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14. ABSTRACT
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# RPPR Final Report

## as of 20-Dec-2019

Agency Code:

Proposal Number: 68745MA

**Agreement Number: W911NF-16-1-0088**

**INVESTIGATOR(S):**

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**Report Date:** 31-Dec-2019

Date Received: 20-Dec-2019

**Final Report** for Period Beginning 01-Apr-2016 and Ending 30-Sep-2019

**Title:** Multimodal Subspace Learning and Modeling of Complex Systems

**Begin Performance Period:** 01-Apr-2016

**End Performance Period:** 30-Sep-2019

**Report Term:** 0-Other

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**STEM Degrees:** 10

**STEM Participants:** 10

**Major Goals:** This project deals with the modeling of multimodal data. In the era of big data, one might ask if multimodal data can provide any type of information that can't be obtained with a single modality. We recently addressed such question, and formally showed the answer to be yes, and even detailed cases when in theory multimodality is needed and when it is not. Beyond such important foundations, multimodal data is critical when data is scarce, noisy, and uncertain, as it is common in the Department of Defense applications, challenges often ignored in the current big data research emphasis. Different modalities can help to do joint inference, as for example here addressed in the network analysis case. Another example of the potential of multimodal data is our recent work for arousal and emotion analysis, where the combination of multimodal images allows to produce at extremely low-cost results that were possible only with high-end devices before. Moreover, often the data available for training is from a very different modality than the one for testing, as in the case of infrared face recognition discussed in this project. Finally, connections between modalities goes beyond recognition, and inferring a condition from unexpected data sources, as we recently did for individual emotion analysis via tweeter, is of paramount importance in disciplines ranging from marketing to health care and defense. The exploitation of multimodal data is therefore one of the unifying themes of this project. We should note that in this project we want to consider both usual and unusual sources of multimodal data, including but not limited to airborne data, ground data, RGB and infrared data, tweeter, Internet traffic, images and videos from the media, and audio. Moreover, with a bit of abuse of notation, we consider multiple instances of the same modality, e.g., population studies, as "multimodal." This is both because considering the models here studied, both multiple-instances and multimodal can be studied with the same tools and because multiple-instances are often so diverse, e.g., due to noise and acquisition variability, that considering them as multimodal is beneficial. This includes for example images or video taken from multiple cameras, a critical aspect for example in wide area surveillance and surveillance/monitoring from multiple personal cameras.

The second unifying theme is the underlying mathematical foundation we develop and exploit, sub-space modeling. These mathematical tools have been demonstrated by many researchers, including the PI, to be very powerful both for theoretical analysis and state-of-the-art practical applications. We develop and bring tools from subspace modeling in the form of learning multimodal low-rank representations, modeling multimodal sparse networks, and solving for big data matrix decompositions.

Finally, all the work has efficiency behind it, this being manifested from the development of memory and computational efficient hashing forests to the development of a novel algorithm for non-negative matrix factorization.

## RPPR Final Report as of 20-Dec-2019

While developing fundamental theory and computational tools, we address critical problems such as multimodal face recognition, dynamic multimodal graph inference, and multimodal network analysis. The entire project is in collaboration and motivated in part by close interactions with the Department of Defense, including ARL. Some of these collaborations will be further detailed below.

The overall goal is to efficiently exploit the multimodal data to help in making a decision, being this recognizing an individual or understanding communities or detecting anomalies.

This project will develop a comprehensive framework for modeling multimodal complex and dynamic data. As demonstrated throughout the document, to advance the state-of-the-art in the important applications here addressed, the incorporation of novel analysis and computation tools is critical. While the goal is to deliver general and fundamental frameworks, that form the basis for numerous and diverse applications, we here concentrate on applications coming from image and video analysis, text, and networks. These applications will be also addressed considering the scenario of significantly reduced training data, an area widely ignored in the era of big data, but critical for Department of Defense applications where data is limited and costly. Close interactions with the Department of Defense in general and the Army in particular will help to constantly deliver the technological advances as well as to dynamically shape this research effort. This follows our extensive experience reflected in numerous technology transfers to entities ranging from NRL to NGA and ARL, as detailed above.

**Accomplishments:** As reported in the annual progress report and the extensive publications, the project has achieved all its goals and beyond. This includes not only scientific publications (over 60 in peer reviewed journals/conferences) but also patents, technology transfers, and opening of new directions of research.

The scientific publications are listed in the attached document.

The patents include:

G. Sapiro, Q. Qiu, and A. Bronstein,

``System and methods for large scale face identification and verification,"

U.S. Patent, November 2018.

M. Delbracio and G. Sapiro,

``System and methods for burst image deblurring,"

U.S. Patent 9,998,666, June 2018.

G. Sapiro, N. Harel, Y. Duchin, and J. Kim,

``Method for a brain region location and prediction,"

U.S. Patent 9,600,778, March 2017.

N. Harel and G. Sapiro,

``Methods and systems for high-resolution brain image pipeline and database program,"

U.S. Patent 9,412,076, July 2016.

Technology transfers and licenses include to Adobe, Apple, SmartFaceID, Duke Health, DoD (multiple recipients as detailed in annual reports).

Entire new scientific frameworks discussed in previous reports and publications include:

- Deep learning with decomposable filters.
- Invariance in deep learning.
- Low-rank embedding and learning.
- Semantic hashing.
- Learning and manifold regularization.
- Behavioral analysis via computer vision and machine learning.
- Stochastic deep learning.

All the above works include new theory, new computational tools, and state-of-the-art results. The contributions are therefore not just about getting better results for a particular dataset, but providing universal frameworks broadly applicable.

Finally, the work opened new venues of research, including:

## RPPR Final Report as of 20-Dec-2019

- Privacy as a collaborative compromise between user-defined utility and privacy.
- Fairness as a Pareto optimality framework.
- Unification theoretical direction between privacy, causality, fairness, transfer learning, and robustness.
- Merging of deep learning with more traditional frameworks such as dictionary learning and hashing.

To recapp, this project delivered all the expected results (via publications and technology transfers) and opened numerous new directions for research.

**Training Opportunities:** We have trained 3 high-school students (all later on accepted to top colleges), ~10 undergraduate students, ~10 graduate students (those that graduated are currently either in Academia or companies such as Google, DeepMind, Raytheon), and ~5 postdocs (also currently in Academia or industry). The project provided a unique opportunity for vertically and horizontally integrated research.

The individual names of the trainees are included in the "Participants" sections in the annual reports.

We had additional training via Coursera (over 200,000 students) and dissemination.

**Results Dissemination:** As with the other components of the project, dissemination has been very unique. This includes tools being used for several thousands patients at Duke Health and popular science articles/videos:

<https://www.wired.com/brandlab/2019/05/researchers-using-machine-learning-screen-autism-children/>

[https://www.youtube.com/watch?time\\_continue=17&v=YQpTlnWYAqE&feature=emb\\_logo](https://www.youtube.com/watch?time_continue=17&v=YQpTlnWYAqE&feature=emb_logo)  
(watched over 1 million times between all published sources)

Additional earlier dissemination results, including technology transfers, are discussed in the annual reports.

**Honors and Awards:** [2015-2016] Distinguished Israel Pollack Lecturer, Technion, Haifa.

[2017:] Stansell Family Distinguished Research Award.

[2017:] International Society for Autism Research - IMFAR 2017, Cultural Diversity Award, A. J. Kumm, K. Campbell, S. Marsan, J. Hashemi, S. Espinosa, R. Bloomfield, G. Dawson, G. Sapiro, H. Egger, and P. J. de Vries, "Feasibility of a smartphone application to identify young children at risk for Autism Spectrum Disorder in a low-income community setting in South Africa."

[2018:] Plenary Speaker, SIAM Annual Meeting, July 2018.

[2018:] Fellow, American Academy of Arts and Sciences.

[2019:] Microsoft Data Science Investigator.

[2019:] Test of Time Award, International Conference Machine Learning 2019, for the paper J. Mairal, F. Bach, J. Ponce, and G. Sapiro, "Online dictionary learning for sparse coding," International Conference Machine Learning, Montreal, Canada, June 2009.

[2019:] Best Paper Award, Autonomous Driving ICCV Workshop, Z. Wang, S. Ding, Y. Li, M. Zhao, S. Roychowdhury, A. Wallin, G. Sapiro, and Q. Qiu, "Range adaptation for 3D object detection in LiDAR," South Korea, October 2019.

**Protocol Activity Status:**

**Technology Transfer:** Please see accomplishment sections and previous annual reports.

**PARTICIPANTS:**

**RPPR Final Report**  
as of 20-Dec-2019

**Participant Type:** PD/PI

**Participant:** Guillermo Sapiro

**Person Months Worked:** 12.00

**Funding Support:**

Project Contribution:

International Collaboration:

International Travel:

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Other Collaborators:

**ARTICLES:**

**Publication Type:** Journal Article

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Publication Location:

**Article Title:** Patient-specific anatomical model for deep brain stimulation based on 7 Tesla MRI

**Authors:** Duchin, Shamir, Patriat, Kim, Vitek JL, Sapiro G, Harel N.

**Keywords:** Image processing, brain surgery

**Abstract:** OBJECTIVE: Deep brain stimulation (DBS) requires accurate localization of the anatomical target structure, and the precise placement of the DBS electrode within it. Ultra-high field 7 Tesla (T) MR images can be utilized to create patient-specific anatomical 3D models of the subthalamic nuclei (STN) to enhance pre-surgical DBS targeting as well as post-surgical visualization of the DBS lead position and orientation. We validated the accuracy of the 7T imaging-based patient-specific model of the STN and measured the variability of the location and dimensions across movement disorder patients. METHODS: 72 patients who underwent DBS surgery were scanned preoperatively on 7T MRI. Segmentations and 3D volume rendering of the STN were generated for all patients. For 21 STN-DBS cases, microelectrode recording (MER) was used to validate the segmentation. For 12 cases, we computed the correlation between the overlap of the STN and volume of tissue activated (VTA) and the monopolar review for a

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Peer Reviewed: Y

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**Journal:** Hum Brain Mapp.

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Publication Identifier: 10.1002/hbm.24404

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Publication Location:

**Article Title:** Automatic localization of the subthalamic nucleus on patient-specific clinical MRI by incorporating 7 T MRI and machine learning: Application in deep brain stimulation

**Authors:** Kim J, Duchin Y, Shamir RR, Patriat R, Vitek J, Harel N, Sapiro G

**Keywords:** 7T MR imaging; deep brain stimulation; machine learning; neuromodulation; patient-specific sub-region targeting; subthalamic nucleus

**Abstract:** Deep brain stimulation (DBS) of the subthalamic nucleus (STN) has shown clinical potential for relieving the motor symptoms of advanced Parkinson's disease. While accurate localization of the STN is critical for consistent across-patients effective DBS, clear visualization of the STN under standard clinical MR protocols is still challenging. Therefore, intraoperative microelectrode recordings (MER) are incorporated to accurately localize the STN. However, MER require significant neurosurgical expertise and lengthen the surgery time. Recent advances in 7 T MR technology facilitate the ability to clearly visualize the STN. The vast majority of centers, however, still do not have 7 T MRI systems, and fewer have the ability to collect and analyze the data. This work introduces an automatic STN localization framework based on standard clinical MRIs without additional cost in the current DBS planning protocol. Our approach benefits from a large database of 7 T MRI and its clinical MRI pairs.

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**RPPR Final Report**  
as of 20-Dec-2019

**CONFERENCE PAPERS:**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 2-Awaiting Publication  
**Conference Name:** International Conference on Human-Computer Interaction, Canada, July 2016.  
Date Received: 14-Jul-2016 Conference Date: 17-Jul-2016 Date Published: 17-Jul-2016  
Conference Location: Canada  
**Paper Title:** Synthesis-based Low-cost Gaze Analysis  
**Authors:** Zhuoqing Chang, Qiang Qiu, and Guillermo Sapiro  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** AISTATS  
Date Received: 26-Jul-2017 Conference Date: 01-Jul-2017 Date Published:  
Conference Location: United States  
**Paper Title:** Generalization Error of Invariant Classifiers  
**Authors:** J. Sokolic, R. Giryes, G. Sapiro, M. Rodrigues  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** IEEE-CVPR  
Date Received: 26-Jul-2017 Conference Date: 25-Jul-2017 Date Published:  
Conference Location: United States  
**Paper Title:** Nonnegative Matrix Underapproximation for Robust Multiple Model Fitting  
**Authors:** M. Tepper, G. Sapiro  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 0-Other  
**Conference Name:** IEEE 9th Sensor Array and Multichannel Signal Processing Workshop  
Date Received: 26-Jul-2017 Conference Date: 31-Jul-2016 Date Published:  
Conference Location: Brazil  
**Paper Title:** TELL ME WHERE YOU ARE AND I TELL YOU WHERE YOU ARE GOING: ESTIMATION OF DYNAMIC MOBILITY GRAPHS  
**Authors:** M. Fiori, P. Muse, M. Tepper, G. Sapiro  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** IEEE-CVPR  
Date Received: Conference Date: 24-Jul-2017 Date Published:  
Conference Location: Hawaii  
**Paper Title:** Not Afraid of the Dark: NIR-VIS Face Recognition via Cross-spectral Hallucination and Low-rank Embedding  
**Authors:** J. Lezama, Q. Qiu, G. Sapiro  
Acknowledged Federal Support: **Y**

**RPPR Final Report**  
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**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** IEEE-CVPR  
Date Received: 26-Jul-2017 Conference Date: 24-Jul-2017 Date Published:  
Conference Location: Hawaii  
**Paper Title:** Self-learning Scene-specific Pedestrian Detectors using a Progressive Latent Model  
**Authors:** Q. Ye, T. Zhang, Q. Qiu, J. Chen, G. Sapiro, B. Zhang  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** IEEE-CVPR  
Date Received: 26-Jul-2017 Conference Date: 24-Jul-2017 Date Published:  
Conference Location: Hawaii  
**Paper Title:** Deep Video Deblurring for Hand-held Cameras  
**Authors:** S. Su, M. Delbracio, J. Wang, G. Sapiro, W. Heidrich, O. Wang  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** ICCV International Workshop on Cross-domain Human Identification  
Date Received: 22-Jun-2018 Conference Date: 01-Oct-2017 Date Published:  
Conference Location: Italy  
**Paper Title:** Intelligent Synthesis Driven Model Calibration: Framework and Face Recognition Application  
**Authors:** J. Hashemi and Q. Qiu and G. Sapiro  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** CVPR 2018  
Date Received: 22-Jun-2018 Conference Date: 18-Jun-2018 Date Published:  
Conference Location: Salt Lake City  
**Paper Title:** LDMNet: Low Dimensional Manifold Regularized Neural Networks  
**Authors:** Wei Zhu, Qiang Qiu, Jiaji Huang, Robert Calderbank, Guillermo Sapiro, and Ingrid Daubechies  
Acknowledged Federal Support: **Y**

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**Conference Name:** Computer Vision Pattern Recognition CVPR  
Date Received: 22-Jun-2018 Conference Date: 18-Jun-2018 Date Published:  
Conference Location: Salt Lake City  
**Paper Title:** OLE: Orthogonal Low-rank Embedding, A Plug and Play Geometric Loss for Deep Learning  
**Authors:** J. Lezama, Q. Qiu, P. Muse, G. Sapiro  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** Proc. IEEE ICASSP 2018  
Date Received: 22-Jun-2018 Conference Date: 01-Apr-2018 Date Published:  
Conference Location: Canada  
**Paper Title:** A PRACTICAL GUIDE TO MULTI-IMAGE ALIGNMENT  
**Authors:** C. Aguerrebere, M. Delbracio, A. Bartesaghi, G. Sapiro  
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**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** International Conference Machine Learning  
Date Received: 22-Jun-2018 Conference Date: 16-Jul-2018 Date Published:  
Conference Location: Sweeden  
**Paper Title:** Deep Neural Network with Decomposed Convolutional Filters  
**Authors:** Qiang Qiu, Xiuyuan Cheng<sup>L</sup>, Robert Calderbank, and Guillermo Sapiro  
Acknowledged Federal Support: **Y**

**Publication Type:** Conference Paper or Presentation **Publication Status:** 1-Published  
**Conference Name:** International Conference Learning Representations  
Date Received: 15-May-2019 Conference Date: 06-May-2019 Date Published: 06-May-2019  
Conference Location: New Orleans  
**Paper Title:** ROTDCF: DECOMPOSITION OF CONVOLUTIONAL FIL-TERS FOR ROTATION-EQUIVARIANT DEEP NETWORKS  
**Authors:** Xiuyuan Cheng, Qiang Qiu, Robert Calderbank, Guillermo Sapiro  
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**Conference Name:** International Conference Learning Representations  
Date Received: 15-May-2019 Conference Date: 02-Jul-2018 Date Published: 02-Jul-2018  
Conference Location: Canada  
**Paper Title:** DCFNet: Deep neural network with decomposed convolutional filters  
**Authors:** Q. Qiu, X. Cheng, R. Calderbank, and G. Sapiro  
Acknowledged Federal Support: **Y**

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**Conference Name:** International Conference Machine Learning  
Date Received: 15-May-2019 Conference Date: 10-Jun-2019 Date Published: 11-Jun-2019  
Conference Location: CA, USA  
**Paper Title:** Adversarially Learned Representations for Information Obfuscation and Inference  
**Authors:** M. Bertran, N. Martinez, M. Rodriguez, G. Reeves, Q. Qiu, A. Papadaki, G. Sapiro  
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**Conference Name:** International Conference Image Processing  
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Conference Location: Taiwan  
**Paper Title:** Optimal shrinkage for non-contact photoplethysmogram and instantaneous heart rate estimation from infrared face video  
**Authors:** N. Martinez, M. Bertran, G. Sapiro, H.-T. Wu  
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**Conference Name:** IEEE Computer Vision Pattern Recognition  
Date Received: 05-May-2019 Conference Date: 18-Jun-2018 Date Published: 18-Jun-2018  
Conference Location: Salt Lake City  
**Paper Title:** OL 'E: Orthogonal Low-rank Embedding, A Plug and Play Geometric Loss for Deep Learning  
**Authors:** J. Lezama, Q. Qiu, P. Muse, G. Sapiro  
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**Conference Name:** European Conference Computer Vision  
Date Received: 05-May-2019 Conference Date: 17-Sep-2018 Date Published: 17-Sep-2018  
Conference Location: Germany  
**Paper Title:** ForestHash: Semantic Hashing With Shallow Random Forests and Tiny Convolutional Networks  
**Authors:** Q. Qiu, J. Lezama, A. Bronstein, G. Sapiro  
Acknowledged Federal Support: **Y**

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**Conference Name:** IEEE Computer Vision Pattern Recognition  
Date Received: 05-May-2019 Conference Date: 18-Jun-2018 Date Published: 18-Jun-2018  
Conference Location: Salt Lake City  
**Paper Title:** LDMNet: Low Dimensional Manifold Regularized Neural Networks  
**Authors:** W. Zhu, Q. Qiu, J. Huang, R. Calderbank, G. Sapiro, and I. Daubechies  
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**Conference Name:** International Conference Computer Vision  
Date Received: 06-May-2019 Conference Date: 21-Oct-2019 Date Published: 21-Oct-2019  
Conference Location: Korea  
**Paper Title:** Domain Adaptive Filter Decomposition  
**Authors:** Z. Wang, X. Cheng, Q. Qiu, G. Sapiro  
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**Conference Name:** International Conference Computer Vision  
Date Received: 06-May-2019 Conference Date: 21-Oct-2019 Date Published: 21-Oct-2019  
Conference Location: Korea  
**Paper Title:** Range Adaptation for 3D Object Detection in LiDAR  
**Authors:** Ze Wang, Qiang Qiu, Sihao Ding, Sohini Roychowdhury, Andreas Wallin, Guillermo Sapiro  
Acknowledged Federal Support: **Y**

# PUBLICATIONS

GUILLERMO SAPIRO

December 20, 2019

1. D. Isaev, S. Major, M. Murias, K. Carpenter, D. Carlson, G. Sapiro, and G. Dawson, “Relative average look duration and its association with neurophysiological activity in young children with Autism Spectrum Disorder,” *Scientific Reports*, 2019, to appear.
2. J.M. Fellous, G. Sapiro, A. Rossi, H. S. Mayberg, and M. Ferrante, “Explainable artificial intelligence for neuroscience: Behavioral neurostimulation,” *Frontiers in Neuroscience*, 2019, to appear.
3. H. Azami, S. E. Arnold, S. Sanei, Z. Chang, G. Sapiro, J. Escudero, and A. S. Gupta, “Multiscale fluctuation-based dispersion entropy and its applications to neurological diseases,” *IEEE Access*, 2019, to appear.
4. M. Boverly, G. Dawson, J. Hashemi, and G. Sapiro, “A Scalable off-the shelf framework for measuring patterns of attention in young children and its application in autism spectrum disorder,” *IEEE Transactions on Affective Computing*, 2019, to appear.
5. J. Hashemi, G. Dawson, K. L. H. Carpenter, K. Campbell, Q. Qiu, S. Espinosa, S. Marsan, J. P. Baker, H. L. Egger, and G. Sapiro, “Computer vision analysis for quantification of autism risk behaviours,” *IEEE Transactions on Affective Computing*, 2019, to appear.
6. A. K. Simhal, Y. Zuo, M. M. Perez, D. V. Madison, G. Sapiro, and K. D. Micheva, “Multifaceted changes in synaptic composition and astrocytic involvement in a mouse model of Fragile X Syndrome,” *Scientific Reports*, September 2019.
7. M. Asiedu, A. Simhal, U. Chaudhary, J. Mueller, C. T. Lam, J. W. Schmit, G. Venegas, G. Sapiro, and N. Ramanujam, “Development of

- algorithms for automated detection of cervical pre-cancers with a low-cost, point-of-care, Pocket Colposcope,” *IEEE Transactions Biomedical Imaging* **66:8**, pp. 2306-2318, 2019.
8. W. Zhu, Q. Qiu, J. Lu, I. Daubechies, and G. Sapiro, “Stop memorizing: A data-dependent regularization framework for intrinsic pattern learning,” *SIAM Journal on Mathematics of Data Science (SIMODS)* **1:3**, August 2019.
  9. G. Dawson and G. Sapiro, “The potential for digital behavioral measurement tools to transform the detection and diagnosis of Autism Spectrum Disorder,” *JAMA Pediatrics* **173(4)**, pp. 307, April 2019.
  10. G. Sapiro, J. Hashemi, and G. Dawson, “Computer vision applications to computational behavioral phenotyping: An autism spectrum disorder case study,” *Current Opinion in Biomedical Engineering*, December 2018.
  11. G. Dawson, K. Campbell, J. Hashemi, S. Lippmann, V. Smith, K. Carpenter, H. Egger, S. Espinosa, S. Vermeer, J. Baker, and G. Sapiro, “Atypical postural control can be detected via computer vision analysis in toddlers with autism spectrum disorder,” *Scientific Reports* **8**, November 2018.
  12. J. Kim, Y. Duchin, R. R. Shamir, R. Patriat, J. Vitek, N. Harel, and G. Sapiro, “Automatic localization of the subthalamic nucleus on patient-specific clinical MRI by incorporating 7T MRI and machine learning: Application in deep brain stimulation,” *Human Brain Mapping*, October 2018.
  13. Y. Duchin, R. R. Shamir, J. Kim, J. L. Vitek, G. Sapiro, and N. Harel, “Patient-specific anatomical model for deep brain stimulation based on 7 Tesla MRI,” *PLoS ONE*, August 2018.
  14. A. Simhal, B. Gong, J. S. Trimmer, R. Weinberg, S. Smith, G. Sapiro, and K. Micheva, “A computational synaptic antibody characterization tool for array tomography,” *Frontiers in Neuroanatomy*, July 2018.
  15. H. L. Egger, G. Dawson, J. Hashemi, K. L. H. Carpenter, S. Espinosa, K. Campbell, S. Brotkin, J. Shaich-Borg, Q. Qiu, M. Tepper, J. P.

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