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1. REPORT DATE (DD-MM-YYYY) 19-04-2022	2. REPORT TYPE Final Report	3. DATES COVERED (From - To) 25-Aug-2017 - 24-Aug-2021
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4. TITLE AND SUBTITLE Final Report: Scaling up models of decisions from experience: Information and incentives in networks	5a. CONTRACT NUMBER W911NF-17-1-0431
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER 611102

6. AUTHORS	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES AND ADDRESSES Carnegie Mellon University Associate Director, Sponsored Programs 5000 Forbes Avenue Pittsburgh, PA 15213 -3890	8. PERFORMING ORGANIZATION REPORT NUMBER
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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS (ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211	10. SPONSOR/MONITOR'S ACRONYM(S) ARO
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) 70878-NS.14

12. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.
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13. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.
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14. ABSTRACT
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15. SUBJECT TERMS
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16. SECURITY CLASSIFICATION OF:	17. LIMITATION OF ABSTRACT	15. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Cleotilde Gonzalez
a. REPORT UU	b. ABSTRACT UU	c. THIS PAGE UU	19b. TELEPHONE NUMBER 412-268-6242

# RPPR Final Report

as of 11-Jan-2023

Agency Code: 21XD

Proposal Number: 70878NS

Agreement Number: W911NF-17-1-0431

## INVESTIGATOR(S):

**Name:** Cleotilde Gonzalez  
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**Phone Number:** 4122686242  
**Principal:** Y

Organization: **Carnegie Mellon University**

Address: Associate Director, Sponsored Programs, Pittsburgh, PA 152133890

Country: USA

DUNS Number: 052184116

EIN: 250969449

**Report Date:** 24-Nov-2021

Date Received: 19-Apr-2022

**Final Report** for Period Beginning 25-Aug-2017 and Ending 24-Aug-2021

**Title:** Scaling up models of decisions from experience: Information and incentives in networks

**Begin Performance Period:** 25-Aug-2017

**End Performance Period:** 24-Aug-2021

**Report Term:** 0-Other

Submitted By: Cleotilde Gonzalez

Email: COTY@CMU.EDU

Phone: (412) 268-6242

**Distribution Statement:** 1-Approved for public release; distribution is unlimited.

**STEM Degrees:** 1

**STEM Participants:** 2

**Major Goals:** In this research we built upon the insights of research of Decisions from Experience (DfE), developments in network science and collective intelligence research to create models of collective behavior that are emergent from individual cognition.

Models that start with strong representations of individual behavior should be able to explain and make more accurately represent the aggregate effects of network-based tasks, compared to network science models that mostly assume simple and non-cognitive agents.

We aim at advancing the current state of the art in network science by contributing to: methods of information aggregation; strategies to learn from observation of other members in a network; generalizing rational benchmarks to simple social strategic games; and connecting incentives to social preferences such as cooperation, fairness, trust, and reciprocity.

Our efforts entail experimentation in choice tasks where individuals, pairs, and small groups interact and where we vary the levels of information provided to group members. This project also involves the construction of new models that represent the aggregate behavior of pairs or small groups from the emergent behavior of individual cognitive agents. Specifically, we work on: (1) systematic expansions of mechanisms of instance-based learning theory (IBLT) through the inclusion of methods known in social dilemmas and network science research; (2) the empirical investigation of the interaction between information, incentives, and network structure on efficient networks and social welfare; and (3) the computational implementation of cognitive models to test new theoretical expansions of collective network models, against experimental data.

There are at least three current scientific challenges that this research is currently addressing:

- 1) The Network-Cognitive Science Gap – Two scientific communities (Network Science and Cognitive Science) are often interested in diverse levels of understanding of behavioral phenomena. Cognitive Scientists on the one hand, study human behavior and cognition mostly from an individual perspective. Many psychology experiments often approach DfE in learning studies individually. Often experiments involve learning tasks out of context, with minimum instructions, and in isolation from others for reasons of experimental control. Social scientists on the other hand, are interested in precisely what studies of individual want to control for: the interaction with others and understanding how decisions are made in the presence of others and by observing others. However, they are often less interested in each of the individual's cognition and how that impacts the group behavior. Thus, cognitive and social sciences vary in their "unit of analysis": the group or the individual.
- 2) Scaling up experimentation from individuals to groups. – Although executing experiments in large groups may

## RPPR Final Report as of 11-Jan-2023

seem like something that psychologist “should have figured out”, the reality is that the execution of large team experiments and the technology behind such endeavor are relatively new and the developments are relatively recent.

3) Scaling up cognitive models of learning and DfE to learning and DfE in groups. – Most well-known cognitive models of learning represent individual learning. We scale up current Instance-Based Learning (IBL) models of learning by building on current efforts to expand the cognitive theories and models of decisions from experience in simple social situations. A new theoretical integration is expected to provide understanding of how people appraise their own actions and actions of others when making decisions from experience, and a clarification of the role of information and the incentives in a network.

**Accomplishments:** Overall, this project produced 12 publications; 6 journal articles and 6 conference proceedings publications.

During the first year we analyzed human data reported and collected in team studies conducted by Mason, Jones, and Goldstone (2008) to demonstrate how the dynamics emerging from various network structures and function complexity suggest the emergence of exploration and exploitation in networks. We also proposed a model of dynamic decision-making by networked individuals in which agents probabilistically select from all available options, in contrast to models in which choices are made among explicitly encoded strategies. We observe exploitation-exploration trade-offs in human networks and explain the decrease of exploration and increase in exploitation over time using cognitive models.

Also, during the first year we investigated a number of platforms to run experiments with large number of participants online. We programmed and ran an online group experiment using the using game.

During the second year we invested our efforts in: (1) conducting a set of experiments of pairs and groups; (2) analyzing existing data sets to investigate of learning and decision making of individuals and groups, particularly the concept of exploration-exploitation in problem solving tasks done in groups; (3) improve our Python IBL modeling architecture (PyIBL) to address the possibility of creating models that involve multiple IBL agents; (4) generate new agent-based models, independent form IBL, to propose how emergent group behavior may form from individual self-interest decisions.

During the third year of this grant we invested our efforts in: (1) Emergence of cooperation by trusting other’s decisions; (2) generate new agent-based algorithms that demonstrate the emergence of collective intelligence from individual selfish behavior; (3) explore variability and aggregation in models; (4) analyze existing data sets to investigate of learning and decision making of individuals and groups, particularly the concept of exploration-exploitation in problem solving tasks done in groups.

**Training Opportunities:** This project supported two Ph.D. students in Social and Decision Sciences. They were both trained in Cognitive Modeling, particularly introduced to Instance-Based Learning Models and Bayesian approaches. After graduation, Erin McCormick has continued her research career at the Air Force Research Laboratories.

This grant also supported four Post-Doctoral fellows. The post-docs were introduced to cognitive modeling and experimental approaches for testing and verifying predictions of an agent-based model.

## RPPR Final Report as of 11-Jan-2023

**Results Dissemination:** Overall this grant produced 6 journal papers and 6 papers in conference proceedings:

Journal papers:

1. Konstantinidis, E., Harman, J.L. & Gonzalez, C. (2022). Patterns of choice adaptation in dynamic risky environments. *Memory & Cognition*. <https://doi.org/10.3758/s13421-021-01244-4>.
2. McCormick, E., Cheyette, S., & Gonzalez, C. (2022). Choice Adaptation to Changing Environments: Trends, Feedback and Awareness of Change. *Memory & Cognition* (In Press).
3. Sloman, S. J., Goldstone, R., & Gonzalez, C. (2021). A Social Interpolation Model of Group Problem-Solving. *Cognitive science*. 45(12), e13066. <https://doi.org/10.1111/cogs.13066>
4. Mahmoodi, K., West, B. J., & Gonzalez, C., (2020). Selfish Algorithm and Emergence of Collective Intelligence. *Journal of Complex Networks*. Volume 8, Issue 3, June 2020, cnaa019, <https://doi.org/10.1093/comnet/cnaa019>
5. Rajivan, P., Aharonov-Majar, E., Gonzalez, C. (2020). Update now or later? Effects of experience, cost, and risk preference on update decisions. *Journal of Cybersecurity*., 6(1). <https://doi.org/10.1093/cybsec/tyaa002>
6. Aharonov-Majar, E., Rajivan, P., Gonzalez, C., Erev, I. (2019). The impact of variability and prechoice experience on taking safety measures: The case of security updates. *Journal of Behavioral Decision Making*. 2019; 1-12, <https://doi.org/10.1002/bdm.2131>

Conference proceedings:

7. Sloman, S., Goldstone, R., & Gonzalez, C. (2022). A cognitive computational model of collective search with social information. The fifth Multi-disciplinary Conference on Reinforcement Learning and decision Making (RLDM 2022). Brown University, Providence, RI, USA, June 8-11, 2022.
8. McCormick, E., Blaha, L., & Gonzalez, C (2020). Analyzing variability in instance-based learning model predictions using recurrence quantification analysis. 53rd Annual Meeting of the Society for Mathematical Psychology (MathPsych 2020). July 20-July 31, Virtual meeting.
9. McCormick, E., Blaha, L., & Gonzalez, C (2020). Exploring Dynamic Decision Making Strategies with Recurrence Quantification Analysis. 42nd Annual Meeting of the Cognitive Science Society (CogSci 2020). July 29-August 1, Virtual meeting. pp. 3041-3047.
10. Sloman, M., Goldstone, R. & Gonzalez, C. (2019). Complex exploration dynamics from simple heuristics in a collective learning environment. 41th Annual Meeting of the Cognitive Science Society (CogSci 2019). July 24-27, 2019, Montreal, Canada.
11. Mahmoodi, K. & Gonzalez, C. (2019). Emergence of Collective Cooperation from Selfish-Imitation and Selfish-Attachment. 41th Annual Meeting of the Cognitive Science Society (CogSci 2019). July 24-27, 2019, Montreal, Canada.
12. Sloman, S., Goldstone, R., & Gonzalez, C. (2019). Individual and Group-Level Exploration in a Collective Search Task. ACM Conference on Collective Intelligence. June 13-14, 2019, Carnegie Mellon University. Pittsburgh, PA, USA.

**Honors and Awards:** 2021 Lifetime Fellow of the Cognitive Science Society. Formal recognition at the 2021 Cognitive Science Society annual meeting, Vienna, Austria.

2020 Best Paper Award. International Conference on Decision and Game Theory for Security (GameSec; October 26-30, 2020) – “Exploiting Bounded Rationality in Risk-based Cyber Camouflage Games”.

2020 Best Paper Award. 53rd Hawaii International Conference on System Sciences (HICSS; January 8-10, 2020) - Digital Government Track - "Adaptive cyber deception: Cognitively informed signaling for cyber defense" (from Cyber Deception for Defense Minitrack).

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as of 11-Jan-2023

## Protocol Activity Status:

**Technology Transfer:** Potential technology transfer:

- 1) Augmented NodeGame: a platform for network experimentation over the web (Gonzalez, Morrison, Bailetti)
- 2) PyIBL: An IBL modeling architecture for network science (Gonzalez, Ben-Asher, Morrison, in preparation; DDMLab, 2016) (<http://www.hss.cmu.edu/departments/sds/ddmlab/downloads.html#pyibl>)

## PARTICIPANTS:

**Participant Type:** Graduate Student (research assistant)

**Participant:** Sabina Sloman

**Person Months Worked:** 12.00

**Funding Support:**

Project Contribution:

National Academy Member: N

**Participant Type:** Graduate Student (research assistant)

**Participant:** Erin McCormick

**Person Months Worked:** 15.00

**Funding Support:**

Project Contribution:

National Academy Member: N

**Participant Type:** Postdoctoral (scholar, fellow or other postdoctoral position)

**Participant:** Efrat Aharonov

**Person Months Worked:** 12.00

**Funding Support:**

Project Contribution:

National Academy Member: N

**Participant Type:** Postdoctoral (scholar, fellow or other postdoctoral position)

**Participant:** Korosh Mahmoody

**Person Months Worked:** 15.00

**Funding Support:**

Project Contribution:

National Academy Member: N

**Participant Type:** Postdoctoral (scholar, fellow or other postdoctoral position)

**Participant:** Hanshu Zhang

**Person Months Worked:** 12.00

**Funding Support:**

Project Contribution:

National Academy Member: N

**Participant Type:** Postdoctoral (scholar, fellow or other postdoctoral position)

**Participant:** Farnaz Tehranchi

**Person Months Worked:** 12.00

**Funding Support:**

Project Contribution:

National Academy Member: N





**RPPR Final Report**  
as of 11-Jan-2023

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** . 41th Annual Meeting of the Cognitive Science Society &#x28;CogSci 2019&#x29;.  
Date Received: Conference Date: 24-Jul-2019 Date Published: 24-Jul-2019  
Conference Location: Montreal, CA  
**Paper Title:** Emergence of Collective Cooperation from Selfish-Imitation and Selfish-Attachment  
**Authors:** Mahmoodi, K. & Gonzalez, C  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** ACM Conference on Collective Intelligence.  
Date Received: 14-Jul-2019 Conference Date: 13-Jun-2019 Date Published: 13-Jun-2019  
Conference Location: Pittsburgh, PA  
**Paper Title:** Selfishness Drives Collective Cooperation and Network Formation  
**Authors:** Mahmoodi, K. & Gonzalez, C  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** ACM Conference on Collective Intelligence.  
Date Received: Conference Date: 13-Jun-2019 Date Published: 13-Jun-2019  
Conference Location: Pittsburgh, pa  
**Paper Title:** Individual and Group-Level Exploration in a Collective Search Task.  
**Authors:** Sloman, S., Goldstone, R., & Gonzalez, C  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 0-Other  
**Conference Name:** 42nd Annual Meeting of the Cognitive Science Society (CogSci 2020).  
Date Received: 09-Aug-2020 Conference Date: 29-Jul-2020 Date Published: 01-Aug-2020  
Conference Location: virtual meeting  
**Paper Title:** Exploring Dynamic Decision Making Strategies with Recurrence Quantification Analysis  
**Authors:** McCormick, E., Blaha, L., & Gonzalez, C  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 0-Other  
**Conference Name:** 53rd Annual Meeting of the Society for Mathematical Psychology (MathPsych 2020)  
Date Received: 09-Aug-2020 Conference Date: 20-Jul-2020 Date Published: 31-Aug-2020  
Conference Location: virtual conference  
**Paper Title:** Analyzing variability in instance-based learning model predictions using recurrence quantification analysis.  
**Authors:** McCormick, E., Blaha, L., & Gonzalez, C  
Acknowledged Federal Support: **Y**

**RPPR Final Report**  
as of 11-Jan-2023

**Partners**

,

I certify that the information in the report is complete and accurate:

Signature: Cleotilde Gonzalez

Signature Date: 4/19/22 2:54PM

**FINAL REPORT Requirement for Proposal Number: 70878-NS, Agreement Number: W911NF-17-1-0431**

Final Report for **Contract Number: W911NF1710431 - Dates Covered: Aug, 25 2017 to Aug, 24 2021**

**Project Title:** Scaling up models of decisions from experience: Information and incentives in networks

**Grant/Contract #:** W911NF-17-1-0431

**PI Name and University:**

Prof. Cleotilde Gonzalez  
Research Professor of Decision Science  
Founding Director of Dynamic Decision Making Laboratory  
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Fax: 412-268-6938  
E-mail: [coty@cmu.edu](mailto:coty@cmu.edu)  
[www.cmu.edu/ddmlab](http://www.cmu.edu/ddmlab)

**Major Goals**

A description of the major goals of the project.

Major Goals are determined by agreement between the researcher and the sponsor.

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In this research we built upon the insights of research of Decisions from Experience (DfE), developments in network science and collective intelligence research to create models of collective behavior that are emergent from individual cognition.

Models that start with strong representations of individual behavior should be able to explain and make more accurately represent the aggregate effects of network-based tasks, compared to network science models that mostly assume simple and non-cognitive agents.

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- 2) Scaling up experimentation from individuals to groups. – Although executing experiments in large groups may seem like something that psychologist “should have figured out”, the reality is that the execution of large team experiments and the technology behind such endeavor are relatively new and the developments are relatively recent.
- 3) Scaling up cognitive models of learning and DfE to learning and DfE in groups. – Most well-known cognitive models of learning represent individual learning. We scale up current Instance-Based Learning (IBL) models of learning by building on current efforts to expand the cognitive theories and models of decisions from experience in simple social situations. A new theoretical integration is expected to provide understanding of how people appraise their own actions and actions of others when making decisions from experience, and a clarification of the role of information and the incentives in a network.

### **Accomplished under Goals**

A description of what was accomplished under the goals during the reporting period.

Text Only. A PDF document can be uploaded in the "Upload" section.

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Overall, this project produced 12 publications; 6 journal articles and 6 conference proceedings publications.

During the first year we analyzed human data reported and collected in team studies conducted by Mason, Jones, and Goldstone (2008) to demonstrate how the dynamics emerging from various network structures and function complexity suggest the emergence

of exploration and exploitation in networks. We also proposed a model of dynamic decision-making by networked individuals in which agents probabilistically select from all available options, in contrast to models in which choices are made among explicitly encoded strategies. We observe exploitation-exploration trade-offs in human networks and explain the decrease of exploration and increase in exploitation over time using cognitive models.

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During the second year we invested our efforts in: (1) conducting a set of experiments of pairs and groups; (2) analyzing existing data sets to investigate of learning and decision making of individuals and groups, particularly the concept of exploration-exploitation in problem solving tasks done in groups; (3) improve our Python IBL modeling architecture (PyIBL) to address the possibility of creating models that involve multiple IBL agents; (4) generate new agent-based models, independent form IBL, to propose how emergent group behavior may form from individual self-interest decisions.

During the third year of this grant we invested our efforts in: (1) Emergence of cooperation by trusting other's decisions; (2) generate new agent-based algorithms that demonstrate the emergence of collective intelligence from individual selfish behavior; (3) explore variability and aggregation in models; (4) analyze existing data sets to investigate of learning and decision making of individuals and groups, particularly the concept of exploration-exploitation in problem solving tasks done in groups.

### **Training Opportunities**

A description of Opportunities for training during the reporting period.

Nothing to Report

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This project supported two Ph.D. students in Social and Decision Sciences. They were both trained in Cognitive Modeling, particularly introduced to Instance-Based Learning Models and Bayesian approaches. After graduation, Erin McCormick has continued her research career at the Air Force Research Laboratories.

This grant also supported four Post-Doctoral fellows. The post-docs were introduced to cognitive modeling and experimental approaches for testing and verifying predictions of an agent-based model.

### **Results Dissemination**

A description of dissemination during the reporting period.

Nothing to Report  
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1. Konstantinidis, E., Harman, J.L. & Gonzalez, C. (2022). Patterns of choice adaptation in dynamic risky environments. *Memory & Cognition*. <https://doi.org/10.3758/s13421-021-01244-4>.
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4. Mahmoodi, K., West, B. J., & Gonzalez, C., (2020). Selfish Algorithm and Emergence of Collective Intelligence. *Journal of Complex Networks*. Volume 8, Issue 3, June 2020, cnaa019, <https://doi.org/10.1093/comnet/cnaa019>
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7. Sloman, S., Goldstone, R., & Gonzalez, C. (2022). A cognitive computational model of collective search with social information. *The fifth Multi-disciplinary Conference on Reinforcement Learning and decision Making (RLDM 2022)*. Brown University, Providence, RI, USA, June 8-11, 2022.
8. McCormick, E., Blaha, L., & Gonzalez, C (2020). Analyzing variability in instance-based learning model predictions using recurrence quantification analysis. *53<sup>rd</sup> Annual Meeting of the Society for Mathematical Psychology (MathPsych 2020)*. July 20-July 31, Virtual meeting.
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12. Sloman, S., Goldstone, R., & Gonzalez, C. (2019). Individual and Group-Level Exploration in a Collective Search Task. ACM Conference on *Collective Intelligence*. June 13-14, 2019, Carnegie Mellon University. Pittsburgh, PA, USA.

### Honors and Awards

Honors and Awards received during the reporting period.

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- 2021 ***Lifetime Fellow of the Cognitive Science Society***. Formal recognition at the 2021 Cognitive Science Society annual meeting, Vienna, Austria.
- 2020 ***Best Paper Award***. International Conference on Decision and Game Theory for Security (GameSec; October 26-30, 2020) – “Exploiting Bounded Rationality in Risk-based Cyber Camouflage Games”.
- 2020 ***Best Paper Award***. 53rd Hawaii International Conference on System Sciences (HICSS; January 8-10, 2020) - Digital Government Track - "Adaptive cyber deception: Cognitively informed signaling for cyber defense" (from Cyber Deception for Defense Minitrack).

### Technology Transfer (patent applications, inventions, licenses, interaction with DoD laboratories)

Technology Transfer

Nothing to Report

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Potential technology transfer:

- 1) Augmented NodeGame: a platform for network experimentation over the web (Gonzalez, Morrison, Bailetti)
- 2) PyIBL: An IBL modeling architecture for network science (Gonzalez, Ben-Asher, Morrison, in preparation; DDMLab, 2016) (<http://www.hss.cmu.edu/departments/sds/ddmlab/downloads.html#pyibl>)

### Participants

Please be sure to list all supported participants including: Undergraduate Student, Graduate Student (research assistant), PD/PI, Co PD/PI, Co-Investigator, Faculty, Community College Faculty, Technical School Faculty, K-12 Teacher, Postdoctoral (scholar, fellow or other postdoctoral

position), Other Professional, Technician, Staff Scientist (doctoral level), Statistician, Non-Student Research Assistant, Technical School Student, High School Student, Consultant, Research Experience for Undergraduates (REU) Participant, Other (specify)

### Graduate Students

1. Sloman, Sabina, Department of Social and Decision Sciences, 2017-2018.
2. McCormick, Erin, *Decisions under time pressure*. 2021. Department of Social and Decision Sciences, Carnegie Mellon University. 2015-present. My role: Co-Chair of Ph.D. dissertation committee.
3. Dr. Farnaz Tehranchi, October 2020-August 2021. Ph.D. Computer science (2020), Penn State University, State College, PA. Dr. Tehranchi took an Assistant Professor position in the School of Engineering and Design, Technology and Professional Programs at Penn State University.
4. Dr. Hanshu Zhang, September 2019- August 2020. Ph.D. Human Factors and Industrial/Organizational Psychology (2019), Wright State University. Dr. Zhang took an Assistant Professor position in the school of Psychology at the Central China Normal University in Wuhan, China.
5. Dr. Korosh Mahmoody, September 2018-June 2020. Ph.D. Physics (2018), University of North Texas.
6. Dr. Efrat Aharonov, September 2016 – August 2018. Ph. D. Psychology, Ben-Gurion University of Negev, Israel. Dr. Aharonov took a Researcher Position at CET-Center for educational Technology.

### Papers:

1. Konstantinidis, E., Harman, J.L. & Gonzalez, C. (2022). Patterns of choice adaptation in dynamic risky environments. *Memory & Cognition*. <https://doi.org/10.3758/s13421-021-01244-4>.
2. McCormick, E., Cheyette, S., & Gonzalez, C. (2022). Choice Adaptation to Changing Environments: Trends, Feedback and Awareness of Change. *Memory & Cognition* (In Press).
3. Sloman, S. J., Goldstone, R., & Gonzalez, C. (2021). A Social Interpolation Model of Group Problem-Solving. *Cognitive science*. 45(12), e13066. <https://doi.org/10.1111/cogs.13066>
4. Mahmoodi, K., West, B. J., & Gonzalez, C., (2020). Selfish Algorithm and Emergence of Collective Intelligence. *Journal of Complex Networks*. Volume 8, Issue 3, June 2020, cnaa019, <https://doi.org/10.1093/comnet/cnaa019>
5. Rajivan, P., Aharonov-Majar, E., Gonzalez, C. (2020). Update now or later? Effects of experience, cost, and risk preference on update decisions. *Journal of Cybersecurity*., 6(1). <https://doi.org/10.1093/cybsec/tyaa002>

6. Aharonov-Majar, E., Rajivan, P., Gonzalez, C., Erev, I. (2019). The impact of variability and prechoice experience on taking safety measures: The case of security updates. *Journal of Behavioral Decision Making*. 2019;1-12, <https://doi.org/10.1002/bdm.2131>
7. Sloman, S., Goldstone, R., & Gonzalez, C. (2022). A cognitive computational model of collective search with social information. *The fifth Multi-disciplinary Conference on Reinforcement Learning and decision Making (RLDM 2022)*. Brown University, Providence, RI, USA, June 8-11, 2022.
8. McCormick, E., Blaha, L., & Gonzalez, C (2020). Analyzing variability in instance-based learning model predictions using recurrence quantification analysis. *53<sup>rd</sup> Annual Meeting of the Society for Mathematical Psychology (MathPsych 2020)*. July 20-July 31, Virtual meeting.
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