

Contact Information

address	Donders Institute for Brain, Cognition and Behaviour Centre for Cognition Montessorilaan 3 6525 EN Nijmegen, the Netherlands
phone (office)	+31 (0) 24 36 11777
e-mail	h.denouden@donders.ru.nl
website	hannekenouden.ruhosting.nl

Research Domains

Interests: Decision-making; Motivational control; Reinforcement learning; Fronto-striatal circuits; Computational Psychiatry (compulsivity disorders, OCD, addiction); Neural prediction error coding; Serotonin; Dopamine; Behavioural Pharmacology & Genetics; Neuroimaging (fMRI, (i)EEG).

Quantitative Skills: Advanced (model-based) neuroimaging analysis methods, particularly Dynamic Causal Modelling; Computational modelling of behaviour.

Academic Positions and Education

Donders Institute for Brain Cognition and Behaviour	Assistant professor (Oct 2016 – present) Veni Laureate Fellow (Jul 2012 – present) Senior Researcher (Jan 2015-Sep 2016) Radboud University Nijmegen, Nijmegen, Netherlands
New York University	Postdoctoral Fellow Advisor: Prof. N Daw, Center for Neural Science & Department of Psychology (Jun 2011 – Jun 2013)
Donders Institute for Brain Cognition and Behaviour	Postdoctoral Fellow Advisor: Prof. R. Cools, Radboud University Nijmegen, Nijmegen, Netherlands (April 2009-May 2011)
University College London	Wellcome Trust PhD in Neuroscience , Submitted: April 2009; Defended: July 2009. Thesis: Prediction-error dependent changes during associative learning. Advisors: Prof. KE Stephan, Prof. KJ Friston
Utrecht University	MSc Neuroscience, <i>cum laude</i> (August 2004) Incl. research project at Institute of Cognitive Neuroscience, University College London, and Department of Psychology, Harvard University. Thesis supervisor: Prof. SJ Blakemore, UCL
University College Utrecht	BSc Life Sciences, <i>summa cum laude</i> (Sept 2002) GPA 3.98, 1 st of class Honours thesis in Psychology

Research Grants

2016	Wellcome Trust & Royal Society Henry Dale Fellowship (declined)	£ 940,000
2015	Donders Centre for Cognition Research Fellowship	€ 10,000
2014	Research talent grant by the Netherlands Organisation for Scientific Research (NWO) for a PhD student Project title: Overcoming affective biases of decision-making - Combining neurophysiology, neurostimulation and computational psychology	€ 171,362
2011	Veni grant by the Netherlands Organisation for Scientific Research: Project title: Learning to go - Frontostriatal coupling and the interaction between motivation and action	€ 250,000
2010	AXA Research Fund postdoctoral fellowship Project title: The role of dopamine in learning to approach or avoid - Pharmacological neuroimaging and connectivity in Parkinson's disease (declined because of conflict with VENI grant)	€ 50,000
2004	4 year PhD Neuroscience Wellcome Trust Prize Studentship , University College London	£ 126,000

Research and Training Fellowships

2007	<i>Computational Neuroscience</i> summer school, Okinawa Institute of Science and Technology, Japan	
2006	<i>Schizophrenia and Related Disorders</i> summer school, Cold Spring Harbor Laboratories, USA	
2004	Royal Society Summer studentship with Prof. S.J. Blakemore, UCL, UK	£ 5,000

Honours and Awards

2012	Federation for European Neurosciences Travel Award	€ 750
2009	Brain Travel Award for travel to OHBM with abstract: Striatal prediction error modulates cortical coupling during associative learning.	£ 800
2009	OHBM Student Travel Award with abstract: Striatal prediction error modulates cortical coupling during associative learning.	\$ 800
2006	Brain Connectivity Workshop Travel Grant , Sendai, Japan	£ 1,500
2003	Hersenstichting student travel grants for MSc project on: Adolescent development of the neural circuitry for thinking about intentions.	€ 800
2003	Dutch society for neuropsychology travel grant for MSc project on: Adolescent development of the neural circuitry for thinking about intentions.	€ 1000
2002	Student travel award University College Utrecht for conference on Touch, Blindness and Neuroscience, UNED, Madrid, with abstract: The role of locomotor information in distance reproduction without vision.	€ 500
2002	Class Valedictorian , University College Utrecht. <i>Top grades in class</i>	

Peer-reviewed Journal Publications

‡ indicates equal contribution

H – index (google scholar): 19
I – 10 index (google scholar): 21
Total number of citations: >2000

1. Dirx M, **den Ouden HEM**, Aarts E, Timmer M, Bloem B, Toni I, Helmich R. (2016) Dopamine controls Parkinson's tremor by inhibiting the cerebellar thalamus. *Brain, in press*
2. Dirx M, **den Ouden HEM**, Aarts E, Timmer M, Bloem B, Toni I, Helmich R. (2016) The cerebral network of Parkinson's tremor - an effective connectivity fMRI study. *Journal of Neuroscience* 36(19):5362-72
3. Heinze J, Koopmans PJ, **den Ouden HEM**, Raman SS, Stephan KE (2016). A hemodynamic model for layered BOLD signals. *NeuroImage* 125: 556–570
4. Kroes MCW, Tona KD, **den Ouden HEM**, Vogel S, van Wingen GA, Fernandez G. (2016). How administration of the beta-blocker propranolol prior to extinction can prevent the return of fear. *Neuropsychopharmacology* 41(6):1569-78.
5. **den Ouden HEM**, Swart JC, Schmidt K, Fekkes D, Geurts DEM, Cools R. (2015) Acute serotonin depletion releases motivated inhibition of response vigour. *Psychopharmacology* 232(7): 1303-1312
6. Piray P, **den Ouden HEM**, van der Schaaf ME, Toni I, Cools R. (2015) Dopaminergic modulation of the functional ventrodorsal architecture of the human striatum. *Cerebral Cortex (epub ahead of print)*
7. Van Schouwenburg MR, **den Ouden HEM**, Cools RC (2015). Selective attentional enhancement and inhibition of fronto-posterior connectivity by the basal ganglia during attention switching. *Cerebral Cortex* 25(6):1527-34
8. Sjoerds Z, **den Ouden HEM** (2015). Computationale Psychiatrie. *Neuropraxis* 19(6): 141-152
9. Cook J, **den Ouden HEM**, Hayes C, Cools R. (2014) The social dominance paradox: learning from others when you believe you're self-sufficient. *Current Biology* 24: 2812-2816
10. **den Ouden HEM**, Daw ND, Fernandez G, Elshout JA, Rijpkema M, Hoogman M, Franke B, Cools R (2013). Dissociable effects of serotonin and dopamine on reversal learning. *Neuron*, 80(4):1090-1100
11. Sescousse GS[‡], **den Ouden HEM**[‡] (2013). Gambling rats and gambling addiction: reconciling the role of dopamine in irrationality. *Journal of Neuroscience*, 33(8), 3256-3258
12. Geurts DEM, Huys QJM, **den Ouden HEM**, Cools R (2013) Serotonin and aversive Pavlovian control of instrumental behavior in humans. *Journal of Neuroscience* 33(48),18932-18939
13. Iglesias S, Mathys C, Brodersen KH, Kasper L, Piccirelli M, **den Ouden HEM**, Stephan KE (2013). Hierarchical prediction errors in dopaminergic and cholinergic regions during sensory learning. *Neuron*, 80(2), 519-530
14. Geurts DEM, Huys QJM, **den Ouden HEM**, Cools RC (2013). Aversive Pavlovian control of instrumental behaviour in humans. *Journal of cognitive neuroscience*, 25(9), 1428-1441
15. Volman I, Verhagen L, **den Ouden HEM**, Toni I, Roelofs K (2013). Reduced serotonin transporter availability decreases prefrontal control of the amygdala. *Journal of neuroscience*, 33(21), 8974-8979
16. **den Ouden HEM**, Kok P, De Lange F (2012). Prediction errors in perception, attention and motivation. *Frontiers in Psychology*, 3, 548

17. Crockett MJ, Clark L, Roiser JP, Robinson OJ, Cools RC, Chase HW, **den Ouden H**, Apergis-Schoute A, Campbell-Meikeljohn, Seymour B, Sahakian BJ, Rogers RD, Robbins TW (2012). Converging evidence for central 5-HT effects in acute tryptophan depletion. *Molecular psychiatry*, 17(2), 121-123
18. Van Leeuwen T, **den Ouden HEM**, Hagoort P (2011). Effective connectivity determines subjective experiences in grapheme-color synesthesia. *Journal of Neuroscience*, 31(27), 9879-9884
19. **den Ouden HEM**, Daunizeau J, Roiser J, Friston KJ, Stephan KE (2010). Striatal prediction error drives cortical connectivity changes during associative learning. *Journal of Neuroscience*, 30(9), 3210-3219
- covered in Journal Club article de-Wit et al. *Journal of Neuroscience* 2010.
20. Daunizeau J, **den Ouden HEM**, Pessiglione M, Stephan KE, Kiebel SJ & Friston KJ (2010). Observing the observer(I): Meta-Bayesian models of learning and decision-making. *PLoS One*, 5(12), e15554
21. Daunizeau J, **den Ouden HEM**, Pessiglione M, Stephan KE, Kiebel SJ & Friston KJ (2010). Observing the observer (II): Deciding when to decide. *PLoS One*, 5(12), e15555
22. Van Schouwenburg M, **den Ouden HEM**, Cools RC (2010). The human basal ganglia modulate frontal-posterior connectivity during attention shifting. *Journal of Neuroscience*, 30(29), 9910-9918
23. Roiser JP, Stephan KE, **den Ouden HEM**, Friston KJ, & Joyce EM (2010). Adaptive and aberrant reward signals in the human brain. *NeuroImage*, 50(2), 657-664
24. Stephan KE, Penny WD, Moran RJ, **den Ouden HEM**, Daunizeau J, Friston KJ (2010). Ten simple rules for Dynamic Causal Modelling. *NeuroImage*, 49(4), 3099-3109
25. **den Ouden HEM**, Friston KJ, Daw ND, McIntosh AR, & Stephan KE (2009). A dual role for prediction error in associative learning. *Cerebral Cortex*, 19(5), 1175-1185
26. Roiser JP, Stephan KE, **den Ouden HEM**, Barnes TR, Friston KJ, & Joyce EM (2009). Do patients with schizophrenia exhibit aberrant salience? *Psychological medicine*, 39(2), 199-209
27. Stephan KE, Kasper L, Harrison LM, Daunizeau J, **den Ouden HEM**, Breakspear M, & Friston KJ (2008). Nonlinear dynamic causal models for fMRI. *NeuroImage*, 42(2), 649-662
28. Blakemore S-J, **den Ouden HEM**, Choudhury S, & Frith C (2007). Adolescent development of the neural circuitry for thinking about intentions. *Social Cognitive and Affective Neuroscience*, 2(2), 130-139
29. **den Ouden HEM**, Frith U, Frith C, & Blakemore S-J (2005). Thinking about intentions. *NeuroImage*, 28(4), 787-796
30. **den Ouden HEM**, van Ee ER, & de Haan EH (2005). Colour helps to solve the binocular matching problem. *Journal of Physiology*, 567(Pt 2), 665-671

Invited Book chapters

1. Volman I, **Den Ouden HEM**, Roelofs K. Emotional action control: the role of serotonin in health and disease. In *Genes, Brain and Emotions: From Resilience to Psychopathology*. Editors: Miu AC, Homberg JR, Lesch KP. In pres
2. Cools R, **den Ouden HEM**, Ly V, Huys QJM, Cools R. (*in press*). How do emotions and cognition interact? In Fox, A. S., Lapate, R. C., Shackman, A. J. & Davidson, R. J. (Eds.), *The nature of emotion. Fundamental questions* (2nd edition). New York: Oxford University Press. .
3. **den Ouden HE**, Pijpers WGE, Jehoel S, Wiersma V, Postma A (2004). The role of locomotor information in distance reproduction without vision. In: *Touch, Blindness, and Neuroscience*. Editors: Ballesteros S & Heller. UNED Press, Madrid

Teaching

International Teaching & Workshops

Each course includes lectures and workshops/tutorials. In the methodological courses I teach on a range of topics, including brain connectivity (DCM, PPI) and other model-based fMRI analyses, Bayesian model comparison and behavioural models of reinforcement learning.

2016	Computational Psychiatry Summer School, ETH Zurich, Switzerland
2015-2016	Neurocomputational approaches to Neuroimaging Toolkit, Donders Institute, Nijmegen, Netherlands
2015	Neurocomputational approaches to Decision Making Summer School, Donders Institute, Nijmegen, Netherlands
2013	Summer school on Brain Networks and Neural Communication, Nijmegen, Netherlands
2009 – 2016	Advanced methods in Neuroimaging SPM course, ETH / University of Zurich
2009 – 2014	Advanced SPM short course, NeuroImage Nord, Hamburg, Germany
2009 – 2014	Donders Toolkit for Advanced fMRI Analysis, Donders Institute, Radboud University, Nijmegen.
2007 – 2014	SPM short course, Wellcome Trust Centre for NeuroImaging, UCL, London, UK
2010	A practical and theoretical introduction to fMRI, FENS satellite symposium, Utrecht University
2006 – 2008	Advanced methods in Neuroimaging SPM course, ETH / University of Zurich

(Under)graduate Teaching

2016-2017	Course organiser – Communication in Cognitive Neuroscience. MSc Cognitive Neuroscience, Donders Institute.
-----------	--

Guest Lectures

Each course includes 1.5 hr lecture and exam question preparation/marking

2015 – 2016	MSc Artificial Intelligence, <i>Reinforcement Learning</i> , Computational cognitive neuroscience. Radboud University, Netherlands. Including (development of) practical tutorial.
2014 – 2016	BSc Pharmacology, <i>Dopaminology</i> , Psychopharmacology and Psychopathology, Radboud University, Netherlands

2013 – 2016	MSc Cognitive Neuroscience, <i>Dopamine and Reinforcement learning</i> , Cognitive Control, Radboud University, Netherlands
2015 – 2016	MSc Cognitive Neuroscience, <i>Cruise control or in control? The neural and cognitive mechanisms of reflective versus reflexive decision-making</i> , Cognitive Control, Radboud University, Netherlands
2009 – 2014	MSc Cognitive Neuroscience, <i>Brain Connectivity</i> , Neuroimaging II: Haemodynamic methods, Radboud University, Netherlands. Including tutorial session
2010 – 2013	BSc Computer Science, <i>DCM and fMRI measures of effective connectivity</i> , Brain Dynamics & Connectivity, Radboud University Nijmegen, Netherlands
2007 – 2008	Course organiser, <i>Methods for Dummies</i> , Wellcome Trust Centre for Neuroimaging, University College London, UK

Academic Supervision

Primary supervisor

- Jennifer Swart, Research assistant (2013-2014), PhD Cognitive Neuroscience (2014-present), Radboud University
Overcoming affective biases of decision-making: Combining neurophysiology, neurostimulation and computational psychology.
- Annelies van Nuland (2013 –present), Radboud University
MSc: The role of striatal GABA in human reward processing (cum laude honours)
PhD: Pavlovian and instrumental control in Parkinson's disease – DCCN TopTalent grant
- Dr. Martin Guthrie (2014-2015), post-doctoral research assistant
Dopamine and serotonin genetic pathways in reversal learning
- Emma van Dijk (2016-present), MSc Cognitive Neuroscience, Radboud University
Temporospatial dynamics of pavlovian control, a combined EEG-fMRI study
- Ahnjili Zhuparris (2016-present), MSc Cognitive Neuroscience, Radboud University
Manipulating focus: the case of reversal learning
- Jessica Maatta (2015-2016), MSc Cognitive Neuroscience, Radboud University
Prefrontal theta: Credit assignment or Pavlovian control?
- Joris van Elshout (2009-2010), post-graduate research assistant
current position: PhD candidate at Radboud University (supervisor: prof. Bert van den Berg)
- Kristin Schmidt (2010-2011), post-graduate research assistant
current position: PhD candidate at Oxford University, UK (supervisor: prof. Catherine Harmer)

Co-supervisor

- Marpessa Rietbergen (2015-present), PhD Cognitive Neuroscience, Radboud University
Basal ganglia thalamocortical mechanisms of cognitive control in speaking - Copromotor
- Dirk Geurts (2010-present), PhD Neuroscience / Psychiatrist in training, Radboud University
Neuropharmacology and psychiatry of Pavlovian-Instrumental transfer - Copromotor
- Dr. Martine van Schouwenburg (2009-2011), PhD Cognitive Neuroscience
Fronto-striatal mechanisms of attentional control - Copromotor
current position: postdoctoral fellow at University of Amsterdam (supervisor: Dr. Heleen Slagter)
- Ilse Thompson (2014-2015), MSc Neuroscience & Cognition, Utrecht University,
Striatal GABA and glutamate in reversal learning

Outreach

Online Reinforcement Learning tutorial

I developed an online tutorial to get started with modelling of behavioural data using a reinforcement learning model. This popular Matlab-based tutorial receives **~100 participants per week**, and consists of a full dataset, reversal learning task for the participant to complete, and a full step-by-step introduction to the theoretical and practical aspects of modelling behavioural data:

<http://hannekedenouden.ruhosting.nl/RLtutorial/Instructions.html>

Public Engagement

- Coach, Donders Education Hackathon 2016. 24-Hour hackathon aimed to develop innovative brain-inspired software solutions for education.
- Donders Institute Open Day, Live demonstration experiments: *Mind Reading & Fear in the Brain*, jointly with with Illusionist Victor Mids, Nijmegen, Netherlands, September 2016
- *Leren van je fouten*. Full-day workshop for psychiatric nursing staff, Psychiatrisch Centrum St. Amandus, Beernem, Belgium, March 2011
- *Brain Landing*. Live real-time fMRI experiment. DCCN Nijmegen & Paradiso Pop podium, Amsterdam, the Netherlands. March 2010
- *Learning from your mistakes*. Lecture for Dutch final year secondary school students, Liemers College Zevenaar, Netherlands, 2009
- *How your brain tries to predict the world*. Lecture for Dutch final year secondary school students, Lorenz College Arnhem, Netherlands, 2010
- *Can you see what I'm thinking?* Live real-time fMRI experiment for children (age 8-12). NEMO science museum, Amsterdam, October 2009

Selected media coverage

- **Radio:** BBC - The Naked Scientists, BBC (2014): <http://tinyurl.com/q8mnhh9>
- **Print:** The Guardian: In Praise of Uncertainty. (2013) <http://tinyurl.com/khhxabb>. De Telegraaf (Dutch newspaper, 2013).
- **Online media:** Psychology Today, Financial Post, PsychCentral, DailyNews, Medical Xpress, Alpha Galileo

Invited Talks

1. *Bernstein Centre for Computational Neuroscience*, Berlin, Germany, February 2017
2. *Amsterdam Medical Centre*, Department of Psychiatry, Grand Round, February 2017
3. *University of Zurich*, Department of Clinical Psychiatry, Switzerland, August 2016
4. *Institute of Cognitive Neuroscience*. UCL. UK. March 2016
5. *National Institutes of Health*, Affective Neuroscience and Pain Lab, USA, September 2015
6. *Cambridge University*, Department of Psychology. UK. October 2015
7. *Oxford University*, Department of Experimental Psychology. UK. June 2015
8. *Max Planck Institute for Human Cognition*, Leipzig, Germany, March 2015
9. *Charité Hospital*, Berlin, German, March 2015
10. *Oxford University*, Experimental Psychology Seminar Series, UK. October 2014.

11. *Danish Research Center for Magnetic Resonance*, Global Excellence lecture, Hvidovre Hospital, Copenhagen, Denmark. October 2014.
12. *Technical University Madrid*, Centre for Biomedical Technology, Madrid, Spain. September 2014.
13. *University College London*, ICN seminar Series, Institute of Cognitive Neuroscience, UK, May 2014
14. *Harvard Medical School*, Department of Molecular & Cellular Biology, April 2013
15. *Neuroimage Nord*, Universitätsklinikum Hamburg-Eppendorf, Hamburg, Germany, April 2013
16. *University of Groningen*, Research Discussion Series, Department of Psychiatry, April 2013
17. *Cornell University*, Sackler Science series, Weil Medical College, September 2012
18. *Aarhus University*, Keynote lecture, Annual retreat, Mindlab, Denmark, August 2012
19. *Rutgers University*, Center for Molecular and Behavioural Neuroscience, USA, November 2011
20. *University of Amsterdam*, Amsterdam center for the study of adaptive control in brain and behavior, Netherlands, March 2011
21. *University of Hamburg*, Brown Bag seminar, NeuroImage Nord, Germany, September 2009
22. *Oxford University*, fMRIB seminar series, Oxford, UK, January 2009
23. *Cambridge University*, Department of Psychology, UK, December 2008
24. *Ecole Normale Supérieure*, Seminar series, Département des Etudes Cognitives, France, October 2008

Conference Talks

1. Computational Psychiatry Course, Zurich, September 2017
2. Cognitive Neurosciences (CNS) symposium, March 2017
3. Computational Psychiatry Symposium, Donders Institute, December 2016
4. Control Processes Meeting, Datablitz Session, La Jolla, November 2016
5. Computational Psychiatry Course, Zurich, September 2016
6. British Association of Psychopharmacology, July 2016, speaker – plenary symposium: *New perspectives on functions of 5-HT sub-systems*
7. Biological Psychiatry, May 2016, speaker – symposium: The computational neuroscience of disrupted learning and memory in depression.
8. NVP Winter Conference, December 2015, **speaker** –symposium: *The brain in control*
9. Federation for European NeuroSciences annual conference, Milan, Italy, July 2014, **speaker**
10. How cognitive neuroscience can guide therapy, Workshop at the Royal Netherlands Academy of Arts and Sciences, Netherlands, May 2013, **symposium chair**
11. Neuroplasticity symposium, Dopamine 2013, Sardinia, Italy, May 2013. **speaker**
12. Neuroimaging in Psychiatry Symposium, University of Groningen, April 2013, **speaker**
13. Workshop on Dynamic Causal Modelling, Brain & Spine Institute (ICM) Paris, France, August 2012, **speaker**
14. Workshop on model-based cognitive neuroscience, University of Amsterdam, November 2012, **speaker**
15. European Science Foundation Workshop on Attention, Motivation and Action, Copenhagen , August 2012, **speaker**
16. Attention, Expectation and Awareness workshop, *Columbia University*, New York, USA , November 2011, **speaker**

17. Symposium "Verwongen vooruitblik, schizofrenie als verstoring van de neurobiologische fundering van voorbewuste geestesprocessen". *Psychiatric Center St Amandus*, Beernem, Belgium, March 2011, **speaker**
18. Annual meeting of Human Brain Mapping, Chicago , May 2009, **speaker**
19. Schizophrenia Workshop, University College London, UK , March 2006, **speaker**
20. EndoNeuroPsycho meeting, Doorwerth, The Netherlands , June 2006, **speaker**
21. Touch, Blindness & neuroscience meeting, UNED, Madrid, Spain, October 2002, **speaker**

Professional Service

Associate Editor

Journal of Neuroscience

Journal reviewer

Acta Psychologica, Biological Psychiatry, Brain, Cerebral Cortex, Cortex, Current Biology, Developmental Cognitive Neuroscience, E-Life, Journal of Cognitive Neuroscience, Journal of Neuroscience, Molecular Psychiatry, NeuroImage, Neuron, Neuroscience and Biobehavioural Reviews, Psychological Science, Social Cognitive and Affective Neuroscience (SCAN), PLoS Computational Biology, PLoS ONE, Psychopharmacology, Wiley Interscience Reviews (WIRE)

Grant Reviewer

Fonds Wetenschappelijk Onderzoek (Flemisch Fund for Scientific Research)
Fonds de recherche du Québec

Thesis Examination

12/2016	Tobias Navarro Schroeder, Radboud University, Donders Institute. Examiner
12/2016	Payam Piray, Radboud University, Donders Institute. Examiner
2014 - now	James DeRaeve, University of Ghent. External member of thesis committee
06/2016	Shiuyan Liu, Charite University Berlin, Medical Faculty. Examiner
06/2015	Joern Horschig, Radboud University, Donders Institute. Examiner
06/2015	Ana Todorovic, Radboud University, Donders Institute. Examiner

Organiser

- *Growing Up in Science lecture series*. Donders Institute for Brain, Cognition and Behaviour. Organisation and moderation of monthly series about becoming and being a scientist, by senior scientists, for PhDs and postdocs. Since 2016
- Symposium, Biological Psychiatry, Atlanta, USA, May 2016 (co-organiser)
- Symposium, Dutch Neuroscience Meeting, *Title: When affect meets effect: A translational view on how motivation influences action*, June 2015 (main organiser)
- Workshop, Royal Netherlands Academy of Arts and Sciences, *Title: How cognitive neuroscience can guide therapy*, May 2013 (co-organiser)
- Chair Sustainable Science Committee Donders Institute: Postdoctoral career trajectory development