Cédric COLAS, PhD

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Education

Nov 2017 - June 2021 **PhD in Artificial Intelligence**, *INRIA - Flowers Lab*, Bordeaux, FR.
Title: *Towards Vygotskian Autotelic Agents: Learning Skills with Goals, Language and Intrinsically Motivated Deep Reinforcement Learning.* See list of publications below. Defended on June 30, 2021.

2016-2017 **Master in Cognitive Science**, *École Normale Supérieure*, Paris, FR.
Top-tier French university. Main subjects: Cognitive Neuroscience of the Prefrontal Cortex, Human Reasoning, Human Psychology Experimentations, Neuroscience of Consciousness. Results: 16.98/20, ranked 2/48.

2015-2016 **MSc in Biomedical Engineering**, *Imperial College*, London, UK.
Top-tier English university. Neurotechnology Stream. Main subjects: Biomedical Imaging, Speech Processing, Image Processing, Computational Neurosciences, Brain-Machine Interfaces. Results: 78/100, with distinctions.

2013-2016 **BSc and MSc in Electrical Engineering, Computer Science and Telecommunications**, *Supelec*, Gif-sur-Yvette, FR.
Now CentraleSupelec, 2nd best French engineering school (Usine Nouvelle ranking). The biomedical engineering MSc degree was an exchange year unlocking Supélec's MSc. Main subjects: Algorithmic, Signal Processing, Optimization, Statistics, Probability Theory. GPA: 3.7/4.

Research Projects

Nov 2017 - June 2021 **PhD Projects**, *INRIA - Flowers Lab*, Bordeaux, FR.
See list of publications below. Highlights:
- Supervised by Dr. Pierre-Yves Oudeyer and Pr. Olivier Sigaud;
- Technical skills: self-taught in Python, Pytorch, Tensorflow, computing infrastuctures, LaTeX;
- Doctoral training: Ethics, Scientific Integrity, Answer Set Programming, Random Forest, Reproducibility, Ecological Impact of Research, Epistemology of Science;
- Supervision experience: 2 master students, 2 bachelor students;
- Developed collaborations with UberAI labs, Microsoft Research Montreal/Cambridge, OpenAI, SISTM team (Inria) and CNRS.

Jun-Sept 2019 **Research Internship**, *Uber AI Labs*, San Francisco, US.
Project: scaling the Quality-Diversity algorithm *Map-Elites* to Deep Neuroevolution via the use of Evolution Strategies. Highlights:
- Supervised by Dr. Vashisht Madhavan and Dr. Jeff Clune;
- Research experience: International collaboration, in a private research lab in San Francisco;
- Technical skills: use of massively parallel computing (1000 cpus);
- Complementary research skills: Deep NeuroEvolution (deep Genetic Algorithms, Evolution Strategies), Quality-Diversity (Map-Elites, Novelty-Search (NS), NS-ES).
- Led to a publication at GECCO 2020 (see below).

Jan-Jun 2017 **Master Project**, *Brain and Spine Institute - Motivation, Brain and Behavior Lab*, Paris, FR.
Project: computational models of the exploration-exploitation dilemma in a two-armed bandit task using variational Bayesian inference. Highlights:
- Supervised by Dr. Jean Daunizeau;
- Complementary research skills: human cognitive modeling, models of human curiosity, variational Bayesian inference, model selection, navigating cognitive science literature.

May-Sept 2016 **MSc Project**, *Imperial College - Brain and Behaviour Lab*, London, UK.
Project: design of a brain-machine interface using EEG and convolutional neural networks to control an avatar in a video game for the international Cybathlon competition. Highlights:
- Supervised by Dr. Aldo Faisal;
- Technical skills: EEG setup, EEG data processing, Python, Theano, CNNs;
- Research experience: collaborative project with colleague Dr. Pablo Ortega; deployment in an international competition (Cybathlon 2016, Zurich).

Apr 2016	**MSc Project**, *Imperial College - Brain-Machine Interfaces Class*, London, UK.

Project: offline decoding of a monkey's hand trajectories from 98 neuronal spike trains. Highlights:
- Research experience: team project (team of 4);
- Technical skills: feature selection, random forest, linear regression, nearest neighbors;
- Ranked 2nd.

Jul-Aug 2015	**Internship**, *Center of Psychiatry and Neuroscience*, Paris, FR.

Project: I assisted a PhD student in the development of a fear renewal protocol in rats exploring wide environments. I setup the controlled experiment (rat conditioning, camera for movement detection, automatic protocol for stimuli).

Publications (peer-reviewed, main author)

Epidemiology and RL
(1) **Colas, C.**, Hejblum, B., Rouillon, S., Thiébaut, R., Oudeyer, P-Y., Moulin-Frier, C. & Prague, M. (2020). *EpidemiOptim: A Toolbox for the Optimization of Control Policies in Epidemiological Models.* Accepted to **JAIR**. General software library developed in collaboration with epidemiologists to facilitate the design and comparisons of epidemiological models and automatic intervention strategies to fight epidemics. Link: arxiv.org/pdf/2010.04452.pdf. 1 citations.

RL
(2) Akakzia A., **Colas, C.**, Oudeyer, P-Y., Chetouani, M. & Sigaud, O. (2020). *Grounding Language to Autonomously-Acquired Skills via Goal Generation.* Accepted at **ICLR 2021**. An intrinsically motivated agents that builds its own curriculum to solve complex stacking tasks autonomously. Link: arxiv.org/pdf/2006.07185.pdf. Equal contributions of the two first authors. 9 citations.

RL
(3) **Colas, C.**, Akakzia A., Oudeyer, P-Y., Chetouani, M. & Sigaud, O. (2020). *Language-Conditioned Goal Generation: a New Approach to Language Grounding for RL.* Accepted at **LaReL workshop, ICLR 2020**, 2nd best paper. A new model that turns linguistic descriptions into concrete goal embeddings for agents to target. This enables efficient generalization, and behavioral diversity, as several goals can be sampled for a given linguistic description. Link: arxiv.org/pdf/2006.07043.pdf. 3 citations.

Evolutionary Algorithms
(4) **Colas, C.**, Huizinga, J., Madhavan, V., & Clune, J. (2020). *Scaling MAP-Elites to Deep Neuroevolution.* Accepted at **GECCO 2020**. Scaling of the most popular Quality-Diversity algorithm to the era of deep neural networks. New problems can be solved (hard exploration problems, high-dimensional behavioral adaptation). Link: arxiv.org/pdf/2003.01825.pdf. 20 citations.

RL
(5) **Colas, C.**, Karch, T., Lair, N., Dussoux, J. M., Moulin-Frier, C., Dominey, PF. & Oudeyer, P-Y. (2020). *Language as a Cognitive Tool to Imagine Goals in Curiosity-Driven Exploration.* Accepted at **NeurIPS 2020**. The first autotelic agent using language as a cognitive tool to support the imagination of goals. Is currently leading to several PhD and postdoc projects in the lab. Link: arxiv.org/pdf/2002.09253.pdf. 18 citations.

RL
(6) **Colas, C.**, Sigaud, O. & Oudeyer, P-Y. (2018). *CURIOUS: Intrinsically Motivated Modular Multi-Goal Reinforcement Learning.* Accepted at **ICML 2019**. The first autotelic agents based on state-of-the-art deep reinforcement learning methods. It uses automatic curriculum learning to craft its own learning trajectory learn to target multiple goals involving multiple types of affordances. Link: arxiv.org/pdf/1810.06284.pdf. 88 citations.

RL
(7) **Colas, C.**, Sigaud, O. & Oudeyer, P-Y. (2018). *GEP-PG: Decoupling Exploration and Exploitation in Deep Reinforcement Learning Algorithms.* Accepted at **ICML 2018**. First steps to merge developmental robotics autotelic methods with deep reinforcement learning. An intrinsically motivated exploration helps bootstrap a standard Deep RL algorithm. This led to multiple works on decoupling exploration and exploitation in RL. Link: arxiv.org/pdf/1802.05054.pdf. 98 citations.

Publications (peer-reviewed, second author)

RL
(8) Portelas, R., **Colas, C.**, Weng, L., Hofmann, K. & Oudeyer, P-Y. (2020) *Automatic Curriculum Learning For Deep RL: A Short Survey.* Accepted at **IJCAI 2020**. A useful survey and framework to think about automatic curriculum learning methods in deep RL. Link: arxiv.org/pdf/2003.04664.pdf. 33 citations.

RL (9) Portelas, R., **Colas, C.**, Hofmann, K. & Oudeyer, P-Y. (2019). *Teacher Algorithms for Curriculum Learning of Deep RL in Continuously Parameterized Environments.* Accepted at **CoRL 2019**. A novel automatic curriculum learning method to shape agents learning trajectory in complex domains. Link: arxiv.org/pdf/1910.07224.pdf. 30 citations.

RL (10) Fournier P., **Colas, C.**, Chetouani, M. & Sigaud, O. (2019). *CLIC: Curriculum Learning and Imitation for feature Control in non-rewarding environments.* Accepted at **IEEE Transactions on Cognitive and Developmental Systems**. A discrete variant of the CURIOUS algorithm that integrates natural demonstrations. Link: arxiv.org/pdf/1901.09720.pdf. 11 citations.

BCI (11) Ortega, P., **Colas, C.** & Faisal, AA. (2018). *Compact Convolutional Neural Networks for Multi-Class, Personalised, Closed-Loop EEG-BCI.* In 2018 7th **IEEE International Conference on Biomedical Robotics and Biomechatronics** (Biorob) (pp. 136-141). The first BCI to consider CNN implementations to allow disabled people to control machines. Link: ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8487644. 6 citations.

Publications (preprints or in review)

RL (12) Sigaud, O., Caselles-Dupré, H., **Colas, C.**, Akazia, A., Oudeyer, P-Y. & Chetouani, M. (2021). *Towards Teachable Autonomous Agents.* **In review**. An opinion paper on the need for agents that are both intrinsically motivated and interactive (teachable). Link: arxiv.org/pdf/2105.11977.pdf. 0 citation.

RL (13) **Colas, C.**, Karch, T., Sigaud, O. & Oudeyer, P-Y. (2021). *Intrinsically Motivated Goal-Conditioned Reinforcement Learning: a Short Survey.* **In review**. A useful review and framework to think about goal-conditioned RL approaches and their relation to intrinsically motivated learning and the quest for autonomous open-ended agents. Link: arxiv.org/pdf/2012.09830.pdf. 6 citations.

Stats for RL (14) **Colas, C.**, Sigaud, O. & Oudeyer, P-Y. (2019). *A Hitchhiker's Guide to Statistical Comparisons of Reinforcement Learning Algorithms.* A useful comparative study of statistical methods to meaningfully compare RL algorithms, and associated guidelines. Link: arxiv.org/pdf/1904.06979.pdf. 24 citations.

Stats for RL (15) **Colas, C.**, Sigaud, O. & Oudeyer, P-Y. (2018). *How Many Random Seeds? Statistical Power Analysis in Deep Reinforcement Learning Experiments.* A discussion of the lack of statistical testing in the comparison of RL algorithms. Link: arxiv.org/pdf/1806.08295.pdf. 43 citations.

Non-scientific publications

Blog post *Language as a Cognitive Tool: Dall-E, Humans and Vygotskian RL Agents.* March 2021. Link: developmentalsystems.org/language_as_cognitive_tool_vygotskian_rl.

Blog post *Intrinsically Motivated Modular Multi-Goal RL.* March 2020. Link: developmentalsystems.org /curious_intrinsically_motivated_multi_modular_goal_rl.

Blog post *How Many Random Seeds?* February 2020. Link: developmentalsystems.org/how_many_random _seeds.

Blog post *Bootstrapping Deep RL with Population-Based Diversity Search.* February 2020. Link: developmentalsystems.org/bootstraping_rl_with_diversity.

Technological Development

EpidemiOptim Demo — Online demonstration of a pre-trained lockdown policy in the context of simulated COVID19 epidemics. epidemioptim.bordeaux.inria.fr.

EpidemiOptim library — Library interfacing optimization algorithms with models of epidemic propagation. Epidemiological models are wrapped in OpenAI Gym interfaces, making them readily compatible with state-of-the-art optimization algorithms. github.com/flowersteam/epidemioptim.

ME-ES — Software of the ME-ES architecture. github.com/uber-research/Map-Elites-Evolutionary.

Playground — RL learning benchmark. Designed to facilitate the study of systematic generalization in language-conditioned RL architectures. Easy to extend to more objects, more interactions and more complex language. github.com/flowersteam/playground_env.

Imagine	Software of the IMAGINE architecture. github.com/flowersteam/imagine.
Curious	Software of the CURIOUS architecture. github.com/flowersteam/curious.
GEP-PG	Software of the GEP-PG architecture. github.com/flowersteam/geppg.
RL stats	Library providing easy-to-use tools to compare the performance of RL algorithms. Allows the replication of the experiments from *A Hitchhiker's Guide to Statistical Comparisons of Reinforcement Learning Algorithms.* github.com/flowersteam/rl-difference-testing.

Communications

PhD Defense	*Towards Vygotskian Autotelic Learning: Learning Skills with Language, Goals and Intrinsically Motivated Deep Reinforcement Learning.* June 2021 (online). Link: youtube.com/watch?v=x4vS557rhAM.
Invited Talk	EpidemiOptim: A Toolbox for the Optimization of Control Policies in Epidemiological Models. DeepMind Seminar, January 2020 (online).
Conference Talk	*Scaling MAP-Elites to Deep Neuroevolution.* Accepted at GECCO 2020. GECCO conference, July 2020 (online). Link: youtube.com/watch?v=m2peevXlgKY.
Conference Talk	*Language as a Cognitive Tool to Imagine Goals in Curiosity-Driven Exploration.* NeuRIPS conference, December 2020 (online). Link: slideslive.com/38937386/language-as-a-cognitive-tool-to-imagine-goals-in-curiosity-driven-exploration?ref=speaker-28788-popular.
Conference Talk	*CURIOUS: Intrinsically Motivated Modular Multi-Goal Reinforcement Learning.* ICML conference, Long Beach CA (US), June 2019. Link: youtube.videoken.com/embed/v-W4JSWUX28?tocitem=24.
Conference Talk	*GEP-PG: Decoupling Exploration and Exploitation in Deep Reinforcement Learning Algorithms.* ICML conference; Stockholm (SW), June 2018. Link: youtu.be/MK-oAqHjdmg?t=2080.

Grants & Awards

PhD Fellowship	3 years (2018-2021). Co-funded by INRIA and DGA (Direction Général de l'Armement, FR). 59k€ each.
Thesis Award	PhD Thesis Award 2022 from the French AI Association (AfIA).
MSCA Postdoctoral Fellowship	Marie Skłodowska-Curie Postdoctoral Fellowship for 3 years (2022-2025). Obtained for the project *Help Me Grow: Artificial Cognitive Development via Human-Agent Interactions Supported by New Interactive, Intrinsically Motivated Program Synthesis Methods.* 273k€.

Supervision Experience

Feb-Aug 2021	I supervised two 2nd year master student from Univ Paris-Sorbonne (Paris, FR). With one of them, we worked on a new benchmark and dataset to train scene captioners to enhance cutting-edge autotelic reinforcement learning algorithms (to be released soon). With the other, we worked on the addition of minimal social interventions to help autotelic agents explore in a block manipulation domain (publication submitted for review).
Feb-June 2020	I supervised two bachelor students from Ecole de Cognitive (Bordeaux, FR). I mentored them in their project on the parallels between cognitive science and recent developments in autonomous AI systems.
Feb-Aug, 2018	I supervised a 2nd year master student from Ecole Normale Supérieure (Rennes, FR). We worked on coupling curiosity mechanisms with model-based reinforcement learning.

Misc Training & Qualifications

Programming Languages	Python (proficient), Matlab (proficient), LaTeX (proficient), Processing (intermediary), Arduino-C++ (beginner).
Languages	French (native), English (fluent, 1 year in the UK, 4 months in the US), Spanish (beginner).