humans vary greatly in their abilities, with some people better suited for certain tasks than others. Individuals have their own strengths and weaknesses and can vary in their optimal performance levels across time, experiences, and situations. Such inter- and intraindividual variability provides a powerful means to explore fundamental questions about the nature of cognitive processes and human performance while offering insights for improving human performance in demanding situations. Research tasks were aimed at overcoming several scientific and pragmatic issues that have hindered the study of individual differences by leveraging previous collaborative efforts and developing new methodological approaches and resources.					
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1. Introduction and Proposed Approach

The primary goal of this cooperative agreement was to address fundamental and applied questions related to variability in human performance by leveraging the collective strengths and resources from two complementary teams. Humans vary greatly in their abilities, with some people better suited for certain tasks than others. Individuals have their own strengths and weaknesses and can vary in their optimal performance levels across time, experiences, and situations. Such inter- and intraindividual variability provides a powerful means to explore fundamental questions about the nature of cognitive processes and human performance while offering insights for improving human performance in demanding situations, like those faced by U.S. Soldiers.

Individual differences are a critical and understudied aspect of task performance. Cognitive science has typically focused on central tendencies in the search for mechanisms that generalize across everyone. In doing so, it has often treated individual variation as something to be overcome rather than understood. However, analyses of the Airport Scanner dataset—a massive dataset comprising approximately 4 billion observations of a gaming app, *Airport Scanner* (The Kedlin Company, Bellevue, Washington), from more than 15.6 million unique devices (see Mitroff et al. 2015)—indicate that the impact of individual differences is quite large and reliable. Moreover, it is precisely these differences that can inform the assignment of personnel to critical positions and to help optimize intelligent agent behaviors in their teaming interactions with humans. In this project, we pursued two research tasks aimed at overcoming several scientific and pragmatic issues that have hindered the study of individual differences by leveraging previous collaborative efforts and developing new methodological approaches and resources.

1.1 Task 1

Understanding how individual differences drive performance requires a large dataset, which contains the necessary variability and multiple measures of those differences. No single metric can capture all state (short-term) and trait (long-term) differences that drive variability between individuals. Moreover, the impact of any particular metric is highly likely to be small and contingent on its relationship to other metrics. Without large multidimensional datasets, this question cannot be addressed and modeled satisfactorily. This sort of data collection has been difficult to achieve at reasonable cost in budget and schedule, but our collaborative team has developed and is now optimizing a platform for crowdsourced data collection that

alleviates those concerns. Task 1 was designed to leverage this existing platform and to tap into a related project that involved gathering individual difference surveys (e.g., impulsivity, personality, fatigue, attention-deficit/hyperactivity disorder) and psychophysics data on a large number of participants.

1.2 Task 2

Understanding how individual differences drive performance requires extremely sensitive metrics. Our work on “touch-and-swipe” methods (see below) suggests that using this response increases the sensitivity of experiments and the degree to which they reflect individual differences. In a recent project, we found that using touch and swipe responses allowed for an extremely clean quantification of an interaction between short-timescale/state (fatigue) and long-timescale/trait (conscientiousness) variables, finding that conscientiousness strongly alleviated the impact of fatigue on participants’ time to swipe. As this response method has been well-validated with data from approximately 100,000 participants in the Airport Scanner dataset, and it can be applied to any discrimination task, we proposed to use it to provide a metric sensitive enough to allow us to model not just the impact of single metrics but their joint impact on performance.

2. Research Accomplishments

Over the course of this award’s period of performance, the George Washington University (GWU) and U.S. Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) research teams worked together to address both Task 1 and Task 2 goals. This resulted in multiple accomplishments, including successful completion of all project deliverables, and scientific advances, which have been reported in numerous knowledge products. These are itemized in the Appendix. At a high level, this award contributed to 4 manuscripts published or in process, 4 conference talks, 15 conference poster presentations, and 4 invited talks. Fifteen of these works were jointly authored by GWU and ARL collaborators. Ongoing efforts that extend from the research results and advances made within this project will expand these numbers further.

2.1 Deliverables and Notable Advances

2.1.1 Individual Differences Data: Phase 1

As a primary project goal, we designed and executed Phase 1 of a planned multiphase large-scale data collection effort implemented on the online platform Prolific (prolific.com). The effort leverages funding from an internal GWU award

and resulted in an initial dataset of more than 1,150 participants. Participants completed a series of 12 previously validated questionnaires, basic demographic surveys, and a behavioral task, which together provide a battery of metrics to enable the assessment of the complex interrelated effects among individual differences.

2.1.2 Theory-Informed Analyses of Individual Differences

Previous analyses of very large ($N > 15$ million) datasets were extended upon to explore new approaches to evaluating theory-informed models that capture the effects of multiple factors which simultaneously affect complex human task behavior. This decision was made due to the increased data requirements for models that include multiple variables. Comparisons were made of the fits and parameters of multifactorial models describing dimensions of task context, participant experience, and individual differences. Initial results demonstrated that all tested variables contributed meaningfully to observed performance variation, consistent with the project's working hypothesis that human behavior is simultaneously shaped by multiple factors. Importantly, these results also showed the critical advantage of using very large datasets in analyses that reflect the high variability and multidimensionality of real-world human behavior (Siqi-Liu et al. 2024). These results provide a foundation for theory-driven approaches to develop models that could improve the current state-of-the-art approaches for the prediction of individual performance and long-term ability.

2.1.3 Individual Differences Data: Phase 2

As part of the planned multiphase large-scale data collection effort, we designed and executed Phase 2, inviting only participants who completed Phase 1 to participate. The Phase 2 effort included a different set of questionnaires than Phase 1 and expanded a complex visual search task with new theoretical and practical extensions. New capabilities were developed that enabled the collection of data describing the trajectories of the participants' mouse movements during their response. The effort achieved an 87% rate of participant return and resulted in an augmented Phase 1 dataset with more than 1,000 participants having completed both Phase 1 and Phase 2. The visual search task augments the capacity for the complete dataset to interrogate the complex interrelationships among individual measures in the joint battery across phases with the novel capacity to examine those relationships in relation to cognitive and motor task performance.

2.1.4 Exploring Cognitive and Motor Aspects of Task Performance

We conducted multiple analyses to explore the relationship between motor and cognitive processes during task performance. In the task, stimulus objects appeared

on the screen, and the participant was asked to sort the task into one of two categories. Motor and cognitive components were operationally defined as “touch” (i.e., from stimulus onset to participant touching the object on the screen) and “swipe” (i.e., from participant touching the object on the screen to the end of their moving the object to one of the task goal areas) parts of their total response. It was found that the touch-and-swipe response decomposition reliably defines separable contributions to observed task performance. Importantly, while these analyses examined largely unrelated aspects of the task behavior—the effects of evidence accumulation and stimulus similarity on visual attention (Grady et al. 2024) and the effects of pre-error speeding on the temporal dynamics of repeated task performance (Malykke et al. 2024), respectively—both analyses revealed a differential sensitivity of models when the motor and cognitive components were separated as compared to when they were not. In addition, initial analyses of the Phase 2 visual search task data revealed that participants employed context-dependent search patterns that could be used to accurately predict errors up to approximately 500–1000 ms prior to response onset (Siqi-Liu et al. 2025). Together, these results support the project’s proposal that consideration of motor response dynamics in human task performance can enhance the sensitivity of model analyses, including the potential to increase the dimensionality of theory-driven models to address the challenges of predicting and explaining real-world human behavioral variation.

3. References

- Grady JN et al. Getting more out of response time measures: delineating separable motor and cognitive subcomponents of response time via drift diffusion modeling. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.
- Malykke SB et al. Dissecting the mistake: investigating separable motor and cognitive processes of post-error slowing. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.
- Mitroff SR et al. What can 1 billion trials tell us about visual search? *J Exp Psychol Hum Percept Perform.* 2015;41(1):1–5.
- Siqi-Liu A, Siritzky EM, Callahan-Flintoft C, Grady JN, Oie KS, et al. Comparing apples to oranges to bananas: a big data approach to understanding the joint influences of stimulus properties, trial history, and individual differences. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.
- Siqi-Liu A, Malykke SB, Oie KS, Kravitz DJ, Mitroff SR. Computer cursor trajectories are predictive of upcoming success in visual search. VSS 2025: 25th Annual Meeting of the Vision Sciences Society; 2025 May 16–20; St. Pete Beach, FL.

Appendix. Project Knowledge Product Metrics

A.1 Research Team

The George Washington University (GWU)

Co-Principal Investigator:	Stephen R. Mitroff
Co-Principal Investigator:	Dwight J. Kravitz
Postdoctoral Fellow:	Audrey Siqu-Liu
Ph.D. Graduate Student:	Samoni Nag
Ph.D. Graduate Student:	Emma Siritzky
Ph.D. Graduate Student:	Justin Grady
Ph.D. Graduate Student:	Sarah Malykke
Undergraduate Researcher:	Sarah Hodgdon
Post-baccalaureate Researcher:	Victor Platzner
Programmer:	Adam Hereth

DEVCOM Army Research Laboratory

Co-Principal Investigator:	Kelvin S. Oie
Co-Investigator:	Chloe Callahan-Flintoft
Co-Investigator:	Sean M. Fitzhugh
Co-Investigator:	Paul Fedele
AEOP Postdoctoral Fellow:	Ellie Robbins
ORAU Postdoctoral Fellow:	Melanie Bancelhon

A.2 Accomplishments by Category*

Publications and Manuscripts

Kravitz DJ, Mitroff SR, **Callahan-Flintoft C**, **Oie KS**. Crowdsourced data collection opens new avenues for the behavioral sciences to impact real-world applications. Policy Insights Behav Brain Sci. 2024;11(2):123–131. <https://doi.org/10.1177/23727322241274745>

Cahalan S, Mitroff SR, Subiaul F, Rosenblau G. Using the cognitive-rigidity-flexibility dimension to deepen our understanding of the autism spectrum. Manuscript accepted at Pers Neurosci.

Callahan-Flintoft C, Cox PH, Siritzky EM, Mitroff SR, **Oie KS**, Kravitz DJ. Repeated exposure to task-relevant and task-irrelevant information—and their interaction—affect visual search performance. Manuscript under review at Atten Percept Psycho.

* ARL authors in **bold**.

Fitzhugh SM, Nag S, Cox PH, Kravitz DJ, Mitroff SR, **Oie KS**. Leveraging outliers to predict rare behaviors in a massive sample. Manuscript under review at PNAS Nexus.

Conference Podium Presentations

Siqi-Liu A, Malykke SB, **Oie KS**, Kravitz DJ, Mitroff SR. Computer cursor trajectories are predictive of upcoming success in visual search. VSS 2025: 25th Annual Meeting of the Vision Sciences Society; 2025 May 16–20; St. Pete Beach, FL.

Siqi-Liu A, Siritzky EM, **Callahan-Flintoft C**, Grady JN, **Oie KS**, Mitroff SR, Kravitz DJ. A big data approach to modeling the joint influences of stimulus, trial hysteresis, and individual differences on variability in trial-by-trial visual search performance. Psychonomic Society 65th Annual Meeting; 2024 November 21–24; New York, NY.

Cox PH, **Callahan-Flintoft C**, Kramer MR, Mitroff SR, Kravitz DJ. An extremely high-fidelity quantification of the time course of learning consolidation from a massive behavioral dataset. Psychonomic Society 64th Annual Meeting; 2023 November 16–19; San Francisco, CA.

Grady JN, Cox PH, Nag, S, Mitroff SR. Conscientiousness protects visual search performance from the impact of fatigue [Presented by Mitroff S]. Psychonomic Society 64th Annual Meeting; 2023 November 16–19; San Francisco, CA.

Conference and Workshop Poster Presentations

Dochnal M, Siqi-Liu A, Malykke SB, Mitroff SR. Using mouse tracking data to examine adaptation of visual search behaviors to transitions in task complexity. GWU CCAS Research Showcase; 2025 April 2; Washington, D.C.

Grady JN, Siritzky EM, Kravitz DJ, Mitroff SR. Characterizing the independent and joint impacts of previous category evidence and visual and semantic similarity on visual attention. VSS 2025: 25th Annual Meeting of the Vision Sciences Society; 2025 May 16–20; St. Pete Beach, FL.

Malykke SB, Siqi-Liu A, **Oie KS**, Kravitz DJ, Mitroff SR. The time course of an error: Benefits of examining pre-error speeding and post-error slowing simultaneously. VSS 2025: 25th Annual Meeting of the Vision Sciences Society; 2025 May 16–20; St. Pete Beach, FL.

- Siqi-Liu A, Malykke S, Kravitz DJ, Mitroff SR. Computer cursor trajectories are predictive of upcoming success in visual search. VSS 2025: 25th Annual Meeting of the Vision Sciences Society; 2025 May 16–20; St. Pete Beach, FL.
- Callahan-Flintoft C**, Cox PH, Kramer, MR, Mitroff SR, Kravitz DJ. A high-fidelity quantification of the time course of learning consolidation from a massive visual search dataset. HCxS Human-Autonomy Teaming VIP Day; 2024 August 24; Aberdeen Proving Ground, MD.
- Carter EC, Callahan-Flintoft C, Fitzhugh SM**, Kravitz DJ, Mitroff SR, **Oie KS**. Theory-driven big data for Soldier characterization. HCxS Human-Autonomy Teaming VIP Day; 2024 August 24; Aberdeen Proving Ground, MD.
- Cox PH, **Callahan-Flintoft C**, Kramer, MR, Mitroff SR, Kravitz DJ. A high-fidelity quantification of the time course of learning consolidation from a massive visual search dataset. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.
- Grady JN, Siqi-Liu A, Malykke SB, Cox PH, Kravitz DJ, Mitroff SR. Getting more out of response time measures: Delineating separable motor and cognitive subcomponents of response time via drift diffusion modeling. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.
- Malykke SB, Siqi-Liu A, Siritzky EM, Grady JN, **Oie KS**, Kravitz DJ, Mitroff SR. Changes in response times before and after making a mistake reveal distinct motor and cognitive mechanisms of error monitoring. OPAM 32: Object Perception, Attention, and Memory Workshop; 2024 November 21; New York, NY.
- Malykke SB, Siqi-Liu A, Siritzky EM, Grady JN, Kravitz DJ, Mitroff SR. Dissecting the mistake: Investigating separable motor and cognitive processes of post-error slowing. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.
- Robbins E**, Kravitz DJ, Hereth A, **Oie KS**, Mitroff SR. PARADIGMS: a new system for precise, accurate, and efficient measurement of human behavior: collaboration opportunities. University of Colorado Human-Machine Teaming Paradigms Meeting; 2024 March 15–16; Boulder, CO.
- Siritzky EM, Siqi-Liu A, Kravitz DJ, Vickery, TJ, Mitroff SR. Examining differential effects of target and context repetition in visual search: Insights from a big data approach. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.

Siqi-Liu A, Siritzky EM, **Callahan-Flintoft C**, Grady JN, **Oie KS**, Mitroff SR, Kravitz DJ. Comparing apples to oranges to bananas: A big data approach to understanding the joint influences of stimulus properties, trial history, and individual differences. VSS 2024: 24th Annual Meeting of the Vision Sciences Society; 2024 May 17–22; St. Pete Beach, FL.

Siqi-Liu A, Siritzky EM, **Callahan-Flintoft C**, Grady JN, **Oie KS**, Mitroff SR, Kravitz DJ. A Big Data approach to understanding the joint influences of stimulus properties, trial history, and individual differences [Presented by Oie KS]. HCxS Human-Autonomy Teaming VIP Day; 2024 August 24; Aberdeen Proving Ground, MD.

Callahan-Flintoft C, Cox PH, Siritzky EM, Kravitz DJ, Mitroff SR, **Oie KS**. Characterizing exposure history effects on visual search performance using big data. OPAM 31: Object Perception, Attention, and Memory Workshop. 2023 November 16; San Francisco, CA.

Other Invited Talks

Mitroff SR. Using “theory-driven big data” to advance psychology research. National Academies, Board on Behavioral, Cognitive, and Sensory Sciences. National Academies of Science and Engineering; 2025.

Kravitz DJ. Function, plasticity, neuroanatomy, and behavior. Neuroscience Symposium; 2023; Georgetown University.

Kravitz DJ. Function, plasticity, neuroanatomy, and behavior. Neuroscience Symposium; 2023; Johns Hopkins University.

Kravitz DJ. Function, plasticity, neuroanatomy, and behavior. Neuroscience Symposium; 2023; University of California, Davis.

Brownbag Talks

Bancilhon M. The effect of individual differences and presentation formats on decision-making. The George Washington University, Department of Psychological & Brain Sciences, Cognitive Neuroscience Brownbag Series, 2024.

Malykke SB. Mapping the time course of errors in task performance. The George Washington University, Department of Psychological & Brain Sciences, Cognitive Neuroscience Brownbag Series, 2024.

Siritzky EM Examining differential effects of target and context repetition in visual search: Insights from a big data approach. The George Washington University,

Department of Psychological & Brain Sciences, Cognitive Neuroscience Brownbag Series, 2024.

Siritzky EM Associative learning for both task-relevant and task-irrelevant features in visual search. The George Washington University, Department of Psychological & Brain Sciences, Cognitive Neuroscience Brownbag Series, 2024.

Awards

Hodgdon SV. Undergraduate Research and Service Grant. The George Washington University; 2024 (\$500).

Hodgdon, SV. Sigelman Undergraduate Research Enhancement (SURE) Award. The George Washington University; 2024 (\$1000).

Degrees and Promotions

- Hodgdon SV. Accepted to Lehigh University Ph.D. program, June 2025
- Siritzky EM. Comprehensive examinations, June 2025
- Malykke SB. Comprehensive examinations, April 2025
- Malykke SB. Master's degree, December 2024
- Siritzky EM. Master's degree, December 2024

List of Symbols, Abbreviations, and Acronyms

AEOP	Army Educational Outreach Program
ARL	Army Research Laboratory
DEVCOM	U.S. Army Combat Capabilities Development Command
GWU	The George Washington University
ORAU	Oak Ridge Associated Universities

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