MAX PLANCK INSTITUTE
FOR PSYCHOLINGUISTICS

RESEARCH REPORT 2019 | 2020

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MAX PLANCK

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

PREFACE

Since its creation in 1980, the Max Planck Institute for Psycholinguistics has been at the forefront of interdisciplinary research into the foundations of language and communication. The research conducted at the Institute combines perspectives from diverse disciplines, including linguistics, psychology, neuroscience, genetics, anthropology, and computer science. The Institute investigates how children and adults acquire language(s), how speaking and listening happen in real time, how the brain processes language, how the human genome contributes to building a language-ready brain, how language is related to cognition and culture, and how it is shaped by evolution. The Institute's approach to the science of language and communication is unique because these fundamental issues are addressed at multiple levels, from molecules and cells to circuits and brains, all the way through to the behaviour of individuals and populations.

This report demonstrates the value of such an integrated strategy, providing some highlights of our work in 2019 and 2020. Readers who want to learn more about our research can find details in the news archives, on the departmental pages, in blogs on the Institute's website (www.mpi.nl), and in the many primary publications, review articles, chapters, books, and PhD dissertations produced during this time.

The year 2019 was a good year for the Institute in many respects. For instance, we had a very successful evaluation of our IMPRS for Language Sciences and an equally successful evaluation by our Scientific Advisory Board. The year 2020 was meant to be special, as the Institute was to celebrate its 40th anniversary. The year started very well with the opening of the Bruner Library in January. However, due to the pandemic, all further festive events had to be postponed or cancelled.
Since the middle of March 2020, access to the institute has been restricted, and at the time of writing most members of the Institute have been working almost exclusively from home for well over a year. A dedicated Covid-19 team has ensured maximum security for everyone at the Institute. The Operations Department and the Technical Group have worked hard to ensure a safe building, provide information updates for all employees and help everyone optimise their home office, improve online data collection and organise conferences and workshops online.

With all of these resources in place, research could continue, though often not exactly as envisioned, and many planned events could go ahead online. This included the IMPRS for Language Sciences Conference on "Interdisciplinary Approaches in the Language Sciences" organised by the IMPRS students, the workshops "Many paths to language" and "The future of linguistics", and many guest lectures and colloquia. In addition, 28 PhD students defended their theses, mostly in online or 'hybrid' events with small audiences.

I am extremely grateful to everyone involved in dealing with the unanticipated challenges of this year – for their hard work, flexibility and professionalism. The cover image of this report, as well as the spread on pages 40-41 depict the togetherness and perseverance of the members of the institute, when our much-needed communication mostly took place online. All in all, 2020 was not a happy year. Nonetheless, excellent research was done, demonstrating the resilience and resourcefulness of the researchers and support teams. You can read about our work in this edition of our research report.

Antje Meyer
Managing Director

VISIT
SCIENTIFIC ADVISORY BOARD

The visit of the Scientific Advisory Board in 2019. On this photo we see, starting at the top, from left to right: Michael Owen, Thomas Bourgeron, Pienie Zwitserlood, Paul Fletcher, Manual Carreiras, Jeffrey Binder, Gary Dell, Marta Kutas, Ron Mangun (Chair of the Scientific Advisory Board), Randi Martin, Dorret Boomsma, Matthew Collins, Holly Branigan and Faraneh Vargha-Khadem.

WORK
DURING THE PANDEMIC

A participant is being prepared for an EEG experiment. Work in the behavioural and neurobiological laboratories has been continuing, albeit on a very small scale, throughout the Covid years.

OPENING
JEROME BRUNER LIBRARY

The Bruner Library was officially opened in January 2019. Jerome Bruner's library comprised of more than 3000 books. They are an important resource for psychologists, linguists, and historians. The library can be visited by people from outside the institute upon request, and is accessible online via our library catalogue.

ORGANISATION OF THE INSTITUTE
2019 | 2020

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(Westfälische Wilhelms-Universität, Institut für Psychologie, Münster, Germany)

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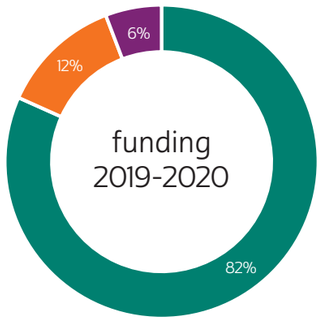
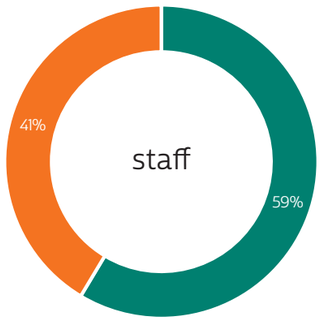
Communications Department
Marjolein Scherphuis *(senior communications advisor)*

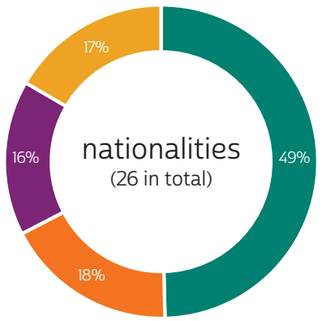
Technical Group
Reiner Dirksmeyer *(head)*

The Language Archive
Paul Trilsbeek *(head)*

IMPRS for Language Sciences
Kevin Lam *(coordinator)*







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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.

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HONOURS AND AWARDS

2019
Falk Huettig was appointed Professor of Psycholinguistics and Cultural Cognition at Radboud University.
Sara Busquets Estruch was awarded the Otto Hahn Medal from the Max Planck Society.
Peter Hagoort was inducted as new member of the American National Academy of Sciences.
Caroline Rowland was appointed Professor by special appointment of First Language Acquisition.
Evan Kidd was named as Australia's leading researcher in Language and Linguistics.
Stephen Levinson was voted the Huxley Medalist and Lecturer for 2020 by the Council of the Royal Anthropological Institute.
Linda Drijvers was awarded a Minerva Fast Track Fellowship for her project investigating how oscillatory dynamics support in situ multimodal human communication.
Asli Özyürek was elected to the Academia Europea.

2020
Luis Miguel Rojas-Berscia received the Anéla/AVT dissertation award for the best 2019 doctoral dissertation in linguistics in the Netherlands.
Sonja Vernes was awarded a UK Research and Innovation (UKRI) Future Leaders Fellowship to study vocal learning in bats as a model for human speech and language evolution.
Director Emeritus Anne Cutler was awarded the ASA Silver Medal.
Director Emeritus Anne Cutler was welcomed as new Fellow by the British Academy.
Mark Dingemanse received the Heineken Young Scientists Award 2020 in the Humanities from the Royal Netherlands Academy of Arts and Sciences.
Andrea Martin was chosen as a Lise Meitner Leader by the Max Planck Society. This Excellence Programme is aimed at identifying highly motivated and committed women scientists in the breakthrough phase of their careers.
Sonja Vernes received a Consolidator Grant from the European Research Council (ERC) to develop her project 'Revealing the biological bases of speech and language by studying bat vocal learning'.
Else Eising received a VENI award from the Netherlands Organisation for Scientific Research (NWO) for her project 'Finding the genes that make you stutter'.
Naomi Nota and Evelyn Bosma were the winners of the 5th Klokhuis Science Award for their study 'How do bilingual children in Friesland read?'
The Australian TV documentary 'Old People's Home for 4 Year Olds', to which **Evan Kidd** contributed, won an International Emmy award.

PHD COMPLETIONS

2019

Jana Baskanova Beyond the language given: The neurobiological infrastructure for pragmatic inferencing

Linda Drijvers On the oscillatory dynamics underlying speech-gesture integration in clear and adverse listening conditions

Amie Fairs Linguistic dual-tasking: Understanding temporal overlap between production and comprehension

Claire Goriot Early-English education works no miracles: Cognitive and linguistic development in mainstream, early-English, and bilingual primary-school pupils in the Netherlands

Paul Hömke The face in face-to-face communication: Signals of understanding and non-understanding

Merel Maslowski Fast speech can sound slow: Effects of contextual speech rate on word recognition

Annika Nijveld The role of exemplars in speech comprehension

Jon-Ruben van Rhijn The role of FoxP2 in striatal circuitry

Luis Miguel Rojas-Berscia From Kawapanan to Shawi: Topics in language variation and change

Elliot Sollis A network of interacting proteins disrupted in language-related disorders

Johanna de Vos Naturalistic word learning in a second language

2020

Zeynep Azar Effect of language contact on speech and gesture: The case of Turkish-Dutch bilinguals in the Netherlands

Julija Baranova Reasons for every-day activities

Mathias Barthel Speech planning in dialogue: Psycholinguistic studies of the timing of turn taking

Saoradh Favier Individual differences in syntactic knowledge and processing: Exploring the role of literacy experience

Svetlana Gerakaki The moment in between: Planning speech while listening

Ferdy Hubers Two of a kind: Idiomatic expressions by native speakers and second language learners

Sara Iacozza Exploring social biases in language processing

Jana Thorin née Krutwig Can you hear what you cannot say? The interactions of speech perception and production during non-native phoneme learning

Ella Z. Lattenkamp Vocal learning in the pale spear-nosed bat, *Phyllostomus discolor*

Valeria Mongelli The role of neural feedback in language unification: How awareness affects combinatorial processing

Limor Raviv Language and society: How social pressures shape grammatical structure

Joe Rodd How speaking fast is like running: Modelling control of speaking rate

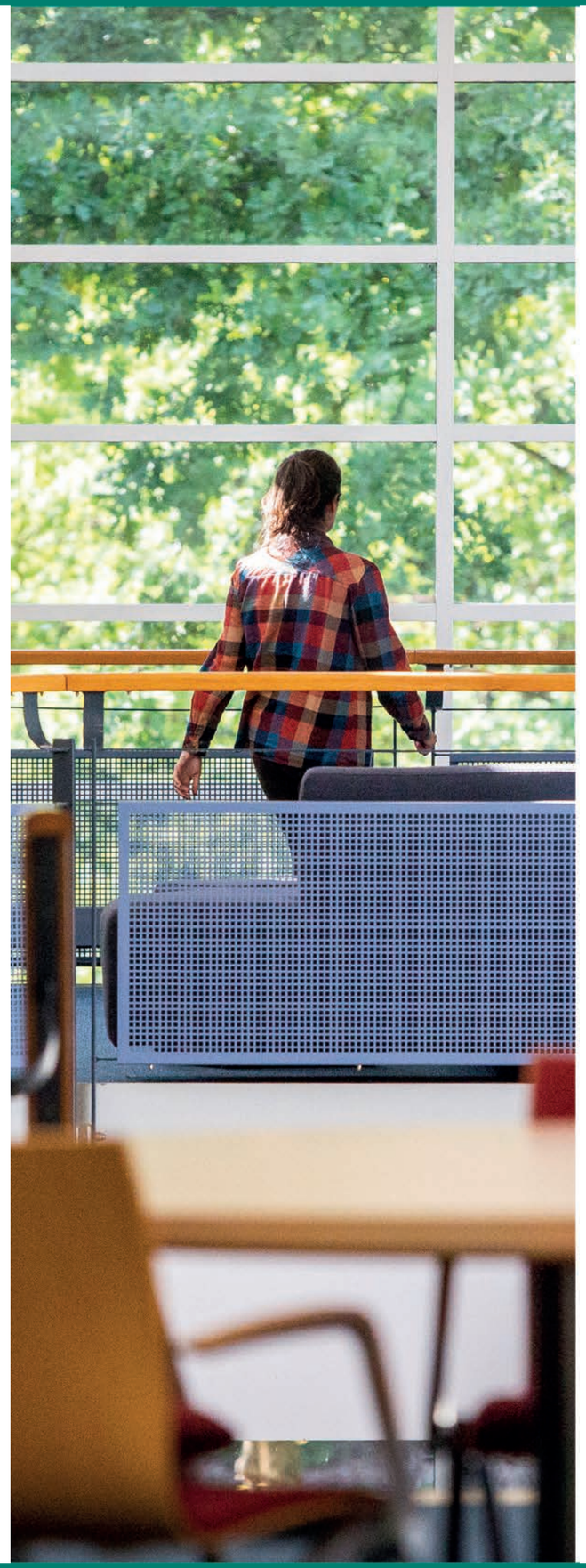
René Terporten The power of context: How linguistic contextual information shapes brain dynamics during sentence processing

James Trujillo Movement speaks for itself: The kinematic and neural dynamics of communicative action and gesture

Marvin Uhlmann Neurobiological models of sentence processing

Xiaochen Zheng Control and monitoring in bilingual speech production: Language selection, switching and intrusion

Eirini Zormpa Memory for speaking and listening



ACRONYMS

ATL	anterior temporal lobe
ACE	atypical communication expertise
ASD	autism spectrum disorder
BOLD	blood oxygen level dependent
CLARIAH	common lab research infrastructure for the arts and humanities
CT	computer tomography
DOBES	documentation bedrohter sprachen (documentation of endangered languages)
ELN	electronic laboratory notebook
EEG	electroencephalogram
ENIGMA	enhancing neuro-imaging 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 Gökberk Alagöz, Mariska Barendse, Jasper Bok, Jelle de Boer, Amaia Carrión Castillo, Pattarawat Chormai, Marjolein van Donkelaar, Lucía De Hoyos, Karthikeyan Devaraju, Else Eising, Soha Farboud, Clyde Francks, Margot Gerritse, Jurgen Heijsen, Joery den Hoed, Roos Kampen, Xiangzhen Kong, Barbara Molz, Merel Postema, Beate St Pourcain, Dick Schijven, Fenja Schlag, Zhiqiang Sha, Cleo Smeets, Lot Snijders Blok, Amanda Tilot, 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. We use 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, tracing connections between genes, cells and brain development in model systems, and making use of custom-built wet-lab facilities with dedicated tissue-culture and microscopy suites. In parallel, we 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. We are also interested in what molecular studies may reveal about evolutionary origins of language and other aspects of the human condition.

Deciphering the roles of FOXP genes in the neurobiology of speech and language
In 2001, Fisher and colleagues demonstrated that disruptions of the *FOXP2* gene lead to childhood apraxia of speech, together with problems in language production and comprehension, against variable backgrounds of general cognitive performance. A decade later, mutation of a closely related gene, *FOXP1*, was associated with a severe neurodevelopmental syndrome involving autistic features and/or intellectual disability, often accompanied by impaired language skills. Research led by Snijders Blok has now uncovered a novel brain-related disorder due to FOXP dysfunction (Figure 1), identifying DNA variants in the *FOXP4* gene that cause speech/language delays, growth abnormalities and an array of other non-neural features that vary between cases. *FOXP2, FOXP1* and *FOXP4* encode proteins that are highly similar, that can directly interact with each other, and that share the same primary function – to regulate activity of other genes. For each FOXP, there are rare DNA variants that alter the same critical part of the encoded protein (the DNA-binding domain) but cause a distinct disorder with differences in symptoms and severity. When Snijders Blok and colleagues used human cell-culture assays to investigate the consequences of the newly identified *FOXP4* mutations, they found that these damaged the regulatory capacities of the resulting mutated protein, just as for prior studies of similar variants in *FOXP2* and *FOXP1*. The shared and unique neural deficits of the various FOXP-related disorders may be explained in part by similarities and differences in when and where each gene is active in the brain. Ongoing investigations in a range of model systems are uncovering the broader molecular pathways and genetic networks that these genes participate in, to better understand links to brain and behaviour. In addition to the FOXPs, whole-genome sequencing studies by the Language and Genetics department have shown that rare variants in several other regulatory genes (such as *CHD3, SETBP1, POU3F3)* can disrupt speech and language development; the researchers are currently studying such genes using CRISPR/Cas9 gene-editing and human brain organoids grown in the laboratory.

Altered brain asymmetries in neurodevelopmental disorders
The Imaging Genomics Group, led by Francks, uses cutting-edge methods to investigate the biological basis of asymmetrical structural and functional features of the human brain, and to uncover links to cognition and behaviour. In earlier literature, altered left-right brain asymmetries have been suggested for a range of conditions, from dyslexia and language impairments to depression and schizophrenia, but studies typically involved small samples and there have been few independent replications to validate the claimed effects. Postema and colleagues sought to resolve this question in relation to autism, a major class of neurodevelopmental disorders characterised by impaired social cognition, repetitive behaviour and restricted interests. Working with the international ENIGMA (Enhancing Neuro-Imaging Genetics through Meta-Analysis) consortium, the researchers analysed the neuroanatomy of 1,774 people with autism spectrum disorders (ASD) and 1,809 healthy controls, bringing together MRI scans from 54 datasets collected in different countries over a >20-year period. ASD was associated with altered asymmetries of cortical thickness (multiple regions including medial frontal, orbitofrontal, cingulate and inferior temporal areas) and surface area (limited to the orbitofrontal region) in ways that were independent of age, sex, IQ, severity of symptoms, and medication use. In this investigation, by far the largest ever study of the issue, differences mainly involved reduced asymmetry in ASD compared to controls, but were very subtle, limiting their utility for clinical predictions. Nonetheless, the findings might inform understanding of ASD neurobiology. Given that the bulk of the data were from children, ASD may involve altered development of the brain's left-right axis, affecting widespread brain regions supporting diverse functions, including language. The group is going on to study genetic contributions to variation in brain asymmetry in tens of thousands of healthy individuals, and to test whether the same genetic factors influence susceptibility to ASD and other brain-related conditions. This work may help identify important developmental processes and brain systems that are disrupted in psychiatric disorders.

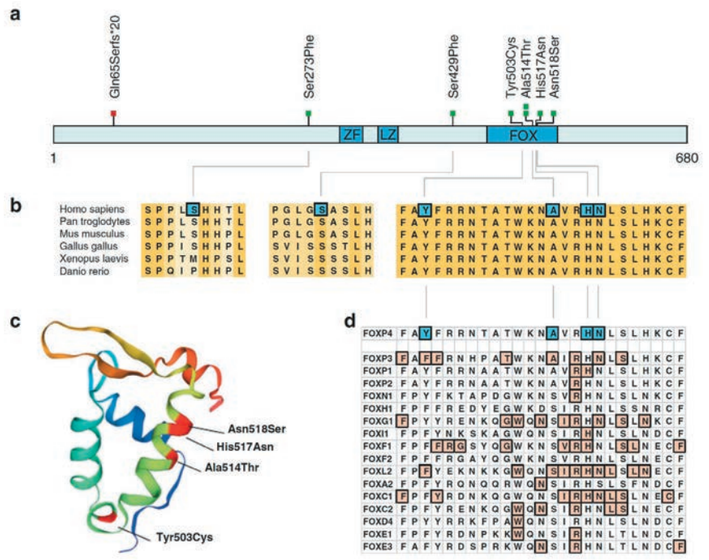


Figure 1. Rare variants disrupting the FOXP4 gene cause a neurodevelopmental disorder. (a) Linear representation of the protein encoded by FOXP4, with functional domains annotated and sites of rare variants indicated: FOX = forkhead box DNA-binding domain, LZ = leucine zipper, ZF = zinc finger. (b) Evolutionary conservation of FOXP4 across different species, including human (Homo sapiens), chimpanzee (Pan troglodytes), mouse (Mus musculus), chicken (Gallus gallus), clawed frog (Xenopus laevis), and zebrafish (Danio rerio). (c) The identified variants alter the amino-acid sequences at key points of the DNA-binding domain, as shown by the three-dimensional structure. (d) Rare disruptive variants in this part of the DNA-binding domain cause disorders in multiple different FOX proteins.

Disentangling genetic contributions to development of language and literacy
The Population Genetics of Human Communication Group, led by St Pourcain, investigates cohorts with thousands of participants for whom multiple aspects of behaviour and cognition have been followed from birth through to adulthood, coupled to the collection of biological data such as DNA. Using these rich longitudinal datasets together with information on common variable genetic markers, as obtained by microarray analysis, St Pourcain's team applies the latest genetic epidemiology tools, including methods developed within the group, to disentangle the way that genetic factors contribute at different points in development. The value of this approach is illustrated by recent work by Verhoef and colleagues, who studied relationships between early expressive and receptive vocabulary at 38 months, and an array of language and literacy related abilities at ages 7-13 years in 6,092 unrelated children from the Avon Longitudinal Study of Parents and Children.

DEPARTMENT
LANGUAGE AND GENETICS

Employing structural equation modelling methods that incorporate the available DNA information from the participants, the researchers showed that genetic contributions to early childhood vocabulary (especially those unique to receptive skills) become amplified in later development, accounting for the majority of genetic variance underlying language and literacy skills in mid childhood and early adolescence. In follow-up studies, the researchers demonstrated that the genetic foundations of later reading and cognition are diverse, involving at least two independent factors emerging at different stages during early language development. As well as yielding insights beyond those of prior twin studies, the new genetic epidemiology approaches further offer the potential to identify the nature of the biological pathways involved. Moreover, the group uses these methods to discover more about how social, language and literacy skills go awry in common neurodevelopmental disorders, including ASD and ADHD.

Biological underpinnings of distinctive features of the human brain

Modern human skulls have a unique globular shape, distinct from the elongated skulls of Neanderthals and most primates (Figure 2). This shape difference may reflect evolutionary changes in the relative sizes of structures of the human brain, perhaps even in the ways that key brain areas are connected to each other. Since brain tissue does not fossilise, the underlying biological explanations remain elusive. Collaborative work, led by the Language and Genetics Department of the MPI for Psycholinguistics and the Human Evolution Department of the MPI for Evolutionary Anthropology (Leipzig, Germany), seeks to address this gap. Gunz, Tilot and colleagues developed an integrated strategy, combining analysis of fossil skulls, ancient genome sequence data, neuroimaging and gene expression. The researchers derived a single metric capturing degree of globularity, based directly on comparing skull shapes of humans and Neanderthals, and applied it to MRI data of thousands of healthy present-day humans. They then studied the genomes of the participants to identify rare introgressed fragments of Neanderthal DNA, remnants of ancient interbreeding events between different hominins. The team found Neanderthal fragments on chromosomes 1 and 18 that were associated with less globular (more elongated) brains, and linked these to altered activity of two genes, *UBR4* and *PHLPP1*, which are known to play roles in aspects of brain development (neurogenesis and myelination respectively). The strongest evidence for effects of these Neanderthal DNA fragments on gene activity were in the putamen (in the basal ganglia) and the cerebellum, but they nonetheless account for only a tiny proportion of variation in globularity. The strategy is now being extended to much larger cohorts of tens of thousands of participants, allowing for systematic genome-wide association screens of globularity. The researchers are using similar integrated approaches to investigate other aspects of human brain evolution, including changes in surface area and connectivity that may relate to the emergence of speech and language in our ancestors.

Figure 2. One of the features that distinguishes modern humans from Neanderthals is a globular shape of the braincase. Left: Computed tomographic (CT) scan of a Neanderthal fossil (La Ferrassie 1). Right: CT scan of a modern human; the cranium was cut open virtually to reveal the inside of the braincase. Licence: CC BY-NC-ND 4.0; Image by Philipp Gunz.

Selected Publications

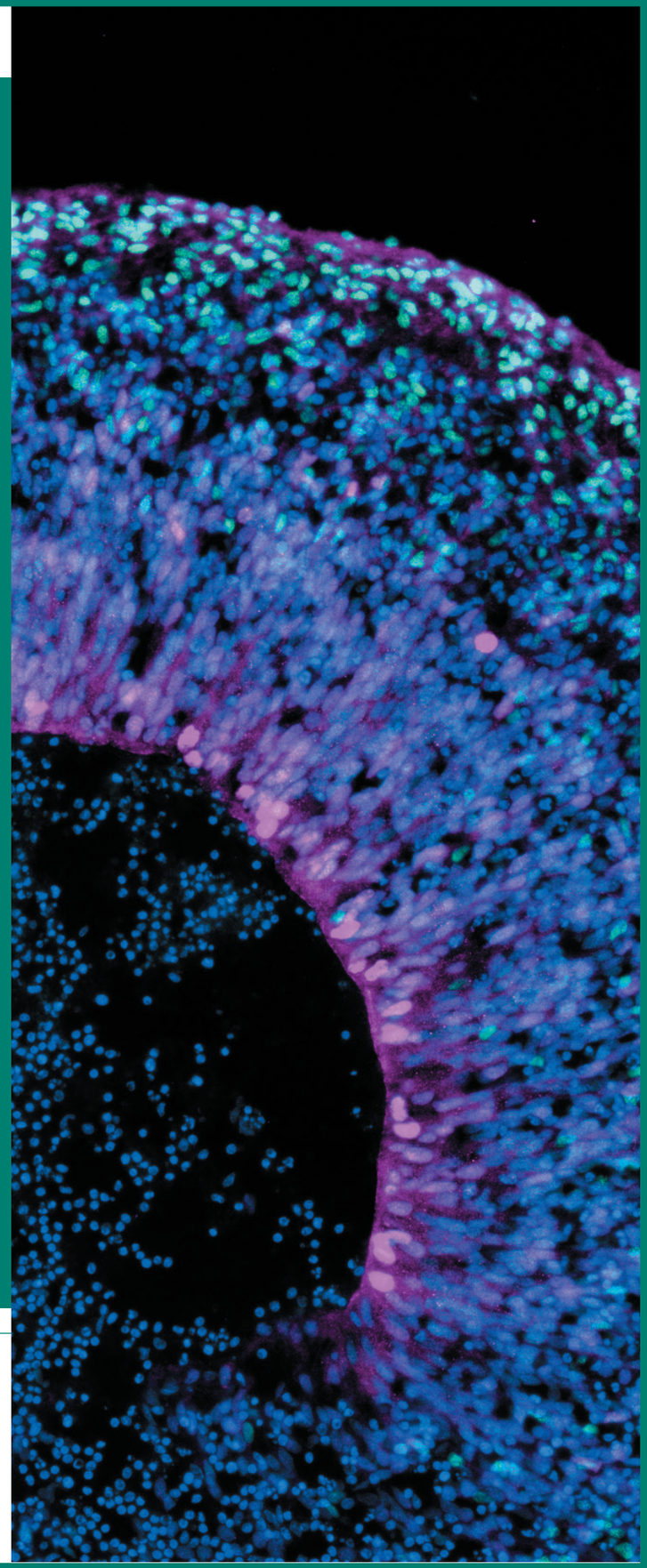
Gunz, P., Tilot, A. K., Wittfeld, K., Teumer, A., Shapland, C. Y., Van Erp, T. G. M., Dannemann, M., Vernot, B., Neubauer, S., Guadalupe, T., Fernandez, G., Brunner, H., Enard, W., Fallon, J., Hosten, N., Völker, U., Profico, A., Di Vincenzo, F., Manzi, G., Kelso, J., St Pourcain, B., Hublin, J.-J., Franke, B., Pääbo, S., Macciardi, F., Grabe, H. J., & Fisher, S. E. (2019). Neandertal introgression sheds light on modern human endocranial globularity. *Current Biology*, 29, 120-127. doi:10.1016/j.cub.2018.10.065.

Postema, M., Van Rooij, D., Anagnostou, E., Arango, C., Auzias, G., Behrmann, M., Busatto Filho, G., Calderoni, S., Calvo, R., Daly, E., Deruelle, C., Di Martino, A., Dinstein, I., Duran, F. L. S., Durston, S., Ecker, C., Ehrlich, S., Fair, D., Fedor, J., Feng, X., Fitzgerald, J., Floris, D. L., Freitag, C. M., Gallagher, L., Glahn, D. C., Gori, I., Haar, S., Hoekstra, L., Jahanshad, N., Jalbrzikowski, M., Janssen, J., King, J. A., Kong, X., Lazaro, L., Lerch, J. P., Luna, B., Martinho, M. M., McGrath, J., Medland, S. E., Muratori, F., Murphy, C. M., Murphy, D. G. M., O'Hearn, K., Oranje, B., Parellada, M., Puig, O., Retico, A., Rosa, P., Rubia, K., Shook, D., Taylor, M., Tosetti, M., Wallace, G. L., Zhou, F., Thompson, P., Fisher, S. E., Buitelaar, J. K., & Francks, C. (2019). Altered structural brain asymmetry in autism spectrum disorder in a study of 54 datasets. *Nature Communications*, 10, 4958. doi:10.1038/s41467-019-13005-8.

Snijders Blok, L., Vino, A., Den Hoed, J., Underhill, H. R., Monteil, D., Li, H., Reynoso Santos, F. J., Chung, W. K., Amaral, M. D., Schnur, R. E., Santiago-Sim, T., Si, Y., Brunner, H. G., Kleefstra, T., & Fisher, S. E. (2020). Heterozygous variants that disturb the transcriptional repressor activity of FOXP4 cause a developmental disorder with speech/language delays and multiple congenital abnormalities. *Genetics in Medicine*. Advance online publication. doi:10.1038/s41436-020-01016-6.

Udden, J., Hulten, A., Bendt, K., Mineroff, Z., Kucera, K. S., Vino, A., Fedorenko, E., Hagoort, P., & Fisher, S. E. (2019). Towards robust functional neuroimaging genetics of cognition. *Journal of Neuroscience*, 39, 8778-8787. doi:10.1523/JNEUROSCI.0888-19.2019.

Verhoef, E., Shapland, C. Y., Fisher, S. E., Dale, P. S., & St Pourcain, B. (2020). The developmental origins of genetic factors influencing language and literacy: Associations with early-childhood vocabulary. *Journal of Child Psychology and Psychiatry*. Advance online publication. doi:10.1111/jcpp.13327.



A human brain organoid after 50 days of growth in the lab. Magenta stain indicates dividing neural progenitor cells, while green stain indicates neurons expressing CHD3, one of the genes being studied by the Language & Genetics department. Image by Joery den Hoed.

DEPARTMENT **LANGUAGE DEVELOPMENT**

Director Caroline Rowland
Department members Ibrahim Abdullah, Christina Bergmann, Marleen Berkhout, Nanjo Bogdanowicz, Marisa Casillas, Melis Çetinçelik, Julia Egger, Judit Fazekas, Vicky Fisher, Rebecca Frost, Rowena Garcia, Raquel Garrido Alhama, Gabriela Garrido Rodriguez, Jeroen Geerts, Elske Gros, Cielke Hendriks, Daphne Jansen, Andrew Jessop, Evan Kidd, Shanthi Kumarage, Jefta Lagerwerf, Patricia Manko, Naomi Nota, Ingeborg Roete, Nienke Rulkens-Dijkstra, Yevheniy Skyra, Tineke Snijders, Katja Stärk, Inge Stok, Liz Tollenaar, Ilse van den Dobbelsteen, Merel Wolf

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 build and test 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?

How (not) to boost children's language
Every year, governments spend millions of dollars, euros, or other currency of choice, on intervention programmes designed to improve children's language. These programmes often focus on children living in poverty, since the effects of poverty on children's language development can be severe. However, all too often, such programmes are driven by good intentions rather than strong evidence.

For example, we know that shared reading has an important role in children's early language development. Children whose parents read to them frequently in the first years of life have bigger vocabularies and a more sophisticated knowledge of grammar by the time they start school. But how to create effective shared reading interventions programmes is another matter.
In a series of studies over the last few years, Rowland and a team from four UK universities showed that it is not easy, nor simple, nor cheap to improve children's language in this way. These studies carefully evaluated the effect of interventions designed to help parents read with their children. All studies yielded the same result: no effect on children's language.

The project culminated in the publication of a meta-analysis (Noble et al., 2019) in which the team re-analysed results from dozens of reading intervention studies published in the last few years. Again the results were stark; the effect of these

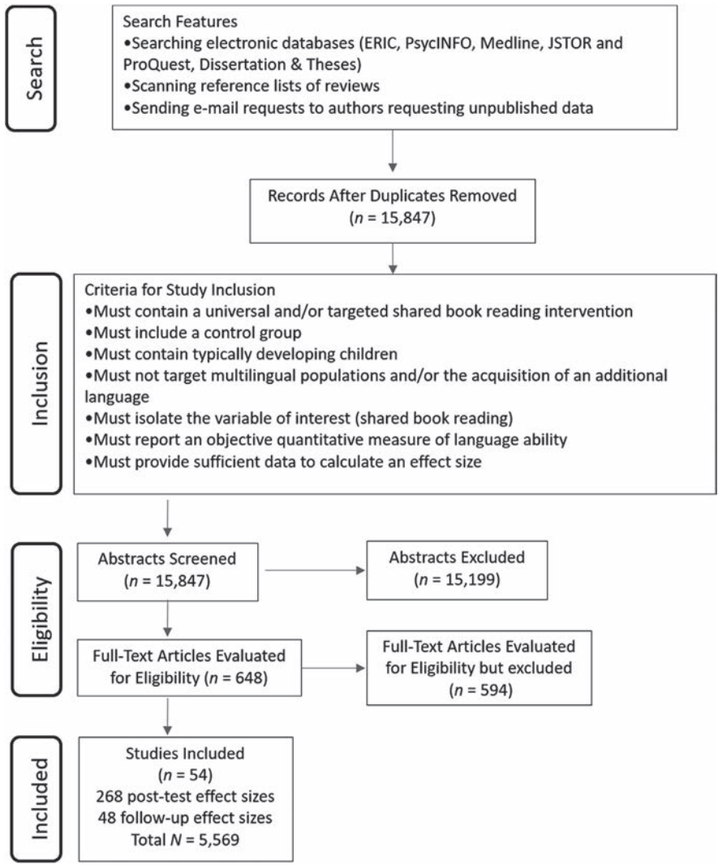
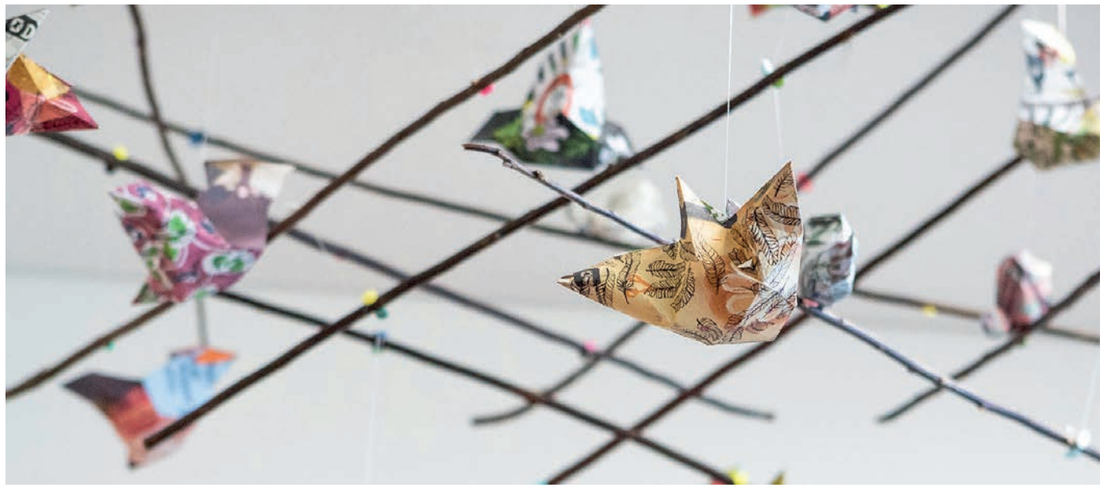


Figure 1. Flow diagram of the studies included and excluded in the meta-analysis of shared reading interventions. Reproduced from Noble et al.(2019) with permission from the publishers.



programmes on children's language was small. In fact, it was negligible in the most carefully constructed and robust studies.

Why is this? Put simply, it is extremely difficult to engender substantial, lasting change in parents' behaviour and in children's language. Short-term, inexpensive intervention programmes are not enough. For example, another study in this series (Lingwood et al., 2020) reported on the barriers facing parents who want to take part in such programmes. The stresses and strains of everyday life got in the way, even for the most enthusiastic parents who were initially determined to attend all sessions.

The project did yield positive messages too. It is possible to encourage parents to read more with their children. However, it requires a nuanced, systematic approach, based on a comprehensive understanding of family practices and the role of reading within a family's daily life. In other words, we first have to understand parents, and the pressures they are under in their daily lives, before we intervene.
(This project was funded by the ESRC in the UK (ES/M003752/1), whose support we gratefully acknowledge.)

Reading with children can be an effective way to boost their language development.

Learning to process languages across the world

The world has about 7,000 languages. But most of what we know about how language is learned and processed comes from a small fraction of them (less than two percent), with a skew towards 'big' European languages like English and German. The Learning through Processing Research Group, led by Evan Kidd, studies how humans can acquire any one of the world's thousands of languages by studying how they process them. In the past two years, the group has conducted research on several languages, including Cantonese, Mandarin, Tagalog (Philippines), and the Australian Indigenous languages Murrinhpatha and Pitjantjatjara, as well as the more well-studied languages English, German, and Italian.

A common thread in this work is how children's in-the-moment processing is guided by the frequency with which they hear different words and sentences. For example, in a series of studies conducted with colleagues at the Hong Kong Polytechnic University, the researchers investigated whether input frequencies influence what kind of relative clauses Cantonese- and Mandarin-speaking children prefer (e.g. whether they prefer to produce sentences like 'the dog that chased the cat' or 'the cat that the dog chased'). In European languages, speakers generally prefer the former ('the dog that chased the cat'), but Chinese languages have different typological properties that make the latter more accessible.
In Yang et al. (2020), the group showed that the preference for different relative clause types in Mandarin is modulated by the frequency with which children hear different structures in the input. The same effect occurs in Cantonese, see Chan et al. (2018). Notably, different forms of structural modification have different distributions in the input, and children use these to rapidly process syntactic structure. The group are currently working on similar issues in Tagalog (Rowena Garcia), an Austronesian language spoken in the Philippines, and in Russian and German (Yevheniy Skyra).

Language development through a global lens: First findings from the ManyBabies consortium

Psychology has recently been through a replication crisis in which we discovered that many of our experiments cannot be replicated. Developmental psychology is no different. ManyBabies was founded in 2015 to address the replicability crisis, and ensure that developmental studies are built on a robust evidence base. ManyBabies has now become a world-spanning consortium with over 400 members from all permanently inhabited continents. Christina Bergmann, Senior Investigator at the Language Development Department, is one of seven members of the governing board.

The first ManyBabies project was completed recently and shows that this large-scale approach to developmental studies gives us insights that are virtually impossible for single labs to obtain. Sixty-nine different labs across four continents tested almost 3000 monolingual infants to determine whether they preferred to listen to infant-directed speech (IDS) over adult-directed speech (ADS). Infant-directed speech has special acoustic properties that may grab children's attention, encourage them to focus on what is being said, and thus facilitate language learning. But the question of whether children do, in fact, attend to infant-directed speech more closely has never been comprehensively answered. The ManyBabies team found that infants across the world do show a preference for IDS, although it is smaller than expected. The team also found an effect of age and whether the stimuli matched infants' native language and dialect. These findings have important implications for our understanding of how children use their input to learn language. Follow-up studies and analyses of the publicly available data, as well as six new experimental studies, are in progress. Such large-scale projects, and the robust, global insights they provide, are possible only through cooperation and coordination. The Language Development Department is proud to contribute to the ManyBabies consortium.

A child at home with her parents wearing a small daylong audio-recorder in a specially-designed vest. Picture provided by Marisa Casillas.

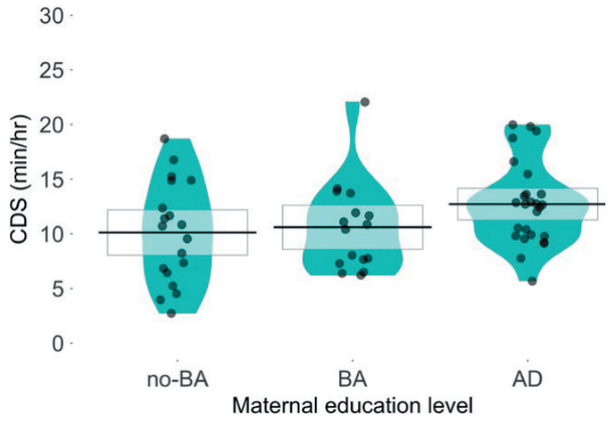


Figure 2. The average amount of child-directed speech in minutes per hour produced by North American parents. Reproduced from Bergelson et al. (2019) with permission from the publishers.

Immersed in a sea of sound? How much language do children really hear?

You will sometimes hear it said that children learn language because they are 'immersed in a sea of sound and sights' in their daily lives. But is this actually true? How much language do children really experience every day? The answer is important because it is not possible to learn a language in isolation. If we want to understand how children learn language, we first have to understand what information is available in their environments.

Until recently, estimates of children's language input were based on small-scale audio or video recordings capturing perhaps 30 minutes or an hour of their life per week. Even some of the most intensive studies only managed to record one hour a day, and only for a few weeks of the child's life. But recent advances in large-scale data storage and processing have revolutionised this work. We now have small scale audio-recorders that fit neatly into specially designed pockets in children's clothes and can record what they hear for a full day (so-called daylong recordings). And we now have sophisticated analysis programs that can automatically extract information directly from these recordings, including estimates of the number of adult words that children hear and more.
The team are using these automated techniques in combination with human speech tagging to discover new facts about children's language environments. For example, in a recent study, Marisa Casillas, a postdoctoral researcher in the department, and her colleagues, analysed daylong audio-recordings from 61 homes across four North American cities (Bergelson et al, 2019). As expected, women produced substantially more child-directed speech than men, and children with university educated parents heard a little more child-directed speech than those with parents who left education after high school.
However, the absolute amount of speech addressed to children during the day was less than previous studies had led us to expect (about 11.36 minutes per hour). This meant that the absolute differences between groups were also smaller than expected. For example, parents with a university bachelor's degree produced on average only 1.3 minutes more speech per hour than high school educated parents. There were also large differences across families in the relative amount of speech addressed to children, compared to the amount of other speech occurring around them. Casillas's more recent studies with families in Papua New Guinea and Mexico also reveal fewer differences in children's language environments than might be expected across cultures. It seems that, cross-culturally, it is rare for adults to direct a lot of speech to children during their waking days at home. However, surprisingly, the infrequent use of child-directed speech seems to have a smaller effect on language development than might be expected, especially when it comes to early milestones such as when children produce their first words and sentences. Much more of this work is needed, across many different cultures and across different spoken and signed languages, if we are to fully understand the 'sea of sounds and sights' in which our children learn.

Selected publications

Bergelson, E., Casillas, M., Soderstrom, M., Seidl, A., Warlaumont, A. S., & Amatuni, A. (2019). What do North American babies hear? A large-scale cross-corpus analysis. *Developmental Science*, 22(1), e12724. doi:10.1111/desc.12724.

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Noble, C., Sala, G., Peter, M., Lingwood, J., Rowland, C. F., Gobet, F., & Pine, J. (2019). The impact of shared book reading on children's language skills: A meta-analysis. *Educational Research Review*, 28, 100-290. doi:10.1016/j.edurev.2019.100290.

The ManyBabies Consortium (2020). Quantifying sources of variability in infancy research using the infant-directed speech preference. *Advances in Methods and Practices in Psychological Science*, 30(1), 24-52. doi:10.1177/2515245919900809.

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DEPARTMENT **NEUROBIOLOGY OF LANGUAGE**

Director Peter Hagoort
Department members Sophie Arana, Kristijan Armeni, Jana Baskanova-Hanulova, Geertje van Bergen, Dick van de Broek, Cas Coopmans, Hartmut Fitz, Monique Flecken, Laura Giglio, Teun van Gils, Karin Heidlmayr, Micha Heilbron, Maarten van den Heuvel, Nienke Hoeksema, Eleanor Huizeling, Birgit Knudsen, Natalia Levshina, Ashley Lewis, Xin Liu, Margot Mangnus, Branka Milivojevic, Julia Misersky, Valeria Mongelli, Guillermo Montero-Melis, Mante Nieuwland, Markus Ostarek, David Peeters, Karl Magnus Petersson, Fenna Poletiek, Eva Poort, Alessio Quaresima, Iris Schmits, Daniel Sharoh, Ksenija Slivac, Rowan Sommers, Atsuko Takashima, Yingying Tan, Renee Terporten, Marvin Uhlmann, Kirsten Weber

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 using neuroimaging, behavioural and Virtual Reality techniques to investigate the language system and its neural underpinnings. The research facilities of the 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.

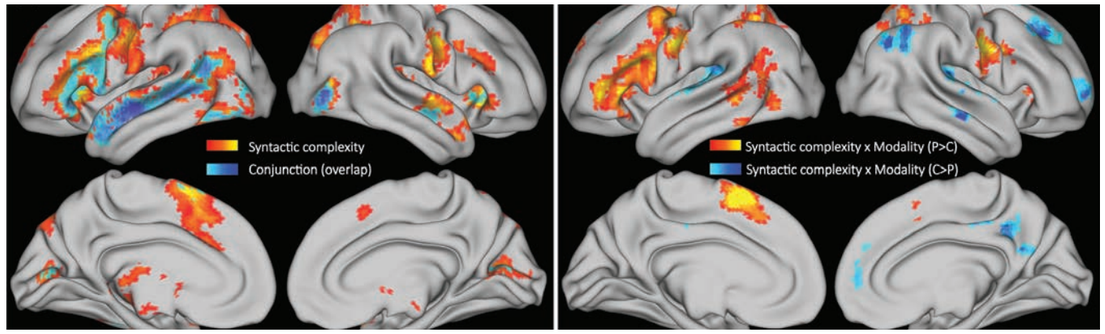
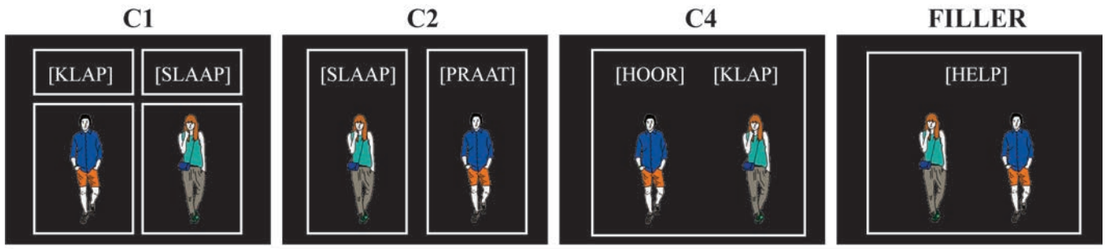


Figure 2. Whole-brain fMRI results. A: Orange: main effect of syntactic complexity. Blue: conjunction analysis of production and comprehension of syntactic complexity effects, representing areas active in both production and comprehension. The blue area is superimposed on the corresponding cluster found as main effect of syntactic complexity. B: Interaction between syntactic complexity and modality. Orange: areas with larger response to syntactic complexity in production than comprehension. Blue: areas with larger response to syntactic complexity in comprehension than production.

The neurobiological infrastructure for language production and comprehension
The neurobiology of language has focused mainly on language comprehension and largely ignored language production. The department aims to correct this tendency. In an fMRI study, the neural response to sentences with increasing structural complexity were investigated. Specifically, the similarities and differences in the production and comprehension of the same sentences were studied. Participants had to either produce or listen to stimuli with different levels of syntactic complexity (see Figure 1).

Laura Giglio found in her PhD project that more complex structures engaged the left inferior frontal gyrus (LIFG) and middle temporal gyrus (LMTG) extending to inferior parietal areas in both production and comprehension. These results indicate that the neural resources for syntactic encoding and decoding are largely overlapping (see Figure 2).
In addition, a modality-specific dissociation was found, with production recruiting the LIFG more strongly than comprehension, and comprehension recruiting the LMTG more strongly than production. Finally, syntactic structure had opposite effects on BOLD peak latencies in comprehension and production: increasing complexity elicited later peaks in comprehension but earlier peaks in production. These results show that syntactic encoding and parsing engage overlapping areas. However, within this common network there are asymmetries in regional activation patterns and their time courses, as a consequence of the different processing requirements of speaking and listening.



klappen, slapen, de man, de vrouw	de vrouw slaapt, de man praat	de man hoort dat de vrouw klapt	de vrouw helpt de man
clap, sleep, the man, the woman	the woman sleeps, the man talks	the man hears that the woman claps	the woman helps the man

Figure 1. Example of each condition (identical in production and comprehension) with the corresponding expected output. The white boxes clarified the type of output that was required. C1: word sequence, C2: coordinated sentences, C4: embedded sentence.

Hesitations influence the prediction of upcoming speech: eye-tracking evidence from immersive virtual reality
Listeners can predict upcoming speech, possibly to assist incredibly fast speech processing. For example, participants make anticipatory eye movements towards depicted objects before hearing their associated noun. The extent to which subtle speech cues (e.g. hesitations) inform these predictions is unknown. A hesitation could indicate to listeners that the speaker is about to say something challenging. In her project Ellie Huizeling provided novel insights into whether hesitations in speech ("uhh") inform one's predictions in real-life like environments. Gazes towards 3D objects and a virtual speaker were investigated. Participants' eye movements were continuously recorded while they listened to Dutch sentences spoken by the virtual agent, during a virtual tour of eight scenes (e.g., office, street; see Figure 3). Sentences within each set were identical apart from a) the presence ("uhh") or absence of a hesitation (fluent sentences); and b) the verb, which was either related to a single target object or multiple objects in the scene (restrictive/unrestrictive respectively). The researchers found increased looks towards the target object in restrictive (predictable) sentences, compared to unrestrictive (unpredictable) sentences before noun/hesitation onset. After hearing a hesitation, however, there was no longer an increase in target fixations. Instead, looks towards the virtual agent increased. Hence, when fluent speech breaks down, the listener's attention moves towards the speaker. Such findings raise new theoretical questions. Are listeners looking for cues to aid speech comprehension, or are they passively waiting for a disambiguation?

Figure 3. Virtual reality CAVE. The virtual agent is displayed in the street scene, with six target objects. Participants wore 3D glasses to immerse them in the environment. Infrared motion tracking cameras track participants' head positions.

The VR-Brain project
The VR-Brain project aims to provide better insights into brain data for researchers and educators. Teun van Gils and his RA team visualise MRI data in a 3-dimensional, interactive fashion, and overlay human brain atlas information or MEG activity from experimental studies. Allowing people to interact with the data themselves facilitates learning and understanding in a hands-on way, and gives a better overview of the data and anatomy than a series of 2D images can provide (see Figure 4).

The data-processing software can take common (f)MRI and MEG data formats and prepare them for use in VR, while allowing additional data such as a brain atlas to be attached. Data can also be downsampled to allow use on slower devices, such as mobile phones or cheaper VR headsets, making the toolset widely accessible. Furthermore, the VR-Brain project can easily display pre-configured views or sequences of views to highlight specific brain regions, neural activity or connections. Brain regions can be toggled on or off to get a better view of the subcortical areas, and to further emphasise the region of interest. This software works on desktop computers, but is developed for a large part with Virtual Reality in mind, where you can switch to a more 'immersive' view and move along the white fibre tracts through the brain; it supports the immersive VR Cave system, as well as regular head-mounted displays. A tour through the annotated brain can make a great teaching device, where instead of moving from image to image, the brain visually rotates and scales to the new position, facilitating a better understanding of the complex three-dimensional structure of the brain and its intricate activation patterns.

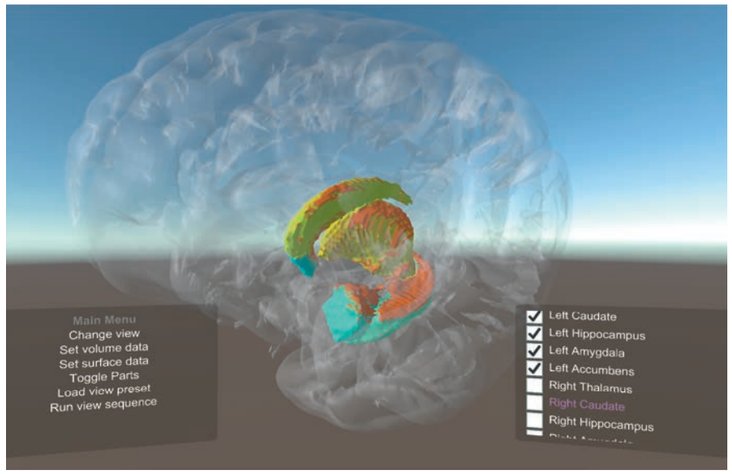
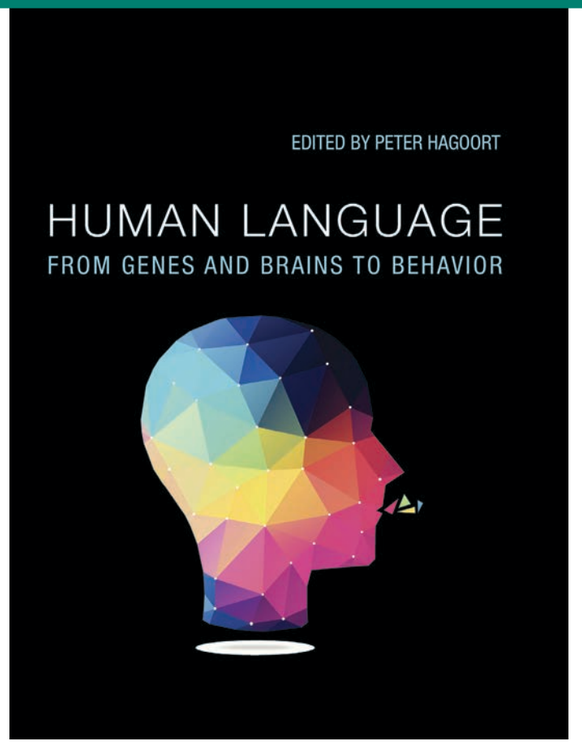


Figure 4. A 2D view of the 3-D immersive VR-Brain.

A hierarchy of linguistic predictions during natural language understanding
Modern neuroscientific theories describe the brain as a prediction machine. According to these theories, the brain constantly generates predictions about incoming input, which then guide information processing. In Psycholinguistics, there has long been evidence in line with this idea. For instance, it is well known that the brain responds more strongly to words that are highly unexpected. However, it remained controversial whether all language processing is predictive. First, it is disputed whether the brain constantly predicts language – or only in specific situations. Second, it is disputed at what level of analysis such prediction might occur: is the brain predicting abstract meaning, syntax, or perhaps even individual speech sounds?

In his PhD project, Micha Heilbron addressed in a natural setting: participants listening to audiobooks. Instead of manipulating participants' expectations, In the project expectations were studied as they naturally arise while listening to the story. To this end, a Deep Neural Network (GPT-2) was used to quantify the predictability of each word in the story. Micha found that brain responses tightly tracked the fluctuations in unexpectedness. Importantly, this effect was not limited to highly predictable words, but was found for all words throughout the story. Next, a new technique was introduced, to quantify not just how much a word was unexpected, but also at what linguistic level – modelling unexpectedness at the semantic, syntactic, and phonological level (see Figure 5a). Strikingly, dissociable neural signatures for different types of unexpectedness were found (see Figure 5b). Specifically, words that were semantically unexpected evoked later, spatially distributed brain responses. By contrast, syntactic and phonemic unexpectedness evoked earlier responses, centred on specific cortical areas. Together, these results demonstrate that the brain spontaneously predicts upcoming language at multiple levels of abstraction. As such, the results demonstrate that language processing in the brain is shaped by domain-general principles of predictive information processing.



Hagoort, P. (Ed.). (2019). Human language: From genes and brains to behavior. Cambridge, MA: MIT Press. To date the most complete overview of the research and sciences involved in studying the uniquely human capacity for language.

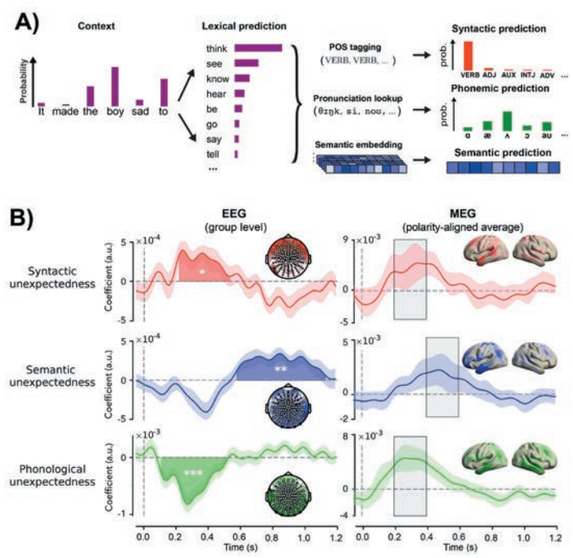


Figure 5. A) Computational procedure to quantify multiple linguistic predictions. The word-level prediction was disentangled from the deep neural network GPT-2 into distinct linguistic dimensions, by analysing the linguistic content of each prediction. For instance, in the example sentence ("it made the boy sad to") it is clear that the syntactic prediction is very strong (the next word will most likely be a verb) but the precise next phoneme is much less certain. B) Dissociable prediction signatures. In two experiments (left EEG; right: MEG) dissociable responses to syntactic, semantic and phonological unexpectedness were observed. This implies that the brain is engaged in prediction at each of these linguistic levels. These results imply a hierarchy of linguistic predictions.

Selected publications

Fitz, H., Uhlmann, M., Van den Broek, D., Duarte, R., Hagoort, P., & Petersson, K. M. (2020). Neuronal spike-rate adaptation supports working memory in language processing. *Proceedings of the National Academy of Sciences of the United States of America*, 117(34), 20881-20889. doi:10.1073/pnas.2000222117.

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DEPARTMENT **PSYCHOLOGY OF LANGUAGE**

Director Antje S. Meyer
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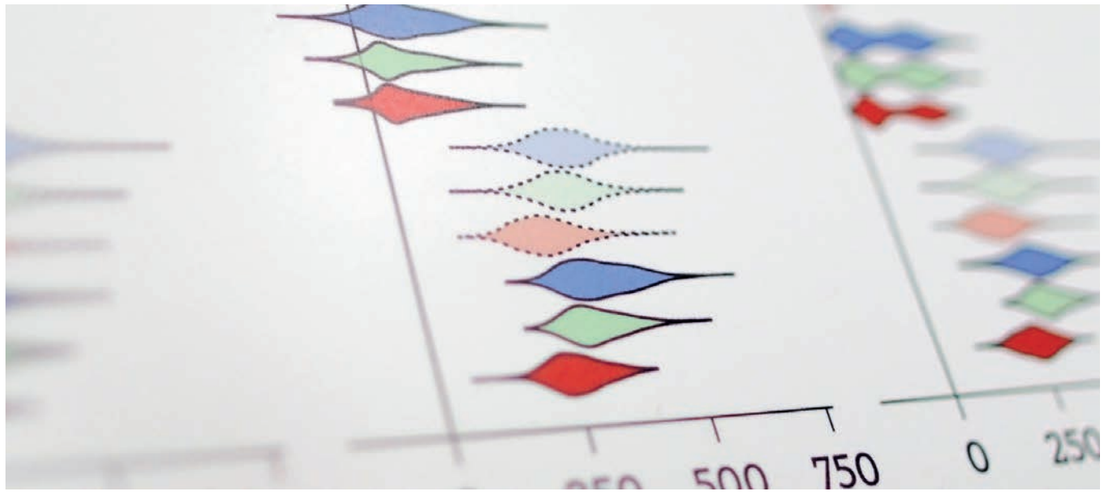
Goal of the Department
The goal of the department is to generate parsimonious, yet sufficiently detailed and comprehensive functional models of the different ways people use language in everyday contexts and in the lab. A key assumption is that there is a small set of basic cognitive tools that people use in different combinations to accomplish tasks involving language. The department aims to identify these tools and to describe how they are combined in different tasks, for instance speaking in conversation, or understanding speech in noise. Another aim is to describe and explain individual differences in language skills. These questions are addressed with a broad range of methods including analyses of corpora of spoken language, computer simulations, classic behavioural experiments, individual differences studies, and neurobiological methods. The work in the department is organised into the clusters introduced below.



The Cultural Brain Cluster
Learning to read during childhood or adulthood transforms people's lives. It gives readers access to a wealth of information, for instance through novels, factual articles, and public notices. Reading also improves language knowledge and processing skills. This is because typical 'book language' is more sophisticated in terms of grammar and word choice than typical conversational speech. Literacy experience also enhances anticipation of upcoming language. Strikingly, experience with written language enhances prediction of spoken language.
Huettig and Pickering (University of Edinburgh) developed a theory of how literacy abilities enhance prediction beyond reading and transfer to spoken language processing. They distinguish between primary influences of reading, stemming from the exposure to orthographic representations, and secondary influences, both of which affect core processes and representations that are common to written and spoken language. Secondary influences arise from exposure to 'book language', which is syntactically more elaborate, has higher demands on verbal memory, and is lexically more extensive and sophisticated than conversational speech. Secondary influences can be attained not only through reading, but also through listening to 'book-like' auditory materials (e.g., audiobooks). In line with this view are findings showing that the amount of shared book reading with parents children enjoy at 24 months predicts their auditory comprehension of syntactically complex sentences at 30 months, and that for children and adults alike, the amount of book reading is related to vocabulary knowledge and verbal working memory. Reading also has primary influences on the prediction of speech. Reading provides excellent conditions, in particular a stable environment, for training the predictive system. The regularity of eye-movements – together with the extreme regularity and form-invariance of printed forms and the parallel processing of multiple letters in written text – allow for precise honing of prediction. Reading leads to increased awareness of the compositional nature of speech units, word boundaries, orthographic representations, and perhaps also more fine-grained phonological representations. All of this sharpens the lexical representations and supports prediction, as sharper representations can be retrieved and predicted more easily. Thus, reading trains core processes and representations involved in language prediction that are common to both reading and listening. Literacy therefore has primary and secondary influences on prediction, because people develop predictive skills through reading and these skills transfer from reading to language processing as a whole.

The Juggling Act: Speaking and Listening Cluster
In conversation, people perform a mental juggling act, often listening and preparing utterances at the same time. To examine how this juggling act works, the cluster studies how speaking and listening are coordinated in turn-taking and how this coordination is supported by linguistic and domain-general cognitive mechanisms, such as attention and memory.

The researchers developed a simple paradigm that serves as a distillation of key parts of conversation: Pairs of individuals produce names of pictures, either simultaneously or in alternation. Their speech and eye movements are recorded. As eye gaze is tightly linked to the focus of visual attention, tracking where speakers look shows when and for how long they attend to their own or the partner's pictures. Research using this paradigm has shown that speakers suffer interference in picture naming from knowing (but not hearing) that another person is talking, even without visual attention to the partner's objects. Whether the partner names the same object as the participant or a different one does not affect the amount of interference. This suggests that speakers only sparsely represent the partner's behaviour.
This idea was tested in further experiments, where participants heard a recorded partner name a picture that was either occluded or visible to the participant, and then had to name another picture precisely at the offset of the partner's turn. Participants had ample time to prepare the picture name and only had to focus on utterance timing. On average, they began to speak 227 ms after the offset of the partner's turn, which is close to the modal turn transition time in corpora of conversation. Applying machine learning techniques to the elicited speech disclosed that cues associated with the timing of the partner's speech were more useful for utterance timing than cues associated with the content of the partner's speech. A predictive statistical model of speech onset times containing only three cues (partner speech onset and offset, and visibility/occlusion of the partner picture) predicted turn taking to within the limits of human motor error (see Figure 1). In everyday conversations, utterances may be timed in a similar way: knowing when a conversation partner will (cease to) speak may be more useful for coordinated turn-taking than knowing what they will say.

The TEMPoral Organisation of Speech (TEMPOS) Cluster
Producing and comprehending speech are easy tasks for most people. Still, they take place under extreme time pressure: talking too fast, too slow or too late can seriously disrupt communication. The TEMPOS cluster studies how humans manage to successfully produce and perceive speech, with a particular interest in the temporal aspects of speech, such as speech rate, rhythm, and prosody.

People can adjust their speaking style to the situation: For instance, we may slow down to give listeners extra time to understand an important part of the message, or we may speed up to say more in the same period of time. But how do people control their speech rate? Existing theories of speech planning – from choosing a word to the actual movements of your tongue and lips – rarely take variability in speech rate into account. This is surprising given the obvious importance of speech rate for communicative success.
In his dissertation research, Rodd asked whether talking faster is simply a speeded version of talking slowly (i.e., a linear speed-up) or whether it involves a qualitatively different gait (e.g., running vs. walking). Perhaps we adopt a 'walk-speaking' gait to speak slowly, but switch to a 'run-speaking' gait to speak fast.

To investigate how people control their speech rate, Rodd developed a new computational model of speech production, called EPONA, and examined how it adapted to speaking at different rates. To test the model, speech production data from human participants were collected by asking speakers to pronounce strings of Dutch nouns at three different speech rates (slow, medium, and fast). The durations of the nouns were simulated with the model, such that the model's timing closely resembled that of the human speakers. These computer simulations clearly showed evidence for 'gaits' of speech planning. Model parameters for slow, medium, and fast speaking were not arranged in a linear fashion, but instead showed a triangular configuration, indicating qualitatively distinct 'gaits' (see Figure 2). Follow-up experimental research demonstrated that switching between these 'gaits' of speech production incurs a processing cost for speakers, in line with the simulation work. These findings are important for our understanding of the cognitive

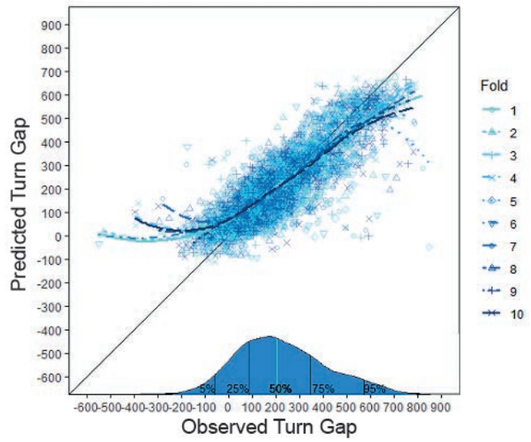


Figure 1. Observed versus predicted turn gaps for the best-fitting cross-validation model of turn gaps between single-word utterances. Model contains predictors of prior utterance onset, prior utterance offset, and prompt picture visibility. Adapted from Brehm & Meyer (2021).

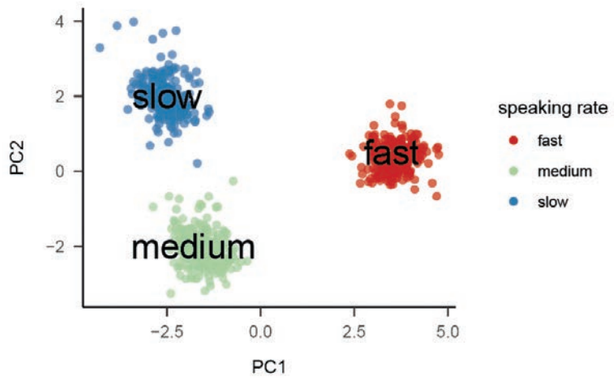


Figure 2. The Pareto optimal solutions identified for the fast (red), medium (green), and slow (blue) rate conditions, plotted for PC1 (x-axis) and PC2 (y-axis). Adapted from Figure 10 in Rodd et al. (2020).

architecture that supports speech planning at the interface of cognitive control and articulation.

Individual Differences in Language Skills (NWO Language in Interaction)
Most people acquire their native language effortlessly, yet there is great variability in how they use it. To understand this variability, the cluster conducts research into the principal dimensions of language skills and their relationships. Together with researchers in the Neurobiology of Language and the Language and Genetics departments, the cluster investigates how individual differences in language skills relate to the language users' neurobiological and genetic makeup.

To assess language skills, the cluster has developed a comprehensive test battery measuring nine key constructs reflecting language skills and skills assumed to be involved in linguistic processing: word production, word comprehension, sentence production, sentence comprehension, linguistic experience, non-verbal processing speed, working memory, inhibition, and non-verbal intelligence. Except for non-verbal intelligence, each psychological construct is assessed in multiple tests. The battery has been implemented as web experiments and can be run via the internet. It will be made available to other researchers to facilitate individual-differences research, for instance in multi-lab studies with large samples of participants.

In a first study, the test battery was administered to 112 adult speakers of Dutch. Using principal component analysis, the researchers first assessed how strongly each test loaded on the construct it was assumed to measure. The results confirmed that most tests loaded strongly on their respective construct. The researchers then extracted one score for each of the nine constructs for each participant and correlated these scores (Figure 3 Panel A). Finally, the correlation matrix was converted into a distance matrix and submitted

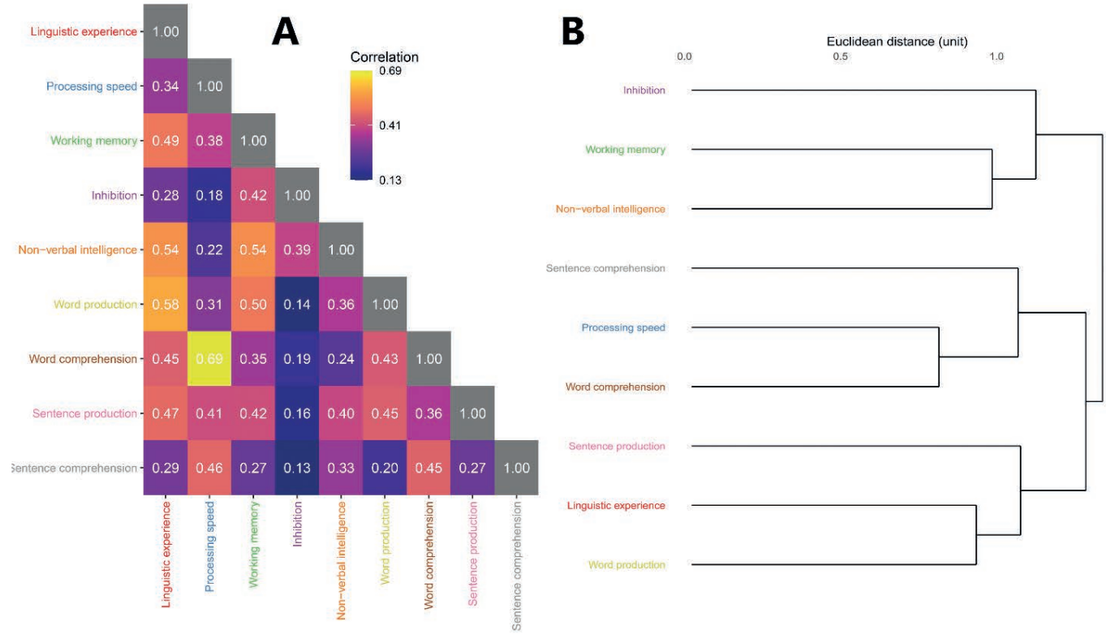


Figure 3. Panel A presents a correlation matrix based on the nine PCA-derived scores. The scale ranges from the weakest to the strongest correlation between any two scores in the set. Panel B shows the outcome of the hierarchical clustering analysis, based on the correlations in Panel A. Similar scores cluster together.

to a hierarchical clustering analysis (Figure 3 Panel B). The correlation and hierarchical clustering analyses revealed strong correlations between non-verbal processing speed and language comprehension, especially word comprehension, and between linguistic experience and language production, especially word production. While word-level and sentence-level skills were related, the hierarchical clustering analysis yielded separate clusters for comprehension and production, suggesting that production and comprehension skills are less related than one might have thought. In line with previous research, working memory, non-verbal intelligence, and to a lesser extent inhibition clustered together. These general cognitive skills correlated weakly to moderately with the word- and sentence-level constructs. These results constitute an important step towards a comprehensive quantitative characterisation of the principal dimensions of language skills.

Selected publications

Brehm, L., & Meyer, A. S. (2021). Planning when to say: Dissociating cue use in utterance initiation using cross-validation. *Journal of Experimental Psychology: General*. Advance online publication. doi:10.1037/xge0001012.

Huettig, F., & Pickering, M. J. (2019). Literacy advantages beyond reading: Prediction of spoken language. *Trends in Cognitive Sciences*, 23(6), 464-475.

Maslowski, M., Meyer, A. S., & Bosker, H. R. (2019). Listeners normalize speech for contextual speech rate even without an explicit recognition task. *The Journal of the Acoustical Society of America*, 146(1), 179-188. doi:10.1121/1.5116004.

Rodd, J., Bosker, H. R., Ernestus, M., Alday, P. M., Meyer, A. S., & Ten Bosch, L., (2020). Control of speaking rate is achieved by switching between qualitatively distinct cognitive 'gaits': Evidence from simulation. *Psychological Review*, 127(2), 281-304.

Hintz, F., Jongman, S. R., Dijkhuis, M., Van 't Hoff, V., McQueen, J. M., & Meyer, A. S. (2020). Shared lexical access processes in speaking and listening? An individual differences study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 46(6), 1048-1063.

MAX PLANCK RESEARCH GROUP
COMPARATIVE BIOACOUSTICS

Group Head Andrea Ravignani
Group members Diandra Düngen, Yannick Jadoul, Koen de Reus, Laura Verga

Goals of the Group
While each species has its own unique capacities, an aptitude for speech and music may be distinctive for humans. 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, sounds that 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: Not only are these abilities linked, they are both common in humans but rare in mammals. Researchers in the group take a comparative approach to study the 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 this way, they hope 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? Comparing rhythm and vocal learning across species
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), researchers in the group compare similar processes in as many species as possible. Their cross-species animal work maps different speech-related and music-related features to the mammalian tree of life, testing in what cases either common ancestry or similar environmental pressures lead to similar traits in different species. For example, they are currently testing whether human vocal and rhythmic flexibility have a joint evolutionary history. They study 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.

How do seal pups learn their vocalisations and develop rhythm?
In addition to large-scale, cross-species comparisons, the group focuses on two animal species: harbour seals and grey seals. Because of their capacity for rhythm and vocal learning, work with seals is key to testing hypotheses about our own linguistic and musical abilities.
This strand of work focuses on how baby seals learn to produce new sounds, and integrates controlled cognitive experiments with sound analyses. The researchers record new-born seal pups and track their vocal learning capacities across development. Non-invasive behavioural work probes seals' ability to learn new sounds and the mechanisms to accommodate to another 'speaker', as occurs in human turn-taking. Initial findings suggest that a seal pup's acoustic environment strongly shapes its sound production and rhythmic attitudes.

Comparative neurobiology and vocal tract anatomy in seals
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 members are investigating the similarities and differences between the neural and vocal tract anatomy of humans and seals. To do this, the researchers collect and analyse post-mortem samples from seals that died of natural causes. Vocal tract samples can tell us, for instance, which muscles and cartilages underpin flexible sound production. The researchers then use brain imaging techniques that show – in the seal brain – how developed and interconnected the areas are that, in humans, are key for speech and rhythm. This line of research tells us more about the evolutionary precursors of human speech production, both at the neural and the anatomical level.

Musicality: The biology and culture of human rhythmicity
Human culture and biology are strongly linked, and our sense of rhythm is no exception. In humans, the researchers test how cultural transmission produces rhythmic features, e.g. the alternation of weak and strong beats found across most musical cultures. The group tests each of those features in humans, using both behavioural and electrophysiological methods. This work aims at mapping which features of human rhythm cognition are modulated by cultural transmission.

Mathematical and computational modelling of rhythmic and interactive communication
Mathematical and computational models provide a unifying framework for all the research in the group. Models are developed for a number of purposes; for example, discovering how behavioural rhythmicity arises from neural oscillations, comparing alternative hypotheses before experiments are run, and predicting how synchrony and other group rhythms emerge.

Selected publications

Garcia, M., & Ravignani, A. (2020). Acoustic allometry and vocal learning in mammals. *Biology Letters*, 16, 20200081. doi:10.1098/rsbl.2020.0081.

Hoeksema, N., Verga, L., Mengede, J., van Roessel, C., Villanueva, S., Salazar-Casals, A., Rubio-Garcia, A., Curcic-Blake, B., Vernes, S.C., & Ravignani, A. (in press). *Neuroanatomy of the grey seal brain: bringing pinnipeds into the neurobiological study of vocal learning. Phil Trans Roy Soc B.* doi:10.1101/2020.12.19.423579

De Reus, K., Soma, M., Anichini, M., Gamba, M., de Heer Kloots, M., Lense, M., Bruno, J.H., Trainor, L. and Ravignani, A. (in press). Rhythm in dyadic interactions. *Phil Trans Roy Soc B.* doi:10.31234/osf.io/9yrkv

MAX PLANCK RESEARCH GROUP
LANGUAGE AND COMPUTATION IN NEURAL SYSTEMS

Group Head Andrea E. Martin
Group members Fan Bai, Cas Coopmans, Rong Ding, Olivia Guest, Greta Kaufeld, Karthikeya Kaushik, Ryan Law, Aline-Priscillia Messi, Sanne ten Oever, Sophie Slaats, Filiz Tezcan Semerci, Đang Thu Ngân, Yangyi Shao, Lorenzo Titone, Bob van Tiel, Hugo Weissbart, Junyuan Zhao, Ioanna Zioga

Goals of the Group
When we use language, our brains go beyond the physicality of the given stimulus, using both statistical information and rule or grammar-based knowledge to arrive at or express meaning. The research group strives to understand how the mind and brain achieve this, and to uncover the computations and representations at work during language processing. The group aims to do so by building theories that are constrained by known principles in linguistics, neuroscience, and computational cognitive science. Most importantly, it endeavors to do science in an inclusive and supportive manner, training and lifting up scientists from all over the world.

How do we break free from statistics?
When we tailor our language use to everyday situations, we quickly see that the expressive flexibility we display means that we could not have stored such spontaneously generated language in our brain. We build sentence meanings on the fly, with a small repertoire of stored information: grammar, words, speech sounds, and sign. Statistical regularities are stored in the brain, drawn from experience, and are highly sensitive to contextual factors – yet the human brain manifests a paradox when it comes to language: Despite the clear importance of stored statistical knowledge and distributional information in language use and acquisition, our everyday language behaviours exemplify the ability to break free from statistics and understand and say things we have never heard before. Although we might learn a word in a phrase or sentence context, or experience that word more often in a certain context, we are not limited to recognising or using the word only in that context, or only in related contexts, or only in the contexts that we have ever experienced the word in. While this capacity may seem pedestrian to us, it sets language apart from other perception-action systems, from artificial intelligence, and it makes language behaviour vexingly difficult to account for from a neuroscientist's and computationalist's point of view. The research group uses computational and neuroscientific approaches to tackle these fundamental questions, to derive a theory of language representation and processing that is faithful to what is known about linguistics, computational cognitive science, the cognitive neuroscience of language, and neurophysiological bounds on computation.

Tracking speech depends on our linguistic predictions (Sanne ten Oever)
Speech naturally contains temporal structure, as words orderly follow one after another. It has been proposed that brain oscillations track this temporal structure. However, it is unknown how relatively isochronous (regularly timed) brain oscillations can track non-isochronous speech signals. The hypothesis is that tracking is not only a function of the acoustic timing of words, but also dependent on the predictability of words given the sentence context. The group demonstrated that speech timing is influenced by linguistic constraints. Using a computational model, they showed how oscillations can be sensitive to this property. Tracking of temporal speech dynamics relies not only on the input acoustics, but also on the linguistic constraints flowing from knowledge of language. In other words, 'what' and 'when' are intrinsically linked in the brain.

Concepts and categories as basic units of representation (Olivia Guest and Aline-Priscillia Messi)
Language refers to concepts and categories in the world, and often relies on their structure to have meaning. Any theory of language interacts with how humans compute – derive, organise, and use – concepts and categories. To this end, this project models conceptual organisation to investigate how people represent and generate semantic meaning. Importantly, people do not only extract environmental regularities, but also organise concepts using more than one dimension. Formal and computational modelling mediates between theories and observations, and thus can allow researchers to explore how people represent and generate categories and imbue words and objects with semantic meaning. Thus, the researchers aim to formally and computationally capture: a) the well-known abilities of extant (e.g., machine learning) models in finding statistical regularities in their environment, which people are also skilled at uncovering, and b) the capacity currently only found in humans which allows us to produce novel semantic meaning, such as new categories or even new ontologies (meta-categories) and use them generatively in propositions.

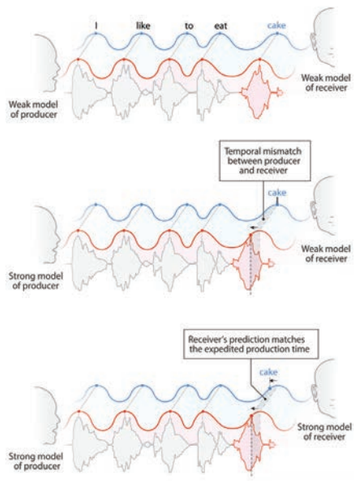


Figure 1. Tracking speech depends on our linguistic predictions (Sanne ten Oever). Illustrations created by Jan Karen Campbell

Meaning is not only a function of semantic and syntactic structure (Bob van Tiel)
It is often assumed that language is strongly compositional. According to strong compositionality, the meaning of a sentence is uniquely determined by the meaning of its words and their syntactic structure. Strong compositionality is naturally connected to the idea that the language faculty is modular, i.e., that our capacity for assigning meaning relies exclusively on lexical and syntactic knowledge. The researchers put the idea of strong compositionality to the test. They aim to show that meaning composition also critically relies on extralinguistic knowledge about the world and the surrounding context. For instance, knowing the meaning of the phrase 'fake' draws upon encyclopedic knowledge about the noun it modifies. Compare 'fake doctor' and 'fake name', where a fake doctor is presumably not a doctor but a fake name is undoubtedly a name. Hence, lexical and syntactic information serve as important cues for, but do not uniquely determine, meaning.

The brain tracks linguistic structures not present in the acoustics (Greta Kaufeld)
When we understand spoken language, our brain has to turn 'sounds' into 'meanings'. In essence, spoken language is an acoustic signal – but in order to understand it, the brain has to combine the stimulus-inherent, acoustic information with endogenous, internally generated, inferential knowledge and meaning. Much previous research has investigated the stimulus-driven response, yet relatively little is still known about how 'understanding' can arise from this. In a recent experiment, researchers from this research group have focused on the goal of language behaviour: conveying structure and meaning. Participants' brain responses were recorded while they listened to naturalistic stimuli that contrasted acoustic-prosodic and lexical-semantic information. The findings showed that during spoken language comprehension, oscillatory modulations reflect computations related to inferring structure and meaning from the acoustic signal. The brain doesn't just 'react to' the acoustics; it tracks the signal more closely when meaningful information can be inferred from it.

Hierarchical structure in language and action are not the same (Cas Coopmans and Karthikeya Kaushik)
The syntax of natural language is organised hierarchically, which means that words group into constituents of increasingly larger size. A similar organisation might underlie everyday actions, such as coffee-making, which can also be thought of as decomposable into hierarchically structured constituents. Based on this similarity, it has been argued that the structure of language and actions is similar. The researchers argue that understanding a sentence requires you to know how a sentence was constructed (e.g., in the ambiguous sentence 'the man saw the woman with binoculars' the structure is relevant to understand who holds the binoculars). In contrast, to understand the goal of an action, it is not needed to understand how the action structure was set up. This project derives a formal model that illustrates how the structure of actions is fundamentally different from what we find in language.

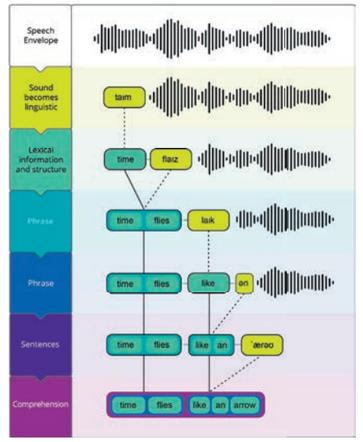


Figure 2. A schematic visualisation of all processes involved in transforming a purely acoustic signal to something we can comprehend.

Selected publications

Martin, A. E. (2020). A compositional neural architecture for language. *Journal of Cognitive Neuroscience,* 32(8), 1407-1427.

Kaufeld, G., Bosker, H. R., Ten Oever, S., Alday, P. M., Meyer, A. S., & Martin, A. E. (2020). Linguistic structure and meaning organize neural oscillations into a content-specific hierarchy. *Journal of Neuroscience,* 40(49), 9467-9475.

Guest, O., & Martin, A. E. (2021). How computational modeling can force theory building in psychological science. *Perspectives Psychological Science.* Advance online publication. doi:10.1177/1745691620970585.

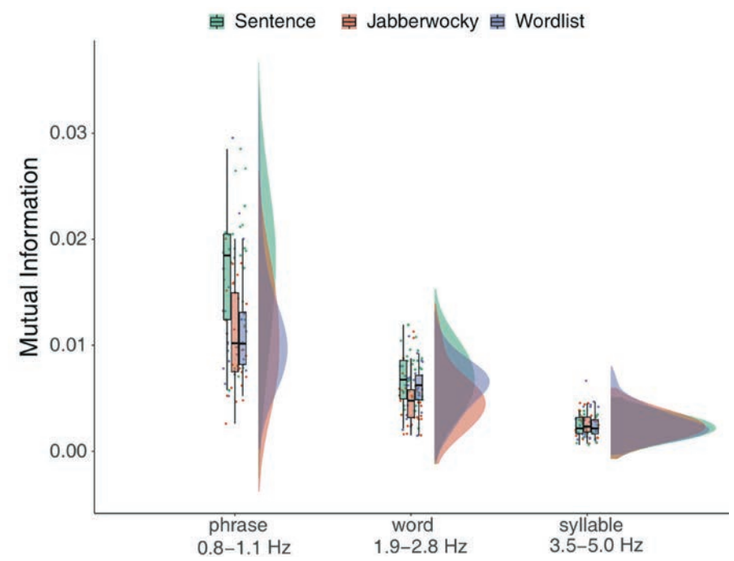


Figure 3. The brain is more sensitive to low frequency information present in sounds (0.8-1.1 Hz) when it has to track meaningful (sentences) versus meaningless (jabberwocky and wordlist) speech.

MAX PLANCK RESEARCH GROUP
NEUROGENETICS OF VOCAL COMMUNICATION

Group Head Sonja C. Vernes
Group members Ine Alvarez van Tussenbroek, Midas Anijs, Paolo Devanna, Katharina Foreman, Stephen Hörpel, Ella Lattenkamp, Ksenia Lavrichenko, Meike Mai, Janine Mengede, Jon-Ruben van Rhijn, Kai Wanke

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. The research group addresses this by studying speech and language-relevant traits in animal models – in particular in bat species. The group aims to understand the neurogenetic mechanisms underlying these behaviours including the neural circuitry, molecular pathways, and genomic factors underlying these behaviours. The researchers also investigate the causes of language disorders in clinical populations to gain insight into these disorders, but also 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 – the ability to learn new vocalisations – 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 & Wilkinson, 2020). 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.

Establishing the pale spear nosed bat as a model for vocal learning
The group has been working to establish the pale spear-nosed bat (*Phyllostomus discolor*) as a model species in which we can study these traits. To this end, PhD candidate Ella Lattenkamp investigated the vocal repertoire of these bats, and established an automated behavioural training set up to demonstrate their ability to learn vocalisations (Lattenkampet al., 2020) in collaboration with Prof. Lutz Wiegrebe (LMU, Munich, Germany). The group also sequenced and annotated the first reference quality genome of this species (Jebb et al., 2020), and performed brain imaging studies and expression profiling in the brains of this species. Together, this work has established the tools necessary to use the pale spear-nosed bat as a model system to uncover the genetic and neural mechanisms underlying vocal learning.

Ine Alvarez van Tussenbroek catching bats in the rainforests of Panama during fieldwork. Photo credit: Ine Alvarez van Tussenbroek

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

An explosion of bat genomes
As a founding director of the Bat1K genome project (www.bat1k.com), Dr Sonja Vernes has been leading an effort to sequence the genomes of all living bat species (approximately 1400 species). This project has attracted membership from over 250 scientists in around 50 countries. In 2020, the pilot phase of this project was published in Nature (Jebb et al., 2020), reporting the completion of the first six reference quality bat genomes and providing clues to the origins of bats' unique adaptive traits.

Harnessing bat diversity
In addition, PhD candidate Ine Alvarez van Tussenbroek undertook field work in collaboration with Mirjam Knörnschild and Constance Scharff (FU Berlin, Germany), to collect samples from a diverse range of bats in Panama, building a tissue bank of more than 12 bat species that will contribute to many studies in the future. Together with the genomic resources, these diverse samples are now facilitating cross species studies into the evolution of vocal learning in bats and mammals. Taken together, these studies have provided the groundwork for further investigations into the origins of mammalian vocal learning, and may ultimately give insight into how human spoken language evolved, and how language abilities are encoded in the genome and the brain.

Bats are featured on the cover of 'Nature'; together with the publication of the first 6 reference quality bat genomes. Dr. Sonja Vernes was a lead author of this work published as part of the Bat1K consortium, Volume 583, No. 7817, 23 July 2020.

Selected publications

Jebb, D., Huang, Z., Pippel, M., Hughes, G.M., Lavrichenko, K., Devanna, P., Winkler, S., Jermiin, L.S., Skirmuntt, E.C., Katzourakis, A., Burkitt-Gray, L., Ray, D.A., Sullivan, K.A.M., Roscito, J.G., Kirilenko, B.M., Dávalos, L.M., Corthals, A.P., Power, M.L., Jones, G., Ransome, R.D., Dechmann, D., Locatelli, A.G., Puechmaille, S.J., Fedrigo, O., Jarvis, E.D., Hiller, M., Vernes, S.C., Myers, E.W., & Teeling, E.C. (2020). Six new reference quality bat genomes illuminate the molecular basis and evolution of bat adaptations. *Nature*, 583, 578-584. doi:10.1038/s41586-020-2486-3.

Lattenkamp, E.Z., Vernes, S.C., & Wiegrebe, L. (2020). Vocal production learning in the pale spear-nosed bat, Phyllostomus discolor. *Biology Letters*, 16, 20190928. doi:10.1098/rsbl.2019.0928.

Vernes, S.C., & Wilkinson, G. (2020). Behaviour, biology, and evolution of vocal learning in bats. *Philosophical Transactions of the Royal Society B.*, 375, 20190061. doi:10.1098/rstb.2019.0061.

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 the production of a single word involves a number of processing steps from 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.

Tracking the spatiotemporal dynamics of meaning-to-speech mapping using MEG
To probe predictions from competing language production models positing cascaded/serial and parallel architectures the research group tracks the cortical dynamics that enables the mapping of conceptual meaning onto speech by combining the millisecond precision of magnetoencephalography (MEG) with cutting-edge multivariate pattern analyses (MVPA). By comparing psycholinguistic properties of depicted objects with the patterns of neural activity elicited when naming them, this approach sheds light on the activation time course of representations of semantic and phonological information in the language system. For instance, recent results from picture naming suggested earlier differentiation of brain responses to conceptual categories compared to a phonological variable (word length) affecting syllabification (see Figure 1).

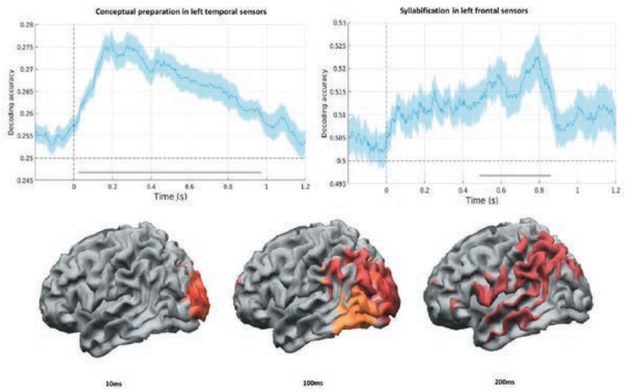


Figure 1. Top: Time course of picture-locked MEG activity specific to conceptual preparation (left panel) and syllabification (right panel) during object naming, respectively decoded early on (~50ms) from left temporal sensors, and at later time windows (~450ms) from left frontal sensors (horizontal grey bars indicate accuracy significance p<0.05, sign permutation test, participants n=34, cluster defining threshold p < 0.05). Bottom: Averaged stimulus-locked minimum-norm source activity associated with picture naming within the first 200 ms from picture onset. Activity starts from visual regions at 10 ms, progressing to occipitoparietal and inferior temporal cortex around 100ms, and spreading anteriorly over parietal, middle temporal and anterior frontal cortex at ~200ms.

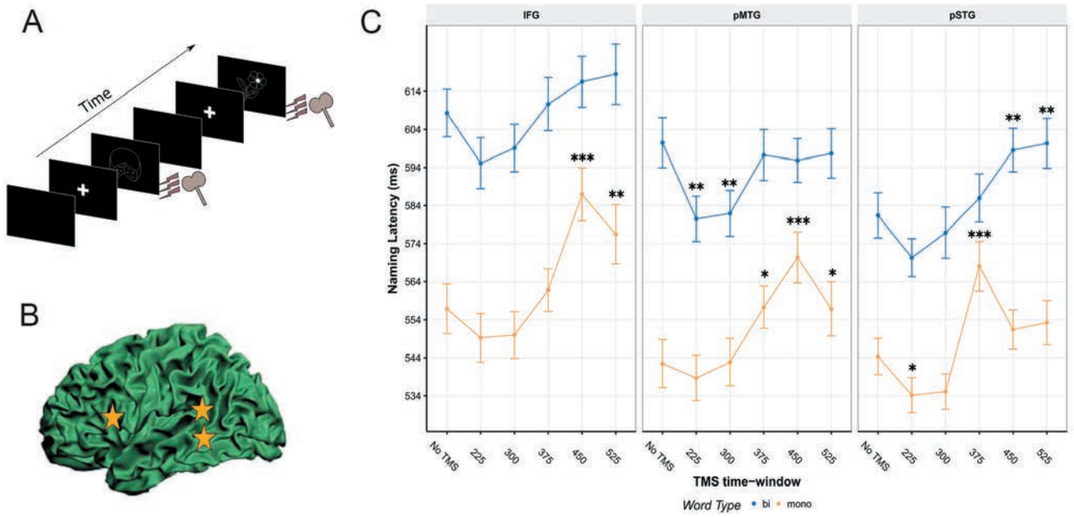
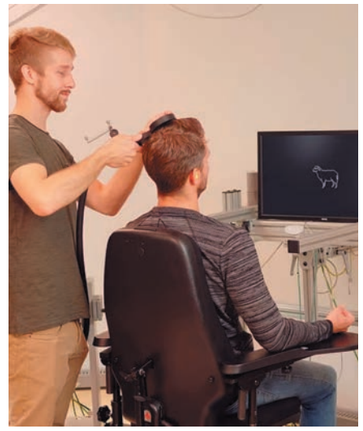


Figure 2. A) Experimental design. B) Brain template demonstrating the three stimulation sites. C) Mean naming latencies across TMS time-windows for each stimulated brain region (bi = bisyllabic words, mono = monosyllabic words).

Chronometric TMS in Language Production
Transcranial magnetic stimulation (TMS), a common non-invasive brain stimulation technique, allows for testing 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 temporal contribution. In one such study, the research group stimulated three different brain regions (left IFG, left pMTG, left pSTG) at different time-points during a picture-naming task. Participants would name pictures while they received a triple-pulse TMS stimulation in one of five time-windows post-stimulus onset (225, 300, 375, 450, 525). With this design, the researchers are able to provide temporal estimates of when these brain regions functionally contribute to processing during picture naming. It was found that all three brain regions seem to play an important role in later stages of word production (Figure 2). In the literature, these brain regions are commonly attributed to phonological stages and thus the late time-window effects fall broadly in line with the literature. Additional experiments of this type seek to investigate the efficacy of chronometric TMS across different brain regions and different production tasks.



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Carota, F., Nili, H., Pulvermüller, F., & Kriegeskorte, N. (2021). Distinct fronto-temporal substrates of distributional and taxonomic similarity among words: Evidence from RSA of BOLD signals. *NeuroImage*, 224, 117408. doi:10.1016/j.neuroimage.2020.117408.

Lemhöfer, K., Schriefers, H., & Indefrey, P. (2020). Syntactic processing in L2 depends on perceived reliability of the input: Evidence from P600 responses to correct input. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 46(10), 1948-1965. doi:10.1037/xlm0000895.

Redmann, A., FitzPatrick, I., & Indefrey, P. (2019). The time course of colour congruency effects in picture naming. *Acta Psychologica*, 196, 96-108. doi:10.1016/j.actpsy.2019.04.005.

AFFILIATED RESEARCH GROUP
MULTIMODAL LANGUAGE AND COGNITION

Group Head Asli Özyürek
Group members Mark Dingemanse, Linda Drijvers, Dilay Karadoller, Ezgi Mamus, Francie Manhardt, Wim Pouw, Marlou Rasenberg, Louise Schubotz, Kazuki Sekine, Anita Slonimska, Beyza Sümer, James Trujillo

Goals of the Group
The general mission of the research group is to understand the architecture of human language as a flexible and adaptive system, that is, how it is shaped by and interacts with human biological, neural, and cognitive constraints as well as the requirements of culturally bound communicative contexts. A multimodal approach is adopted, to investigate how language can be expressed flexibly and adaptively in situated and face-to-face contexts through visual (e.g., gestures used by hearing communities and (emerging) sign languages created by Deaf communities) and auditory (speech) modalities. This approach provides a novel window into our language capacity, beyond what can be derived by looking at spoken or written forms of language alone. Visual articulators – unlike speech – have unique affordances for visible iconic, indexical and simultaneous representations. The group asks how a multimodal approach to language enhances our understanding in three domains of language: a) its structure and use in interactive and discursive contexts, b) its neural and cognitive processing, and c) its transmission (learning, acquisition and evolution). The researchers use multimodal corpora collected from different languages, (bimodal) bilinguals, and special populations (e.g., blind people, adults with autism, deaf individuals with no access to spoken language), as well as multiple experimental and neuroimaging methods. Finally, the research group develops new techniques (e.g. using Kinect and OpenPose) to analyse visual communicative behaviours automatically, to detect and understand kinematic regularities that contribute to patterns at different levels of language.

Gesture contributes to speech comprehension in noise more than lips in native and non-native listeners
Comprehending speech becomes challenging in the noisy contexts that arise in most contextual uses of language. Much previous research has focused on whether listeners can recruit information from visual articulators such as lips (i.e., visible speech) to enhance comprehension of degraded speech. As a novel contribution, the group investigated the role of iconic gestures and asked whether they contribute to speech comprehension in noise beyond using cues from the lips in native and non-native listeners. The brain processes involved in this process were also investigated, using MEG. Native and proficient (German) non-native speakers of Dutch were presented with videos in which an actress uttered a degraded or clear verb, accompanied by a gesture or not. The participants completed a cued-recall task after every video. Both groups benefited more from gestures that provided a semantic cue than from lips. However, this effect was stronger in native than non-native listeners. An alpha/beta power suppression revealed engagement of the extended language network, motor and visual regions during gestural enhancement of degraded speech comprehension, supporting general unification and lexical access processes involved in the disambiguation of degraded speech. However, non-native listeners showed less engagement of the mouth area of the primary somatosensory cortex, left insula (beta), LIFG and ATL (alpha) than native listeners, which suggests that non-native listeners might be hindered in processing the degradedphonological cues and coupling them to the semantic information conveyed by the gesture – unlike native listeners. Thus, seeing gestures disambiguates degraded speech more efficiently than seeing lips, recruiting language areas of the brain modulated by experience with language. This finding underscores the benefits of using gestures in language/speech therapies related to hearing impairment.

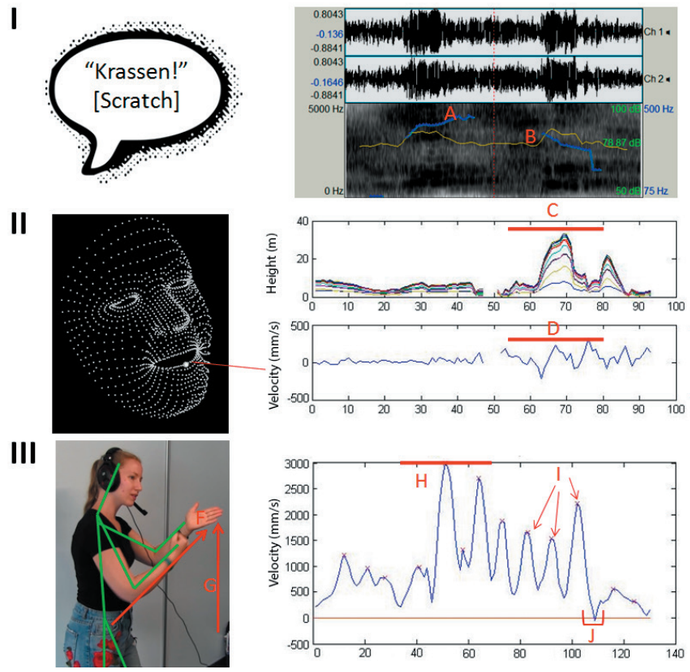


Figure 1. Graphical overview of automatic extraction of information from multiple channels of communication from face, hands and speech in synchrony (Trujillo, Holler, Ozyurek Drijvers, preprint)

Iconicity and simultaneity are recruited for efficient communication in sign language
A fundamental assumption about language is that, regardless of language modality, it faces the linearisation problem, i.e., an event that occurs simultaneously in the world has to be split in language to be organised on a temporal scale. However, the visual modality of signed languages allows its users not only to express meaning in a linear manner, but also to use iconicity and multiple articulators together to encode information simultaneously. In an international collaboration, researchers investigated whether the modality-specific use of iconic and simultaneous structures contributes to efficient communication. In speech, which allows only linear structures, this is achieved by reducing dependency length distances. Deaf adult users of Italian Sign Language (LIS) participated in a director-matcher game in which they described images of events that varied in the amount of information they contained. As the information that had to be encoded increased, signers also increased their use of iconic signs and multiple articulators (i.e., simultaneity) in their production, to achieve efficient communication. Thus sign languages can recruit modality-specific ways to encode information efficiently – questioning the necessity of reducing dependency of length distance in this process.

Evolving language in dialogue: The primacy of multimodal alignment in converging on shared symbols for novel referents
Participants in a conversation are known to align their utterances at multiple levels of language to achieve mutual understanding. It is not clear however whether and how this alignment in speech is coordinated with alignment in gestures with semantic content, or how this is deployed in initial evolving stages of new linguistic conventions, that is in co-creation of new labels for new referents. To investigate this, researchers systematically tracked the emergence of lexical and gestural alignment in a referential communication task with novel objects. Quantitative and qualitative analyses revealed that while people frequently used a combination of lexical and gestural alignment flexibly to fit communicative pressures, multimodal alignment was preferred more frequently and emerged earlier compared to unimodal alignment. Using multimodal expressions might play a crucial role in the early stages of emerging conventions across participants, through facilitating alignment at multiple levels.

Multimodal recording of communicative interaction in NOISE in Lowlands music festival

Selected publications

Drijvers, L., Van der Plas, M., Özyürek, A., & Jensen, O. (2019). Native and non-native listeners show similar yet distinct oscillatory dynamics when using gestures to access speech in noise. *NeuroImage*, 194, 55-67.

Rasenberg, M., Özyürek, A., & Dingemanse, M. (2020). Alignment in multimodal interaction: An integrative framework. *Cognitive Science*, 44(11), e12911. doi:10.1111/cogs.12911.

Slonimska, A., Özyürek, A., & Capirci, O. (2020). The role of iconicity and simultaneity for efficient communication: The case of Italian Sign Language (LIS). *Cognition*, 200, 104246. doi:10.1016/j.cognition.2020.104246.

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 Communication in Social Interaction research group investigates how social agents communicate meaning. The group's focus is on face-to-face interaction where human language is a multimodal phenomenon: at any given movement, speech is accompanied by visual bodily signals conveyed by a multitude of articulators, including the torso, hands, head, eyes, eyebrows, nose and mouth.
A core question is how the visual and verbal information streams work together in creating and transmitting meaning. The group's work focuses on the compositional architecture and the comprehension of multimodal utterances in interaction, as well as on how these are adapted to the temporal and social affordances that emerge from the communication process, such as conversational turn-taking, recipient characteristics and (problems in) mutual understanding. The group employs experiments combined with language corpora, using approaches from the disciplines of conversation analysis, psycholinguistics, and neuroscience. In terms of tools, the group draws upon mobile eye-tracking, motion capture, and Virtual Reality in addition to more traditional methods.

A new framework for studying human language processing

Much of the group's current work focuses on developing a model that captures situated human language processing (Figure 1). Its foundation is the fact that the natural habitat of human language is in face-to-face interaction, the very environment in which language has evolved, is acquired, and used most also in adulthood. Critically, in this sort of environment, language goes beyond the words we speak. The many visual signals we convey while speaking – such as manual depictions of objects and actions, pointing, eyebrow raises and frowns, head tilts, shakes and nods – are bound to profoundly influence message processing. However, current comprehension theories do not take them into account. Much of our daily communication is based on conversation, and we seem to be highly practised in it. So much so that alternating speaking turns follow one another in split seconds. Extant theories have argued that this is rather extraordinary in the light of our limited cognitive capacities, even when we consider speech alone. However, in face-to-face interaction, multiple layers of visual signals, all offset in time, are added to the mix. These need to be integrated with the layers of vocal signals and bound into coherent, meaningful wholes, a process one may expect would be cognitively costly.
Intriguingly, the presence of these visual bodily signals appears to speed up processing, as results from the group's corpus analyses have shown. The situated language processing framework proposes that prediction may be one mechanism (next to others) accountable for this effect. It is hypothesised that, at least in part, this is due to the fact that visual bodily signals often precede corresponding elements in the speech stream, or may even begin prior to any phonation. The temporal architecture of multimodal utterances, combined with statistical regularities in multimodal communicative patterns, are claimed to form the basis of this facilitatory effect. Part of the group's current research activity focuses on testing this claim.

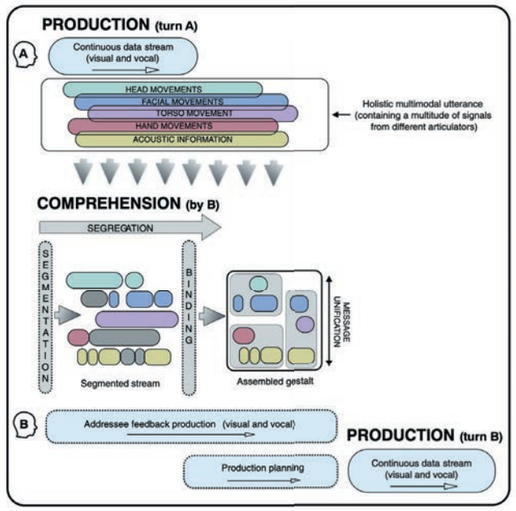


Figure 1. Multimodal Language Processing in Interactional Situ. Reproduced from Holler & Levinson (2019) with permission from the publisher.

Shadowing multimodal language

Perceiving language multimodally is the default mode when we engage in face-to-face interaction. Yet, very little is known about how we process language in this context. Does perceiving the plethora of visual movements and signals produced by a speaker help or hinder processing of the spoken signal? This was tested with an experimental study using the classical shadowing paradigm. Participants listened to extracts from casual conversation corpora (extended stretches of speech produced by just one speaker) in three conditions: (a) with the speaker's head, face, hands, arms and torso visible (AV), (b) identical to (a) but with the lips blurred (AB), and (c) audio-only (AO). Their task was to shadow what was said as precisely and fast as possible. Analyses showed that the presence of visual signals helped, with most errors being made when speakers were only audible, fewer when all visual signals were present minus the lips, and fewest when all visual signals were present. When analysing the speed with which words were uttered before they were heard (thus tapping into prediction), we again found a clear advantage of visual signals being present (especially for content words, see Figure 2). This suggests that visual bodily signals help when processing continuous conversational language, and hints that predictive mechanisms may indeed play a role.

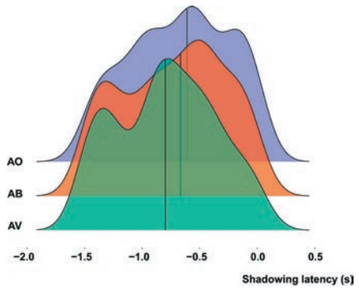


Figure 2. Shadowing latencies for content words. AO: audio-only, AB: lips blurred, AV: all visual signals visible.

The multimodal architecture of conversational utterances

In on-going work, the group currently investigates how utterances in conversation are composed in terms of the verbal and visual elements that constitute them, including their temporal interplay. This involves analyses of a large conversation corpus for speakers' use of manual co-speech gesture (those that depict actions, objects and their attributes, as well as those that convey pragmatic meaning and regulate social interaction) as well as their torso movements, head gestures and facial signaling (Figure 3).

The first results provide evidence that these visual signals are not only manifold in conversation, but also that they occur early on during speaking turns, thus giving them 'predictive potential'. The next steps involve analyses of specific meanings speakers convey, including statistical regularities in form-meaning mappings for multimodal signal combinations. Experiments using the corpus data as a basis – by feeding it into an avatar environment where isolated variables can be manipulated to test their role in comprehension – are currently underway (Figure 4).

Figure 3. The group currently investigates how utterances in conversation are composed in terms of the verbal and visual elements that constitute them.

Tool development

Some of the group's activity focuses on toolkit development to facilitate the annotation of gestures (Figure 5). In its current version, the tool identifies movements in spontaneous conversation with high fidelity. Based on this, manual coders can move more speedily through video data to select gestural movements from the tool's movement annotations, making the gesture annotation process about twice as fast. The next steps will involve developing the algorithm further to allow it to segment stretches of movement, with the ultimate goal being the autonomous detection of gestural movements specifically.

Figure 4. Experiments using the corpus data as a basis – by feeding it into an avatar environment where isolated variables can be manipulated to test their role in comprehension – are currently underway.

Selected publications

Holler, J., & Levinson, S. C. (2019). Multimodal language processing in human communication. *Trends in Cognitive Sciences*, 23(8), 639-652. doi:10.1016/j.tics.2019.05.006.

Ripperda, J., Drijvers, L., & Holler, J. (2020). Speeding up the detection of non-iconic and iconic gestures (SPUDNIG): A toolkit for the automatic detection of hand movements and gestures in video data. *Behavior Research Methods*, 52(4), 1783-1794. doi:10.3758/s13428-020-01350-2.

Schubotz, L., Ozyurek, A., & Holler, J. (2019). Age-related differences in multimodal recipient design: Younger, but not older adults, adapt speech and co-speech gestures to common ground. *Language, Cognition and Neuroscience*, 34(2), 254-271. doi:10.1080/23273798.2018.1527377.

Mute Stop Video 153 Participants Chat Record Reactions

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, 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 spoken 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
After several years of development, the archive was migrated to a new technical infrastructure in February 2018. A first version of a new deposit tool that forms an integral part of the new system was released in the spring of 2018 and was made available more widely in October 2018. The new infrastructure has a more user-friendly and up-to-date front-end, is easier and less costly to maintain. Since 2018, the team have also added a number of new features including:

- A new online viewer for annotated media files that enables users to view annotations and video material together, straight from the browser
- A new image gallery for TIFF and JPEG images that includes a viewer for faster zooming and navigating in high-resolution images
- New colour coded access labels as well as an access level filter
- A division of the archive into two access portals, one for The Language Archive and one for the MPI's own research data (see https://archive.mpi.nl/)
- New manuals, online screencasts and new user support forums

The TLA team also maintain and develop the popular annotation tool ELAN. Two major releases in 2020 implemented new features such as improved interoperability through a new exchange format, support for online audio/video files, an improvement to the interlinearisation mode, and improvements to the documentation. Modularisation of the codebase is ongoing. ELAN continues to be in demand, with over 8000 downloads of the new ELAN version (6.0) and over 25,000 current users.

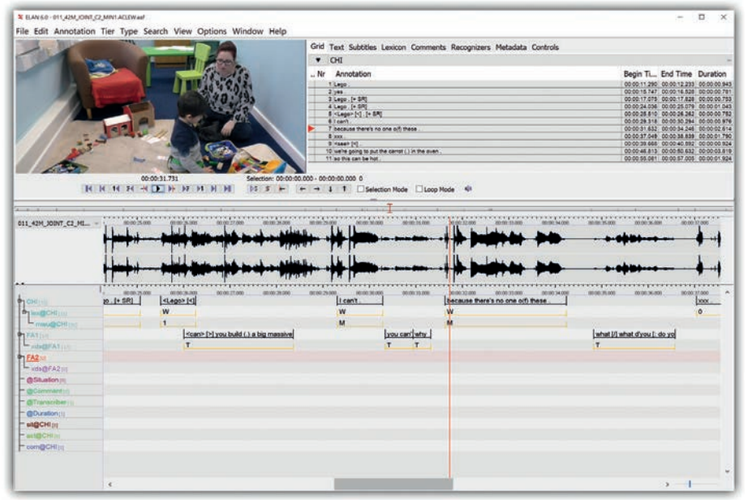
Working together
Since January 2019, TLA has been a member of the CLARIAH-PLUS project, funded by the Dutch Research Council (NWO). CLARIAH-PLUS's joint goal is to further develop and utilise the CLARIAH research infrastructure (Common Lab Research Infrastructure for the Arts and Humanities). TLA contributes to two Work Packages (WPs). As part of WP3 (Linguistics) the team are improving metadata of existing TLA collections, building better tools for extracting statistics from collections, and updating agreements and licenses. Within WP5 (Media Studies),

A painted warrior from Tauwema. This photo was taken on the Trobriand Islands in 1997 by Gunter Senft.

they have started working on interoperability with the MediaSuite (Beeld en Geluid) by means of an export to the WebAnnotation format and initial support for online content (audio, video and EAF files).

In 2019, TLA partnered with the Centre for Language and Speech Technology (CLST) at Radboud University to create the CLARIN Knowledge Centre for Atypical Communication Expertise (ACE). The mission of ACE is to support researchers working with languages that pose particular challenges for analysis. This includes language use by second language learners, people with language disorders or those suffering from learning disabilities, and languages that pose unique challenges for analysis, such as sign languages and languages spoken in a multilingual context. This research often involves working with multiple modalities (text, speech, sign, gesture) and encompasses different developmental stages. Within ACE, TLA provides advice, as well as a storage facility, to enable researchers to host their data and corpora and make them accessible in a FAIR manner (Findable, Accessible, Interoperable, Reusable). The target audience for ACE includes linguists, psychologists, neuroscientists, computer scientists, speech and language therapists and education specialists.
In 2020, TLA partnered with a team at the Laboratoire de Sciences Cognitives et de Psycholinguistique in Paris, and colleagues at MPI's Language Development Department, to start developing a new speech annotation management system called Seshat.

Seshat will substantially improve the speed, accuracy and security of the transcription, coding and analysis of big datasets of real-life spoken language. The Seshat system will enable 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. Seshat is designed for researchers working on real-life language use, including endangered languages, language development across cultures, and language in clinical populations.



A screenshot of the ELAN annotation tool being used for language development research.

Collection updates
A number of new collections were recently added to the archive. These include the 'Teiwa embedding corpus', deposited by František Kratochvíl, containing unique recordings, annotations and other materials about the Teiwa language spoken on the Pantar island in eastern Indonesia. Another notable new collection is the 'Polish cued speech corpus of hearing-impaired children', collected by Anita Lorenc. The archiving of this collection was done in collaboration with the ACE Knowledge Centre and the TalkBank project at Carnegie Mellon University. Non-sensitive parts of the collection are now available via TalkBank, while the sensitive audio recordings are only archived at TLA. The team also updated incomplete or outdated collections. They added several types of data including audio and video files, annotations, photos, and field notes to the collections of the MPI's former Language & Cognition department. Notably, they made improvements to Stephen C. Levinson's collection of Yélî Dnye (Rossel Island, Papua New Guinea), a collection that dates back to 1995, and added new data from the latest Rossel Island fieldtrip, including photos, ethnographic recordings, and experiments done in collaboration with Marisa Casillas.

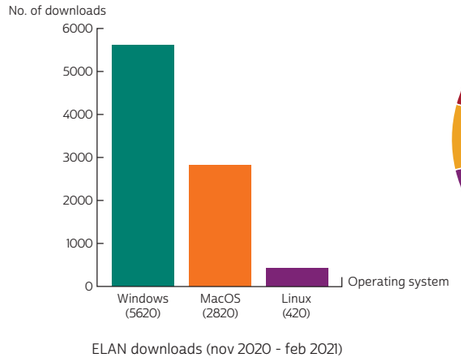


Figure 1a. Number of ELAN downloads.

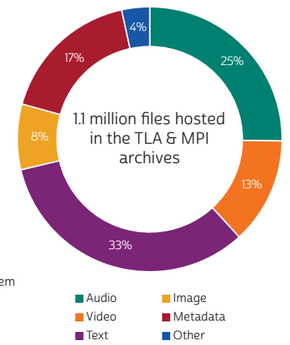


Figure 1b. Number and types of file in The Language Archive.

Selected publications

Van den Heuvel, H., Oostdijk, N., Rowland, C. F., & Trilsbeek, P. (2020). The CLARIN Knowledge Centre for Atypical Communication Expertise. In N. Calzolari, F. Béchet, P. et al. (Eds.), *Proceedings of the 12th Language Resources and Evaluation Conference* (LREC 2020) (pp. 3312-3316). Marseille, France: European Language Resources Association.

Wittenburg, P., Lautenschlager, M., Thiemann, H., Baldauf, C., & Trilsbeek, P. (2020). FAIR Practices in Europe. *Data Intelligence*, 2(1-2), 257-263. doi:10.1162/dint_a_00048.

LIBRARY

Head of Library Karin Kastens
Members Meggie Uijen, Rob Matser

Goals of the Library
The Library Team supports our researchers in 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.

Hybrid Library
The library's collection closely follows the research focus of the Institute. Due to Covid-19 measures, remote access became even more important. Therefore, an eZproxy server is introduced to enhance remote access and more e-books are acquired next to the print collection. Max Planck-wide licences, together with locally licensed subscriptions, provide access to about 15,000 academic e-journals. The library services continued seamlessly via email and Zoom.

Jerome Bruner Library
In 2016, 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 library team finished processing the books including scans of all dedications and notes. The Bruner Library was officially opened on January 8th, 2020. In collaboration with the Rietveld Academy Amsterdam, we published the booklet 'The Jerome Bruner Library: From New York to Nijmegen', which contains talks from the opening event and images of this unique 'Gelehrtenbibliothek'. The library can also be visited by people from outside the institute upon request, and is accessible online via our library catalogue.

Publication Repository and Open Access Support
The librarians archive the complete publication output of the MPI researchers in the institutional repository MPG.PuRe (http://pure.mpg.de). The publication data are uploaded onto the Institute's website. The layout and functionality of the new website's publication lists have been set up in close collaboration with the library team. Information about Open Access publishing is an important part of the library's services. In 2019-2020 almost 50 percent of the Institute's publications were published Open Access (see Figure 1).

Figure 1. Percentage of Open Access (OA) publications from January 2019 until December 2020

COMMUNICATIONS DEPARTMENT

Senior communications advisor / Press officer Marjolein Scherphuis

Goals of the Communications Department
The communications department advises the directors and the Institute's COO. They also facilitate media contacts and provide media coaching for the researchers at the Institute. Besides monitoring the excellent reputation of the Institute, building a solid media network and maintaining relevant contacts with the Max Planck Society (MPS) and surrounding stakeholders - such as Radboud University and the Donders Institute - are high on the agenda. In terms of the overall strategy, major results stemming from research conducted at the MPI always take priority.

Communication Strategy
In 2019, the communications department developed a communication strategy to attain the institute's priorities for internal and external communication. This now enables the Institute to act proactively on achieving essential goals through communication. The focal points highlighted in the strategy include internal communication, the communication of fundamental insights, local, regional and national renown, and participant recruitment.
The transformation of the strategy into operational actions provides the institute with new means of communication and new methods. As of 2020 the Institute communicates to societal audiences via the science blog MPI TalkLing. The recruitment of participants is now done through small targeted campaigns for specific research projects. A pilot project was launched for facilitating researchers in their science communication through small films and podcasts. A plan was also drawn up to develop and distribute internal and differentiated external newsletters from 2021 onwards. In order to be able to carry out these operational actions, it has been decided to allocate additional capacity to the department from 2021 onwards.

Public outreach
By writing engaging press releases, and by coordinating attractive images, the communication department brings the work of the researchers to the attention of media all over the world. In addition to using Eurekalert for worldwide exposure, the Dutch media network has been expanded. From 2021 onwards, these contacts will be more closely involved with the Institute through online network activities. In 2019/2020 the research of the Max Planck Institute for Psycholinguistics was internationally featured in The New York Times, BBC News, Nature, The Guardian, 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 Gelderlander, De Brug, De Volkskrant, Trouw and NRC, and MPI researchers were interviewed for radio and television in programmes such as De Taalstaat, NOS Jeugdjournaal, Omroep MAX and RTL4.

Postdoctoral researcher Else Eising of the Department of Language & Genetics explains her search for participants for her research into the genetics of stuttering in the NOS Jeugdjournaal.

40 Year Anniversary
In 2020, the Institute celebrated its 40th anniversary. This was highlighted through several international webinars with relevant topics. In order to draw festive attention to these anniversary activities, a variant of the existing MPI logo was developed.

40th ANNIVERSARY FOUNDED IN 1980 | MAX PLANCK INSTITUTE FOR PSYCHOLINGUISTICS

Covid-19 crisis communication
When the pandemic was declared in March 2020, the communications department sent out daily updates to provide all staff with clear information about the impact of the pandemic on the Institute. The measures taken were explained and channels were referred to where the international population of the Institute could go for further guidance and mental health care.

MPI TalkLing
MAX PLANCK INSTITUTE FOR PSYCHOLINGUISTICS

Science Blog MPI TalkLing
The trilingual science blog MPI TalkLing went live in November 2020. The articles on psycholinguistics are written by PhD candidates and edited and translated by colleagues within the Institute. Led by editor-in-chief and PhD candidate Merel Wolf, the blog website had 566 unique visitors after going live and now has a weekly regular audience. The communication department provides an annual blog writing training for the writers and editors. The aim of the blog website is to make the MPI for Psycholinguistics more well-known in the Netherlands and to address young people who may be considering a career in language sciences. Visit the blog at mpi-talkling.mpi.nl.

Social Media
The Institute interacts with various target groups via Facebook, Twitter and Linkedin. The Institute's Twitter account @MPI_NL now has more than 8,000 followers.

INTERNATIONAL MAX PLANCK RESEARCH SCHOOL (IMPRS) FOR LANGUAGE SCIENCES

Spokesperson Caroline Rowland
Coordinator Kevin Lam

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 in an interdisciplinary approach, 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 successfully secured renewed funding for its next six-year term (2021-2027). Among other things, the revised curriculum and organisation will better equip our doctoral students with the skills and support needed to complete their projects, whilst enhancing their postdoctoral career profiles.

Despite the restrictions on in-person gatherings, the second edition of the Interdisciplinary Approaches to the Language Sciences 2020 conference successfully reached out to an even wider audience around the world, thanks to its fully virtual format.

The second edition of the two-day alumni and career event connected invited alumni working in academia and beyond with the current student body to speak about their experiences and impart actionable advice.

The new MPI TalkLing blog was launched, an initiative of PhD candidate Merel Wolf, who saw the potential in the IMPRS course Current Issues in the Language Sciences for science communication. In the near future, the student body will regularly produce articles on a range of language science topics for a broader readership.

Student body composition
As of December 2020, there were 57 active members, forming cohorts 2017 through 2020, with women making up 60% of the student body. The student body is highly international; over 50% have nationalities other than Dutch or German. There is a roughly equal distribution between projects funded by the MPI (58%) and its two partner institutes at Radboud University (42%).

Student body achievements
By the end of 2020, 99 IMPRS members had successfully defended their dissertations.
Notable individual achievements include:

- Sara Busquets Estruch, *Otto Hahn Medal*
- Luis Miguel Rojas-Berscia, *Anéla/AVT Dissertation Award*
- Joe Rodd, *NWO Rubicon grant*
- Naomi Nota, *Klokhuis Science Award*

Selection of research projects

- Shanthi Kumarage (MPI) *Structural Priming in Language Development*
- Jieying He (MPI) *Speaking in noise: how spoken production is influenced by irrelevant background speech*
- Figen Karaca (CLS) *Predictive Processing Skills of Bilingual Speakers*
- Hanno Mueller (CLS) *Morphology in spoken word recognition models*
- Natascha Roos (DI) *Unravelling how prefrontal cortex recruitment supports language functioning*
- Giulio Severijnen (DI) *Understanding prosodic talker variability in speech perception*

TECHNICAL GROUP

Head of Technical Group
Reiner Dirksmeyer
Group members Ibrahim Abdullah, Gert-Jan de Bresser, Ludy Cilissen, Jeroen Derks, Maurice van Deutekom, Alex Dukers, Ronald Fischer, Maarten van den Heuvel, Peter Nijland, Albert Russel, Olha Shkaravska, 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, including: 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). Furthermore, the group has extensive knowledge and experience in the field of managing and archiving scientific data.

Computer systems
In 2019 the parallel file system (BeeGFS) of our HPC cluster was extended by two nodes and 45 TByte. The parallel file system now consists of eight storage nodes and 152 TB of disk space. In 2019 and 2020 our VMware cluster was updated by four new servers (replacements for old servers). Our VMware cluster is hosting about 126 virtual servers.

General IT support
In conjunction with the Covid-19 lock-down, additional resources have been made available to provide the best possible support for working from home. Conference rooms were converted or expanded for the operation of hybrid meetings.

Experimental labs
The institute has built and maintains eight reaction time labs, six eye movement labs, various portable eye-tracker setups (glasses and remote eye-tracker), one HMD based Virtual-Reality lab, two EEG labs (Faraday-caged), one gesture lab, one baby lab and two interaction labs. In 2020, a new Electronic Laboratory Notebook (ELN) system was implemented. This new system (LabFolder) is hosted on the institute's own server. Data from the old system was migrated to the new, web-based system. In 2020, the virtual reality software Unity was adopted to support our three-sided cave VR-lab. During the coronavirus measures, 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. With Frinex, about 61 online experiments were carried out in 2019 and about 162 were carried out in 2020.

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

Molecular Biology Labs
Housed in the extension of the institute are state-of-the-art wet lab facilities that are 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 largely 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.

EVENTS AND ACTIVITIES

2019

Workshop
Neuroanatomical foundations of cognitive computation
Organised by Peter Hagoort, Ashley Lewis, Daniel Sharoh and Joanna Sierpowska (Donders Institute). February 26.

Symposium
200 jaar F.C. Donders (200 years F.C. Donders)
Organised by Peter Hagoort.
Location: Royal Netherlands Academy of Sciences, Amsterdam. March 4.

Symposium
Language in Interaction symposium: Crossing the boundaries
Organised by Lotte Eijk, João Ferreira, Guilherme Freches and Marlou Rasenberg. April 9.

Workshop
Bits & Brains: Brain-inspired materials and architectures for low energy information technology
Organised by Peter Hagoort and Theo Rasing (Radboud University).
Location: Royal Netherlands Academy of Sciences, Amsterdam. April 17-18.

Symposium
Berichten uit de bovenkamer (Messages from the brain)
Organised by Peter Hagoort.
Location: Royal Netherlands Academy of Sciences, Amsterdam. May 13.

Colloquium & Masterclass
Deciphering the biology of human musicality through state-of-the-art genomics
Organised by Simon Fisher, Henkjan Honing, Reyna Gordon, Bruno Gingras.
Location: Royal Netherlands Academy of Sciences, Amsterdam. June 19-21.

Course
Practical mixed effect regression modelling for psychology and language science
(Radboud University Summer School)
Organised by Laurel Brehm and Phillippe Alday. August 5-9.

Course
Trends and topics in neurolinguistics
(Radboud University Summer School)
Organised by Francesca Carota and Karin Heidlmayr. August 5-9.

Conference
Bridging gaps: From genes to cognition
(2019 Cognomics Conference)
Organised by Simon Fisher, Barbara Franke and Sophie Akkermans. September 4-5.

Workshop
Unifying vocal learning.
Organised by Sonja Vernes, W. Tecumseh Fitch (Vienna University), Vincent Janik (University of St Andrews), Constance Scharff (Free University Berlin).
Location: Lorentz Center@Oort, Leiden. September 9-13.

Workshop
Rate and rhythm in speech recognition
Organised by the TEMPOS research group, headed by Hans Rutger Bosker.

EVENTS AND ACTIVITIES

2020

Symposium
Opening of the Jerome Bruner Library
January 8.

Public event
Kletskoppen Kindertaal Festival ('Chatterboxes' Child Language Festival)
Organised by Sharon Unsworth and Caroline Rowland.
Location: Central Library (Mariënburg) Nijmegen. February 29.

Conference
IMPRS for Language Sciences Conference
Organised by Federica Bartolozzi, Nienke Hoeksema, Paolo Devanna, Julia Egger, Merel Wolf, Sophie Arana, Adrian Jodzio, Chen Shen, Joery den Hoed, Katja Stärk, Melis Çetinçelik. (Online). June 3-5.

Workshop
Masterclass Profielwerkstuk (school research project)
Organised by Nienke Rulkens-Dijkstra and Cielke Hendriks. (Online). October 8.

Workshop
Many Paths to Language Workshop (MPaL)
Organised by Marisa Casillas, Caroline Rowland and Rana Abu-Zhaya. (Online). October 23-25.

Workshop
The future of linguistics 1/4
Organised by Caroline Rowland. (Online). December 2.

Kletskoppen Kindertaal Festival 2020. Image by Marcel Krijgsman

LECTURES AND COLLOQUIA

Simon E. Fisher at the joint Radboud Reflects - MPI Lectures. Image by Ted van Aanholt.

Nijmegen Lectures

2020
(Due to Covid-19 the Nijmegen Lectures were postponed to December 2021)

Adam Rutherford at the joint Radboud Reflects - MPI Lectures. Image by Ted van Aanholt.

Donders Lectures

2019
February 14 | Yael Niv, Princeton University
Carving the world into useful task representations
June 27 | Catherine Harmer, University of Oxford
How do antidepressant drugs work?
September 27 | Karel Svoboda, Janelia Research Campus.
Neural circuits underlying short-term memory and decision-making
October 24 | Marina Bedny, Johns Hopkins University
Nature and nurture in neurocognitive development: Insights from studies of blindness

2020
January 27 | Christof Koch, Allen Institute for Brain Science
Team Science, Big Science and Open Science - in the Service of Neuroscience
October 1 | Elisabeth Binder, Max Planck Institute for Psychiatry (Online)
Deciphering mechanisms of gene-environment interactions of stress - possibilities for individualized diagnosis and treatment of stress-related disorders
November 12 | Linda B. Smith, Indiana University (Online)
Visual learning; babies, bodies and machines

Joint Radboud Reflects - MPI Lectures

2019
January 14 | Adam Rutherford, University College London
How we became unique animals

(Due to Covid-19 no Joint Radboud Reflects - MPI Lectures event took place in 2020)

LECTURES AND COLLOQUIA

MPI Colloquium Series

2019
January 22 | Kate Nation, Oxford U.
Charting the development of lexical quality in children's reading: going big and staying small
February 22 | Laurent Cohen, Hôpital de la Salpêtrière, Paris
Words in the visual cortex
March 12 | Alain Chetodal, Inserm Paris
Development, function and evolution of brain commissures
April 30| Alex Christia, EHESS Paris
The role of input quality and quantity of early language acquisition
June 18 | Paul Hoffman, Edinburgh U.
Executive regulation of semantic knowledge and its importance for coherent speech
September 19 | Ewa Dąbrowska, Birmingham U.
The fundamental similarity of L1 and L2 learning
November 12 | Rochelle Newman, Maryland U.
When listening to language is hard
November 20 | Dianne Newbury, Oxford Brooks U.
Genetic contributions to speech and language; a complex dialogue
December 3 | Gesa Hartwigsen, MPI Leipzig
Plasticity in the language network

2020
January 29 | Anna K. Kuhlen, Institute for Psychology Humboldt-U. Berlin
Language production in shared task settings: Neurocognitive experiments
February 18 | Ofer Tchernichovski, Hunter College New York
Vocal culture in songbirds and humans
September 1 | Nivedita Mani, Georg-Elias-Müller Institute for Psychology, Gottingen
Why do children learn words?
October 6 | Madeleine Lancaster, Cambridge U.
Exploring human brain evolution using cerebral organoids

Other Guest Lectures

2019
June 19 | Ping Li, Penn State U.
The Second Language Learning Brain: Neurocognitive and Computational Approaches
September 6 | D. Kimbrough Oller, University of Memphis
New findings relevant to the origin of language from research on human and non-human primate infants

Nijmegen Gesture Centre Lecture Series

2019
January 24 | Antonia Hamilton, University College, London
Neurocognitive mechanisms of human social interaction
January 24 | Adrian Bangerter, University of Neuchâtel
Shared intentionality, joint commitments and joint action in humans and great apes
October 1 | Lisette de Jonge-Hoekstra, University of Groningen
Put it into context - How do changes in task properties influence children's hand movements and speech?
November 12 | Wim Pouw, Radboud University
Multimodal language production as a radically embodied innovation

2020
January 14 | Alice Cravotta, University of Padova
Restraining and encouraging the use of gestures - Exploring the effects on speech
February 13 | workshop
From Action to Communication in Brain, Cognition and Behavior Pre-defense symposium and PhD thesis defense: 'Movement Speaks for Itself: the Kinematic and Neural Dynamics of Communicative Action and Gesture'

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