MAX PLANCK INSTITUTE
FOR PSYCHOLINGUISTICS

RESEARCH REPORT 2021 | 2022

MAX PLANCK INSTITUTE
FOR PSYCHOLINGUISTICS

RESEARCH REPORT 2021 | 2022

MAX PLANCK

Colophon

Coordination Julia von der Fuhr, Marjolein Scherphuis
Design and technical drawing Ludy Cilissen, Doreen Bockweg (Door Doreen - Grafisch Ontwerp)
Text editing Annemarie Kerkhoff
Photography Arjan van der Vegt, de VerBeelding Nijmegen - and others
Layout and print iD Media, Apeldoorn

www.mpi.nl

CONTENTS

The current board of directors (left to right):
Caroline Rowland, Peter Hagoort, Laura Manko, Simon Fisher (Managing Director), Aslı Özyürek, Antje Meyer.

PREFACE

For more than four decades, the Max Planck Institute for Psycholinguistics has been at the forefront of interdisciplinary investigations into the foundations of language and communication. This research now combines perspectives across a highly diverse array of fields, including linguistics, psychology, computer science, neuroscience, genomics, informatics, medicine, anthropology, acoustics, movement science, and beyond. Scientists at the Institute disentangle the genetic and neurobiological underpinnings of language; decipher how children and adults acquire their languages; investigate the real-time processes involved in speaking, listening, reading and writing; study the ways that visual and multimodal aspects influence language structure; and ask how evolution shaped this key human capacity. These fundamental issues are addressed at multiple levels, from molecules and cells to circuits and brains, through to the behaviour of individuals and populations. The current report describes selected research highlights from the years 2021 and 2022, as a flavour of how the unique approach of the Institute contributes to the changing face of the language sciences. Readers wishing to dig deeper into this research can find further information in the news archives, on the departmental pages, in blogs on the Institute's website (www.mpi.nl), and in the large numbers of primary publications, review articles, chapters, books, and PhD dissertations produced during this time.

Any review of recent years is of course incomplete without acknowledging the impact of the Covid-19 pandemic. Thanks to the efforts of many dedicated people, the Institute adapted well to these challenges, maintaining both a high quality and quantity of research, while at the same time ensuring that our scientists and support staff stayed healthy and safe. 2021 and 2022 saw a gradual return of in-person interactions, accompanied by a re-affirmation of the strong spirit of community that has been a hallmark of the Institute from its inception. By the time of the site-visit of the Scientific Advisory Board in November 2022, to carry out an intensive three-day review of the Institute portfolio, the Institute was buzzing with activity. This event was successful not only as a showcase of the cutting-edge research of our talented scientists, but also as a wonderful opportunity for all involved to enjoy the warm collegiate atmosphere. Even now, as many aspects of Institute life appear "back to normal" the pandemic has left its mark, and sometimes in unexpected ways. These include, for example, technical innovations to facilitate enhanced web/app-based studies, greater attention to optimizing work-life balance, and expanded potential for online symposia, workshops and conferences, increasing accessibility for people from diverse backgrounds around the world. Indeed, another notable advance during the review period was the development of a formal "Diversity and Inclusion" strategy, with installation of a dedicated committee that advises the Institute directorate in this area, including helping to establish new initiatives (such as buddy schemes and talent programs to foster recruitment of junior scientists from under-represented backgrounds).

One of the most significant developments in the evolution of an institute is the appointment of a new director, and we were especially excited in August 2022 to welcome Asli Özyürek to our directorate. Renowned as a pioneer in multimodality of language, she is establishing a department at the Institute to investigate how visual aspects, such as gestures used with speech and sign languages of deaf communities, contribute to the uniquely flexible and adaptive nature of human language. To this end, the researchers conduct fieldwork on how gestures are used in spoken languages with different linguistic structures as well as in different sign languages. Her team also studies the role of neural, cognitive and linguistic processing constraints in shaping multimodal structures of language, and draws on state-of-the-art methods including machine learning, virtual reality and motion capture.

During the reporting period the Institute hosted its first two Minerva Fast-Track Fellows, supported by a Max Planck Society initiative aimed at promoting outstanding junior female scientists towards independence: Linda Drijvers established the Communicative Brain group (hosted by the Neurobiology of Language department), while Limor Raviv is head of the Language Evolution & Adaptation in Diverse Situations group (hosted by the Language & Genetics department). Moreover Andrea Martin, leader of the Language and Computation in Neural Systems group, was in 2021 chosen by the Max Planck Society as a Lise Meitner Group Leader, recognized by an excellence program that identifies highly motivated and committed women scientists in the breakthrough phase of their careers.

Before closing, and on behalf of all the MPI community, I would like to pay tribute to our director emirita Anne Cutler, who sadly and unexpectedly passed away in June 2022. Anne was a legend in the language sciences, with an infectious passion for science, admirable dedication to rigour in research, and a devotion to generous mentorship of junior researchers - her contributions will endure long after she has gone.

Simon Fisher
Managing Director

NIJMEGEN LECTURES

After two delays because of Covid-19, the Nijmegen Lectures took place from 5 to 7 July 2022. During three days, Stanislas Dehaene gave a morning lecture in the Aula of the Radboud University, followed by afternoon panel discussions at the MPI.

VISIT
SCIENTIFIC ADVISORY BOARD

The Scientific Advisory Board of the MPI visited to carry out an evaluation of the Institute, from 7-10 November 2022. On this photo we see, from left to right: Kate Watkins, Ron Mangun (Chair of the Scientific Advisory Board), Manuel Carreiras, Matthew Goldrick, Fernanda Ferreira, Holly Branigan, Matt Lambon Ralph, Francesca Happé and Anne Christophe.

IMPRS
CONFERENCE

From 1 to 3 June 2022, the IMPRS welcomed well over 100 attendees to the MPI for three days of talks, poster sessions, discussions and workshops. The theme of the conference was: Interdisciplinary Approaches to the Language Sciences.

ORGANISATION OF THE INSTITUTE
2021 | 2022

Directors
Antje S. Meyer (Managing Director)
Caroline Rowland
Peter Hagoort
Simon E. Fisher
Aslı Özyürek
Laura Manko (COO)

Directors emeritus
Anne Cutler †
Wolfgang Klein
Willem J.M. Levelt
Stephen C. Levinson

Max Planck Research Groups
Sonja Vernes
Andrea Ravignani

Lise Meitner Research Group
Andrea Martin

Max Planck Fellow
Peter Indefrey

Minerva Fast Track
Linda Drijvers
Limor Raviv

External group
Judith Holler

External scientific members
Manfred Bierwisch
David Norris
Pieter Muysken †

Scientific Advisory Board
Prof. Dr. Holly Branigan
(University of Edinburgh, School of Philosophy, Psychology and Language Sciences, United Kingdom)
Prof. Dr. Manuel Carreiras
(Basque Center on Cognition, Brain and Language, Spain)
Dr. Anne Christophe
(Laboratoire des Sciences Cognitives et Psycholinguistique, France)
Prof. Dr. Evan Eichler
(University of Washington, Department of Genome Sciences, USA)
Prof. Dr. Fernanda Ferreira
(University of California, Davis Department of Psychology, USA)
Prof. Dr. Paul Fletcher
(University College Cork, Department of Speech and Hearing Sciences, Ireland)
Prof. Dr. Matthew Goldrick
(Northwestern University, Department of Linguistics, USA)
Prof. Dr. Francesca Happé
(King's College London, Social Genetic and Developmental Psychiatry Centre, United Kingdom)
Prof. Dr. Matt Lambon Ralph
(University of Cambridge, MRC Cognition and Brain Sciences Unit, United Kingdom)
Prof. Dr. Ron Mangun (Chair)
(University of California, Davis Center for Mind and Brain, USA)
Prof. Dr. Ineke Sluiter
(Universiteit Leiden, Faculty of Humanities, Centre for the Arts in Society, Leiden, The Netherlands)
Prof. Dr. Kate Watkins
(University of Oxford, Medical Sciences Division, Experimental Psychology, United Kingdom)

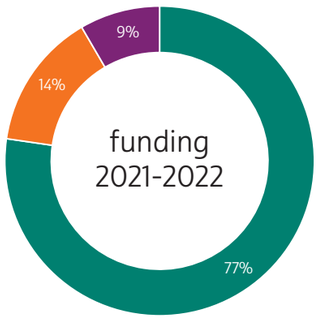
Library
Karin Kastens *(head)*

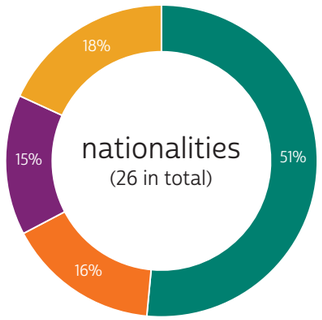
Communications Team
Marjolein Scherphuis *(head)*

Technical Group
Reiner Dirksmeyer *(head)*

The Language Archive
Paul Trilsbeek *(head)*

IMPRS for Language Sciences
Kevin Lam *(coordinator)*





Board of Trustees
The Board of Trustees plays a valuable role at the interface between science and society; it promotes interaction with the public, acts as an ambassador for our research, and advises us on issues of social concern.

Prof. Dr. Mariëtte (Jet) Bussemaker
Professor of Science, Policy and Societal Impact at Leiden University
Leiden, The Netherlands

Rob van Hattum
Science Director for VPRO Public Television
Hilversum, The Netherlands

Sigrid Helbig
CEO of Brightlands Campus Greenport Venlo
Nijmegen, The Netherlands

Wilma de Koning
Managing Director of the Royal Netherlands Academy of Arts and Sciences (KNAW)
Amsterdam, The Netherlands

Dr. Wilhelm Krull (Chair)
The New Institute, Founding Director and Senior Advisor
Hamburg, Germany

Prof. Dr. Gerard Meijer
Director of the Fritz Haber Institute of the Max Planck Society
Berlin, Germany

Prof. Dr. Joybrato Mukherjee
President of the German Academic Exchange Service (DAAD)
Bonn, Germany

Ab van der Touw
Former CEO of Siemens Nederland
Vice Chairman of the Board of VNO-NCW and of FME-CWM
Wassenaar, The Netherlands

HONOURS AND AWARDS

2021
Limor Raviv and **Ella Lattenkamp** received the Otto Hahn Medal of the Max Planck Society.
Andrea Ravignani received the Disciplinary Diversity & Integration Award in Cognitive Science from the Cognitive Science Society.
Peter Hagoort received the Distinguished Career Award of the Society for the Neurobiology of Language.
Limor Raviv was awarded a Minerva Fast Track Fellowship to carry out research on Language Evolution and Adaptation in Diverse Situations.

2022
Stephen Levinson received the Huxley Memorial Medal of the Royal Anthropological Institute (UK).
Sonja Vernes received the Blavatnik Award for Young Scientists (UK).
Hans Rutger Bosker received an ERC Starting grant to study audiovisual communication.
Andrea Ravignani received an ERC Starting grant to study the origins of rhythm.
Clyde Francks was appointed Professor of Brain Imaging Genomics at Radboud University Medical Center.
Ryan Law was awarded a Gates Cambridge Scholarship.
Beate St Pourcain is co-applicant and lead partner at the MPI of a European Commission HORIZON-HLTH-2021 grant for the project “Risk and Resilience in Developmental Diversity and Mental Health” as part of a consortium led by Institute Pasteur.
Hatice Zora received the 'Academic Leadership' award in the 'Ten Outstanding Young Persons of the World' program.

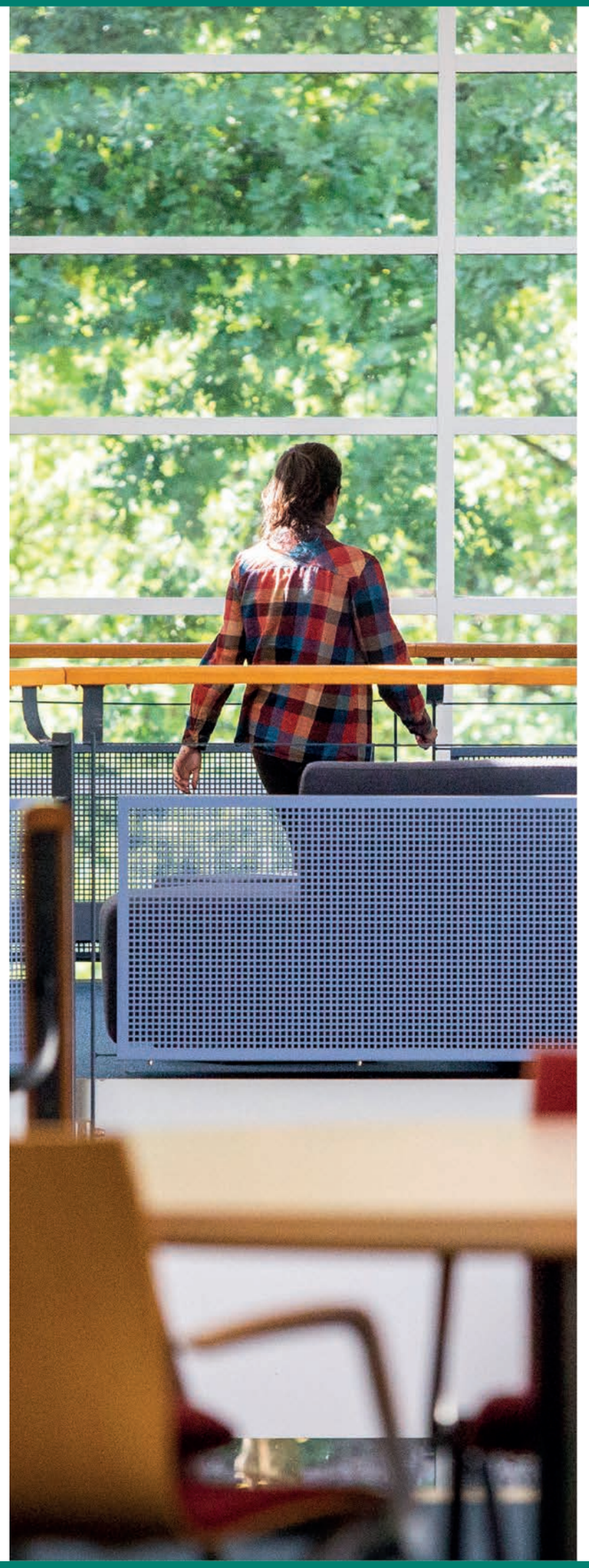
PHD COMPLETIONS

2021

Kristijan Armeni On model-based neurobiology of language comprehension: neuronal oscillations, processing memory, and prediction
Martijn Bentum Listening with great expectations: A study of predictive natural speech processing
Chantal van Dijk Cross-linguistic influence during real-time sentence processing in bilingual children and adults
Emily Felker Learning second language speech perception in natural settings
John Huisman Variation in form and meaning across the Japonic language family with a focus on the Ryukyuan languages
Greta Kaufeld Investigating spoken language comprehension as perceptual inference
Alessandro Lopopolo Properties, Structures and Operations: Studies on language processing in the brain using computational linguistics and naturalistic stimuli
Francie Manhardt A tale of two modalities: How modality shapes language production and visual attention
Anne Mickan What was that Spanish word again? Investigations into the cognitive mechanisms underlying foreign language attrition
Jeroen van Paridon Speaking while listening: Language processing in speech shadowing and translation
Merel Postema Left-right asymmetry of the human brain: Associations with neurodevelopmental disorders and genetic factors
Theresa Redl Masculine generic pronouns: Investigating the processing of an unintended gender cue
Louise Schubotz Effects of aging and cognitive abilities on multimodal language production and comprehension in context
Lot Snijders Blok Let the genes speak! De novo variants in developmental disorders with speech and language impairments
Lara Todorova Language bias in visually driven decisions: computational and neurophysiological mechanisms
Thijs Trompenaars Bringing stories to life: Animacy in narrative and processing
Chara Tsoukala Bilingual sentence production and code-switching: Neural network simulations
Ellen Verhoef Why do we change how we speak? Multivariate genetic analyses of language and related traits across development and disorder
Xiaoru Yu Foreign language learning in study-abroad and at-home contexts

2022

Sophie Arana Abstract neural representations of language during sentence comprehension: Evidence from MEG and Behaviour
Fan Bai Neural representation of speech segmentation and syntactic structure discrimination
Laura Hahn Infants' perception of sound patterns in oral language play
Micha Heilbron Getting ahead: Prediction as a window into language, and language as a window into the predictive brain
Fabian Heim Singing is silver, hearing is gold: Impacts of local FoxP1 knockdowns on auditory perception and gene expression in female zebra finches
Joery den Hoed Disentangling the molecular landscape of genetic variation of neurodevelopmental and speech disorders
Dilay Karadöller Development of spatial language and memory: Effects of language modality and late sign language exposure (in Turkish and Turkish sign language)
Hannah Lutzenberger Kata Kolok phonology - variation and acquisition
Marloes Mak What's on your mind: Mental simulation and aesthetic appreciation during literary reading
Katherine Marcoux Non-native Lombard speech: The acoustics, perception, and comprehension of English Lombard speech by Dutch natives
Danny Merkx Modelling multi-modal language learning: From sentences to words
Julia Misersky About time: Exploring the role of grammatical aspect in event cognition
Nadine de Rue Phonological contrast and conflict in Dutch vowels: Neurobiological and psycholinguistic evidence from children and adults
Gert-Jan Schoenmakers Definite objects in the wild: A converging evidence approach to scrambling in the Dutch middle-field
Chen Shen Individual differences in speech production and maximum speech performance
Ksenija Slivac The enlanguaged brain: Cognitive and neural mechanisms of linguistic influence on perception
Anita Slonimska The role of iconicity and simultaneity in efficient communication in the visual modality
Aurora Troncoso Ruiz Non-native phonetic accommodation in interactions with humans and with computers
Merel Wolf Spoken and written word processing: Effects of presentation modality and individual differences in experience to written language
Jinbiao Yang Discovering the units in language cognition: From empirical evidence to a computational model



ACRONYMS

ACE	atypical communication expertise
ASD	autism spectrum disorder
CLARIAH	common lab research infrastructure for the arts and humanities
DOBES	documentation bedrohter sprachen (documentation of endangered languages)
EEG	electroencephalogram
ENIGMA	enhancing neuroimaging genetics through meta-analysis
ERP	event-related potential
fMRI	functional magnetic resonance imaging
fNIRS	functional near-infrared spectroscopy
HPC	high performance computing
LIFG	left inferior frontal gyrus
LMTG	left middle temporal gyrus
MVPA	multivariate pattern analysis
MRI	magnetic resonance imaging
MEG	magnetoencephalography
PCR	polymerase chain reaction
pMTG	posterior middle temporal gyrus
pSTG	posterior superior temporal gyrus
RNA	ribonucleic acid
TMS	transcranial magnetic stimulation
VR	virtual reality

DEPARTMENT
LANGUAGE AND GENETICS

Director Simon E. Fisher
Department members Danielle Admiraal, Gökberk Alagöz, Jitse Amelink, Mariska Barendse, Martina Bernhard, Giacomo Bignardi, Jelle de Boer, Jasper Bok, Ching Yat (Lewis) Cheung, Willemijn Claassen, Karthikeyan Devaraju, Marjolein van Donkelaar, Else Eising, Clyde Francks, Lukas Galke, Ina Grevel, Paulina Grzenia, Jurgen Heijsen, Sabrina van Heukelum, Joery den Hoed, Danielle Houwing, Lucía De Hoyos, Roos Kampen, Mubeen Khan, Lukas Lütje, Barbara Molz, Limor Raviv, Dick Schijven, Fenja Schlag, Zhiqiang Sha, Yuliia Shevchuk, Sourena Soheili-Nezhad, Beate St Pourcain, Ingrid Szilagyi, Jan Verheijen, Ellen Verhoef, Arianna Vino, Maggie Wong

Goals of the Department
The Language and Genetics Department investigates the biology of key human traits from a genomic perspective. The department uses genetic approaches to decipher how variations at the molecular level affect skills related to speech, language (oral and written), and social behaviours. These are investigated with diverse strategies, including state-of-the-art structural equation modelling in population-based and disorder-related cohorts, large-scale association studies with common DNA variants, and discovery of rare mutations that are sufficient to derail speech and language development, identified by next-generation sequencing. The work goes beyond in silico analyses, to trace connections between genes, cells, and neurodevelopment in model systems, including gene-editing and brain organoids, making use of custom-built wet-lab facilities with dedicated tissue-culture and microscopy suites, as well as pipelines for single-cell transcriptomics. In parallel, the researchers study molecular underpinnings of language-related brain networks, by integrating DNA data with neuroimaging-derived measures of brain structure/ function, and through gene expression analyses of postmortem tissue. The researchers are also interested in what molecular studies may reveal about evolutionary origins of language and other aspects of the human condition.

Massive genome studies inform the biology of reading and language
The use of spoken and written language is a fundamental human capacity.
It is well established that individual differences in the relevant skills are influenced by variations in our genomes, but little is known about the identities of those variations and how exactly they contribute. A large part of the genetic influence on complex human traits involves combined impacts of many different common DNA variants, each of which has (by itself) a tiny effect size, meaning that very large sample sizes are needed to reliably identify them. To address this issue, researchers of the Language and Genetics Department established the GenLang Consortium, an international network of leading experts interested in the genetic underpinnings of speech, language, reading and related traits. In the first major GenLang study to be completed, Else Eising and colleagues were able to study up to ~34,000 participants aged 5-26 years, by bringing together genetic and trait data from 22 cohorts collected worldwide, speaking seven different languages (mostly English, but also Dutch, German, French, Spanish, Hungarian and Finnish). In these cohorts, each participant had been tested using a selection of psychometric measures related to reading and language: word reading, nonword reading, spelling, phoneme awareness (the ability to distinguish and manipulate speech sounds in words), and nonword repetition (a task tapping speech perception, verbal short-term memory, and articulation). The researchers analysed common DNA variants at millions of locations across the genome, testing for associations with each reading-/ language-related measure. In these genome-wide association scans, they found that common DNA variation could account for as much as 26% in the total trait variability in the sample. None of the candidate genes suggested by earlier small studies showed significant

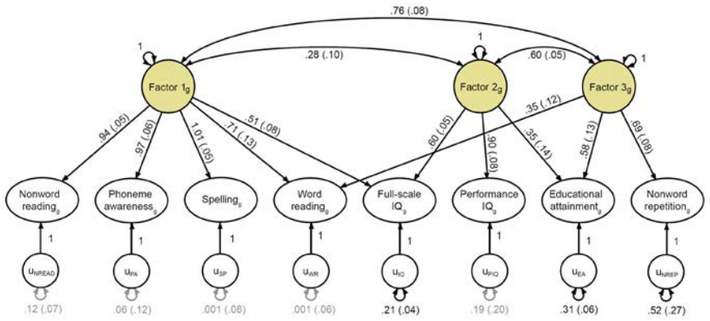


Figure 1. Reading- and language-related traits have a shared genetic architecture that is largely independent of performance IQ. The figure shows a three-factor structural equation model fitted to the genome-wide association data for word reading, nonword reading, spelling, phoneme awareness, nonword repetition, and performance IQ in GenLang (up to 34,000 participants), and to previously published genome-wide summary statistics for full-scale IQ and educational attainment. Black and grey paths represent factor loadings with P < 0.05 and P > 0.05, respectively. Standardized factor loadings are shown, with SE in parentheses. Reproduced from Eising et al. (2022).

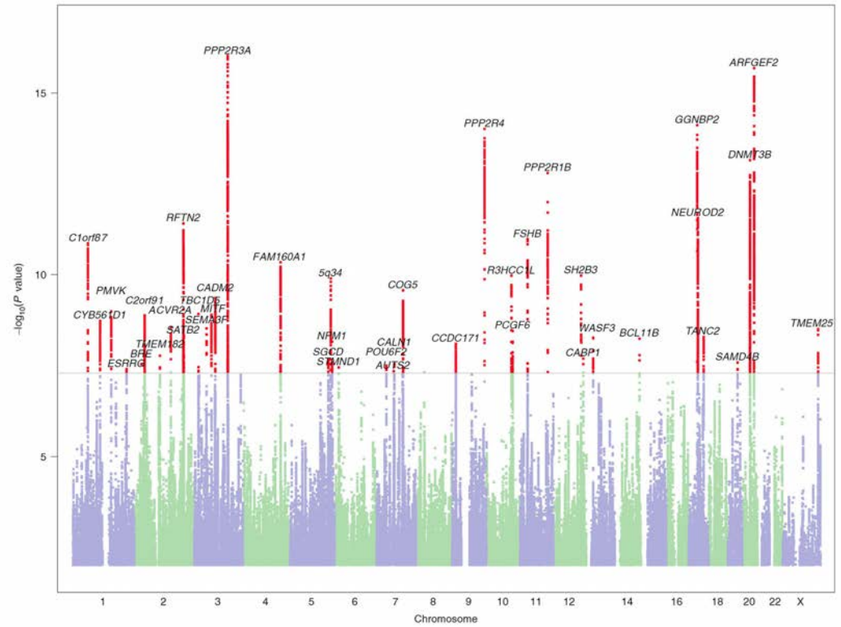


Figure 2. Genome-wide association screen of dyslexia. The x-axis shows positions of the tested DNA variants along each human chromosome. The y-axis represents the −log10 P value for association of each variant with self-reported dyslexia diagnosis from 51,800 individuals and 1,087,070 controls. The threshold for genome-wide significance ($P < 5 \times 10^{-8}$) is represented by a horizontal grey line. Genome-wide significant variants are in red. Reproduced from Doust et al. (2022).

common variant associations in this much larger combined sample, meaning that a major reevaluation of the prior literature is warranted. With a method that uses genome-wide association data for structural equation modelling, the team found that a shared genetic factor explained most variation in word/ nonword reading, spelling, and phoneme awareness, which only partially overlapped with genetic variation contributing to nonword repetition, intelligence and educational attainment (Figure 1). Moreover, by analysing relationships with genetic association of neuroimaging traits available in an independent large cohort (UK Biobank), the researchers identified that this shared genetic factor was linked to variation in surface area of the banks of the left superior temporal sulcus, a brain region involved in the processing of spoken and written language.

The GenLang Consortium also made key contributions to a parallel collaborative study led by Doust and colleagues from the University of Edinburgh, UK, in which they identified 42 genome-wide significant loci associated with self-report of developmental dyslexia in >51,000 people, compared to ~1 million controls (recruited via the personal genomics company, 23andMe, Inc). Although the 23andMe analysis was based on just a single question about dyslexia diagnosis, the researchers demonstrated substantial genetically-mediated overlaps with the directly tested quantitative measures of reading and spelling skills in the independent GenLang dataset of up to 34,000 people. Some of the 42 dyslexia-related genetic loci uncovered by Doust et al. (Figure 2) have been previously associated with other neurodevelopment conditions or with general cognition and academic achievement. However, many are novel and offer new entry points for studying neurobiological processes involved in learning to read.

Distinct neurodevelopmental disorders caused by variants of the same gene
Complementary to investigating the contributions of common DNA variants to language-related traits, another major research strand of the Language and Genetics Department focuses on the impact of rare genetic disruptions of large effect size that derail such abilities. This strand builds on a prior discovery by Simon Fisher and colleagues showing that disruptions of the FOXP2 gene cause childhood apraxia of speech, together with problems in language production and comprehension, against variable backgrounds of general cognition. FOXP2 encodes a type of regulatory protein (known as a transcription

factor) that works together with other molecules to modulate the activity of genetic networks, in ways that can be studied using cellular and animal model systems. For example, in a 2018 study, researchers at the Language and Genetics Department identified a number of regulatory proteins that interact closely with FOXP2 and that may be important for its functions in brain development. One of these interactors, a transcription factor known as SATB1, became the target of a new investigation led by Joery den Hoed, in collaboration with colleagues at Radboud University Medical Centre and University of Lausanne. The team characterised 42 individuals with neurodevelopmental problems due to different types of gene variants disrupting SATB1. Using molecular and cellular assays, they found that missense variants in the DNA-binding domains of the protein resulted in stronger binding to chromatin, along with increased repression of downstream target genes. Clinical examinations revealed that those missense variants were linked to severe intellectual disability, often associated with epilepsy, motor speech impairments, and distinctive facial features. In contrast, variants yielding a complete loss-of-function of the protein were associated with milder clinical presentations, involving reduced cognitive functions and visual problems. A third class of variants yielded truncated SATB1 proteins, which den Hoed and colleagues showed to be aberrantly localised within cells, leading to a similarly mild clinical presentation. Researchers of the Language and Genetics Department are applying integrated approaches such as these to study rare DNA variants in other regulatory genes emerging through genome sequencing of speech apraxia cohorts, including CHD3 and SETBP1. Their latest experiments expand scope of the work by using CRISPR/Cas9 gene-editing, human brain organoids grown in the laboratory, and single-cell transcriptomic analyses.

Variable genetic links between social behaviour and mental health

The *Population Genetics of Human Communication Group*, led by Beate St Pourcain, applies molecular epidemiology tools, including new analytical methods developed within the group, to disentangle how common genetic variation contributes to language and social skills during development, from infancy to adolescence. These genetic epidemiological approaches make it possible to trace biological links to later-life outcomes across health and disorder, as illustrated by recent work from Fenja Schlag and colleagues. The starting point for their study was the observation that people with mental health conditions experience social difficulties which can vary depending on the disorder. In particular, children with attention deficit hyperactivity disorder (ADHD) tend to have peer problems, and those with autism spectrum disorders (ASD) have problems with social interaction and communication, while individuals with major depression and bipolar disorder may withdraw from social interaction, and people with schizophrenia often lack social interest. These mental health conditions are all heritable to some degree-as is social behaviour, a complex set of traits that changes with age and situation. The researchers used data from prior genome-wide screens of common DNA variation in psychiatric disorders to derive polygenic scores (a measure of a person's genetic susceptibility for a condition) in two large UK-based population cohorts: comprising 6,174 individuals from the Avon Longitudinal Study of Parents and Children (ALSPAC) and 7,112 individuals from the Twins Early Development Study (TEDS). The children and adolescents in these samples were rated by parents and teachers at different ages on prosocial behaviour, like helping, sharing or cooperating with others, as well as on peer problems, such as social withdrawal, being bullied, and not getting along with others. The researchers found variable genetic links between mental health conditions (indexed by polygenic scores) and social behaviour ratings, depending on the social traits studied and who reported them (parents or teachers). Polygenic scores for ADHD, ASD, and major depression were more strongly associated with peer problems than low prosocial behaviour, while schizophrenia susceptibility was linked to low prosociality only. In contrast, age-related variation in genetic overlap was similar across several mental health conditions. The disorder-specific association profiles may in future help to refine diagnostic criteria and targeted treatment strategies.

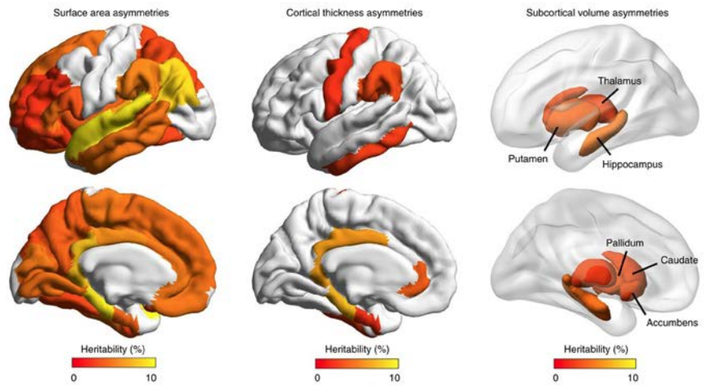


Figure 3. Heritability estimates for human brain asymmetries, based on genome-wide analyses of common DNA variation in the UK Biobank. Only regions for which asymmetries were significantly heritable are indicated in colour. Reproduced from Sha et al. (2021).

Uncovering the biological bases of human brain asymmetries

Left-right asymmetry is an important aspect of human brain organisation for many functions including language, and it can be altered in cognitive and psychiatric disorders, yet the underlying mechanisms remain mysterious. The *Imaging Genomics Group*, led by Clyde Francks, performs cutting-edge investigations of the biological bases of asymmetrical structural and functional features of the human brain. For example, Zhiqiang Sha and colleagues used matched neuroimaging and genetic data in >32,000 participants from the UK Biobank to carry out multivariate genome-wide screens of asymmetries of brain anatomy, focusing on the surface area and thickness of different regions of the cerebral cortex, as well as volumes of subcortical structures (Figure 3). The researchers identified common DNA variants at 21 different genetic loci that were significantly associated with subtle alterations in aspects of brain asymmetry. Among these loci there was an over-representation of genes known to be active in developing human brain tissue during embryogenesis. Moreover, the team found significant enrichment for genes related to microtubules: these are important constituents of the cytoskeleton, a dynamic network of interlinking protein filaments in the cytoplasm of all cells. Common DNA variants of microtubule-related genes are also thought to contribute to handedness, the most well-established human behavioural asymmetry. Since the cytoskeleton has already been linked to left-right axis determination in other organs of invertebrates and frogs, these findings open up promising windows into potential biological mechanisms. DNA variants involved in human brain asymmetries showed overlaps with those associated with ASD and schizophrenia from other studies. In complementary research, Francks' team led the first large-scale international studies of asymmetries in these and other neuropsychiatric disorders, in the context of the laterality working group of the ENIGMA (Enhancing NeuroImaging Genetics through Meta-Analysis) consortium.

Selected publications

den Hoed, J., De Boer, E., Voisin, N., Dingemans, A. J. M., Guex, N., Wiel, L., Nellaker, C., Amudhavalli, S. M., Banka, S., Bena, F. S., Ben-Zeev, B., Bonagura, V. R., Bruel, A.-L., Brunet, T., Brunner, H. G., Chew, H. B., Chrast, J., Cimbalistienė, L., Coon, H., The DDD study, Délot, E. C., Démurger, F., Denommé-Pichon, A.-S., Depienne, C., Donnai, D., Dyment, D. A., Elpeleg, O., Faivre, L., Gilissen, C., Granger, L., Haber, B., Hachiya, Y., Hamzavi Abedi, Y., Hanebeck, J., Hehir-Kwa, J. Y., Horist, B., Itai, T., Jackson, A., Jewell, R., Jones, K. L., Joss, S., Kashii, H., Kato, M., Kattentidt-Mouravieva, A. A., Kok, F., Kotzaeridou, U., Krishnamurthy, V., Kučinskas, V., Kuechler, A., Lavillaureix, A., Liu, P., Manwaring, L., Matsumoto, N., Mazel, B., McWalter, K., Meiner, V., Mikati, M. A., Miyatake, S., Mizuguchi, T., Moey, L. H., Mohammed, S., Mor-Shaked, H., Mountford, H., Newbury-Ecob, R., Odent, S., Orec, L., Osmond, M., Palculict, T. B., Parker, M., Petersen, A., Pfundt, R., Preikšaitienė, E., Radtke, K., Ranza, E., Rosenfeld, J. A., Santiago-Sim, T., Schwager, C., Sinnema, M., Snijders Blok, L., Spillmann, R. C., Stegmann, A. P. A., Thiffault, I., Tran, L., Vaknin-Dembinsky, A., Vedovato-dos-Santos, J. H., Vergano, S. A., Vilain, E., Vitobello, A., Wagner, M., Waheeb, A., Willing, M., Zuccarelli, B., Kini, U., Newbury, D. F., Kleefstra, T., Reymond, A., Fisher, S. E., & Vissers, L. E. L. M. (2021). Mutation-specific pathophysiological mechanisms define different neurodevelopmental disorders associated with SATB1 dysfunction. *American Journal of Human Genetics,* 108(2), 346-356. doi:10.1016/j.ajhg.2021.01.007.

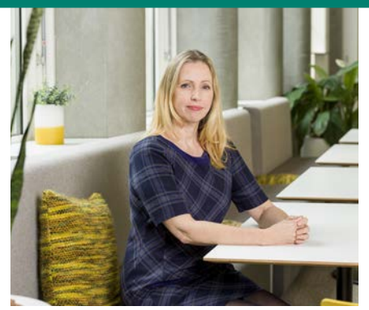
Doust, C., Fontanillas, P., Eising, E., Gordon, S. D., Wang, Z., Alagöz, G., Molz, B., 23andMe Research Team, Quantitative Trait Working Group of the GenLang Consortium, St Pourcain, B., Francks, C., Marioni, R. E., Zhao, J., Paracchini, S., Talcott, J. B., Monaco, A. P., Stein, J. F., Gruen, J. R., Olson, R. K., Willcutt, E. G., DeFries, J. C., Pennington, B. F., Smith, S. D., Wright, M. J., Martin, N. G., Auton, A., Bates, T. C., Fisher, S. E., & Luciano, M. (2022). Discovery of 42 genome-wide significant loci associated with dyslexia. *Nature Genetics*, 54(11), 1621-1629. doi:10.1038/s41588-022-01192-y.

Eising, E., Mirza-Schreiber, N., De Zeeuw, E. L., Wang, C. A., Truong, D. T., Allegrini, A. G., Shapland, C. Y., Zhu, G., Wigg, K. G., Gerritse, M. L., Molz, B., Alagöz, G., Gialluisi, A., Abbondanza, F., Rimfeld, K., van Donkelaar, M., Liao, Z., Jansen, P. R., Andlauer, T. F. M., Bates, T. C., Bernard, M., Blokland, K., Bonte, M., Børglum, A. D., Bourgeron, T., Brandeis, D., Ceroni, F., Csépe, V., Dale, P. S., de Jong, P. F., DeFries, J. C., Démonet, J.-F., Demontis, D., Feng, Y., Gordon, S. D., Guger, S. L., Hayiou-Thomas, M. E., Hernández-Cabrera, J. A., Hottenga, J.-J., Hulme, C., Kere, J., Kerr, E. N., Koomar, T., Landerl, K., Leonard, G. T., Lovett, M. W., Lyytinen, H., Martin, N. G., Martinelli, A., Maurer, U., Michaelson, J. J., Moll, K., Monaco, A. P., Morgan, A. T., Nöthen, M. M., Pausova, Z., Pennell, C. E., Pennington, B. F., Price, K. M., Rajagopal, V. M., Ramus, F., Richer, L., Simpson, N. H., Smith, S. D., Snowling, M. J., Stein, J., Strug, L. J., Talcott, J. B., Tiemeier, H., van der Schroeff, M. P., Verhoef, E., Watkins, K. E., Wilkinson, M., Wright, M. J., Barr, C. L., Boomsma, D. I., Carreiras, M., Franken, M.-C. J., Gruen, J. R., Luciano, M., Müller-Myhsok, B., Newbury, D. F., Olson, R. K., Paracchini, S., Paus, T., Plomin, R., Reilly, S., Schulte-Körne, G., Tomblin, J. B., van Bergen, E., Whitehouse, A. J. O., Willcutt, E. G., St Pourcain, B., Francks, C., & Fisher, S. E. (2022). Genome-wide analyses of individual differences in quantitatively assessed reading- and language-related skills in up to 34,000 people. *Proceedings of the National Academy of Sciences of the United States of America*. 119(35): e2202764119. doi:10.1073/pnas.2202764119.

Schlag, F., Allegrini, A. G., Buitelaar, J., Verhoef, E., van Donkelaar, M., Plomin, R., Rimfeld, K., Fisher, S. E., & St Pourcain, B. (2022). Polygenic risk for mental disorder reveals distinct association profiles across social behaviour in the general population. *Molecular Psychiatry*, 27, 1588-1598. doi:10.1038/s41380-021-01419-0.

Sha, Z., Schijven, D., Carrion-Castillo, A., Joliot, M., Mazoyer, B., Fisher, S. E., Crivello, F., & Francks, C.. (2021). The genetic architecture of structural left–right asymmetry of the human brain. *Nature Human Behaviour*, 5, 1226-1239. doi:10.1038/s41562-021-01069-w.

DEPARTMENT **LANGUAGE DEVELOPMENT**



Director Caroline Rowland
Department members Christina Bergmann, Melis Cetincelik, Ilse van den Dobbelsteen, Seamus Donnelly, Julia Egger, Dilys Eikelboom, Abdel Elouatiq, Rowena Garcia, Cielke Hendriks, Ciske Jansen, Daphne Jansen, Evan Kidd, Shanthi Kumarage, Clara Kunst, Jefta Lagerwerf, Heather Lemen, Patricia Manko, Nienke Rulkens-Dijkstra, Andriana Sabov, Jennifer Sander, Iris Schmits, Yevheniy Skyra, Mieke Slim, Tineke Snijders, Sergio Miguel Pereira-Soares, Katja Stärk, Mirthe Stevelink, Inge Stok, Sam Theunissen, Elea Thijssen, Liz Tollenaar, Hanne van Uden, Merel Wolf, Chih Yeh, Yayun Zhang, Eleni Zimianiti.

Goals of the Department
Language is the most complex communication system in the known universe, yet children master it before they learn to tie their shoelaces. They learn to mimic the sounds of their language, to associate thousands of words with their meanings, to combine these words into long, grammatical sentences, and to use these sentences to convey complex messages about their world, their thoughts, their feelings and beliefs. The research of the Language Development Department (LaDD) is designed to discover how children achieve this. The research team builds and tests models of language acquisition that address the central question: How do the learning mechanisms in children's brains use information in their environment to build mature linguistic knowledge?

Language during lockdown
Covid-19 social isolation measures (lockdowns) transformed the lives of billions of people across the world. But what impact did they have on children's language development? And did this vary across children learning different languages in different countries? The answers are important because a child's language in the preschool years is the foundation for later success in school; for example, children who enter school with bigger vocabularies tend to learn to read and write faster.

Senior Investigator Christina Bergmann and Director Caroline Rowland have been investigating the effect of lockdown on the language of babies and toddlers, together with a consortium of researchers from 13 countries, and with the help of 2,200 parents and caregivers. Shortly after lockdown began in their country, caregivers completed a short online checklist that asked questions about their child's age, exposure to different languages, and number of siblings, and also a long questionnaire that asked detailed questions about language development. At the end of lockdown, caregivers completed a second checklist that asked about activities that they undertook with their child during lockdown, and another detailed questionnaire about language development.

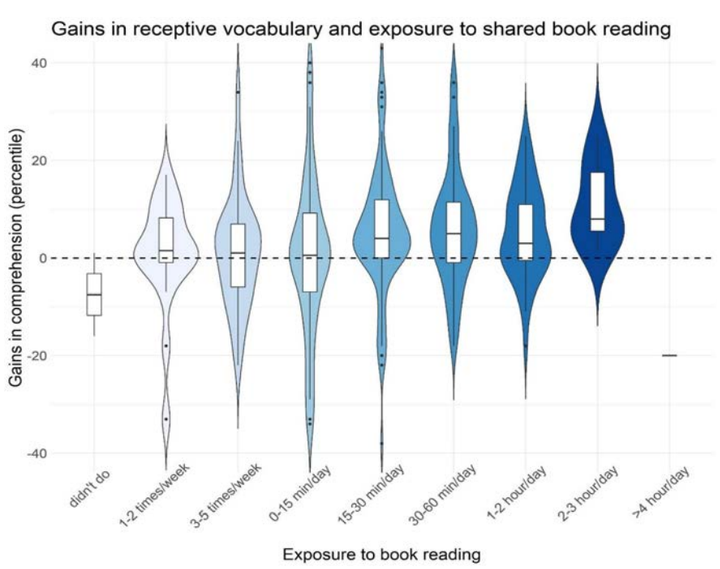
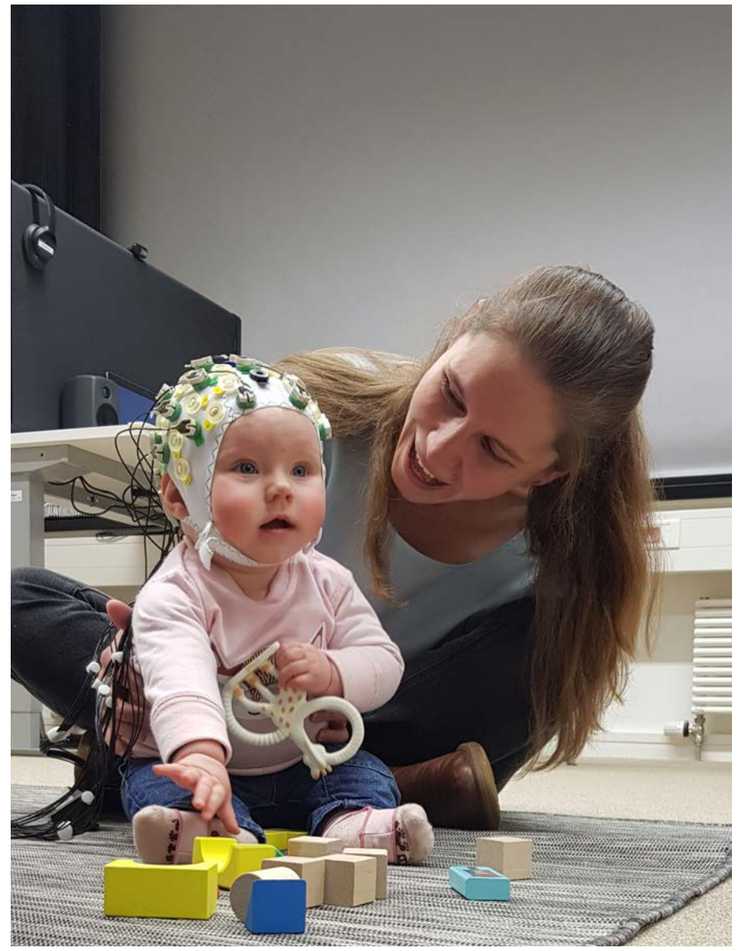


Figure 1. Gains in receptive vocabulary (in percentiles) for different amounts of reported shared book reading time. Gains of zero (dashed line) correspond to expected gains considering normative data. Reproduced from Kartushina et al. (2019) with permission from the publishers.

Overall, children across all 13 countries were reported to have gained more words than expected during lockdown, relative to pre-pandemic levels. However, there were also important differences across children. Children who were read to more frequently were reported to have learned more words, relative to their peers who were read to less often. Children with increased exposure to screens, however, learned fewer words, relative to their peers who had less screen time. In addition, overall, children were exposed to more screen time during lockdown than before.

The authors attributed increased screen time to the unprecedented circumstances that families found themselves in during lockdown, including the closure of day care centres, sport facilities and children's play groups. Nevertheless, it is reassuring, that despite the increased exposure to screen time, children as a whole learned more words during the lockdown period in March 2020 than we would expect. Parents clearly worked hard to provide their children with learning opportunities at home, though the effect of this increased workload on parents' well-being, especially those juggling work and childcare, is yet to be determined.



A baby wearing an EEG cap. EEG is a safe and simple method to detect and measure electrical brain activity in infants and young children.

Language Development in the Philippines
In the last sixty years, thousands of articles have been published on how children learn language. But these articles have focussed on only 103 of the world's 7000 or so languages (Kidd & Garcia, 2022). In fact, most of what we know about language acquisition is based on English and a few other European languages like German and Spanish. This means that we do not yet know if our theories can explain development in all, or even most, of the world's languages.

As a result, examining understudied languages like Tagalog (a language of the Philippines) is important. Tagalog differs substantially from commonly studied languages, providing opportunities to test the predictions of our theories in important new ways. Postdoctoral Researcher Rowena Garcia, who is a fluent Tagalog speaker herself, and Senior Investigator Evan Kidd, have been studying Tagalog for the last few years. Their work is unveiling important new information about how children learn to understand and produce sentences.

For example, two recent projects tested the predictions of competing accounts of how children's knowledge is used as they hear, and try to understand, language. The "early abstraction" account claims that children's learning is supported by powerful innate knowledge of what grammatical structures a language might have. As a result, children should learn to interpret sentences quickly and from a very young age. The "experience-based" account claims that children gradually acquire the necessary knowledge based on its availability in the child's input. As a result, children's pathway to becoming proficient language users is more drawn out. Previous studies on this issue have yielded contradictory results. Studying Tagalog, which has a very different grammar from European languages (using different 'voices' to describe events from different perspectives), provides a new way to test these theories.

In their first project, the researchers collected spontaneous speech from Tagalog-speaking child-caregiver pairs in Metro Manila to determine the frequencies of different sentence structures in the children's input. This is the first corpus of Tagalog child-directed and children's speech ever created, and is available in our Language Archive. In the second project, a mobile eye-tracker was used to track how children interpret different sentences; it tracked where children looked as they saw an action between two animals and heard a sentence describing this action (e.g. English translation: 'the pig is biting the cow vs. the pig is being bitten by the cow').

The children showed clear differences in their ability to interpret different sentences, and these differences corresponded to how frequently they had heard these structures in their input in everyday life. It was not until 7 years of age that children could interpret all the sentences in an adultlike manner. The results are consistent with the experience-based account, and demonstrate how studying previously understudied languages can throw new light on how children acquire language.

Let's take turns
Children who spend a lot of time in conversation with caregivers learn more words. We have known this for a long time, but we still do not know why. One possibility is that it is simply easier to hold conversations with children who know more words, so caregivers and children spend a lot of time in conversation as a result. Another possibility is that children whose caregivers engage them in a lot of conversations have more opportunities to practice language, and thus learn more words. Or it may be that both of these are true and the relationship between vocabulary and the frequency of conversations is reciprocal.

Postdoctoral Researcher Seamus Donnelly and Evan Kidd tested these three explanations with the help of 122 Australian English-speaking children who took part in a large longitudinal study on language development. Every three months, caregivers used a LENA© device to record what children said and heard during a whole day. Then, using recently developed computer algorithms, these recordings were automatically analysed for the number of words the caregiver produced, the number of vocalisations the child produced, and how often child and caregiver took turns in the conversation (conversational turns). The number of words (vocabulary) that children knew at each time point was also recorded.

It is very difficult to distinguish cause and effect in studies of language development but it is possible using complex statistical modelling. Using such modelling techniques, the researchers tested the direction of the relationship between vocabulary and turn-taking in conversation. They found evidence for bi-directional relationships, and this was true even when they controlled for the number of words each individual (caregiver and child) produced. In other words, growth in vocabulary creates more opportunities for conversations and, these, in turn, provide more opportunities to learn vocabulary.

Tracking the rhythm of speech
Infants learn a substantial amount about language in their first year of life, well before they start to talk. For example, by 12 months of age, children have learned to identify the speech sounds of their native language, to identify words in continuous speech, and to recognise the names of familiar people and objects. But how do they learn to do this so quickly and so early in life?

Previous work has shown that an ability called neural tracking may be key. Neural tracking refers to the phenomenon whereby human brain waves automatically synchronise to the rhythm of speech. There is some evidence that neural tracking may facilitate language acquisition, perhaps by making it easier to isolate and identify words in continuous speech, though the nature and strength of the relationship is still unclear.

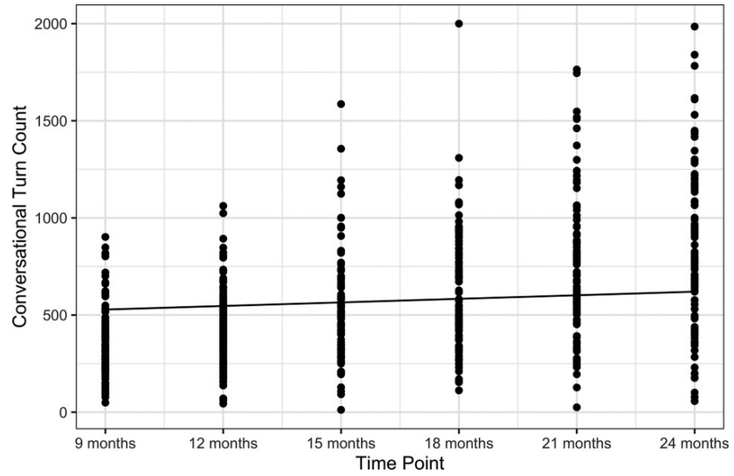


Figure 2. Growth in the number of turns that babies take in conversation from 9 months to 24 months of age. Each dot represents an individual child. Reproduced from Donnelly & Kidd (2021) with permission from the publishers.

In a recent paper, Katharina Menn, a Masters student under the supervision of senior investigator Tineke Snijders, investigated neural tracking in 10 and 14 month old neurotypical babies, and in babies at higher risk of autism (i.e. who had autistic siblings). They played songs (with words) to babies while measuring their brain waves using EEG; a safe and simple way to measure electrical brain activity in babies, which enabled the researchers to track how the babies' brains responded to the songs they were hearing.

The results showed that babies as young as 10 months are able to track the rhythm of speech in songs. In addition, the ability to track, in particular, the rhythm of stressed syllables in speech in songs, predicted language over a year later, at 24 months of age. However, there were no differences between neurotypical infants and those infants at higher risk for autism; both groups seemed to be tracking speech in the same way, and equally well. This suggests that although delayed language learning is often associated with autism, this might not be attributable to difficulties tracking the rhythm of speech.

The study also suggests an important role for songs in language development. Although there are substantial cultural differences in how, and how often, caregivers talk with babies, all caregivers, in all cultures and countries, sing. Singing may thus be an important route for babies to break into language, wherever they live, and whatever language they are learning.

Selected publications

Donnelly, S., & Kidd, E. (2021). The longitudinal relationship between conversational turn-taking and vocabulary growth in early language development. *Child Development,* 92(2), 609-625. doi.org/10.1111/cdev.13511

Garcia, R., & Kidd, E. (2022). Acquiring verb-argument structure in Tagalog: A multivariate corpus analysis of caregiver and child speech. *Linguistics,* 60(6), 1855-1906. doi.org/10.1515/ling-2021-0107

Garcia, R., Garrido Rodriguez, G., & Kidd, E. (2021). Developmental effects in the online use of morphosyntactic cues in sentence processing: Evidence from Tagalog. *Cognition*, 216: 104859. doi.org/10.1016/j.cognition.2021.104859

Kartushina, N., Mani, N., Aktan-Erciyes, A., Alaslani, K., Aldrich, N., Almohammadi, A., Alroqi, H., Anderson, L., Andonova, E., Aussems, S., Babineau, M., Barokova, M., Bergmann, C., Cashon, C., Custode, S., de Carvalho, A., Dimitrova, N., Dynak, A., Farah, R., ... Gibson, S. (2022). COVID-19 first lockdown as a window into language acquisition: Associations between caregiver-child activities and vocabulary gains. *Language Development Research*, 2(1), 1–36. doi.org/10.34842/ABYM-XV34

Menn, K. H., Ward, E., Braukmann, R., van den Boomen, C., Buitelaar, J., Hunnius, S., & Snijders, T. M. (2022). Neural tracking in infancy predicts language development in children with and without family history of autism. *Neurobiology of Language*, 3(3): 495-514. doi.org/10.1162/nol_a_00074

DEPARTMENT **NEUROBIOLOGY OF LANGUAGE**

Director Peter Hagoort
Department members Danbi Ahn, Jana Basnakova, Brigitte Bauer, Talat Bulut, Francesca Carota, Cas Coopmans, Annemarie van Dooren, Linda Drijvers, Ambra Ferrari, Stephanie Forkel, Laura Giglio, Teun van Gils, Ina Grevel, Soheila Hajizadeh Shadiabad, Micha Heilbron, Maarten van den Heuvel, Nienke Hoeksema, Eleanor Huizeling, Birgit Knudsen, Natalia Levshina, Ashley Lewis, Carolin Lorenz, Margot Mangnus, Sara Mazzini, Chinmaya Mishra, Mante Nieuwland, David Norris, Ann-Katrin Ohlerth, Müge Özker Sertel, David Peeters, Karl-Magnus Petersson, Fenna Poletiek, Alessio Quaresima, Michaela Regeer, Jan-Mathijs Schoffelen, Noor Seijdel, Daniel Sharoh, Maria Spychalska, Jakub Szewczyk, Atsuko Takashima, Rinus Verdonschot, Janniek Wester, Roel Willems, Chih Yeh, Hatice Zora.

Goals of the Department
The focus of the Neurobiology of Language Department is on the study of language production, language comprehension, and language acquisition from a cognitive neuroscience perspective. This includes computational modelling and using neuroimaging, behavioural and Virtual Reality techniques to investigate the language system and its neural underpinnings. The research facilities of this department are high-density EEG labs, two Virtual Reality labs, a whole-head 275 channel MEG system, three MRI-scanners at 3 Tesla, a high-field MRI scanner at 7 Tesla, a TMS-lab, an fNIRS lab, several behavioural labs, and a high-performance computing cluster. Most of the research in the department focuses on foundational aspects of language processing beyond the single word level. In addition, human-robot interaction was investigated with the latest addition, the social robot Dr Furhat.

Human-robot interactions
Furhat is a social robot head designed to interact with people. Whereas most social robots are limited to a single face, Furhat projects its face on a plastic facial mold. This gives it the ability to change its persona at will and show very detailed facial expressions making it suitable for many situations. In this department an advanced language model is used (GPT3), which can produce human-like responses, coupled with sentiment analysis (a method which ascertains the emotion of an utterance) to make human-robot interactions more natural and enjoyable. Additionally, together with members of a European project called "conversational brains" (jointly funded by ERC-Horizon and Marie Skłodowska-Curie Actions) a novel gaze control system was implemented allowing the Furhat to make more appropriate gaze cues which, for example, can be used to manage turn taking, guide joint attention, and signal cognitive effort between the Furhat and its conversational partners.

Information Structure in Makhuwa
In a conversation, some information is already shared between the conversational partners (i.e., the "background"), but other information is new. This new or contrasted information is called the 'focus' of the sentence. Languages differ in how they mark focus. For example, English and Dutch can use intonation: in "I heard PETER$_{foc}$" the last word is pronounced with a pitch accent indicating that it was Peter, and not someone else, who was heard. Other ways of marking focus involve syntactic constructions such as "It was Peter$_{foc}$ who talked." Earlier studies from this lab have shown that information that is in focus is processed more deeply than what is backgrounded. These studies measured brain waves while people were processing sentences, and found that semantic and syntactic incongruities resulted in reduced brain responses when they were not in focus. Researchers in the Neurobiology of Language department developed the hypothesis that despite linguistic variation in marking focus, the processing consequence is universal.

To test this hypothesis, Rinus Verdonschot and colleagues in this research group and from the University of Leiden investigated the processing of focus constituents in a language with a very different linguistic focus marker. The language they investigated is Makhuwa, a Bantu language spoken in Mozambique. Makhuwa marks the focused constituent through the inflection of the verb. In the present tense, for example, there are two forms of the verb. If the following word is in focus, the tense marker is n; if it is not, the tense marker is naa.

- Yarupa epula, ki-<u>n</u>-khala mpaani$_{foc}$.
  'If it rains, I stay INSIDE$_{foc}$.
- Yarupa epula, ki-naa-khala mpaani.
  'If it rains, I stay inside.

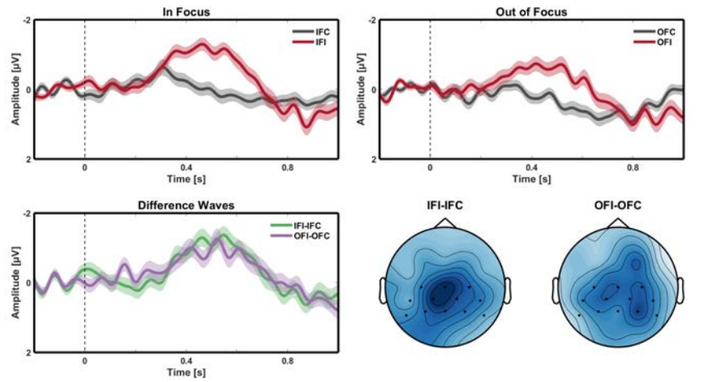
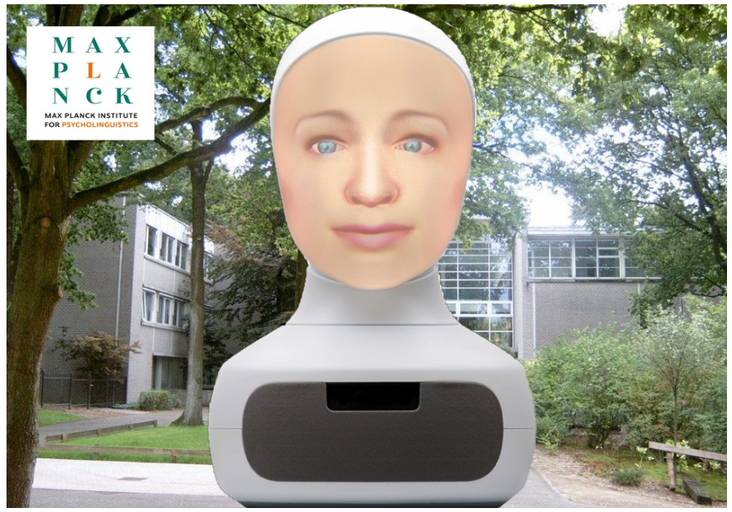


Figure 1. ERP results for the Mozambique study (Makhuwa); IFC: In Focus Congruent; IFI: In Focus Incongruent; OFC: Out of Focus, Congruent; OFI: Out of Focus Incongruent. Averaged ERP waveforms and topographic maps (right below) are depicted.



In the example the word *mpaani* ('inside') is focused in (1) as it is preceded by the n form of the verb (kinkhala), but in (2) it is not focused as indicated by the -naa- form.

Verdonschot and colleagues performed an EEG experiment (Figure 1) looking at semantic (in)congruency (e.g., "I eat bottles" vs. "I eat food") and verb-type (focus, non-focused). They found that when a target word was preceded by a focused verb form a more sustained negative brain potential was present. This may indicate that the postverbal constituent is important and therefore needs to be processed more deeply. This is congruent with a universal mechanism of upregulating (deeper) processing as a result of the linguistic focus marker.

The neural correlates of syntactic processing in narrative production and comprehension
In the last decade there has been an increase in studies of naturalistic language comprehension, often in the context of listening to audiobooks. Studying naturalistic *production* (i.e. speaking) may be even more critical, since most production studies use highly artificial tasks to ensure the production of varied speech output. In this fMRI study, Laura Giglio aimed to gain a better understanding of syntactic processing in spontaneous production and how it differs from naturalistic comprehension.

Giglio and colleagues analysed an existing fMRI dataset where a group of participants freely spoke for several minutes while recalling an episode of a TV series they had just watched. Another group of participants listened to the spoken recall of the speech output of one of the participants. For each recall, Giglio extracted the syntactic structure of every sentence (Figure 3). She then quantified word-by-word syntactic processing by counting the number of syntactic nodes that are built with each word. Nodes were counted with two different parsing strategies that make alternative predictions about the timing of phrase-structure building operations: either highly anticipatory, predicting increased activity when phrases are opened (i.e. at the start of a sentence, tree structure on the left), or integratory, predicting increased activity when they are closed (i.e. at the end of a sentence, tree structure on the right).

Condition	Sentence
Ambiguous	[De fan belaagde de drummer] en [de gitarist pakte de instrumenten in].
	[The fan attacked the drummer] and [the guitarist packed the instruments up].
Unambiguous	[De fan belaagde de drummer], en [de gitarist pakte de instrumenten in].
	[The fan attacked the drummer], and [the guitarist packed the instruments up].
Control	De fan belaagde [de drummer en de gitarist] met een mes in de hand.
	The fan attacked [the drummer and the guitarist] with a knife in his hand.

Figure 2. Stimuli used in the neuropharmacolinguistic project.

Anticipatory node counts were associated with a decrease in neural activity in comprehension. In contrast, they were associated with an increase in neural activity in production.

Both the Posterior Temporal Lobe and BA45 in the Inferior Frontal Gyrus responded to syntactic processing in comprehension. However, only BA45 was responsive in production, confirming that BA45 is a critical hub for syntactic processing across modalities, also in task-free designs. Overall, the results showed that the unfolding of syntactic processing diverges between speaking and listening and highlight the insights that can be gained by studying naturalistic production.

The influence of catecholamine on syntactic unification:
A neuropharmacolinguistic project

A full understanding of how the human brain implements language processing will require knowledge of how neurotransmitters like dopamine support electrochemical signaling in specific brain systems. Dopamine and noradrenaline are two members of the catecholamine (CA) family of neurotransmitters, exhibiting an abundance of receptors throughout the prefrontal cortex and the striatum of the basal ganglia. These brain systems overlap with important nodes of the brain's language networks. In previous electroencephalography (EEG) work the research group established a causal link between CA in the brain, and semantic unification (the operation responsible for combining the meaning of words in a sentence).

A follow-up EEG study addressed the question of whether such a relationship exists with syntactic unification (the operation responsible for creating hierarchical relationships between the words comprising a sentence). Yingying Tan and Ashley Lewis used a classical garden-path paradigm where upon encountering the target word (TW) marked in red, syntactic reanalysis is either required ('Ambiguous' condition) or not ('Control' and 'Unambiguous' conditions). The well-established P600 event-related response to increased syntactic complexity was used as a signature of differential demands on syntactic unification. In order to evaluate the influence of CA in the brain on this signature of syntactic unification, participants took part in two separate EEG sessions. In one session they received 20 milligrams of methylphenidate (commonly known as Ritalin). In the other session they received a placebo.

Since methylphenidate increases the level of CA in the brain, the expectation was that if CA levels are linked to syntactic unification *Drug Status* should influence the size of the P600 effect. Tan and Lewis found a clear P600 effect for the comparison between 'Ambiguous' and 'Control' conditions. Importantly, while there was a main effect of *Drug Status*, the interaction between *Condition* and *Drug Status* was not statistically significant in the P600 time window. The study thus provides evidence that, in contrast to the earlier finding for semantic unification, the level of CA in the brain is not directly linked to syntactic unification, at least not for the type of syntactic reanalysis required by our experimental sentences.

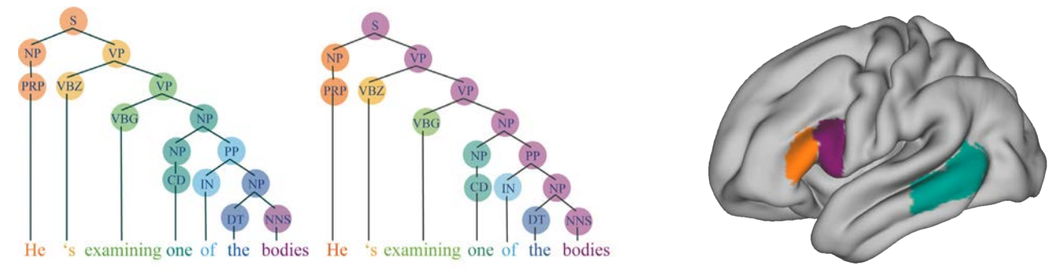


Figure 3. Anticipatory parsing tree (left); Integratory parsing tree (right).

The Tripod neuron as an accurate model of the dendritic tree

To understand how language works in the brain, it is crucial to understand the nature of the underlying basic neural computations. The basic elements involved are the neurons, large cells composed of several lengthy appendices called dendrites and of a central body called the soma. Dendrites are traditionally considered passive elements that the neuron uses to collect inputs from other cells and gather them to the soma, where the computations happen. However, increasing experimental evidence suggests that dendrites may have a prominent role in pre-processing the signal.

Alessio Quaresima and colleagues investigated whether including dendrites in a neuron model can increase its computational capacity and contribute computations relevant for language. To this effect, Quaresima developed a simple but rich neuron model with two dendritic compartments. The dendrites are modelled after human dendrites, with lengths that correspond to actual dendrites of pyramidal cells. The dendrites are endowed with NMDA receptors (NMDARs); NMDARs are slow excitatory receptors with a timescale of hundreds of milliseconds. For NMDAR to activate, it requires that the incoming inputs are matched with a depolarised dendritic membrane. In other words, NMDARs activation depends on previous activity.

The Tripod neuron is simulated against standard neurophysiological protocols. Quaresima and colleagues showed that this simplified dendritic tree can reproduce the principal phenomena associated with dendritic processing, such as coincidence detection and shunting inhibition on the dendrites. Because the conditions for the activation of the NMDAR are satisfied only when two or more stimuli follow in a short time window, the NMDARs naturally endow the Tripod neuron with a biological mechanism to detect sequences. In addition, the dendritic length defines the signal's retention time, which corresponds to the width of the pre-activation window. As a result, short dendrites are sensitive to fast sequences, and longer dendrites to slower ones. Because of this characteristic, the Tripod neuron can distinguish between stimulus sequences containing the same input patterns but arranged differently in time.

The sequence recognition achieved by the Tripod neuron is not attained in neurons without dendrites. This indicates that modelling dendrites may be necessary for future studies of sequence processing. Overall, the researchers demonstrate that accurate models of neurobiology can offer novel insights into the brain mechanisms that support language. It is an important addition to most artificial neural network models, which are based on point neurons without dendritic architecture.

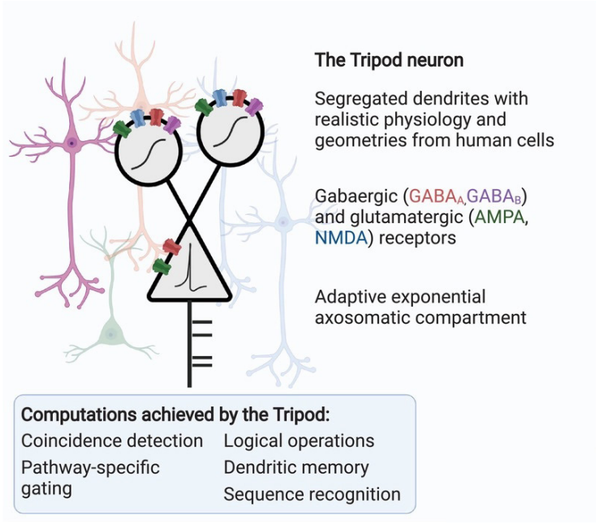


Figure 4. A sketch of the tripod neuron.

Selected publications

Giglio, L., Ostarek, M., Weber, K., & Hagoort, P. (2022). Commonalities and asymmetries in the neurobiological infrastructure for language production and comprehension. *Cerebral Cortex*, 32(7), 1405-1418. doi:10.1093/cercor/bhab287.

Heilbron, M., Armeni, K., Schoffelen, J.-M., Hagoort, P., & De Lange, F. P. *(2022).* A hierarchy of linguistic predictions during natural language comprehension. *Proceedings of the National Academy of Science,* 119(32):e2201968119. doi: 10.1073/pnas.2201968119.

Nieuwland, M. S. (2021). How 'rational' is semantic prediction? A critique and re-analysis of. *Cognition*, 215: 104848. doi:10.1016/j.cognition.2021.104848.

Udden, J., Hulten, A., Schoffelen, J.-M., Lam, N. H. L., Harbusch, K., Van den Bosch, A., Kempen, G., Petersson, K. M., & Hagoort, P. (2022). Supramodal sentence processing in the human brain: fMRI evidence for the influence of syntactic complexity in more than 200 participants. *Neurobiology of Language*, 3(4), 575-598. doi:10.1162/nol_a_00076.

Seijdel, N., Marshall, T. R., & Drijvers, L. (2022). Rapid invisible frequency tagging (RIFT): A promising technique to study neural and cognitive processing using naturalistic paradigms. *Cerebral Cortex*. Advance online publication. doi:10.1093/cercor/bhac160.

DEPARTMENT
PSYCHOLOGY OF LANGUAGE

Director Antje S. Meyer
Department members Phillip Alday, Mrudula Arunkumar, Fan Bai, Federica Bartolozzi, Miguel Borges, Hans Rutger Bosker, Ronny Bujok, Laurel Brehm, Ruth Corps, Ava Creemers, Caitlin Decuyper, Marjolijn Dijkhuis, Saoradh Favier, Jieying He, Florian Hintz, Vera van 't Hoff, Falk Huettig, Cecilia Husta, Sara Iacozza, Suzanne Jongman, Bob Kapteijns, Greta Kaufeld, Andrea E. Martin, Merel Maslowski, Thy Mathu, Jeroen van Paridon, Limor Raviv, Joe Rodd, Aitor San José, Sophie Slaats, Alastair Smith, Elli Tourtouri, Orhun Ulusahin, Annelies van Wijngaarden, Merel Wolf, Eirini Zormpa

Goals of the Department
The mission of the department is to understand how adult native speakers produce and understand language. The researchers in the department develop processing models for linguistic tasks such as object naming or understanding spoken sentences and study how well these models apply to different situations and individuals. Of particular interest are situation variables encountered in everyday contexts, for instance talking in silence or noise, or interacting face-to-face or in a video conference. The researchers assume that across situations speakers and listeners carry out basic language tasks in similar ways, but adapt to the contexts. The same holds for person variability (Figure 1). All listeners and speakers share the basic architecture of the cognitive system, but variations in experience and skills may affect how they carry out linguistic tasks. Important research questions are which processing components are affected in which ways by situation and person variables. By thinking in this way about linguistic tasks, the department brings together individual differences work on linguistic skills with experimental research. The work in the department is organised in the clusters described below.

The Cultural Brain Cluster
The work in the Cultural Brain cluster has focussed on two often intertwined issues: the effects of different degrees of literacy on cognition and the role of prediction in language processing. The work on literacy concerns both variability within groups who can read but differ in linguistic experience, and comparisons between literate and illiterate groups. For instance, in her dissertation project Saoradh Favier showed how differences in literacy experience within a group of Dutch participants with diverse educational backgrounds affected their predictions in spoken language processing, grammaticality judgements, and the use of different Dutch dative structures (Figure 2). Work in India with literate and illiterate groups concerned the impact of literacy on visual skills, including perception of mirror images and faces. This work contributes to the debate on the question whether reading harms or supports face recognition.

The work on prediction overlaps with the work on literacy, as literacy affects prediction in processing written and spoken language. Recent work has concerned prediction in challenging situations. A key finding is that effects of speech rate and participant instructions reveal strong limits on prediction in language processing. These findings are problematic for the view that prediction pervades cognition and that humans are 'prediction machines'. In collaboration with linguists Audring and Jackendoff, cluster leader Falk Huettig developed a novel linguistic perspective on prediction.

The Juggling Act: Speaking and Listening Cluster
The Juggling Act cluster focusses on listening and speaking in conversation. Conversation is of great interest to the department because it is the primary way of using language, and because it is such an intriguing cognitive and social skill. In conversation, different speakers' utterances typically follow each other seamlessly, often even overlap. This shows that speakers manage to rapidly grasp the partner's meaning, integrate it into their own thinking, and begin to plan a response while listening to the conversational partner.

Earlier work in the department had focussed on the temporal coordination of listening and speech planning, studying, for instance, when upcoming speakers begin to plan their utterances. Recent studies explored how much speech planning is affected by concurrent listening to speech and vice versa. This question is important because conversation often takes place in noisy backgrounds, and because speakers in conversation often talk at the same time. This research showed that listening and speech planning interfere with each other, as one might expect, but it also demonstrated that the production and comprehension system are remarkably resilient against interference from the other system. For instance, in her dissertation project, Jieying He showed that planning and producing series of picture names were not affected much more by concurrent Dutch speech, which the speakers understood, than by concurrent Chinese speech, which they did not understand (Figure 3). Similarly, Federica Bartolozzi found in her dissertation project that repetition priming from spoken words was not reduced when the speakers heard the primes while simultaneously planning picture names compared to only hearing the primes. The experimental work is complemented by analyses of corpora of conversational speech.

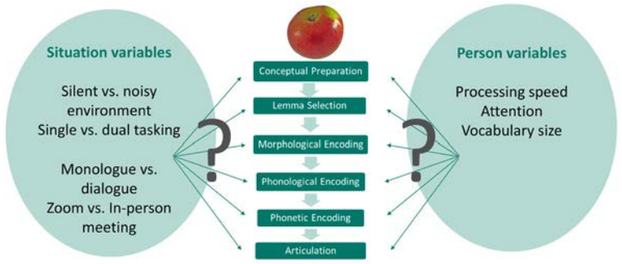


Figure 1. Linguistic tasks, such as object naming, require a number of processing steps. Situation and person variables may affect how they are carried out.

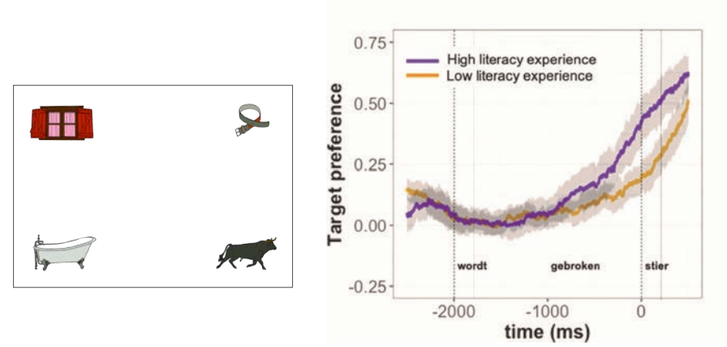


Figure 2. Prediction is moderated by linguistic experience. When hearing a sentence such as '"Het raam wordt nu gebroken door de stier" (The window is now smashed by the bull) participants with high literacy experience look earlier at the target (the bull) than participants with lower literacy experience. The left panel shows the participant display. The right panel shows the preference of looks to the target (stier) relative to the three competitor objects, time-locked to the onset of the target in participants with high literacy (purple line) and lower literacy (yellow line).

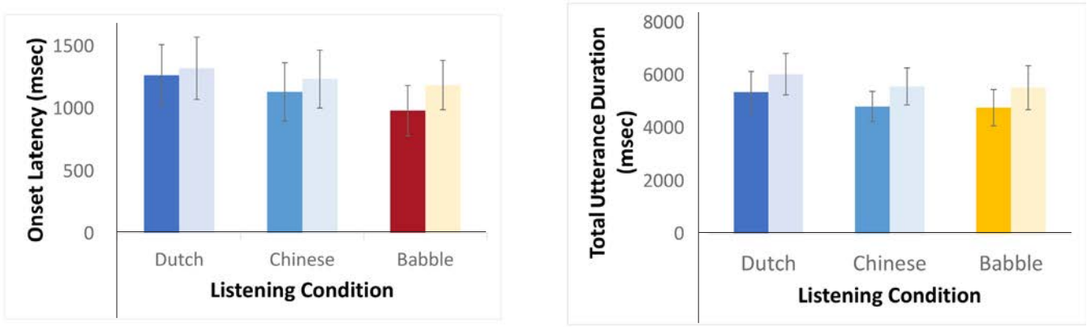


Figure 3. When Dutch speakers name multiple pictures in a list, they are slower to begin to name them (left panel) and take longer to complete their utterances (right panel) when they hear Dutch speech in the background than when they hear Chinese speech, which they cannot understand, or eight-talker "babble". Dark and lighter bars show the results for easy pictures (high name agreement) and harder pictures (lower name agreement), respectively.

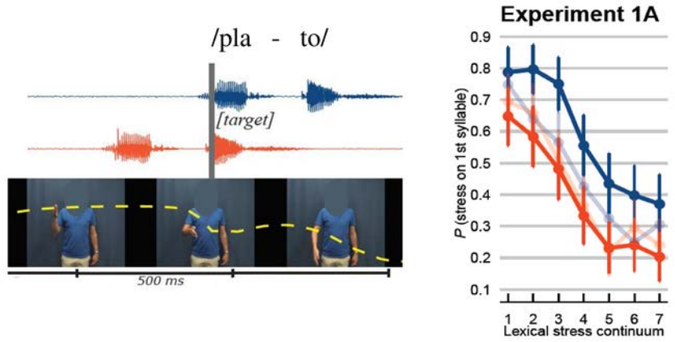


Figure 4. When listeners hear a word with ambiguous stress cues, the timing of a manual beat gesture can bias them to perceive the word as having initial stress ("PLAto") or final stress ("plaTEAU"; Bosker & Peeters, 2021). The top-left panel illustrates the alignment of the gesture with the speech signal. The bottom-left panel shows how the speaker's face was masked in the experimental materials. The yellow line shows the downward movement of the hand. The right panel shows how likely the listeners were to categorise the words as having initial stress when stress cues were varied (1 = unambiguous initial stress, 7 = unambiguous final stress). The solid red and blue lines show how the categorisation changed depending on the timing of the gestures relative to baseline conditions without gestures (faint lines).

The aim of these analyses has been to obtain a clear picture of key properties of conversational speech, for instance the length of turns, the grammatical structures and words speakers prefer and the well-formedness of their utterances. On the basis of this information, hypotheses for experimental work are generated. Corpus analyses revealed, among other things, that automatic annotations of conversational speech often do not provide valid indicators of turn boundaries, and that speakers, contrary to the received view in the literature, often develop their turns in parallel, i.e. speak at the same time about related topics. Future work will be directed at understanding the temporal and conceptual links between utterances in parallel talk.

The TEMPoral Organisation of Speech (TEMPOS) Cluster

The TEMPoral Organisation of Speech (TEMPOS) cluster studies the temporal characteristics of speech perception. A central question concerns the robustness of speech perception in challenging conditions. Challenges arise from talker variability, for instance from the use of different regional or non-native accents, and from contextual variables such as background noise. Much work in the cluster has concerned the processing of speech rate, for instance investigating how listeners use the speech rate in the context to decide whether a Dutch speaker said "tak" ("branch", with a short vowel) or "taak" ("task", with a long vowel). Extending this line of work, the group showed that the mechanisms underlying such rate normalisation are remarkably resilient and function well in noise and under conditions of divided attention.

In new lines of work the group has studied the use of visual information from the lips and from manual gestures in speech processing. The researchers showed, for instance, that the timing of a beat gesture relative to the auditory speech input affects how likely listeners are to categorise a word with ambiguous stress cues as "PLAto", with stress on the first syllable, or "PlatEAU", with stress on the second syllable. This finding demonstrates that the visual information from the gesture affects what listeners understand (Figure 4).

Individual Differences in Language Skills

Healthy adult native speakers of a language differ in their linguistic skills. Given the focus of experimental psycholinguistics on the average performance in students, we do not know how much variability in carrying out linguistic tasks there is and how to account for it. However, such information is crucial for generating comprehensive theories of speaking and listening, and to study, for instance, how speakers with different linguistic skills understand and produce language in challenging situations.

The main goal of the largely NWO-funded cluster Individual Differences In Language Skills over the past five years has been to develop and validate a new test battery of language skills in young adult speakers of Dutch. An important feature of the battery is that it assesses a broad range of skills: It includes tests of linguistic knowledge (grammar and vocabulary), of word and sentence production, of word and sentence comprehension, and of domain-general

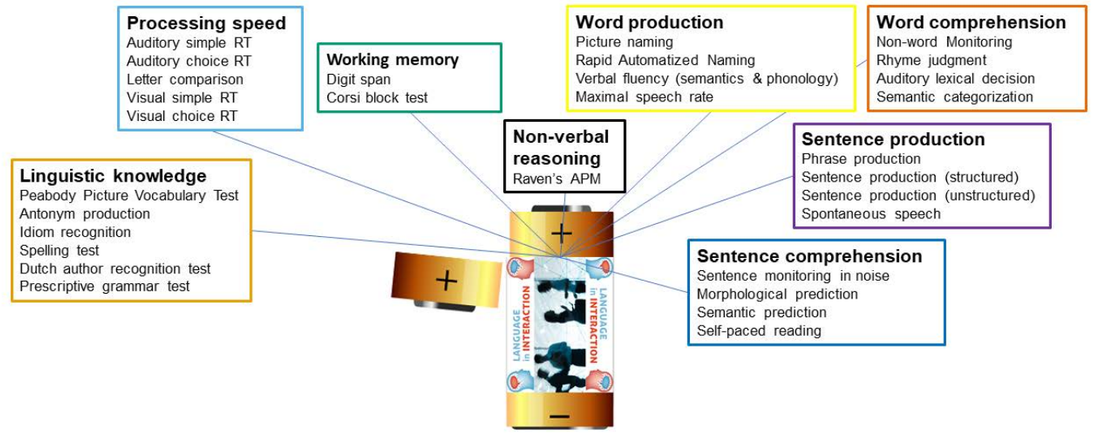


Figure 5. The IDLaS (Individual differences in Language Skills) battery comprehensively assesses linguistic knowledge, domain-general skills that are relevant in speaking and listening (processing speed, working memory, and non-verbal memory) and word and sentence production and comprehension.

cognitive skills implicated in speaking and listening. Each of these domains is assessed with multiple tests. By assessing individuals broadly, researchers can determine the relationships between different components of the cognitive system, and, for instance, study to which extent word production and comprehension rely on shared or unique underlying skills. The battery is now freely available to the research community: www.mpi.nl/idlas-nl.

Selected publications

Bartolozzi, F., Jongman, S. R., & Meyer, A. S. (2021). Concurrent speech planning does not eliminate repetition priming from spoken words: Evidence from linguistic dual-tasking. *Learning, Memory, and Cognition, 47*(3), 466-480. doi:10.1037/xlm0000944

Bosker, H. R., & Peeters, D. (2021). Beat gestures influence which speech sounds you hear. *Proceedings of the Royal Society B: Biological Sciences, 288*: 20202419. doi.org/10.1098/rspb.2020.2419

Corps, R. E., Knudsen, B., & Meyer, A. S. (2022). Overrated gaps: Inter-speaker gaps provide limited information about the timing of turns in conversation. *Cognition, 223:* 105037. doi:10.1016/j.cognition.2022.105037

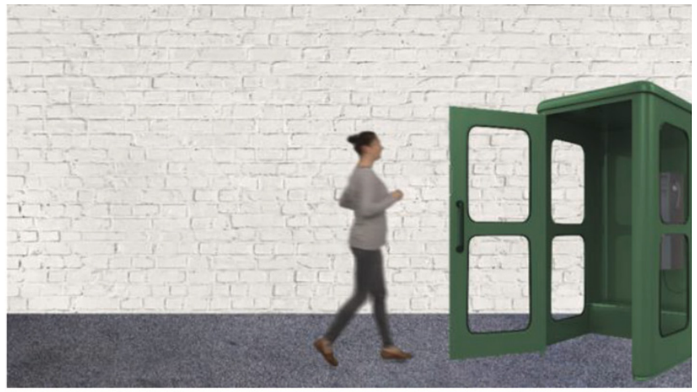
Favier, S., Meyer, A. S., & Huettig, F. (2021). Literacy can enhance syntactic prediction in spoken language processing. *Journal of Experimental Psychology: General, 150*(10), 2167-2174. doi:10.1037/xge0001042

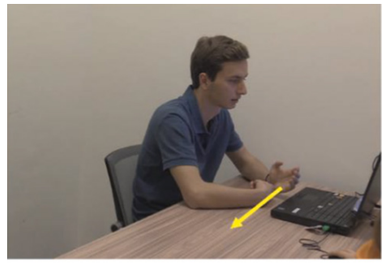
Huettig, F., Audring, J., & Jackendoff, R. (2022). A parallel architecture perspective on pre-activation and prediction in language processing. *Cognition, 224:* 105050. doi.org/10.1016/j.cognition.2022.105050

DEPARTMENT **MULTIMODAL LANGUAGE**

Director Asli Özyürek
Department members Sho Akamine, Mark Dingemanse, Dilay Karadoller, Brigit van Loon, Ezgi Mamus, Wim Pouw, Marlou Rasenberg, Anita Slonimska, Beyza Sumer.

Goals of the Department
The general mission of the department is to understand the architecture of human language as a flexible and adaptive system. To do so the department aims to unravel how language is shaped by and interacts with human biological, neural, and cognitive constraints on the one hand and by the requirements of culturally bounded interactive contexts on the other. Thus it adopts a multimodal approach going beyond what can be derived by looking at spoken or written forms of language alone. Researchers investigate how language can be expressed flexibly and adaptively in situated and face-to-face contexts through visual (e.g., as in gestures used by hearing communities and (emerging) sign languages created by Deaf communities) and auditory (speech) modalities- as a novel window to understand what they reveal about our language capacity. Visual articulators, unlike speech or text, have unique affordances for visible iconic, indexical and simultaneous representations that require to change some of our fundamental assumptions about linguistic structure. The department asks how a multimodal approach to language enhances our understanding in four domains of language: a) structure, b) use in interactive and discourse contexts, c) neural and cognitive processing, and d) transmission (learning, acquisition and evolution). Researchers use multimodal corpora collected from diverse spoken and sign languages, (bimodal) bilinguals, adults and children, and special populations (e.g., blind people, adults with autism, deaf individuals with no access to language) and use multiple experimental, neuroimaging and virtual reality methods. Finally, the department develops new machine learning methods that use computer vision techniques (e.g. Kinect, Open Pose) to analyse visual expressions to understand kinematic regularities that contribute to patterns at different levels of language. The general aim therefore is to unravel new insights about the human language faculty and its cognitive and social foundations by considering its multimodal and cross-linguistic diversity as a fundamental design feature of language.





Speech: Manner + Path
çardağa sekerek giriyor
Manner Path Verb
'(she) is entering the gazebo hopping'
Event: A woman hopping into a gazebo

Figure 1. LEFT is a stimulus motion event used to investigate eye gaze patterns of viewing the event and RIGHT is an example from a Turkish speaker's speech and gesture describing the event. Underline indicates where the gesture occurred during speech.

Links between eye and the hand during language production
It is a well-established phenomenon that visual attention and language production are linked systems. Speakers' visual attention to event components such as manner and path are guided by the linguistic information uttered during speaking and this can vary in language-specific ways. This department examined whether the link between speech production and visual attention also extends to co-speech gesture production (i.e., to relations between eye and hand) and in language-specific ways. The researchers asked Turkish speakers to watch motion events and monitored their eye gaze patterns prior to utterance production and investigated whether their eye gaze to manner and/or path of the motion events predicted how they talked as well as gestured about the event. As Turkish is a verb-framed language, speakers expressed path mostly in the main verb and manner with a subordinate clause (Figure 1). In some cases, however, they expressed path with a postpositional phrase outside the verb. They also used mostly path gestures, in line with the fact that path is expressed in the main verb. Importantly the relative attention allocated to path over manner was higher when speakers (a) encoded path in the main verb versus outside the verb and (b) used additional path gestures accompanying speech versus not. Results strongly suggest that speakers' visual attention is guided by language-specific event encoding not only in speech but also in gesture. This provides evidence consistent with models that propose integration of speech and gesture at the conceptualisation level of language production as opposed to outside of the language production system and not interfacing with it.

Thus during language production not only the eye and the mouth are linked but also the eye and the hand.

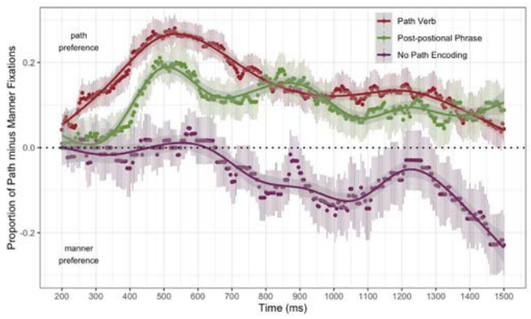


Figure 2. Eye gaze patterns to event components linked to different types of spoken expressions.

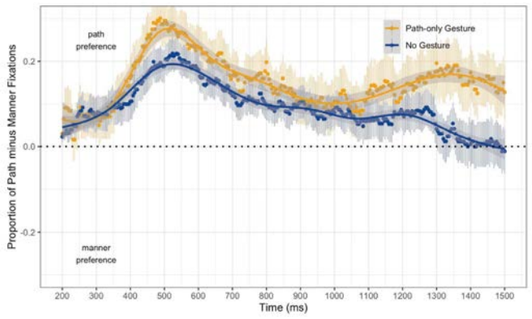


Figure 3. Eye gaze patterns to event components linked to gesture production.

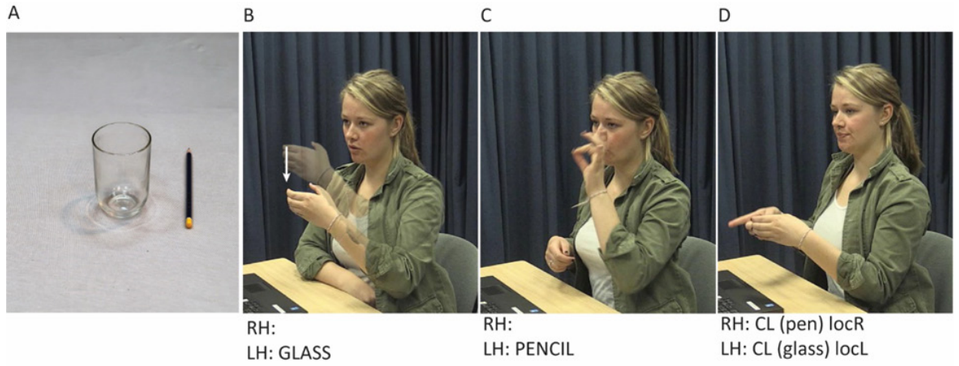


Figure 4. An utterance in Dutch sign language used to express a spatial relation. The screenshot in D shows the iconic way of expressing objects and their spatial relations next to each other (i.e, pencil to the right and glass to the left).

Visual modality in sign and gesture provides faster access to spatial language development than speech
Learning spatial language is challenging for speaking children as it requires mapping a visual format of representations onto arbitrary and discrete symbols of speech. This challenge is found to be even greater for left-right relations, as they require different labels that are about symmetrical sides of a deictic anchor (i.e., learning labels like left vs. right that map each side of the human body). Thus, children learning different spoken languages are known to master expressing spoken labels for left and right relations not until nine years of age. Here we asked for the first time whether having access to information in the visual modality about left-right relations provides children with an advantage, as visual modality allows an iconic mapping of left-right relations onto the visible bodily articulators (i.e., using left hand to express left). Eight-year-old child and adult hearing Turkish speakers and deaf signers of Turkish Sign Language described pictures of objects in various spatial relations (e.g., pen to the left of a paper). Descriptions were coded for informativeness in speech, sign, and speech-gesture combinations for encoding left-right relations. The use of co-speech gestures increased the informativeness of speakers' spatial expressions of left and right compared to speech-only and more so for children than adults. However, signing adults and children were more informative than both child and adult speakers even when co-speech gestures were considered. Thus, both speaking and signing children benefit from iconic expressions in the visual modality and the visual modality facilitates learning spatial relations more than speech.

Cross-modal language transfer in bimodal bilinguals
Bimodal bilinguals are hearing and deaf individuals who can use both a sign and spoken language. Even though most research on bilingualism has focused on the nature of cross-linguistic transfer, this research has been mostly based on spoken languages. Here we asked whether and how hearing individuals who know both a sign (Nederlandse Gebarentaal, NGT) and a spoken (Dutch) language exhibit cross-linguistic transfer bidirectionally, particularly focusing on the spatial domain, where in sign languages iconic expressions are preferred. Unlike spoken languages, sign language uses iconic linguistic forms that resemble physical features of objects and relations between them and thus expresses more specific semantic information than spoken expressions. We investigated if such iconic expressions in sign languages that do not have correspondences in spoken language can be transferred to the spoken language and vice versa. Hearing bimodal bilinguals fluent in Dutch and NGT and their hearing nonsigning and deaf signing peers described left/right relations between two objects. Bimodal bilinguals expressed more specific information about physical features of objects in speech than nonsigners, showing influence from sign language. They also used fewer iconic signs with specific semantic information than deaf signers, demonstrating influence from speech. Thus bimodal bilinguals' speech and signs are shaped by two languages from different modalities bidirectionally, even when expressions in sign are iconic (i.e., in a different format than that of speech). The human ability for cross-linguistic transfer is not specific to any modality or type of semiotic expression.

Computer vision techniques reveal changes In continuous kinematic features in the visual modality and emergent linguistic structures in language evolution
Sign languages are the only languages that can emerge anew among deaf individuals, even when there is no conventional sign language in a deaf community. How this emergence happens can give us clues about language evolution in ways that we can not address studying spoken languages alone. Recent research has shown that simulating sign language emergence in the lab can provide us with insights about the language emergence process. In these simulations hearing speakers are asked to communicate with each other using silent gestures, without using speech, in an iterated learning experimental paradigm where signals are transmitted to other generations iteratively. One of these experiments studied the transmission of silent gestures created to communicate 24 concepts along two broad semantic dimensions: theme (e.g., food, religion) and function (e.g., person, location; see Fig. 5). This study found that over generations of transmission, while the categorical meaning spaces expressed by signs reduced, functional markers about concepts emerged (e.g., different signs to differentiate people versus tools etc. emerged). Using this previous open access data set we applied computer vision techniques and Dynamic Time Warping (DTW) analysis to quantify the kinematics of the original data not in a categorical but in a continuous way. We found that over generations, gesture kinematics reduces its complexity by reducing size, sub-movements and increasing rhythmicity, making the system more communicatively efficient. We also found that gesture kinematic dialects emerged over generations as isolated chains of participants gradually diverged over iterations from other chains. Therefore, from continuous kinematics alone, we can tap into linguistic aspects that were previously only approachable through categorical coding of meaning and some not even detectable. These results also demonstrate that a gesture's form can be transparent to its emergent linguistic functioning. This open access computer vision technique and analysis can be a very useful tool in investigating big data about emerging sign languages in the wild.

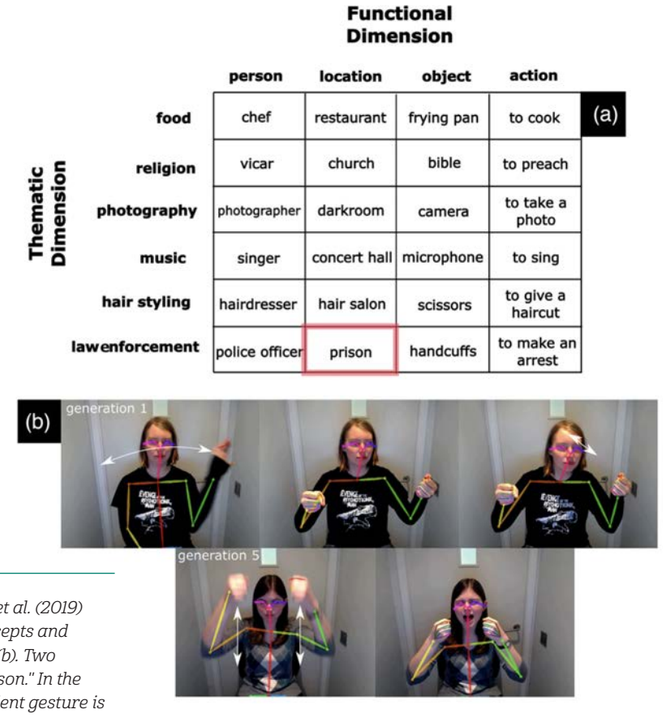


Figure 5. Concepts conveyed in gesture in Motamedi et al. (2019) and (motion tracking) examples showing (a) The concepts and categories that were used in the original experiment (b). Two examples of silent gestures depicting the concept "prison." In the first generation (top), a drawn out multicomponent silent gesture is produced (multiple arm movements and head movement), while in the final generation 5, a simpler gesture is produced with only two components. For the current study, we used motion tracking of the silent gestures, indicated here with a pose-skeleton overlaying the original video data.

Selected publications

Karadöller, D. Z., Sumer, B., Ünal, E., & Özyürek, A (2022). Sign advantage: Both children and adults' spatial expressions in sign are more informative than those in speech and gestures combined. *Journal of Child Language.* Advance online publication. doi:10.1017/S0305000922000642.

Ünal, E., Manhardt, F., & Özyürek, A. (2022). Speaking and gesturing guide event perception during message conceptualization: Evidence from eye movements. *Cognition,* 225: 105127. doi:10.1016/j.cognition.2022.105127.

Manhardt, F., Brouwer, S., & Özyürek, A. (2021). A tale of two modalities: Sign and speech influence each other in bimodal bilinguals. *Psychological Science,* 32(3), 424-436. doi:10.1177/0956797620968789.

Pouw, W., Dingemanse, M., Motamedi, Y., & Özyürek, A. (2021). A systematic investigation of gesture kinematics in evolving manual languages in the lab. *Cognitive Science,* 45(7): e13014. doi:10.1111/cogs.13014.

Trujillo, J. P., Özyürek, A., Holler, J., & Drijvers, L. (2021). Speakers exhibit a multimodal Lombard effect in noise. *Scientific Reports,* 11: 16721. doi:10.1038/s41598-021-95791-0.


L&G

MAX PLANCK RESEARCH GROUP
COMPARATIVE BIOACOUSTICS

Group Head Andrea Ravignani
Group members Diandra Düngen, Maria Goncharova, Taylor Hersh, Yannick Jadoul, Silvia Leonetti, Lianne Peters, Koen de Reus, Anna Salazar-Casals, Laura Verga, Jelle van der Werff

Goals of the Group
The Comparative BioAcoustics group's mission is understanding the biological building blocks of human speech and music also present in another animal species, trying to infer key innovations in human cognitive evolution and point out human-unique traits. While each species has its own unique capacities, an aptitude for speech and music may be a human-distinctive feature. Why are we musical animals? And why do we speak? Do these two human capacities have a joint evolutionary history? To tackle these questions, the group investigates why humans and some other species are skilled at vocal learning and rhythm, how the capacities underlying speech and music may have evolved, and how they may be linked. Rare in other species, a peculiar human feature is our capacity for vocal learning: the ability to imitate and learn to produce new sounds, when these sounds do not belong to our 'innate' repertoire. Humans are also outliers in their sense of rhythm: their enjoyment of rhythmic patterns and drive to synchronise to them. Thus, rhythm and vocal learning, on which human music and speech are based, are somewhat of an evolutionary mystery: Both abilities are linked and common in humans but rare in mammals. The group takes a comparative approach to understanding the existence of, and link between, rhythm and vocal learning; comparing similarities and differences across species to determine what is typically human, what is only human, and what is shared with other species in rhythm and vocal learning. In this way the group hopes to discover which evolutionary precursors of the human capacities for speech and music are present across species, and which are unique to humans.

Only us?
The biological underpinnings of speech and rhythm arose via a series of evolutionary events. To understand their evolution in our species and avoid post-hoc explanations only based on one case, humans, one needs to compare similar processes in as many species as possible. The group's cross-species animal work maps different speech-related and music-related features to the mammalian tree of life, testing in which cases either common ancestry or similar environmental pressures lead to similar traits in different species.

Rhythm and vocal learning: linked across species?
For example, the group is currently testing whether human vocal and rhythmic flexibility have a joint evolutionary history. The group studies the co-occurrence of rhythmicity and vocal learning across mammals, testing for their cross-species association. Initial findings indeed support a cross-species link between the two capacities.
In addition to large-scale, cross-species comparisons, the group's research zooms in on some animal species, mostly seals and primates. Because of their capacity for rhythm and vocal learning, work with seals is key to testing hypotheses about our own linguistic and musical abilities. Likewise, because of their proximity to humans, primate work can complement human data and data from other species.

The mammalian roots of vocal learning
Recent work from the group shows laryngeal modulation abilities in seals. The group studies seals as one of the few mammals capable of vocal production learning. In a playback experiment, they played band pass-filtered noise overlapping with the fundamental frequency of 2 weeks' old seal pups. Unlike most animals that would simply boost the amplitude of their calls to evade noise masking, seal pups lowered the fundamental frequency of their calls as to escape noise. This experiment shows controlled laryngeal modulation in another mammal, also predicting that the direct cortico-bulbar projections hypothesised by Kuipers and Juergens to control the larynx in humans may also be present in seals' brains.

Learning vocalisations and developing rhythm: Lessons from seal pups in the North Sea
This strand of work focuses on how seal pups learn to produce new sounds, and integrates controlled cognitive experiments with sound analysis. The group records new-born seal pups and tracks their vocal learning capacities across development. Non-invasive behavioural work probes seals' ability to learn new sounds and the mechanisms to accommodate to the timing of another pup, roughly similar to human turn-taking. Initial findings suggest that a seal pup's acoustic environment strongly shapes its sound production and rhythmic attitudes. In addition, recent work from the group has shown rhythm perception capacities already in seals of one year of age or even younger.

Primate rhythms from the rainforest of Madagascar
Other recent work from the group shows key features of human rhythm production for the first time in a non-human mammal. One universal feature of human music is that note durations are not uniformly distributed, but cluster around arbitrary values which are however related to each other by small integer ratios. The group has shown that this feature is also present in the group song of one of our relatives, the singing lemur *Indri indri*. Finding this feature in another primate indirectly implies that rhythmic hierarchies may not be unique to the human mind.

Comparative neurobiology and vocal tract anatomy
Humans are capable of flexible sound production because of the interaction of two organs of the body: the vocal tract and the brain. We know quite a lot about how humans use these organs to speak, but very little about whether they work in similar ways in other animals such as seals. In this strand of work, the group investigates the similarities and differences between the neural and vocal tract anatomy of humans and seals.
To do this, the group collects and analyses post-mortem samples from seals that died of natural causes. Vocal tract samples can inform, for instance, which muscles and cartilages underpin flexible sound production. The group then uses brain imaging techniques that show how developed and interconnected the seal brain areas are that, in humans, are key for speech and rhythm. This line of research can shed light on the evolutionary precursors, both at the neural and the anatomical level, of human speech production.

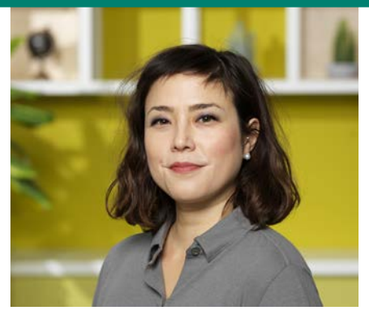
Selected publications

Sroka, M., Verga, L., Varola, M., Villanueva, S., Ravignani, A. (2022). Rhythm perception in a mammalian vocal learner. *Biology Letters*, 18(10). doi.org/10.1098/rsbl.2022.0316

Torres-Borda, L., Jadoul, Y., Rasilo, H., Salazar-Casals, A. & Ravignani, A. (2021). Vocal plasticity in harbor seal pups. *Philosophical Transactions B*, 376(1840). doi.org/10.1098/rstb.2020.0456

De Gregorio, C., ..., Ravignani, A. & Gamba, M. (2021). Categorical rhythms in a singing primate. *Current Biology*. 31(20). doi.org/10.1016/j.cub.2021.09.032.

LISE MEITNER RESEARCH GROUP
LANGUAGE AND COMPUTATION IN NEURAL SYSTEMS



Group Head Andrea E. Martin
Group members Fan Bai, Cas Coopmans, Rong Ding, Anna Mai, Lianne Peters, Sophie Slaats, Noémie te Rietmolen, Filiz Tezcan, Nikolas Vasileadis, Hugo Weissbart, Marieke Woensdregt, Jinbiao Yang, Leonardo Zeine, Ioanna Zioga

Goals of the Group
When we understand language, our brains go beyond the physicality of the stimulus given, using both statistical information and rule or grammar-based knowledge. The goals of the group are to understand how the mind and brain achieve this, namely, how structures and statistics are encoded in the brain and used during language processing. The group builds theories of the neural code for language that are broadly constrained by known principles in linguistics, neuroscience, and computational cognitive science. Most importantly, the group endeavours to do science in an inclusive and supportive manner, training and lifting up the next generation of language scientists.

Building linguistically- and neurophysiologically-constrained computational models
A major scientific goal of the group is to develop models that incorporate constraints from neuroscience, behaviour, and linguistics. However, inferring the particular computations that give rise to patterns in neural data - such that the proposed models explain both how linguistic representations arise, and the neural signals observed during processing - can be extremely tricky. Sanne ten Oever and Karthikeya Kaushik used computational simulations to demonstrate how challenging interpreting neural data can be. They showed that two very different models - one that builds hierarchical structure, and one based on associative sequence processing - can both reproduce benchmark neural readouts that tie neural oscillations to syntactic structure building (Figure 1). The authors argue that computational models must be shaped by existing evidence from linguistics and behaviour in order to yield an explanation for neural tracking phenomena in addition to 'merely' predicting neural data. That is, even if a model can successfully predict data, interpreting that fact in isolation does not necessarily pinpoint the computation that the brain uses. A related project led by Cas Coopmans and Karthikeya Kaushik found that even when neural networks successfully predict human behaviour, they depend upon mechanisms that are cognitively untenable. First, the researchers measured people's tendency to interpret language in terms of hierarchical or sequential information. The behavioural results showed a strong preference for hierarchy: people interpret formally-ambiguous noun phrases, such as *second blue ball*, in terms of their hierarchical structure ("the second among blue balls") rather than their sequential surface order ("the ball that is blue and in second position"). While a neural network can reproduce such behaviour, it required training circumstances and training data that sharply diverged from human experience. Thus, for (neural) models to become cognitively adequate, they likely need to acquire a bias for hierarchical structure.

Understanding Neural Readouts of Linguistic Structure
An increasingly large literature shows that the phase of the neural response aligns with the speech envelope, also known as *neural tracking*. However, whether such tracking serves a linguistic function or is a perceptual epiphenomenon of speech processing is hotly debated. A variety of projects in the group focused on understanding how neural dynamics are modulated by linguistic structure, and what role phase modulation might play in computation of linguistic structure during spoken language comprehension.
Filiz Tezcan and Hugo Weissbart examined whether neural tracking of speech is predominantly driven by acoustic edges in the stimulus, by internally-generated linguistic units, or by an interplay of both signals. They used naturalistic story-listening to investigate whether the tracking of acoustic edges was enhanced or suppressed during comprehension of a first language (Dutch) compared to a statistically familiar but uncomprehended language (French). They found that when speech is not comprehended, acoustic features are more strongly tracked (Figure 2), while, during comprehension, phonemic features are more closely tracked. This trade-off suggests that comprehension functions as a neural filter over acoustic edges as it transforms sensory signals into abstract linguistic units.
But what dimensions of the neural response reflect this transformation from sensation to abstraction?
Fan Bai tackled this question comparing the neural response (EEG) to phrases and sentences. He investigated which dimensions were affected by the processing of additional constituents. Phrases (*the blue ball*) and sentences (*the ball is blue*) were closely matched, both in semantic meaning and in time and physicality. Consistent with predictions from a computational model, sentences showed more power connectivity, and more phase synchronisation than phrases did (Figure 3; left panel), possibly driven by additional distributed networks being recruited as a function of number and type of constituents being built. This pattern suggests that phase synchronization and strength of connectivity are relevant readouts for the constituent structure of language.
These two projects showed that neural readouts are driven by linguistic structure beyond the physicality of the signal. However, this principle can be extended to even more abstract latent dimensions of the neural readout. Hugo Weissbart did just that by focusing on how phase-amplitude coupling (PAC) can reflect top-down modulation by both statistical and syntactic cues in spoken language comprehension. He circumvented the constraints imposed on classical PAC calculations by using forward modelling in the complex plane, allowing the extraction of PAC values from a continuous recording while separating out the contribution of individual features (e.g., surprisal, syntactic features). He showed higher coupling between the delta and beta bands for surprisal and closed-bracket count, while other syntactic features showed significant PAC between theta and gamma. This result highlights cross-frequency coupling as a reliable correlate of linguistic feature encoding, and demonstrates that exploring the high dimensional space of neural readouts is likely necessary to understand how linguistic structure is encoded in neural systems.
In order to gather the strongest evidence as to whether neural tracking indeed reflects linguistic structure computation, the role of stimulus timing and task demands must also be better understood. Sanne ten Oever addressed whether the timescale of stimulus (i.e., syllabic, lexical, and phrasal rate) and the behavioural tasks (which focus participant attention on linguistic units) can explain neural tracking effects. She used MEG to measure brain activity while participants listened to sentences and word lists, and performed four different behavioural tasks that tapped into processing of syllables, words, and phrases. She showed stronger phrasal-rate tracking for sentences compared to word lists across the classical language network in all task conditions. However, in the inferior frontal gyrus (IFG), she found a task effect suggesting stronger phrasal-rate tracking and delta-band connectivity during the word-combination task, independent of the presence of linguistic structure. These results suggest that extracting linguistic information at phrasal rates occurs automatically, regardless of task, but also that IFG might be important for temporal integration across various perceptual domains.
Neural tracking during language comprehension appears to be automatic and related to the transformation of speech into linguistic structure. So how does the transformation from 'just a word' to the meaning of a sentence begin? Sophie Slaats and Hugo Weissbart focused on what happens to the neural representations of words when they form a sentence or not. Using temporal response functions constructed from a large MEG dataset wherein subjects listened to sentences and word lists, they measured how delta- and theta-band neural activity was affected by purely lexical information (word frequency). Delta-band responses peaked earlier for words in sentences, and LIFG was only responsive to lexical information when it occurred in a sentence. This study demonstrated that the encoding of words is affected by sentential context, and as such provides beginning insights into how the brain might use neural transformations to arrive at compositional interpretations.

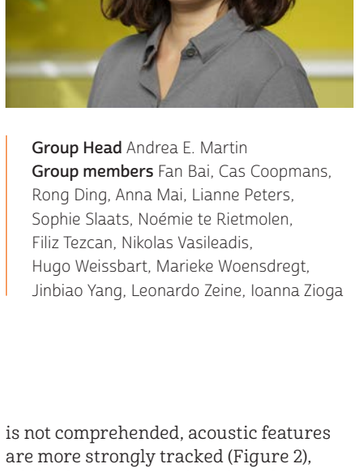


Figure 1. Top: Output of the Berkeley parser using different versions of the Ding et al. (2016) stimuli. Bottom: Any class of stimuli repeating itself at a slower rate will show a 1-2-4 Hz response.

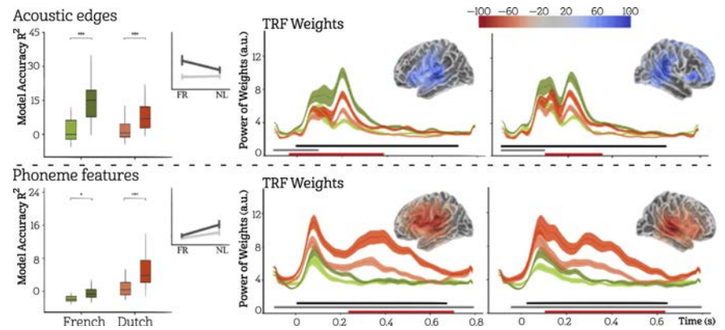


Figure 2. A trade-off between the tracking of acoustic edges and phonemic features as a function of comprehension. Using temporal response functions (TRF), Tezcan et al. (2022) showed that acoustic information is suppressed and linguistic information is enhanced when language is comprehended. A TRF is a model that, via convolution, serves as a filter to quantify the relationship between two continuous signals, here speech features and neural activity. Left: model accuracies (R2). Right: TRFs for acoustic edges and phoneme features.

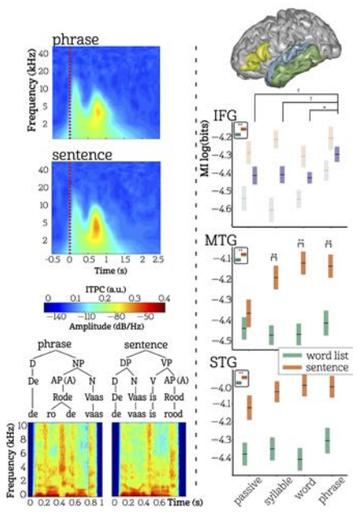


Figure 3. Left panel: Bai et al. (2022) showed that even when phrases and sentences are maximally physically indistinguishable, sentences lead to more phase coherence, possibly driven by distributed networks being recruited to build structure. Right panel: Ten Oever et al. (2022) showed phrases are tracked automatically, independent of behavioural task, with a prominent role for IFG in integrating information across time.

Selected publications

Ten Oever, S., Carta, S., Kaufeld, G., & Martin, A. E. (2022). Neural tracking of phrases in spoken language comprehension is automatic and task-dependent. *eLife*, 11, e77468.

Bai, F., Meyer, A. S, & Martin, A. E. (2022). Neural dynamics differentially encode phrases and sentences during spoken language comprehension. *PLoS Biology*, 20(7), e3001713.

Ten Oever, S., Kaushik, K., & Martin, A. E. (2022). Inferring the nature of linguistic computations in the brain. *PLoS Computational Biology*, 18(7), e1010269.

MAX PLANCK RESEARCH GROUP
NEUROGENETICS OF VOCAL COMMUNICATION

Group Head Sonja C. Vernes
Group members Midas Anijs, Paolo Devanna, Stephen Hörpel, Ksenia Lavrichenko, Meike Mai, Janine Mengede, Lianne Peters, Ine Alvarez van Tussenbroek.

Goals of the Group
The Neurogenetics of Vocal Communication Group studies human speech and language via a range of complementary approaches, from genetics, neuroscience, and behaviour, to understand how these abilities are biologically encoded and how they evolved. The overarching goal is to understand how an organism capable of speech and language is built at a biological level. This group addresses this by studying speech and language-relevant traits in animal models – in particular in bat species. They aim to understand the neurogenetic mechanisms underlying these behaviours including the neural circuitry, molecular pathways, and the genomic factors underlying these behaviours. They also investigate the causes of language disorders in clinical populations to gain insight into these disorders, and to understand the genetic factors underlying normal language development. Candidate genes identified in clinical populations are also explored in cell and animal models to understand what role they play and why their disruption leads to language-related disorders.

What vocal learning bats can tell us about human speech and language

Although language is unique to humans, there are language-relevant traits found in animals that can help us to understand how language might have evolved and how it is biologically encoded. Vocal learning is the ability to learn new vocalisations and is crucial to human spoken language as it gives us the ability to produce the vast range of meaningful sounds that we use to communicate via speech. Many species of mammal, including our primate cousins, have limited vocal repertoires. But a few mammals such as bats, whales and elephants use complex and varied vocalisations that share some characteristics with human speech, such as the ability to learn vocalisations from other members of their social group.

Bats represent an ideal model to explore the biological underpinnings and evolution of vocal learning. Bats famously use vocalisations to navigate their environment via echolocation, but also use them to facilitate complex social interactions. In some bat species, these social interactions rely on learning new calls, which can be thought of as comparable to how humans learn new vocalisations to communicate via speech (Vernes et al., 2021). A major goal of the group is to use a comparative approach to study vocal learning in bats and understand its evolution and its biological encoding in the brain.

The multi-dimensional nature of vocal learning

To facilitate comparative vocal learning research, this group worked with leading experts to create a typology of vocal learning in light of recent advances in the field (Vernes et al., 2021) They proposed a novel classification system that deconstructed vocal learning into key dimensions to aid in understanding the mechanisms involved in this complex behaviour and considered how vocalisations can change without learning, and a usage learning framework that considers context specificity and timing. The researchers identified dimensions of vocal production learning, including the copying of auditory models (convergence/divergence on model sounds, accuracy of copying), the degree of change (type and breadth of learning) and timing (when learning takes place, the length of time it takes and how long it is retained). They considered grey areas of classification and the current mechanistic understanding of these behaviours. This framework identified research needs and will help to inform neurobiological and evolutionary studies endeavouring to uncover the multi-dimensional nature of vocal learning.

Establishing the pale spear nosed bat as a model for vocal learning

The research group has been working to establish the pale spear nose bat (*Phyllostomus discolor*) as a model species in which they can study these traits. To this end they have taken an interdisciplinary approach to exploring this vocal learning bat, providing an integrated understanding across genomics, neurobiology and transgenics (Vernes et al., 2022). In genomic studies, they generated new,

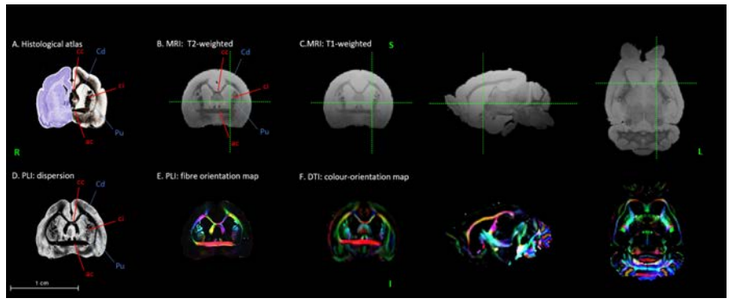


Figure 1. Neuroimaging data of the P. discolor brain. Reproduced from Vernes et al. (2021)

The pale spear nose bat (Phyllostomus discolor) in flight. Photo credit: Brock & Sherry Fenton.

high-quality genome annotations of *P. discolor*, highlighting coding genes and noncoding microRNAs to provide one of the best characterised bat genomes available which is now facilitating functional and evolutionary studies. In neurobiological studies they traced connections between auditory-related brain regions and reported neuroimaging to explore the structure of the brain and gene expression patterns to highlight brain regions. The research team uncovered a novel projection of an auditory responsive frontal cortical area to the pyramidal tracts, pointing to its possible involvement in auditory–vocal–motor integration. Future work will explore the role of this region in vocal learning.

Creation of the first transgenic bat model

Observing the natural state of a behaving animal can reveal potential mechanisms underlying that behaviour. An effective way to demonstrate causal links between neurogenetic mechanisms and behaviour is to perturb gene function. After genetic manipulations, effects on molecular pathways, brain development, and behaviour can be measured. In 2021, the research group reported the first successful manipulation of gene expression in a living bat and the first generation of a transgenic vocal learning mammal. Vernes et al., (2022) showed a successful manipulation of the FoxP2 gene in bat striatal neurons in vivo. Future work will explore the influence of manipulating FoxP2 expression on molecular pathways, cell morphology, neural circuitry, and vocal learning behaviour, using the genetic and neurobiological toolkit developed by the group (Vernes et al., 2022). Together, this work has established the tools necessary to use the pale spear nosed bat as a model system to uncover the mechanisms underlying vocal learning. These interdisciplinary approaches are facilitating a mechanistic and evolutionary understanding of mammalian vocal learning and can contribute to other areas of investigation that utilise *P. discolor* as a study species.

An explosion of bat genomes

As a founding director of the BatIK genome project (www.batik.com), Sonja Vernes has been leading an effort to sequence the genomes of all living bat species (~1400 species). This project has attracted membership from over 350 scientists in about 50 countries. In 2020 the pilot phase of this project, reporting the completion of the first six reference quality bat genomes and providing clues to the origins of bats' unique adaptive traits, was published in Nature (Jebb et al., 2020). In 2021, BatIK worked with the Vertebrate Genome Project to release reference quality genome assemblies for 16 species that represent six major vertebrate lineages including mammals, birds, reptiles, amphibians and fish (teleost fish and cartilaginous fish) (Rhie et al., 2021). These reference genomes are fundamental for the application of genomics to biology, disease, biodiversity conservation and evolution of complex traits.

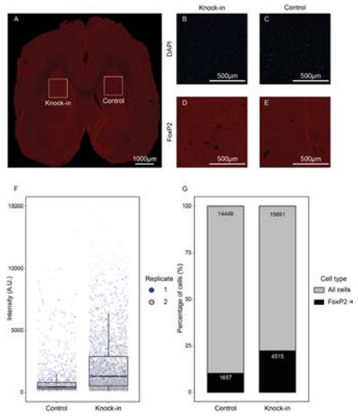


Figure 2. Demonstration of genetic manipulation in the P. discolor brain. Reproduced from Vernes et al. (2021)

Selected publications

Vernes, S. C., Devanna, P., Hörpel, S. G., Alvarez van Tussenbroek, I., Firzlaff, U., Hagoort, P., Hiller, M., Hoeksema, N., Hughes, G. M., Lavrichenko, K., Mengede, J., Morales, A. E., & Wiesmann, M. (2022). The pale spear nosed bat: A neuromolecular and transgenic model for vocal learning. *Annals of the New York Academy of Sciences*, 1517, 125-142. doi:10.1111/nyas.14884.

Vernes, S. C., Kriengwatana, B. P., Beeck, V. C., Fischer, J., Tyack, P. L., Ten Cate, C., & Janik, V. M. (2021). The multi-dimensional nature of vocal learning. *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences*, 376: 20200236. doi:10.1098/rstb.2020.0236.

Rhie, A., McCarthy, S. A., Fedrigo, O., Damas, J., Formenti, G., Koren, S., Uliano-Silva, M., Chow, W., Fungtammasan, A., Kim, J., Lee, C., Ko, B. J., Chaisson, M., Gedman, G. L., Cantin, L. J., Thibaud-Nissen, F., Haggerty, L., Bista, I., Smith, M., Haase, B. et al. (2021). Towards complete and error-free genome assemblies of all vertebrate species. *Nature*, 592, 737-746. doi:10.1038/s41586-021-03451-0.

MAX PLANCK FELLOW GROUP
NEURAL DYNAMICS OF LANGUAGE PRODUCTION

Group Head Peter Indefrey
Group members Francesca Carota, Adrian Jodzio

Goals of the Group
Speaking may seem like a simple task to us but even naming a simple depicted object involves a number of processing steps from object recognition and conceptual planning to lexical access, syllabification, phonetic encoding, and articulation. The research group investigates the time course of brain activation related to these processing steps, to find out if they occur in parallel or rather sequentially as predicted by the theory of language production developed by Pim Levelt, Antje Meyer, and Ardi Roelofs at the MPI. The research group, furthermore, investigates the kind of information speakers extract from a picture in order to name it.

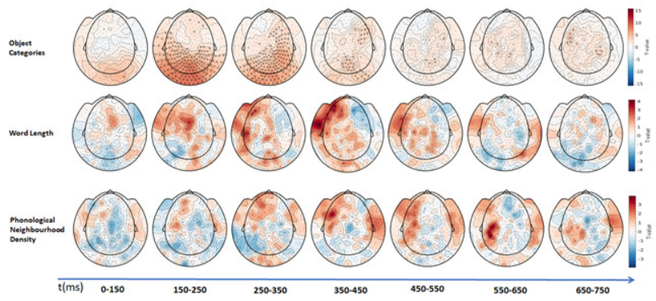


Figure 1. Topographic maps displaying decoding accuracy (expressed as a T-statistic) for the variables Object Category, Word Length, and Phonological Neighbourhood Density.

Tracking the spatiotemporal dynamics of meaning-to-speech mapping using MEG
Current psycholinguistic models make divergent predictions on how a preverbal message is mapped onto articulatory output during language planning. Serial models predict a cascading sequence of hierarchically organised neural computations from conceptualisation to articulation. In contrast, parallel models posit early simultaneous activation of conceptual, phonological, and articulatory information in the language system. Researchers of the group recorded the neural responses elicited by the overt naming of 134 images from 4 semantic object categories (animals, foods, tools, clothes), using magnetoencephalography (MEG). Within each category, word length and the number of similar sounding words (phonological neighbourhood density) were varied to target phonological/phonetic processes. Multivariate pattern analyses (MVPA) searchlights in sensor space distinguished the stimulus-locked spatio-temporal responses to object categories early on, from 150-245 ms post picture onset, whereas word length was decoded in left frontotemporal sensors at 250-345 ms, followed by the latency of phonological neighbourhood density (350-445 ms, see Figure 1). These results suggest a progression of neural activity from posterior to anterior language regions for the semantic and phonological/phonetic computations preparing overt speech, thus supporting serial cascading models of word production.

Chronometric TMS in Language Production
Transcranial magnetic stimulation (TMS), a common non-invasive brain stimulation technique, allows for testing of causality between brain activity and behaviour. In addition to good spatial resolution, TMS also has great temporal resolution. By stimulating a brain region at specific time points during a word production task, TMS can help inform us, not only about the causal contribution of that brain region, but also about its time course. Researchers of the group used chronometric TMS to probe the time-course of three brain regions (see Figure 2, left) during a picture naming task. Because individual variation in naming latency may affect the targeted processing stages, the researchers used a novel, individual baseline-adjusted analysis. They found posterior temporal areas to be causally involved in picture naming in earlier time-windows, whereas all three regions appear to be involved in the later time-windows, suggesting unspecific, potentially non-neural effects induced by TMS (Figure 2, right).

Retrieval of shape information in picture naming
Other research investigated the influence of semantic context on object recognition in picture naming tasks. Pictures were presented in gradually de-blurring image sequences and the researchers measured the de-blurring level that first allowed for correct object naming as an indicator of the perceptual demands of object recognition. Categorically related contexts reduced the level of visual detail required for object naming compared to unrelated contexts. This effect was most pronounced for visually dissimilar objects and in contexts providing reliable category cues, such as the name of the semantic category (see Figure 3). These results suggest that effects of categorically related contexts in picture naming may be due to object recognition rather than word retrieval.

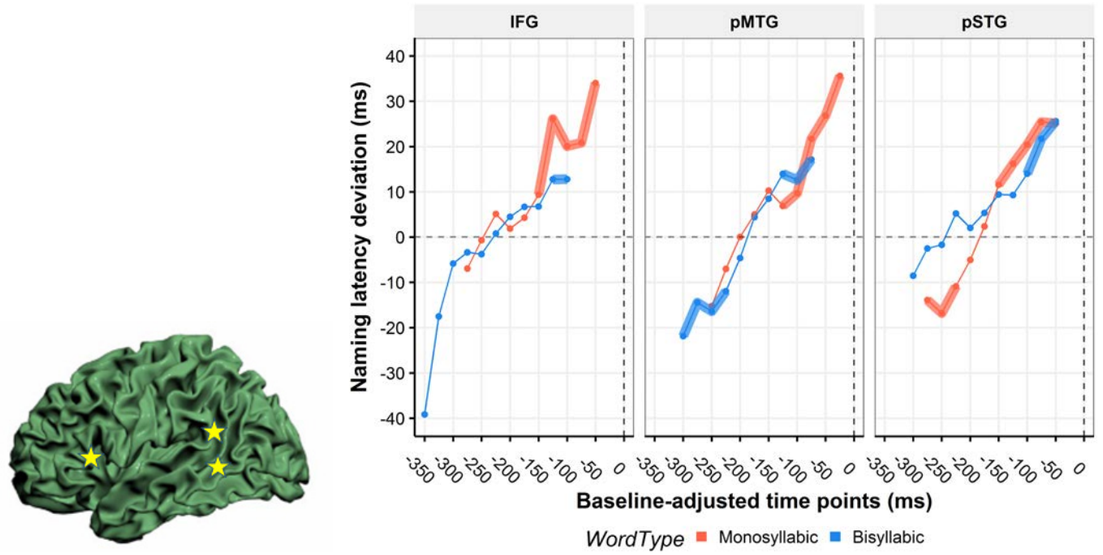


Figure 2. Left: Brain template demonstrating the three stimulation sites. Right: Effects of TMS on naming latencies of monosyllabic and bisyllabic words in the three brain regions depending on stimulation time before expected response onset. IFG = inferior frontal gyrus, pMTG = posterior middle temporal gyrus, pSTG = posterior superior temporal gyrus.

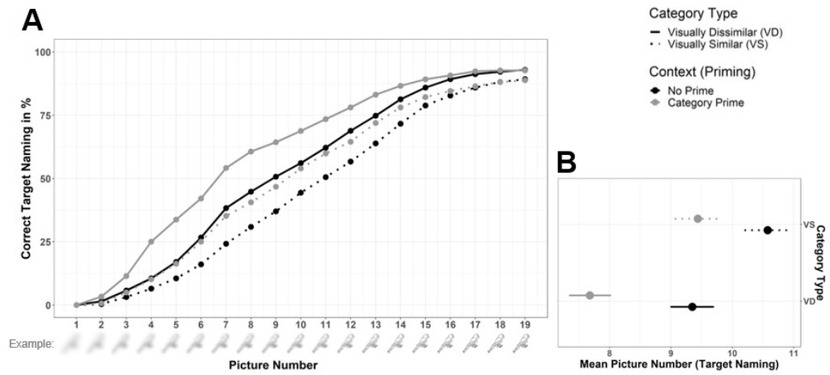


Figure 3. A: Mean percentage of correct target naming at each picture number of the image sequence. B: Mean critical picture numbers of first target naming with 95% confidence intervals.

Selected publications

Jodzio, A., Piai, V., Verhagen, L., Cameron, I., and Indefrey, P. (accepted) Validity of chronometric TMS for probing the time-course of word production: a modified replication. *Cerebral Cortex.*

Carota, F., Schoffelen, J.-M., Oostenveld, R., & Indefrey, P. (2022). The time course of language production as revealed by pattern classification of MEG sensor data. *Journal of Neuroscience*, 42, 5745-5754.

Scheibel, M. & Indefrey, P. (2023). Top-down enhanced object recognition in blocking and priming paradigms. *Journal of Experimental Psychology: Human Perception and Performance,* 49(3), 327-354. doi:10.1037/xhp0001094.

AFFILIATED RESEARCH GROUP
COMMUNICATION IN SOCIAL INTERACTION

Group Head Judith Holler
Group members Marlijn ter Bekke, Linda Drijvers, Mareike Geiger, Naomi Nota, Thijs Rinsma, Louise Schubotz, James Trujillo, Emma Valtersson, Tiziana Vercillo

Goals of the Group
The natural home of human language is face-to-face interaction, where spoken language is embedded in a plethora of visual signals based on movements of the hands, head, face, eye gaze, torso and so forth. The group's aim is to advance understanding of how people communicate multimodally in face-to-face settings, focusing on issues such as how meaning is composed, understood, and mutually agreed on in interaction. This includes the investigation of behavioural patterns and principles that shape interactional conduct during conversation, as well as the (neuro)cognitive mechanisms that underpin the production and comprehension of utterances conveying meaning multimodally. To do so, the group uses a combination of conversational corpus analyses and experimental approaches, with the former informing the latter and vice versa. Wherever possible, the experimental paradigms aim to capture key features of the rich interactional infrastructure of face-to-face conversation, including the use of avatars to manipulate the presence and form of visual signals to test for causal relations.

Multimodal facilitation
One intriguing question is how visual signals influence cognitive processing during language comprehension in conversational interaction. While one could assume that the presence of a multitude of different visual signals, all displaced in time and space, combined with the quick turn transitions in conversation, may quickly overburden limited human processing capacities, the opposite actually seems to hold. In a corpus study of face-to-face conversations, question turns were categorised as being accompanied by a manual gesture or not. The gestures all represented semantic information closely related to the question content (also termed 'representational gestures'), such as the action of 'typing' (hands held next to each other with the palms pointing downwards while all ten fingers wiggle), accompanying the question 'how old were you when you learned to type?' (Dutch: 'hoe oud was je toen je leerde typen?'). Analyses of the speed with which responses to the questions were issued revealed faster turn transitions when questions were accompanied by gestures than when they were not (Ter Bekke et al., under review; see Figure 1).

However, in free conversation, many variables are intertwined and correlate, requiring controlled experimentation to firm up hypotheses about causal links. In a study directly inspired by the above corpus findings, an actor was filmed asking yes-no-questions while performing representational gestures similar to those in the previous example. Participants were asked to respond to the question by yes/no button presses while hearing the question and either seeing the gesture, or seeing a video in which the area the gestures were performed in was blocked. The results converged with those from the corpus study, showing a clear effect of the presence of gestures leading to faster response times (ter Bekke et al., under review; see Figure 1).

Gestural prediction
An important question emerging from these findings relates to the cognitive mechanism(s) that give rise to them. These could be multifaceted, including the benefit of additional semantic information that gestures can contribute, or the perception of biological motion heightening general alertness and processing speed. However, another contributing factor may be multimodal utterances' temporal organisation. The above-mentioned corpus study showed that the onset of the majority of representational gestures significantly preceded the onset of their 'lexical affiliate' (i.e. the semantically most closely related lexical item in the utterance). This predictive potential averaged 215 ms when measuring from the most meaningful part of the gesture (the stroke), and 672 ms when considering the very start of the gesture (which, too, can contain semantic information), thus equipping them with clear predictive potential (Figure 2).

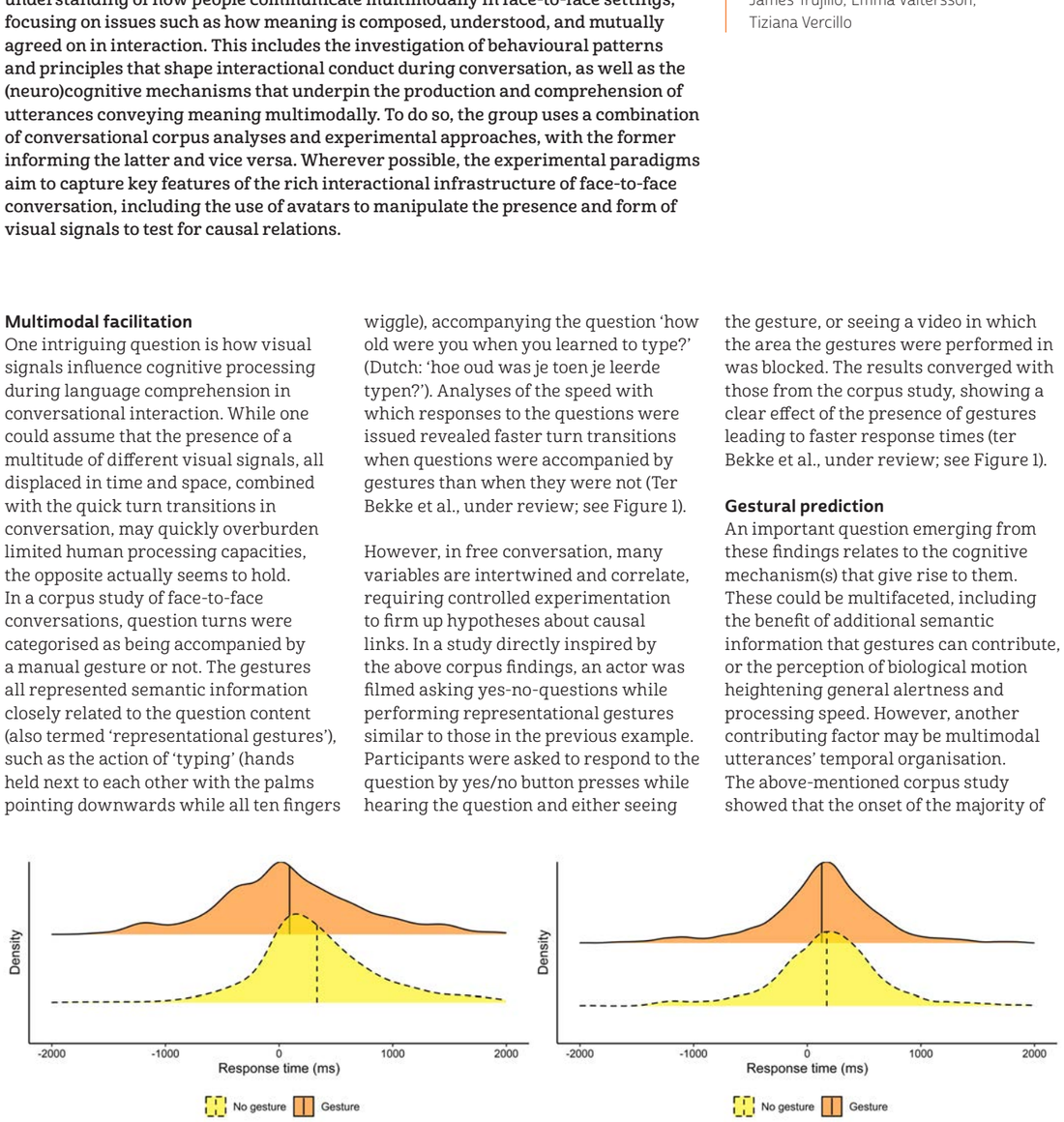


Figure 1. Questions with gestures get faster responses in conversation (left panel) and experimental settings (right panel).

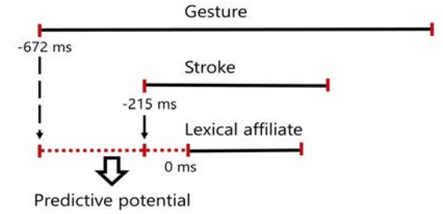


Figure 2. Timing of gesture onset and stroke onset in relation to lexical affiliate onset.

The idea of a gestural predictive potential is in line with findings from a recent experiment using the classical shadowing paradigm, showing that the availability of visual signals benefitted both accuracy and speed when shadowing a speaker's words, especially when the words were shadowed in anticipation (i.e. before they were actually produced by the original speaker) (Drijvers & Holler, 2022a). On-going experimental studies are investigating the predictive power of specific visual signals. An EEG study tests for representational gestures' ability to pre-activate semantic concepts they depict (Fig. 3), thus facilitating easier processing and integration of the corresponding lexical items further downstream. Other work in the group focuses on facial signals, which, too, often occur prior to or early on during utterances, to test their pragmatic predictive potential (Nota et al., 2021; Nota et al., in revision).

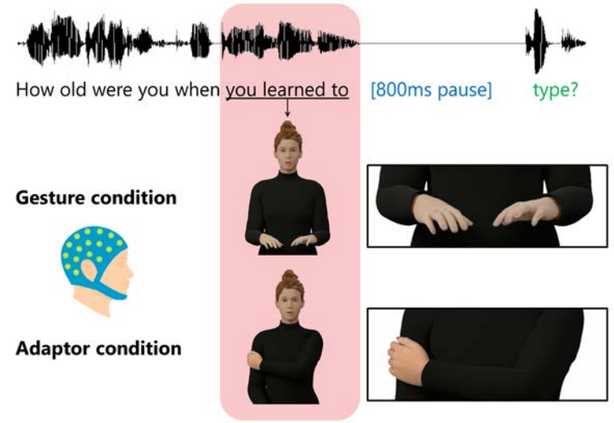


Figure 3. EEG paradigm investigating the predictive power of representational gestures (vs. meaningless 'adaptor' movements) preceding target words in questions.

Interactionally embedded language processing
In the real world, language processing most commonly takes place in interactive situ, where visual signals form complex multimodal gestalts together with other visual and vocal signals (Holler & Levinson, 2019). Importantly, such gestalts shape, and are shaped by, the social-interactional affordances that conversational acts perform (Trujillo & Holler, 2023), and they are core to coordinating minds and bodies in interaction (Holler, 2022). Ultimately, the group's research aims to understand how the communication of meaning happens in the complex environment of social interaction, via these rich, multimodal signal composites, interwoven with the many layers of pragmatic processes constituting the reciprocally fine-tuned social moves that interacting agents produce and need to comprehend. To achieve this, current work investigates the composition and processing of complex multimodal gestalts, as well as developing experimental paradigms that capture an increasing number of factors that are at the heart of human social interaction. As such, the research goes beyond multimodality and the pragmatics and semantics of specific communicative acts by integrating features that define the fundamentals of social interaction—such as the spatial orientation in which we communicate, which appears to induce a special 'social mode' for processing information in conversation, as a recent study revealed (Drijvers & Holler, 2022b). The group's research thus heavily rests on novel paradigms and techniques suitable for capturing socially immersive settings (including dual-EEG and virtual humans) to push a research agenda that strives towards understanding socially contextualised language.

Selected publications

Trujillo, J. P., & Holler, J. (2023). Interactionally embedded gestalt principles of multimodal human communication. *Perspectives on Psychological Science.* Advance online publication. doi:10.1177/17456916221141422.

Holler, J. (2022a). Visual bodily signals as core devices for coordinating minds in interaction. *Philosophical Transactions of the Royal Society of London.* Series B: *Biological Sciences,* 377(1859): 20210094. doi:10.1098/rstb.2021.0094.

Drijvers, L., & Holler, J. (2022b). Face-to-face spatial orientation fine-tunes the brain for neurocognitive processing in conversation. *iScience,* 25(11): 105413. doi:10.1016/j.isci.2022.105413.

THE LANGUAGE ARCHIVE

Scientific Director Caroline Rowland
Head of TLA Paul Trilsbeek
Head of TG Reiner Dirksmeyer
Group members Ibrahim Abdullah, Ludy Cilissen, Jeroen Geerts, Kavon Hooshiar, Divya Kanekal, Han Sloetjes, Pavithra Srinivasa

Goals of the Language Archive

The Language Archive (TLA) maintains one of the largest collections of spoken and signed language data, currently covering more than 200 different languages used around the world. Its goal is to preserve these materials for the long term and to provide access to them now and in the future. The collections stored in the archive include endangered languages data from the DOBES (Documentation of Endangered Languages) programme of the Volkswagen Foundation, first and second language acquisition corpora, and sign language corpora, as well as studies of gesture and multilingualism. TLA is also developing software for improved archiving of research data, as well as linguistic tools such as ELAN, a leading tool for the scientific annotation of multimedia recordings. The archive's infrastructure meets the highest archiving requirements (it is CoreTrustSeal certified) and serves as a model and reference for similar initiatives.

Updates from the archive team

The Fedora/Islandora open-source software solutions that form the basis of the archive's repository system have been rewritten from the ground up and have changed considerably. This necessitates both a migration of the archive's content as well as some significant adaptations of the custom components that TLA has developed. Both tasks have been the focus of the software developments of the past year and are scheduled to be completed in the second half of 2023. Two additional features were implemented for the current system: a "citation" function that displays an automatically generated citation for each item in the archive, and a "metadata template" feature that enables depositors to store and re-use blocks of metadata that they have entered in the metadata editing forms.

The TLA team also maintain and develop the popular annotation tool ELAN. Two major versions of ELAN were released in both 2021 and 2022. A first implementation of a Spectrogram viewer was added as well as visualisations of waveforms and spectograms extracted from video and audio files. There is a new export as an annotation density plot and several other export functions were improved. A WebLicht tool chain can be called and linking of annotations to external resources has been enhanced.

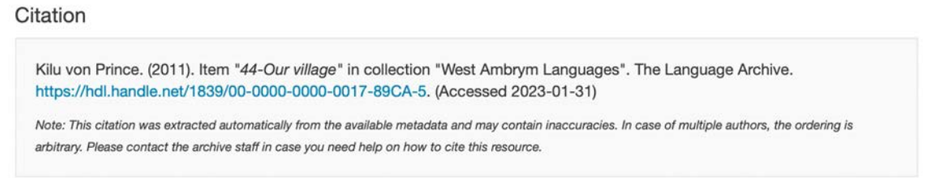
Working together

Since January 2019, TLA has been a member of the CLARIAH-PLUS project, funded by the Dutch Research Council (NWO). CLARIAH-PLUS's joint goal is to further develop and utilise the CLARIAH research infrastructure (Common Lab Research Infrastructure for the Arts and Humanities). TLA contributes to two Work Packages (WPs). In WP3 (Linguistics), the team have been working on locating and archiving existing unarchived collections of Dutch language acquisition researchers. Within WP5 (Media Studies), the ELAN annotation tool was connected to a central "annotation server" in the CLARIAH infrastructure in order to store and retrieve annotations in a common format, such that they can be interchanged with other annotation tools.

In relation to the CLARIN Knowledge Centre for Atypical Communication Expertise (ACE), in which TLA collaborates with the Centre for Language and Speech Technology (CLST) at Radboud University, two workshops were organised by the DELAD initiative (Data Enterprise for Language and Speech Disorders) about issues around archiving and sharing of sensitive data. Topics included voice pseudonymisation, Data Protection Impact Assessments and the recently introduced Data Governance Act by the European Commission.

With our help, the Cognitive Machine Learning Lab at the Ecole Normale Superieure in Paris is developing a new speech annotation management system (Seshat) that will substantially improve the speed, accuracy and security of annotation work on big datasets of real-life spoken language. Seshat enables researchers to easily manage teams of annotators, allows human annotators and automatic speech processing tools to collaborate interactively to produce annotations, and is GDPR-compliant for secure data storage and sharing. Over the last year, TLA members and the Paris team have been holding focus groups with ELAN users to determine what kinds of functionality they would like to see in Seshat. The Paris team are now busy creating the first version.

A child taking part in the Language 0-5 project.



An example of an automatically generated citation which is now included in the archive's functionality.

Collection updates

Every year, The Language Archive accepts new corpora from researchers all over the world who are working with a range of different communities and languages. Highlights from this year include the Swedish Sign Language Corpus by Johanna Mesh and colleagues at Stockholm University. Swedish sign language (*Svenskt teckenspråk*) is the official sign language of Sweden, and is recognised as the first language of Swedish deaf people. The Swedish Sign Language collection at TLA consists of 24 hours of video recordings of 42 native and near-native signers aged between 20 and 82 years of age. The recordings are of semi-spontaneous and elicited dialogues and a significant portion of the materials has been transcribed and translated in ELAN. Much of the material is accessible to registered users of the archive.

Another important collection added this year is the Language 0-5 Project collection, donated by Caroline Rowland and colleagues at the University of Liverpool. The Language 0-5 Project was a long-term study that tracked the cognitive and language development of 90 British English-learning children from 6 months to 4;6 years. This collection contains all data for which the children's caregivers gave permission for sharing, including summary datasheets for data from questionnaires, diaries and experimental tasks, raw audio and audio-video recordings, and transcripts of (some of) the recordings in CHAT or ELAN format. The collection also includes readme documents both for the project itself and for each of the measures, and copies of materials and publicity images and videos.

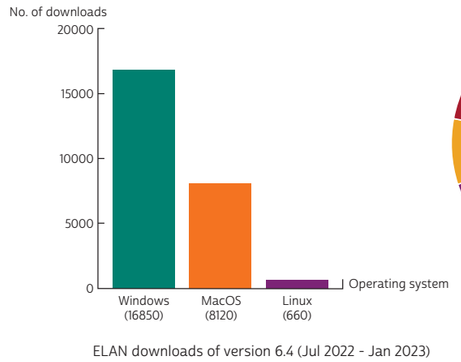


Figure 1a. Number of ELAN downloads.

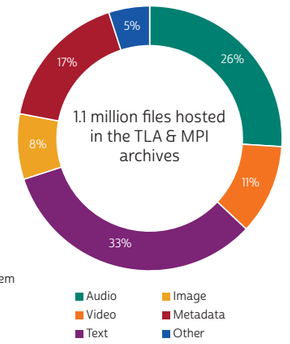


Figure 1b. Number and types of files in the archive.

Selected publications

Van den Heuvel, H., Oostdijk, N., Rowland, C. F., & Trilsbeek, P. (2022). The CLARIN Knowledge Centre for Atypical Communication Expertise. In D. Fišer, & A. Witt (Eds.), *CLARIN: The Infrastructure for Language Resources* (pp. 373-388). Berlin, Boston: De Gruyter.

LIBRARY

Head of Library Karin Kastens
Members Meggie Uijen

Goals of the Library
The Library Team supports our researchers in all their information needs, whether in printed or electronic content. The team supports the publication management and display of the Institute's publications and assists in compiling bibliometric impact measures.

A hybrid library
The library's collection closely follows the research focus of the Institute. Covid-19 measures still played a role in 2021 and supporting remote access was a key element. The library team continued to buy more e-books next to our print collection. Max Planck-wide licenses for journal subscriptions, together with locally licensed content, provide access to about 15,000 academic e-journals through our catalog. Fast interlibrary loan support complements our service.

Jerome Bruner Library
The Bruner family donated Jerome Bruner's personal scientific library of 3,250 books to the Institute. This unique collection includes dedications from famous scholars as well as comments and notes by Bruner himself. The online Bruner Library catalogue entries are enriched with scans of all dedications and notes. The library can also be visited by people from outside the Institute upon request.

Publication Repository and Open Science
The librarians archive the complete publication output of the MPI researchers in the institutional repository MPG.PuRe (pure.mpg.de). The publication data are uploaded daily onto the Institute's website and being displayed on person and group pages. The librarians disseminate new publication alerts via the Institute's Twitter and Mastodon accounts and work closely together with the communications team.

Introduction to library services
News about the library services is communicated via the weekly internal newsletter and during the quarterly General Staff Meeting. The library members take part in the quarterly Newcomer Events, providing a short overview of the library services, which is then complemented by regular in-depth library introduction meetings.

Since we value Open Science, an important part of the library's services is providing information about open access publishing, preprints, open data repositories and open platforms. In 2021-2022, 70% percent of the Institute's publications were published open access (see figure 1).

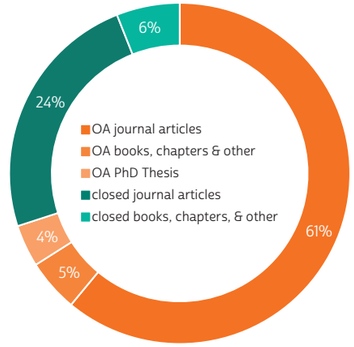


Figure 1. Percentage of Open Access (OA) publications from January 2021 until December 2022.

COMMUNICATIONS TEAM

Head of Communications
Marjolein Scherphuis

Goals of the Communications Team
The communications team of the Max Planck Institute for Psycholinguistics is responsible for the internal and external communication of the Institute. Led by the Head of Communications, who also acts as a senior advisor to the directorate, the team works to raise the profile of the scientists in the world press by issuing engaging press releases on scientific publications, facilitating media contacts and providing media coaching. Besides monitoring the excellent reputation of the Institute, building a solid media network and maintaining relevant contacts with the Max Planck Society and surrounding stakeholders - such as Radboud University and the Donders Institute - are high on the agenda. Efforts have also been made to improve internal communication.

***Communications Team** (from left to right) Marjolein Scherphuis, Julia von der Fuhr, Ludy Cilissen.*

Internal Communication
The communications team actively promotes employee well-being. A newly installed Diversity & Inclusion Committee has been working on a culture shift since 2021. From early 2022, the Institute has an induction programme for newcomers in which members of the support staff actively participate, so that newcomers feel at home. Part of the team's communication strategy is to create a new and interactive intranet.

Internal and external communication channels
Website: In 2021, the Institute's website (www.mpi.nl) had 183,366 visitors generating 363,408 unique page views. In 2022, 196,253 visitors generated 385,099 unique page views. People from 120 countries visited the website, the top 5 countries are: USA, Netherlands, UK, Germany and China.
Social media: The Institute interacts with various target groups via Twitter, Instagram, Facebook and LinkedIn. The number of followers on Twitter is growing organically. The Institute now has more than 11,000 relevant followers. A Mastodon account was created for the Institute in late 2022, as external circumstances caused academia to migrate from Twitter to this relatively new social medium. The Institute temporarily posts simultaneously on Twitter and Mastodon and monitors developments.
Science Blog MPI TalkLing: The trilingual science blog MPI TalkLing, which went live in November 2020, provides blogs on psycholinguistics written by MPI PhD candidates. The blogs are edited and translated by colleagues within the Institute. Led by editors-in-chief Julia von der Fuhr and Sophie Slaats the blog website had 6,341 visitors and 10,001 unique page views in 2021. In 2022, 13,023 readers visited the website, generating 16,208 unique page views. The communications team provides an annual blog writing training for the blog writers and editors. The aim of the blog website is to make the MPI for Psycholinguistics more known in the Netherlands and to address young people who may be considering a career in language sciences. An important side effect is that our scientists learn to write about their research in lay terms.
Please visit the blog at mpi-talkling.mpi.nl

MPI TalkLing
MAX PLANCK INSTITUTE FOR PSYCHOLINGUISTICS

Newsletters: The communications team produces a weekly internal newsletter to inform and inspire the employees and to facilitate mutual commitment. A quarterly external newsletter informs relevant target groups about interesting MPI publications and events, such as the Nijmegen Lectures.

Appreciation: Both the science blog MPI TalkLing and the work of the Diversity & Inclusion Committee have been featured by the Max Planck Society as showcases in their employee magazine MAX MAG (14,000 readers).

Public Outreach Results
In 2021/2022 the research of the Max Planck Institute for Psycholinguistics was internationally featured in WIRED, The Guardian, The Daily Mail, CNN, Smithsonian Magazine, National Geographic, Nature, New Scientist, Le Monde, Metro, The Independent, Die Welt, The New York Times, BBC News, NPR, The Economist, The Scientist, Time, The Times, Science Now, Der Spiegel, Die Welt, and NRZ.
Within the Netherlands, the work of MPI researchers was featured in regional and national newspapers such as De Volkskrant, Trouw, NRC, Het Parool, Kijk Magazine, De Gelderlander, De Brug, and Dagblad van het Noorden.
MPI researchers were interviewed for radio and television in programmes such as BNR Science, De Taalstaat, NOS Jeugdjournaal, Omroep MAX, RTL Nieuws, and NPO Radio 1.
Else Eising of the Language & Genetics Department was a guest on the late-night talk show Beau with NWO president Marcel Levi to talk about her research on the genetics of stuttering on national television. Her appearance created more brand awareness for the Institute and a significant number of additional participants for her research.
The Comparative Bioacoustics research group led by Andrea Ravignani was visited by a Canadian film crew making a documentary on the origins of language and rhythm.

INTERNATIONAL MAX PLANCK RESEARCH SCHOOL (IMPRS) FOR LANGUAGE SCIENCES

Spokesperson Antje S. Meyer
Coordinator Kevin Lam
Secretary Lianne Peters

Goals of the IMPRS
The International Max Planck Research School (IMPRS) for Language Sciences is a joint initiative between the Max Planck Institute for Psycholinguistics and two partner institutes based at Radboud University – the Donders Institute for Brain, Cognition and Behaviour and the Centre for Language Studies. Founded in 2009, the IMPRS continues its tradition of training future language scientists with an interdisciplinary approach, and promoting all aspects of rigorous scientific practice. Its future-oriented curriculum prepares doctoral students for promising and fulfilling careers in academia and beyond.

Highlights
The school began its third 6-year term (2021-2027) after securing renewed funding in 2019. In January 2021, the IMPRS celebrated an important milestone, namely that of 100 doctoral defences. Special-edition mugs and personalised greeting cards were distributed to all 100 alumni members across the globe.
A mini-website featuring interviews and reflections captures the school's history and various IMPRS experiences.

Over the course of the various lockdowns, the IMPRS became better adapted to the various constraints of hosting courses, workshops and other events in both fully online and hybrid forms. Particular effort was made to ensure regular social contact across the cohorts.

The third edition of the *Interdisciplinary Approaches to the Language Sciences* conference (2022) was successfully held in hybrid form. In discovering the greater reach the event had during the fully online edition in 2020, the organising committee wished to remain accessible to attendees from across the globe, especially those who do not have the means to attend in person.

To accompany the yearly PhD Fellowships recruitment, IMPRS profile featurettes were introduced to offer prospective applicants and website visitors a glimpse of what it means to be part of our graduate school.

Student body composition
As of December 2022, there were 54 active members forming cohorts 2019 through 2022, 74% of whom identify as women and over 50% of the student body representing nationalities other than Dutch and German. There is equal distribution between projects funded by the MPI (50%) and its two partner institutes (50%) at Radboud University.

Student body achievements
By the end of 2022, 133 IMPRS members had successfully defended their dissertations. Notable achievements include:

- Limor Raviv, O*tto Hahn Medal; Minerva Fast Track Fellowship*
- Ella Z. Lattenkamp, *Otto Hahn Medal*
- Joery den Hoed, *SATB2 Gene Foundation Grant*

Selection of research projects

- Yevheniy Skyra, *A cross-linguistic study of flexible word order processing in first language acquisition*
- Sho Akamine, *Contextual influences on multimodal alignment in Zoom interaction*
- Patricia Sanchez Carrasco, *Processing pronouns of address: The impact of being addressed with a polite or an informal pronoun*
- Irina Chupina, *Echoes of language in the right hemisphere? Electrophysiological evidence from neurotypical and clinical populations*
- Marlijn ter Bekke, *Multimodal language processing in social interaction*

TECHNICAL GROUP

Head of Technical Group
Reiner Dirksmeyer
Group members Ilbrahim Abdullah, Gert-Jan de Bresser, Ludy Cilissen, Jeroen Derks, Maurice van Deutekom, Alex Dukers, Maarten van den Heuvel, Peter Nijland, Thijs Rinsma, Albert Russel, Pavithra Srinivasa, Tobias van Valkenhoef, Kees van der Veer, Rick van Viersen, Johan Weustink, Peter Withers

Goals of the Group
The Technical Group (TG) has two major goals: (1) to provide the IT infrastructure of workplace, labs, servers, and field equipment for the day-to-day running of the Institute, and (2) to devise experiment systems and software that enable new scientific developments within the Institute. The members of the group have very different skills, such as: High Performance Computing (HPC) and storage technology skills, knowledge and experience in hardware development (Arduino, Raspberry and other microprocessor-driven systems), as well as extensive knowledge of software development (Java, Python, PHP, JavaScript, PostgreSQL- and Oracle Databases). Finally, the TG has extensive knowledge and experience in the field of managing and archiving scientific data.

Computer systems
In 2021 the group updated the storage system for the VMware cluster to solid-state drive (SSD) based storage. The VMware cluster is currently hosting around 200 virtual servers. In 2022 the HPC cluster was extended by 8 new nodes. The HPC cluster now supports singularity as a container system.

General IT support
During the Covid-19 lockdown, additional resources were made available to provide the best possible support for working from home. Conference rooms were optimised for hybrid meetings.

Experimental labs
In 2021 and 2022 a new Faraday-caged child EEG lab was built. The Institute now maintains three Faraday-caged EEG labs, eight reaction time labs, six eye movement labs, various portable eye tracker setups (glasses and remote eye tracker), one gesture lab, one baby lab, three interaction labs and one head-mounted display based Virtual Reality lab.

In the Virtual Reality lab, all new experiments are now created under Unity. During the Covid-19 lockdown there was a greater need for online experiments. This requirement could only be partially covered by our online experiment system Frinex. Simple online experiments could be carried out using commercial software. In 2021 around 209 online experiments were carried out using Frinex. In 2022 around 189 online experiments were carried out using this system.

The main neuroimaging facility is housed in the Donders Centre for Cognitive Neuroimaging, where the dedicated Technical Group maintains 1.5, 3 and 7 Tesla fMRI, MEG and EEG labs.

Molecular Biology Labs
Housed in the extension of the Institute are state-of-the-art wet lab facilities that have been in use since January 2015. There are five dedicated laboratories for general molecular biology, tissue culture, RNA, histology and microscopy, a cold room and an equipped laboratory kitchen. These labs have very specific laboratory equipment, which is mostly controlled by computers. Examples of equipment are Bio-Rad CFX96 real time PCR machines and a Zeiss LSM880 confocal microscope with Airyscan. A high-end computer is installed for high performance tasks such as advanced image analysis. The labs are also equipped with a Chromium Controller, enabling high-throughput transcriptomic and (epi)genomic analyses at the single cell level.

EVENTS AND ACTIVITIES

2021

Workshop
The future of linguistics 2/4 (Online).
Organised by Caroline Rowland, January 6.

Workshop
The future of linguistics 3/4 (Online).
Organised by Caroline Rowland, January 25.

Workshop
The future of linguistics 4/4 (Online).
Organised by Caroline Rowland, February 11.

Workshop
Masterclass Profielwerkstuk (Online).
Organised by Nienke Rulkens-Dijkstra, Cielke Hendriks, April 22.

Conference
Neurobiology of Language: Key Issues and Ways Forward (Online).
Organised by Peter Hagoort, April 8-9.

Conference
Capturing the brain for neuroimaging genomics (Online).
Co-organised by Simon Fisher and Barbara Franke, June 28 and 29.

Conference
The International Workshop on Language Production (Online).
Co-organised by Antje Meyer, November 2, 10 and 15.

2022

Conference
Neurobiology of Language: Key Issues and Ways Forward II (Online). *Organised by* Peter Hagoort and Caroline Rowland, March 16 and 17.

Workshop
Genes & SEM online workshop, *co-organised by* Beate St Pourcain and Brad Verhulst (Texas A&M University), March 28-30.

Conference
Meeting Stedelijk Netwerk Nijmegen (SNN; City Network Nijmegen), *hosted by* Peter Hagoort, April 21.

Conference
18th Conference of NVP, Dutch Society for Brain and Cognition.
Organised by Peter Hagoort, April 28-30.

Workshop
Kletskoppenfestival. *Organised by* Cielke Hendriks and team Kletskoppen, May 22.

Symposium
Mapping the brain: Neuroimaging and connectome approaches to study genetic variation in brain function, structure, and behavior, Annual Meeting of International Behavioural and Neural Genetics Society: Memphis, TN, USA. Chair: Clyde Francks, May 24-27.

Conference
IMPRS conference 2022: Interdisciplinary Approaches in the Language Sciences. Organised by the International Max Planck Research School (IMPRS) for Language Sciences. *Co-organisers*: Gökberk Alagöz, Sara Mazzini, Giulio Severijnen, Rong Ding, Cecília Hustá, Figen Karaca, Laura Giglio, Koen de Reus and Kevin Lam, June 1-3.

Symposium
Animal bioacoustics and human speech symposium.
Organised by Andrea Ravignani, June 8.

EVENTS AND ACTIVITIES

Workshop
TOK dag. *Organised by* Caroline Rowland, Ilse van den Dobbelsteen, Sharon Unsworth (CLS), Paula Fikkert (CLS), Constance Vissers (Koninklijke Kentalis), June 15.

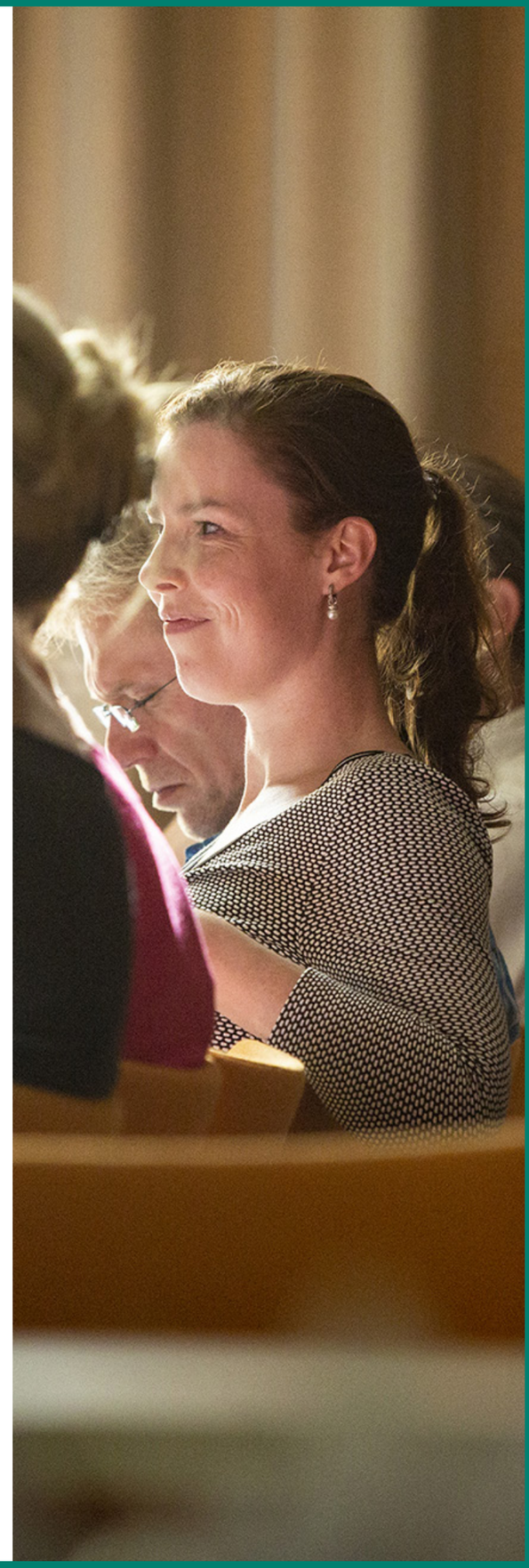
Workshop
Taal en het brein (Language and the brain). Regiodag (regional meeting) 2022 of Probusclub Nijmegen, *co-organised by* Peter Hagoort, August 18.

Workshop
JCoLE Workshop (Kanazawa, Japan / Online): Machine Learning and the Evolution of Language (ml4evolang). *Co-organised by* Lukas Galke, Mathieu Rita (INRIA), Florian Strub (DeepMind), Olivier Pietquin (Google Brain), Emmanuel Dupoux (EHESS / Meta AI Research), Limor Raviv, Bart de Boer (AI Lab, Vrije Universiteit Brussel), September 5-8.

Symposium
Musicality Genomics Consortium meeting, (MusicGens 2022), *co-organised by* Reyna Gordon (Vanderbilt University, Tennessee), Simon Fisher and Henkjan Honing (University of Amsterdam), Trento, Italy, September 9-11.

Symposium
Vanishing Boundaries between child and adult psychiatry: Across development, omics and disorders, World Congress for Psychiatric Genetics, Florence, Italy. Chair: Dorret I. Boomsma (VU Amsterdam), co-chair: Beate St Pourcain, September 13-17.

Conference
Themed session: Self-domestication and prosociality in the service of cultural evolution. The Cultural Evolution Society Conference (CES). *Co-organised* by Antonio Benítez-Burraco (University of Seville) and Limor Raviv, Aarhus, Denmark, September 21–23.



LECTURES AND COLLOQUIA

Stanislas Dehaene speaks at the Nijmegen Lectures 2022.

Nijmegen Lectures

2021
Due to the Covid-19 lockdowns, no Nijmegen lectures were held in 2021, postponed to July 2022.

2022
Advances in understanding human singularity
Stanislas Dehaene, Inserm-CEA Cognitive Neuroimaging Unit, Paris. Organised in collaboration with Radboud University by Simon Fisher, Peter Hagoort, Floris de Lange (DI), Paula Fikkert (CLS), July 5-7.

Peter Hagoort welcomes Stanislas Dehaene at the Nijmegen Lectures 2022.

Lectures

2021
April 26, online | Anne E. Baker, University of Amsterdam
Developing a sentence repetition test for the evaluation of deaf children's use of South African Sign Language

2022
September 29 | Caroline F. Rowland, Max Planck Institute for Psycholinguistics
Inaugural lecture; How humans learn language (and why other animals can't)

Donders Lectures

2021
February 4 | Peter Dayan, Max Planck Institute for Biological Cybernetics
Modelling and manipulating behaviour using recurrent networks
March 25 | Robert A. Barton, Durham University
Sensory-motor control, cognition and brain evolution: exploring the links
June 3 | Yang Dan, University of California, Berkeley
A motor theory of sleep-wake control
September 9 | Sarah Lisanby, National Institute of Mental Health (NIMH)
Innovative/effective depression treatments/interventions
October 14 | Anne Churchland, Cold Spring Harbor Laboratory
Single-trial neural dynamics are dominated by richly varied movements
November 25 | Anne-Lise Giraud, Geneva University
Speech processing with (and without) neural oscillations

2022
February 10 | Adrienne Fairhall, University of Washington Seattle
Variability and robustness in birdsong
June 9 | Tonya White, Erasmus MC, Rotterdam
Paediatric population neuroimaging within a longitudinal framework: Trajectories of psychopathology
September 22 | Catherine Tallon-Baudry, CNRS, Inserm, École Normale Supérieure, Paris
The influence of visceral signals on brain dynamics and cognition.
October 6 | Amir Amedi, IDC Israel
Healing via the brain and multisensory interactions: basic theory, brain imaging and applications.

LECTURES AND COLLOQUIA

MPI Colloquium Series

2021
January 12 | Eva Wittenberg, University of California, San Diego
Using language comprehension to understand event construal
March 16 | Marie Lallier, Basque Center on Cognition, Brain and Language
How the sensitivity to auditory rhythms shapes the reading brain
April 20 | Chet C. Sherwood, George Washington University (Online)
Great apes as models for understanding human brain evolution
June 15 | Roberto Bottini, University of Trento (Online)
Beyond sensorimotor simulations? Visual knowledge in sighted and blind
September 18| Nina Kazanina, University of Bristol (Online)
Neural encoding of syntactic structure
October 26 | Michael Skeide, MPI for Human Cognitive and Brain Sciences
Developmental origins of intelligent behaviour

2022
January 25 | Evelyne Mercure, Goldsmiths University of London (Online)
Experience-dependent plasticity in early language: Insights from hearing infants with deaf mothers
March 22 | Elsje van Bergen, Amsterdam Free University
Decoding the gene-environment interplay of reading ability
April 19 | Wing-Yee Chow, University College London (Online)
Incremental prediction in real-time language comprehension: from meaning to pitch contour
September 13 | Mariska Kret, Leiden University
Emotion processing in Homo and Pan
October 25 | Dean D'Souza, City, University of London
Identifying constraints on early language and cognitive development
November 15 | Thomas Bourgeron, Université de Paris Cité, CNRS, IUF, Institut Pasteur
Phenotypic effects of genetic variants associated with autism beyond diagnosis

Nijmegen Gesture Centre Lecture Series

2021
February 24 | Alexia Galati, University of North Carolina at Charlotte, USA (Online)
Examining the relationship between multimodal interpersonal coordination and task performance
March 17 | Pilar Prieto, ICREA-Universitat Pompeu Fabra, Spain (Online)
Prosodic and body signals act as joint bootstrapping mechanisms in pragmatic development
April 14 | Kensy Cooperrider, University of Chicago, USA (Online)
The deictic urge
May 12 | Yifei He, Philipps University Marburg, Germany (Online)
Gesture-speech integration and interaction: a neural perspective
June 9 | Marieke Schouwstra, University of Amsterdam, The Netherlands (Online)
Improvisation: A fundamental process in language emergence
June 30 | Adriano Vilela Barbosa, Federal University of Minas Gerais, Brazil (Online)
Using optical flow and correlation maps to assess coordination during communicative interaction
November 17 | Petra Wagner, University of Bielefeld, Germany (Online)
Co-ordinating hands, eyes and speech under different conditions of visibility and information structure
December 15 | Olivier Le Guen, CIESAS, Mexico City (Online)
Evolution of linguistic construction of space in Yucatec Maya Sign Language

2022
March 23 | Marlen Fröhlich, University of Tübingen (Online)
Ontogenetic plasticity and behavioural flexibility in great ape gesture
April 20 | Patrick Grosz, Oslo University (Online)
The semantics of face emojis: facial expressions in written digital communication
May 25 | Jan de Wit, Tilburg University
Robots that gesture, and their potential as second language tutors for children
May 31 | Tilbe Göksun, Koc University
Functions of gestures and individual differences: A lifespan approach
June 22 | Spencer Kelly, Colgate University
Exploring the Emotional Function of Co-Speech Gesture in Language and Communication
December 14 | Taras Kucherenko, Electronic Arts, Stockholm
Mapping speech to gestures using machine learning

MAX PLANCK INSTITUTE
FOR PSYCHOLINGUISTICS

VISITING ADDRESS
Wundtlaan 1
6525 XD Nijmegen
The Netherlands

POSTAL ADDRESS
P.O. Box 310
6500 AH Nijmegen
The Netherlands

CONTACT
T +31(0)24 3521 911
F +31(0)24 3521 213
E info@mpi.nl
Twitter @MPI_NL
www.mpi.nl
www.mpi-talkling.mpi.nl