Progress Report - Year 2

NCCR Evolving Language

Edited by Balthasar Bickel, Anne-Lise Giraud and Klaus Zuberbühler
Chapter 1 - Executive Summary

Language is an evolving behavior, with no precedent in evolutionary biology. We have taken on the challenge of understanding the origins and future of this behavior. In doing so, we have adopted an evolutionary stance beyond biology, by distinguishing three different modes of evolution – linguistic, cultural, biological – and by assessing each on their own terms and in interaction with each other (1). With this framework we have created a transdisciplinary science that allows us to investigate language as a web of evolutionary processes, characterizing the past as much as the present and the future.

In the second year of our center, this approach has led to a number of synergistic achievements and discoveries from which we can now build on. First, we have found that syntax and its characteristic long-term preferences in linguistic evolution derive from an inherited agent bias that has increasingly become integrated into hierarchical sentence planning (2,3), and our preliminary results furthermore suggest a preference for nested dependencies in this planning, mirroring more basic action planning. How this evolutionary transition was enabled has now become a key question. We hypothesize that it was facilitated by a neural system capable of exploiting prosody as a means of tracking syntactic structures (as suggested by our ongoing work), but the evolutionary mechanisms remain to be investigated.

A second achievement is a better functional understanding of core neurobiological processes involved in language, for example, beta oscillations for regulating top-down and bottom-up processes (4), theta synchronization for syntax planning (5,6), and neural spiking behavior for speech recognition models (7). Here, our data begin to suggest plausible transitions from primate-like vocal communication to human speech, for example due to the discovery of evolutionarily old and universal theta rhythm in animal vocal behavior, largely independent of anatomy (as suggested by our preliminary results).

A third achievement has come from cross-species and cross-culture research on acquisition, an essential prerequisite of language. Here, we were able to document a gradual and incomplete phylogenetic shift from infant-surrounding to infant-directed speech, driven to a significant extent by the cultural evolution of active intervention in the form of teaching (8) and at present increasingly also in the form of (neuro-)technology (9,10). The evolutionary process appears to have been slow and lengthy in the past, but was presumably facilitated by joint attention, a psychological motivation with a possibly separate evolutionary history (11).

A fourth achievement concerns the finding that communication also plays a key role when nonhuman primates cooperate in joint actions (12) or signal group cohesion (13), suggesting an evolutionarily ancestral process that precedes language but is arguably at the roots of its interactional use patterns and diversification processes (1) through arbitrary conventions (14). A key question here is how language entered and enabled the transition from dyadic cooperation (as seen in animals) to group activity, often bringing unfamiliar partners into the group (as seen in humans). One of our hypothesis is that cooperative breeding acted as a pivotal driver (11), perhaps by increased computational capacities to understand and predict others’ behavior as complex social scripts with antecedent causes that extend into future consequences (15).

These advances and many others that we detail in this report have gone hand-in-hand with methodological innovations. For example, in linguistic evolution, we have developed new approaches to co-estimate horizontal transfer and vertical inheritance (16,17) and predictors of speed of change and long-term preferences (18), and new datasets and models to compare genetic and linguistic diversification (19,20). For biological evolution, we have developed non-invasive imaging techniques for animals and set up a research facility with interactive touch screen and eye-tracking technology for the great apes at Basel Zoo (21), currently to study event cognition comparatively, and we have developed new computational methods for discovering and quantifying compositional structures across species (22–24).
During the reporting period there were also a number of changes in personnel and structures. Marcel Weber (Chair for Philosophy of Science at the U Geneva) replaced Marcelo Sanchez Villagra as PI in our Transversal Task Force (TTF) Concepts and Phil Garner (IDIAP) replaced Hervé Bourlard as PI in our work on speech processing. We have appointed several new associate investigators who bring in new expertise to our consortium and we have enriched our portfolio by three new Special Interest Groups on concepts of meaning, mechanisms of vocal learning, and cultures and action structures. These developments were of key importance to develop our outline proposal for Phase 2.

We have furthermore improved our internal funding scheme, opening up innovation grants to a larger range of applicants, and we have made available top-up grants to compensate COVID-induced delays in data acquisition. With regards to research infrastructure, we have achieved two major goals. First, a Magnetoencephalography (MEG) machine (MEGIN Triux Neo) has been selected and is currently being installed within the Human Neuroscience Platform of the Campus Biotech in Geneva. Second, the TTF DataScience has organizationally been integrated into the Linguistic Research Infrastructure (LiRI), a technology platform for language research at the University of Zurich. This will facilitate collaboration not only within the NCCR but in the larger community of language scientists in Switzerland.

We have also made progress in the implementation of structural measures. At the University of Zurich, PI Martin Meyer has been appointed as Associate Professor *ad personam* in Neuroscience of Language. At the University of Geneva, the professorship in Language Science (previously filled with PI Narly Golestani, who moved to the University of Vienna) has been filled with Valentina Borghesani in the rank of an assistant professor.

In conclusion, we are optimistic that we have moved our research enterprise forward in the key domains, despite the complications of last years’ continued health crisis, and that we are in a favorable position to reach the goals that we set ourselves for Phase 1.
Chapter 2 - NCCR Organization

Structure and organization of the NCCR management activities

Structure of the organization

There were no changes to the organizational structure during the reporting period. The NCCR is led by a Directorate, which consists of Director Balthasar Bickel, Co-Director Anne-Lise Giraud and Deputy Director Klaus Zuberbühler (Figure 1). The Directors are responsible for all upper-level strategic, organizational, and financial decisions and oversee communication and progress across all Projects. To this end, each member of the Directorate serves as a coordinator for one of the three Themes in research and as a coach of one or several TTFs and SIGs. In addition, the Director and the Co-Director each have appointed a delegate at their Home Institution, who in their absence represents them in dealings with the local rectorate and administration. The Directorate met every week during the reporting period, apart from a few breaks.

Figure 1: Organizational structure of the NCCR Evolving Language

The Directors and the two Home Institution Delegates are part of the NCCR’s Steering Committee, together with delegates from the groups of Project PIs (Marina Laganaro), TTF PIs (Richard Hahnloser), Researchers (Amelie Haugg), and NCCR Office staff (Manuel Widmer), all elected at the first General Assembly in 2020. The Steering Committee met three times in the reporting period and has reviewed applications for Innovation Grants, Top-Up Grants, NCCR Mobility Grants, Special Interest Groups (SIGs), and Associate Investigator (AI) status (as per our Rules of Procedure).

The General Assembly includes all members of the NCCR. It has convened once in the reporting period during the second Annual Summer School and Retreat in Engelberg in August 2021, during which new grant formats and measures (NCCR Mobility Grants, etc.) were announced and discussed.
Further, the NCCR is supported by a Scientific Advisory Board, which advises the NCCR in strategic questions, especially with regard to the proposal for Phase 2. The Scientific Advisory Board consists of Stanislas Dehaene (Collège de France), Nicholas Evans (Australian National U), W. Tecumseh Fitch (U Vienna), Angela Friederici (MPI for Human Cognitive and Brain Sciences, Leipzig), Susan Goldin-Meadow (U Chicago), Simon Kirby (U Edinburgh), Mark Steedman (U Edinburgh), and Michael Tomasello (Duke U). The members of the board will be consulted on Phase 2 plans in the context of a meeting scheduled for early 2023.

All management activities are coordinated by the NCCR Office, which serves as the operational center of the NCCR (Figure 2). It is directed by the Head of Administration and the Head of Research Management, who jointly lead the NCCR Office team and report to the Directorate. Additionally, it comprises the professional roles of Administrative Support, Finance Officer, Communication Officer, Education Officer, and Equal Opportunity Officer, some of which are united in one person.

Figure 2: Organizational structure of the NCCR Office

Our research is organized in three Themes. Each Theme is divided into three Projects, which are then again subdivided into two or three Work Packages (WPs) (Table 1). Alongside the three Themes stand the TTFs, which are mostly also organized into individual WPs. In addition, there are (SIGs), competitively established ad-hoc groups comprising PIs from at least two different disciplines and possibly including further (external) collaborators (cf. Chapter 4 for reports on current SIGs and a portrait of new SIGs established in the reporting period).

Table 1: Overview of Themes, Projects and Work Packages (WPs)

<table>
<thead>
<tr>
<th>Theme</th>
<th>Project</th>
<th>WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Grammar</td>
<td>Compositionality</td>
</tr>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Grammar</td>
<td>SemanticRoles</td>
</tr>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Grammar</td>
<td>EmotionIntegration</td>
</tr>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Diversification</td>
<td>Arbitrariness</td>
</tr>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Diversification</td>
<td>Phylo</td>
</tr>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Computation</td>
<td>NeuroComp</td>
</tr>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Computation</td>
<td>SignalRec</td>
</tr>
<tr>
<td>The Dynamic Structures of Language</td>
<td>Reception</td>
<td>TemporalHierarchies</td>
</tr>
<tr>
<td>The Biological Substrates of Language</td>
<td>Reception</td>
<td>ProsodyToMeaning</td>
</tr>
<tr>
<td>The Biological Substrates of Language</td>
<td>Production</td>
<td>StructurePlanning</td>
</tr>
<tr>
<td>The Biological Substrates of Language</td>
<td>Production</td>
<td>SpeechArticulation</td>
</tr>
<tr>
<td>The Biological Substrates of Language</td>
<td>Variability</td>
<td>Aptitude</td>
</tr>
<tr>
<td>The Biological Substrates of Language</td>
<td>Variability</td>
<td>NeuroModulation</td>
</tr>
</tbody>
</table>
Organizational and procedural changes

There were two changes of staff in the NCCR Office during the second year. The Education and Equal Officer Déphine Jochaut resigned by the end of June 2021, to focus on other activities at U Geneva. She was subsequently replaced by Malika Jara Bouimarine. In addition, Administrative Assistant Karoline Zavora left the NCCR Office by the end of November 2021. She was replaced by María Finkhäuser.

Further changes concern the workload of individual positions in the NCCR Office. During the first year, it became clear that we underestimated the amount of work necessary for activities in the management areas of Communication, Education, Equal Opportunities, and KTT. Accordingly, the Directorate decided to increase the workload from 40% to 50% for Communication, from 20% to 40% for Education, from 10% to 20% for Equal Opportunities, and from 30% to 40% for KTT. Table 2 summarizes the composition of the NCCR Office as per May 2022.

<table>
<thead>
<tr>
<th>Name</th>
<th>Professional role</th>
<th>Start date</th>
<th>FTE</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliza Isabaeva</td>
<td>Head of Research Management</td>
<td>01.03.2020</td>
<td>100%</td>
<td>U Zurich</td>
</tr>
<tr>
<td>Manuel Widmer</td>
<td>Head of Administration</td>
<td>01.03.2020</td>
<td>100%</td>
<td>U Zurich</td>
</tr>
<tr>
<td>Sara Bowen</td>
<td>Administrative Support</td>
<td>01.03.2020</td>
<td>10%</td>
<td>U Geneva</td>
</tr>
<tr>
<td>Fabienne Fournichot</td>
<td>Finance Officer</td>
<td>01.06.2020</td>
<td>70%</td>
<td>U Zurich</td>
</tr>
<tr>
<td>Lena Zipp</td>
<td>Administrative Support</td>
<td>01.06.2020</td>
<td>20%</td>
<td>U Zurich</td>
</tr>
<tr>
<td>Malika Jara-Bouimarine</td>
<td>EDU + EO Officer</td>
<td>01.01.2022</td>
<td>40% + 20%</td>
<td>U Geneva</td>
</tr>
<tr>
<td>Emilie Wyss</td>
<td>COM + KTT Officer</td>
<td>01.07.2020</td>
<td>50% + 40%</td>
<td>U Geneva</td>
</tr>
<tr>
<td>Françoise Defferrard</td>
<td>Finance Officer</td>
<td>01.10.2020</td>
<td>40%</td>
<td>U Geneva</td>
</tr>
<tr>
<td>Maria Finkhäuser</td>
<td>Administrative Support</td>
<td>01.01.2022</td>
<td>20%</td>
<td>U Zurich</td>
</tr>
</tbody>
</table>

In addition to the existing category of Associate Investor (AI), we established two new NCCR membership categories to better reflect people’s contribution to our endeavor: (i) Senior Advisors (SA)
and (ii) **Senior Researchers** (SR). The SA status is intended for PIs who will retire during a phase (thereby losing their status as PIs) but whose expertise remains important for the NCCR. SA status will be awarded by the Steering Committee based on a competitive application and comes with an official contract and a low-percentage salary in compliance with local university requirements. (For example, U Zurich minimally requires 15% FTE to continue work under an official contract after reaching the state-mandated retirement age of 65, while U Geneva minimally requires a *benevole* contract but no minimal percentage.)

SR status is intended for experienced researchers whose track record would qualify them as PIs or AIs but who cannot apply for either status as their current position is financed (at least in part) by the NCCR. The SR status thus allows them to contribute to WPs and the Phase 2 plans at a higher conceptual level without having PI or AI status. SR status is granted by the Directors to all researchers as soon as they fulfill the relevant criteria stated above. As of May 2022, the following NCCR members have been granted SR status: Chiara Barbieri (group leader at Department of Evolutionary Biology and Environmental Studies, U Zurich), Chundra Cathcart (group leader at Department of Comparative Language Science, U Zurich), Miren Itsaso Olasagasti Rodriguez (senior researcher at the Department of Basic Neuroscience, U Geneva), and Peter Ranacher (group leader at Department of Geography, U Zurich).

**Activities and measures of the management**

The NCCR Office organized various events in the second year of the NCCR (Table 3).

### Table 3: Events organized by the NCCR Office during reporting period

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biannual Project Meeting</td>
<td>Online via Zoom</td>
<td>June 15–17, 2021</td>
</tr>
<tr>
<td>NCCR Social Event</td>
<td>Neuchâtel</td>
<td>July 15, 2021</td>
</tr>
<tr>
<td>Annual NCCR Summer School and Retreat</td>
<td>Engelberg</td>
<td>August 23–27, 2021</td>
</tr>
<tr>
<td>SNSF Site Visit</td>
<td>Zurich</td>
<td>September 3–5, 2021</td>
</tr>
<tr>
<td>NCCR Presentations at Scientifica science fair</td>
<td>Zurich</td>
<td>September 9–10, 2021</td>
</tr>
<tr>
<td>Symposium “Molecular Anthropology of Language”</td>
<td>Zurich</td>
<td>September 29–30, 2021</td>
</tr>
<tr>
<td>Workshop “Analyzing Bioacoustic Data”</td>
<td>Online via Zoom</td>
<td>November 8 &amp; 10, 2021</td>
</tr>
<tr>
<td>NCCR Social Event (canceled due to COVID-19)</td>
<td>Neuchâtel</td>
<td>December 10, 2022</td>
</tr>
<tr>
<td>Introductory courses to major NCCR disciplines</td>
<td>Online</td>
<td>February 22, 2022</td>
</tr>
<tr>
<td>Biannual Project Meeting</td>
<td>Neuchâtel</td>
<td>February 23–25, 2022</td>
</tr>
<tr>
<td>NCCR Social Event</td>
<td>Neuchâtel</td>
<td>April 28, 2022</td>
</tr>
<tr>
<td>Workshop “Thinking about Evolution”</td>
<td>Neuchâtel</td>
<td>April 29, 2022</td>
</tr>
<tr>
<td>Phase 2 Planning Retreat (PIs only)</td>
<td>Bern</td>
<td>May 4–6, 2022</td>
</tr>
<tr>
<td>Meeting with Swissnex</td>
<td>Zurich</td>
<td>May 17, 2022</td>
</tr>
</tbody>
</table>

During the second year, the NCCR organized two Project Meetings (June 2021, February 2022). The meetings include the entire NCCR community and take place biannually (one online, one in person) to discuss the progress and current activities in each WP. These meetings were complemented by the Annual NCCR Summer School and Retreat (August 2021), which also includes the entire NCCR community. We hosted this in Engelberg over 4 days. The event included three minisymposia (“The concept of meaning in animal communication and theories of language evolution”, “Syllables in speech production and perception”, “Language, cognition and action”), a workshop on comparative approaches to evolution in language, culture and biology, information events on KTT support and the services offered by the TTF DataScience, as well as a poster session.
In the reporting period we additionally organized two NCCR-wide workshops outside our regular scheme, one on evolutionary thinking in April 2022 (with representatives from all WPs) and one on new ideas for Phase 2 (with present and future PIs) in May 2022. Finally, the NCCR Office together with the SNSF organized the first Site Visit (September 2021), which again brought together the entire NCCR community and allowed for a joint review of the achievements of the first year.

During the first two years of the NCCR, several meetings and workshops had to be held in an online format, as the COVID-19 pandemic did not allow for the organization of physical events. Accordingly, the NCCR Office decided to launch a series of regular NCCR Social Events, bringing together NCCR members in a more informal context and allowing for keeping up existing and establishing new contacts within the larger community. These events proved to be a great success and will be continued in the future.

In addition, the NCCR had a major presence at Scientifica (the science fair jointly organized by U Zurich and ETH Zurich every two years) in September 2021. In total, NCCR members organized three science booths, three workshops and one science café and thus made a major contribution to advertising the NCCR to the interested public.

Finally, the NCCR Office met with a Swissnex delegation on May 17, 2022. Swissnex is an internal network financed by the State Secretariat for Education, Research and Innovation and pursues the mission of connecting Switzerland in the domains of education, research, and innovation. The meeting provided the opportunity for mutual networking and exploring possibilities for future collaborations.

Status of collaboration/integration and added-value

At the NCCR level

The collaborative projects that emerged in the course of the first year were continued in the second year. This is illustrated in Figure 4, which visualizes sustained collaborations between WPs as per May 2022 (each line represents a demonstrated collaboration between two WPs as reported to management in a survey; colors indicate the overarching Projects / TTFs).

In addition, the NCCR Office set up a colloquium series in collaboration with the ISLE Center at U Zurich and the Neuroscience Center at U Geneva. The series offers a platform to invite internationally renowned specialists for presentations as well as to invite NCCR members to present their research to the NCCR community. The colloquium thus increases the international visibility of the NCCR and at the same time also propagates scientific exchange and collaboration within the NCCR community.

Another important instrument that encourages and promotes scientific exchange across the NCCR are the four TTFs (DataScience, Technology, Concepts, Ethics). The TTFs offer help and consulting services to all members of the NCCR in their respective areas of expertise. Towards the end of the first year of our NCCR, all TTFs had achieved full operability and had begun to contribute to the NCCR and its research mission in various ways. The TTF DataScience has taken the lead on assessing and answering the NCCR community’s needs with regard to data sharing, storing, and archiving. Also, the team is offering crucial contributions to the NCCR’s Data Management Strategy (cf. last year’s Annual Report). The TTF Technology, in turn, has started to develop technological solutions for other NCCR WPs, for example machine learning models that generate plausible pronunciation variants for the WP EduGame and a sensoric device to study vocal communication in freely moving animals. The TTF Concepts has launched an internal collaborative wiki that will serve as a conceptual framework and ensure terminological consistency and clarity. The TTF Ethics, finally, has conducted a survey on ethical issues within the NCCR and has started to develop ethics charters for animal and human research. Further details on TTF work is available in Chapter 4.
Figure 3: Sustained collaborations between WPs as per May 2022

At the national level
We have set up collaborations with various institutions and partners both from the public and private sector.

University of Zurich
The NCCR has continued its close collaboration with the Interdisciplinary Center for the Study of Language Evolution (ISLE). Together with ISLE and the Brain & Cognition Seminar of the Geneva Neuroscience Center, the NCCR is jointly organizing an interdisciplinary colloquium on the different research areas covered by the NCCR. This will facilitate the mutual integration of the two institutions in a long-term perspective, in line with our long-term strategy to create a National Institute for the Study of Language Evolution (NISLE) at the end of the NCCR (co-hosted by U Geneva).

Another key partner at U Zurich is the Technology Platform Linguistic Research Infrastructure (LiRI), which offers data science and technology services for language research (e.g. phonetics and EEG lab facilities, NLP technology, data management). The TTF DataScience, which acts as the NCCR’s internal data science service, has been set up in close collaboration with LiRI’s data science team to ensure that individual staff members complement each other with their respective expertise and that they can profit from each other’s expertise (see Chapter 5 for more detailed information). To maximize synergies between the TTF DataScience and LiRI, the
directorates of the NCCR and LiRI decided to integrate the TTF DataScience into LiRI as a separate organization unit with the name “NCCR@LiRI”. This allows for close scientific exchange between the data scientists of the TTF and LiRI, with both groups profiting from each other’s expertise and having access to the same infrastructure and IT support. The staff members of the TTF DataScience are now administratively managed by LiRI but financed through NCCR cash contributions. The TTF PIs remain responsible for supervising scientific activities within the relevant WPs.

Finally, the NCCR has signed an agreement with the Citizen Science Center (CSC) at the U Zurich, according to which the CSC will offer matching funds for all NCCR-funded projects. In 2021, the CSC collaborated with PI Xanthos by offering their expertise and infrastructure with regard to large-scale data collection. This collaboration is planned to continue in 2022.

University of Geneva

The NCCR continued to closely collaborate with the Fondation Campus Biotech, where several of our laboratories are based, and most of our neuroscience research takes place. Our main partner is the Human Neuroscience Platform (HNP), which hosts several facilities that are indispensable for our projects, in particular the fMRI, MEG/EEG-BCI, the virtual reality (VR), and Methods&Data facilities.

Our operations build on a virtuous circle whereby the MEG/EEG-BCI and VR facilities benefit from the NCCR research developments and reciprocally the NCCR from the methodological knowledge already existing in the facility.

Regarding KTT, the NCCR collaborates with the ATFM (Accélérateur translationnel de la Faculté de médecine) from the U Geneva medical faculty. A representative of the ATFM participated in our 2021 Annual Retreat in Engelberg and gave a presentation on the services offered by their institution. Since then, a few of our projects have sought advice from the ATFM. We expect more of this as the projects mature and become closer to industrial exploitation. This is particularly the case for WP NeuroModulation which develops methods for treating neurodevelopmental and acquired language disorders (cf Chapter 5, section KTT).

Partners from the public sector

With regard to research on captive great apes, the NCCR continues its close collaboration with Basel Zoo. Based on a memorandum of understanding signed between the zoo and U Neuchatel, NCCR researchers are granted access to the zoo’s great ape collection for non-invasive research. Several lines of research with different methodologies are currently carried out at Basel Zoo: (i) playback experiments, in combination with touch screen technology, to study the role of social learning in the acquisition of meaning; (ii) eye-tracking experiments to study event perception, agency and semantic roles more generally; (iii) subject-experimenter behavior interactions to study risk perception in behavioral economics; (iv) delayed gratification experiments to compare cognitive sophistication across primate species.

The NCCR has also continued its collaboration with the Swiss Society for Linguistics (SSG/SSL) on a joint project to promote linguistics teaching content across high schools in Switzerland with a special focus on the overlap between linguistics and the natural and computational sciences. The ultimate goal is to develop an online teaching platform with content that can be flexibly adapted to various subjects. A project plan has been developed by the SSG/SSL over the past three years and is supposed to be implemented in the course of the next two years.

Partners from the private sector

The NCCR currently has three official partners from the private sector: Google, Sonova, and Wyss Center. The collaboration with Google has currently two components. First, Google provides the NCCR with online collaboration and cloud computing services, managed and made available to our teams by the TTF DataScience. Second, we have launched a collaborative project with Srini Narayanan’s group at Google Research in Zurich in the form of the SIG Metaphors (cf above).

PI Martin Meyer and AI Nathalie Giroud have continued their collaboration with Sonova, a global leader in the development of hearing solutions. Giroud has successfully applied for a four-year grant by Sonova (“Benefits of auditory-cognitive training for hearing rehabilitation and cognitive functioning in older hearing impaired”). In addition, Meyer and Giroud are working on a proposal together with scholars of the University of Queensland (Australia) and Sonova in the context of the U Zurich Innovation Hub “Healthy Longevity”.

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Furthermore, the NCCR collaborates with the Wyss Center in Geneva in the area of bioengineering. Our main collaboration concerns the development of a BCI device for restoring speech communication in patients who have lost the ability to speak (lead: PI Anne-Lise Giraud).

**At the international level**

While all our researchers have extensive networks of long-established international collaborations (as amply evidenced for example by their co-author lists in publications), Table 4 gives an overview of new collaborations that evolved specifically within the NCCR and freshly during the reporting period:

**Table 4: Selected international collaborations**

<table>
<thead>
<tr>
<th>WPs</th>
<th>Collaborating Institution</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aptitude</td>
<td>MPI Nijmegen</td>
<td>MRI and genetic data</td>
</tr>
<tr>
<td></td>
<td>University of Vienna</td>
<td>MRI data</td>
</tr>
<tr>
<td></td>
<td>University of Heidelberg</td>
<td>MRI data</td>
</tr>
<tr>
<td></td>
<td>University of California at Los Angeles</td>
<td>MRI data</td>
</tr>
<tr>
<td></td>
<td>MIT</td>
<td>MRI data</td>
</tr>
<tr>
<td>Diversification</td>
<td>Tokai University, Japan</td>
<td>population genetics (East Asia)</td>
</tr>
<tr>
<td>MentalState</td>
<td>Budongo Conservation Field Station</td>
<td>access to fieldstation / primates</td>
</tr>
<tr>
<td></td>
<td>Tai Monkey Project</td>
<td>access to fieldstation / primates</td>
</tr>
<tr>
<td>SocialContext, StructurePlanning, TemporalHierarchies</td>
<td>Vietnamese National University, Hanoi</td>
<td>establishment of fieldstation, experimental laboratories</td>
</tr>
<tr>
<td></td>
<td>PUCP Lima, Peru</td>
<td>establishment of fieldstation</td>
</tr>
<tr>
<td></td>
<td>Kibale Chimpanzee Project</td>
<td>access to fieldstation / primates</td>
</tr>
<tr>
<td>Temporal Hierarchies</td>
<td>Station de Primatologie, Rousset</td>
<td>access to primates</td>
</tr>
</tbody>
</table>

**Added-value by the NCCR**

The NCCR adds value by bringing together an interdisciplinary network of specialists who are putting their respective expertise not only at the disposal of their WP but at the disposal of the entire NCCR and, with critical help from our conceptual work, increasingly develop a shared perspective on evolution in language. This dense network allows for interactions that – both in terms of their quantity and their quality – would not be possible if WPs were set up as independent projects or organized in small interdisciplinary clusters. In addition, we can only overcome the divide between the humanities and the natural sciences on a broad front if we achieve a critical number of interdisciplinary collaborations. As such, the establishment and maintenance of a great number of interdisciplinary collaborations is mission-critical for our NCCR.

Figure 4 visualizes the number of interdisciplinary collaborations that have emerged through their interdisciplinary make-up of our WPs by being composed of PIs from different disciplines. As the figure illustrates, interdisciplinary research does not only take place within WPs but has also evolved dynamically between WPs in the course of the first two years. This demonstrates that the NCCR is making progress towards its goals of overcoming the divide between different research traditions, and reshaping and redefining the scientific culture at Swiss research institutions and beyond – a goal that could not be reached with independent projects or small-scale project networks.
As summarized in Chapter 1, this radical interdisciplinary approach has led to several synergetic achievements. These strengthened our understanding of the evolutionary processes that characterize language both in the phylogenetic past and in its ongoing dynamics. An example of this added value is our recently submitted paper about the position of linguistic evolution with respect to biological and technological evolution, developed jointly by experts in linguistics, neuroscience, and biology (1), or our cross-disciplinary work on infant-directed vs infant-surrounding vocalization across animals and humans (8). A more general illustration comes from the many ideas and hypotheses that emerged during our brainstorming meetings on Phase 2 and which shaped our Outline Proposal.

Transdisciplinary advances of this kind are simply impossible without the support of a dedicated community and network of the kind the NCCR offers.

Changes to the consortium’s composition

Marcelo Sanchez Villagra (TTF Concepts) withdrew from the NCCR as PI in 2021 because of growing duties at his home department and museum. Marcel Weber (U Geneva) replaced him as a new PI in the TTF Concepts, expanding our expertise in the philosophy of evolutionary biology. In turn, PI Wild moved to the TTF Ethics to strengthen their team. In addition, we appointed Phil Garner (IDIAP) as a new PI, replacing PI Bourlard upon his retirement.
Impact of the COVID-19 pandemic

Management

During the first year, the NCCR Office adapted its mode of operation to the conditions of the pandemic by adopting various tools for collaborative distance working. These tools generally neutralized the negative effects of the pandemic and allowed the NCCR Office to operate effectively under the conditions of the pandemic.

At the same time, the pandemic still limited the NCCR Office’s possibilities of organizing physical meetings and events during the second year. In particular, this was true for the winter 2021/2022, when the rising numbers of corona cases and national containment measures made it nearly impossible to organize meetings of larger groups and we had to move to online meetings. We noted a sharp drop in the quality of our discussions and exchange in online as opposed to in-person meetings.

Once the situation normalized, we organized NCCR social events. These helped enormously in bringing our community together and creating a sense of unity and identity. The first such meeting was organized in Neuchâtel in July 2021, and the format will be continued in the future.

Research

As noted in last year’s report, the COVID-19 pandemic caused severe delays in hiring processes in WPs that had to rely on the international job market in their search for suitable candidates. In addition, we also incurred severe delays in WPs where PIs were absorbed by extra tasks related to the pandemic. This issue primarily affected WP CompuLang, where PI Christian Lovis acts as the Chairman of Medical Information Sciences at the University Hospital of Geneva, and TTF Ethics where PI Samia Hurst was heavily absorbed by her work for the Swiss National COVID-19 Science Task Force.

While hiring processes had generally been completed by the beginning of the reporting period, delayed hirings had a lasting effect on certain WPs, as this meant that the build-up of organizational structures and initiation of related research activities was also delayed by several months. This was especially true for the TTF DataScience, where the search for competent candidates turned out to be a great challenge, as the TTF directly competes with industry, which offers better salaries and more generous remuneration programs.

Last but not least, the pandemic had a negative impact on WPs involving experiments with human participants and non-human primates, most heavily those WPs involving fieldwork in foreign countries (Uganda, Peru, DR Congo, Vietnam). The WP EarlySurround, for example, had only been able to send research staff to our field station in the Peruvian Amazon in summer 2021 (originally planned for autumn 2020). In addition, WPs EarlySurround, JointAction, and StructurePlanning had not been able to build up a new field station in Vietnam until May 2022 (originally planned for autumn 2020). Similarly, the Budongo Conservation Field Station (Uganda), an essential fieldsite for the WP MentalState and WP EarlySurround, had been closed for research during the first year of the pandemic and was only reopened in the course of summer 2021, causing a delay of a full year. Finally, research with the great apes at Basel Zoo also got delayed due to access restrictions (WP SemanticRoles; WP MentalStates).

While fieldwork-based research generally became possible again for most WPs in the course of the second year, the affected WPs are now faced with the challenge of compensating for the delay caused by the pandemic until the end of the first phase of the NCCR. To support WPs in their efforts to make up for the lost time, the Directorate has launched Top-Up Grants in Spring 2022. These grants involve additional funding of max. CHF 50’000 and are supposed to help WPs speed up essential research projects so that they can still achieve their research goals until May 2024. The first call for Top-Up Grants led to seven applications, five of which were approved by the Steering Committee (Table 5).
Table 5: List of WPs that received Top-Up Grants

<table>
<thead>
<tr>
<th>WP</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>EarlySurround</td>
<td>additional staff to compensate for delays in data collection at two field sites (Kokolopori Bonobo research station, Uganda and Shipibo-Konibo field station, Peru)</td>
</tr>
<tr>
<td>EduGame</td>
<td>additional staff for running experiments</td>
</tr>
<tr>
<td>JointAction</td>
<td>additional staff to compensate for delays in data collection at two field sites (Shipibo-Konibo field station, Peru and Hai Phong field station, Vietnam) and coding of large corpora of recordings</td>
</tr>
<tr>
<td>MentalState</td>
<td>additional staff to compensate for set-back in experimental studies with human infants/toddlers, children, and chimpanzees in Switzerland and Uganda</td>
</tr>
<tr>
<td>SemanticRoles, MentalState</td>
<td>additional staff to compensate for set-back in eye-tracking studies with primates at Basel Zoo</td>
</tr>
<tr>
<td>SocialContext</td>
<td>additional staff to compensate for set-back in build-up of Vietnamese corpus of child acquisition</td>
</tr>
</tbody>
</table>

We hope that these additional funds will help the relevant WPs to achieve their research goal until the end of the first phase of the NCCR, although of course more funds and workforce does not necessarily mean more efficient data collection. The pressure on teams is very high and TTF DataScience put aside extra time to support these teams in managing the influx of data in the coming months.
Chapter 3 - Research

In its second year, the NCCR Evolving Language has made significant progress in solidifying its research infrastructure and collaboration mechanisms. After a challenging first year, which was marked by the COVID pandemic, all work packages (WPs) have now been working at full capacity. Regular exchanges on ongoing and future research have taken place, and competitive association and grant schemes have been set up.

In what follows we present the work in our WPs by means of the following structure: (i) Current WP Team; (ii) WP Goals; (iii) Work during the reporting period; (iv) Current findings and interim conclusions. (Note that some WP have an internal division of tasks, while others operate in a less structured manner.) The WP reporting is then followed by TTF and SIG reporting. We conclude the chapter with a report on the new developments in research structure.

Results from Year 2

Grammar Project (Coordinator: Bickel)

The Grammar Project tackles the basic mechanisms that structure communicative expressions, i.e., the mechanisms of combination and division that distinguish a given expression from a holistic signal. The project compares mechanisms in human and animal communication, seeking to identify which mechanisms continue earlier phylogenetic patterns and which ones are evolutionarily derived, either specifically for language or by exaptation. While the main focus of the project is on the chief mechanisms by which meaning is composed (WP Compositionality) and syntax structured (WP SemanticRoles), we also examine the mechanisms by how propositional and referential information is combined with ever-present emotional information (WP EmotionIntegration). In all three work packages we take a comparative, cross-species approach in order to unravel the biological evolution of these mechanisms.

WP Compositionality

**Team:**
PIs: Balthasar Bickel, Paola Merlo, Simon Townsend; NCCR-funded researchers: Aixiu An, Alexandra Bosshard; Internal collaborators: Chunyang Jiang, Judith Burkart, Maël Leroux, Maria Rodriguez, Mélissa Berthet, Sarah Saneei.

**Goals:**
Humans are well-known to prefer compositional over non-compositional structures in language, and it has been shown that compositionality makes language learning and processing particularly efficient (26,27). In this work package we aim at tracing how and when this preference arose in biological evolution by exploring to what extent other primates (both apes and monkeys) have comparable abilities or even preferences. What has hampered progress, however, is the lack of computational models that detect compositionality in language or animal call systems in a fully explicit and generalized way, and this is our point of departure.

**Work during the reporting period:**
We have provided a proof of concept for a new method to learn the components and the combinatorics of an observational dataset of human language data. We generate artificially constructed, structured compositional data, and we develop learning architectures appropriate for the problem. We demonstrate (i) that we can solve this complex structured task and (ii) that the internal representations learnt by the machine to solve the task rely on an explicit decomposition (disentanglement) that aligns with the planned structure of the data (22). The family of architecture we use can also be interpreted as a compression mechanism. Our current work aims to (i) measure the levels of compressions that find the optional spot between compactness and accurate transmission of the message; (ii) inspect the internal representations to identify compositional from non-compositional (entangled) representations.

The next step will be to apply this approach to primate call datasets. This will complement alternative approaches where we started from already known call units and use collocation analysis (24,28) and supra-categorical Markov
Models (23) to detect possible candidate compositional structures in animal vocal behavior. Our current focus is on common marmosets given their rich vocal behavior and similar socio-cooperative breeding systems to humans. Recent analyses have identified various sequential relationships between calls in combinations that point towards potential internal structuring. We have also been working on a review paper that takes apart notions that are often conflated with compositionality, such as productivity, creativity, hierarchy etc. Progress here was slower than expected, however, because we prioritized our computational work.

Findings and interim conclusions:

Appropriately defined deep neural language models can disentangle the different components of complex artificially-constructed human language data, paving the way to controlled computational experiments on compositionality. Since the family of computational architectures are also compression techniques, they open prospects for finding compositionality also in primate call data, going beyond our current approaches centered on quantifying and modeling dependencies between known calls units.

WP SemanticRoles

Team:
Pls: Balthasar Bickel, Klaus Zuberbühler, Moritz Daum; NCCR-funded researchers: Chundra Cathcart, Eva Huber, Vanessa Wilson; Internal collaborators: Arrate Isasi-Isasmendi, Caroline Andrews, Paola Merlo, Sarah Brocard, Sebastian Sauppe, Stefan Schnell; External collaborator: Monique Flecken (U Amsterdam).

Goals:
The differentiation between agents, patients and the core event is fundamental for the structure of human language, governing key aspects of word order, case-marking, verb semantics, and much else. To what extent did this differentiation evolve from prelinguistic cognitive or perceptual abilities shared with our closest primate relatives, and to what extent was event cognition (re)shaped by language?

Work during the reporting period:

We currently focus on what has been called the Agent Bias in language: agents tend to be expressed in simpler forms and in earlier and higher positions than patients across languages; correlated with this, listeners by default predict an agent role for nouns during sentence processing, a prediction that results in an EEG signal (mostly N400) when it fails. Can the Agent Bias be derived from the statistical properties of language alone? Inspired by work that relates the N400 signal to word surprisal in close probability tasks, we extracted verb surprisals from language models (LSTMs and Transformers) but so far found that they only marginally predict the N400 signals triggered by the agent bias during comprehension (29).

Parallel to this work, we assessed the presence of an agent bias and event decomposition with eye-tracking and touch-screen experiments comparing human adults, children, and great apes. Preliminary findings indicate that, in general, apes attend to agents as humans do, but that these responses are mediated by event content, such as whether interactions depicted are social or with an inanimate object (MS in prep).

In an associated SNSF project we continued to corroborate the Agent Bias in languages that go against the general trend and code agents in more complex forms than patients (Basque, MS in prep.). We extended this finding to a language that tends to place patients before agents (“OVS”, Aïwoo), but effects were limited to human referents (MS in prep.). This suggests a possibly parallel limitation as in the apes and raises questions about animacy and world knowledge influencing prediction during processing (cf. WP NeuroComp).

We will present some of our work at the Annual Meeting of the Cognitive Science Society in July 2022 and at a workshop on Event Role Biases that we are organizing at the Joint Conference on Language Evolution in September 2022.

Findings and interim conclusions:
The Agent Bias is a universal principle in language that cannot be derived from the statistics of language experience alone (29,30) and that can only be weakly modulated by differences between languages (5,6,31). This
suggests that the Agent Bias is prelinguistic, and the ape data suggest that it is indeed phylogenetically much older than language (2). At the same time, apes do not seem to communicate agent-patient relations, and this suggests that the critical human innovation was a way to integrate the Agent Bias into a hierarchical event script that also includes patients, defining the core of syntax and semantics in language (32).

**WP EmotionIntegration**

**Team:**


**Goals:**

Emotion is a core aspect of both human and animal communication. We adopt an evolutionary perspective on the interplay between the need to share socio-emotional information and the form and structure of communication systems, including animal vocalizations, human speech and computer-mediated communication.

In animals, we identify the expression of emotions in vocalizations, with the particular aim to identify acoustic parameters and temporal patterns that relate to emotional state in several different contexts, and how they are perceived by conspecific listeners.

In humans we ask how emotional semantic, prosodic, and contextual information are integrated during processing in the brain. In particular we use using fMRI to determine how neural activity and connectivity within the relevant brain regions — including Superior Temporal Gyri and Sulci (STG, STS) and frontal regions such as Inferior Frontal Gyri (IFG) and the orbito-frontal cortices (OFC) — are modulated as function of the systematic experimental manipulations of emotional information at semantic and prosodic levels.

We furthermore study how the constraints imposed by computer-mediated communication and the possibilities that it offers contribute to shaping the expression of emotion over time.

**Work during the reporting period:**

In research on animal vocalization we started a second field season to collect observational data and perform additional experiments on physiological manipulations to identify arousal changes and the expression in animal vocal behavior. We take for now as our animal example meerkats because of their complex social behavior and our long-standing expertise.

In human vocalizations we investigated three factors (context, semantic, prosody) and three emotional modalities (neutral, positive, negative) in sentences spoken by actors with neutral or emotional voices. These stimuli were judged by participants on valence, arousal, and sarcastic dimensions. We currently perform fMRI acquisition on naive participants (French, for practical reasons), listening and judging the selected best subset of the stimulus corpus described above. We have started to prepare a second fMRI experiment, we contrast different sensory inputs of emotional information from auditory, written, and iconic (emojis) stimuli.

To analyze computer-mediated communication, we have developed a web infrastructure for collecting WhatsApp chat donations as well as the consent and demographic information of participants to these chats, with data collection to last from May to September 2022. We started to work on the preprocessing of the collected chats, in particular anonymization and language identification, using a mixture of rule-based and machine learning methods. In a separate but related line of research, we are working on the question of identifying paralinguistic cues in written computer-mediated communication and characterizing their meaning using distributed semantic representations.

**Findings and interim conclusion:**

Reviewing the common underlying mechanisms on emotional expressions in different communications systems from animals to humans and machines revealed the commonalities and the limitations of comparisons to allow conclusions on the evolution of emotional expressions, including on the one hand the presence of emotional
expressions and meanings in all areas of non-human and human animal vocalizations, language and also computer-mediated communication (MS submitted). Thus, emotion is a central element in communications. Another important aspect we found is the controllability of emotional expressions. From an evolutionary perspective, this is present at all levels at different gradients, and this is also the case for the meaning and the referential aspects. In each communication system their specific approaches will enhance knowledge, yet we aim to identify synergistic research programs where in the different communication systems currently different methodological approaches have been used.

**Diversification Project (Coordinator: Manser)**

The Diversification Project develops refined models of how human and animal communication systems and their structures diversify over time and space, taking (genetic) population history and geographical environment into account. A specific test case is the evolution of arbitrary vs motivated forms or expression and signaling, a central prerequisite for diversification within a species. We take this up in the WP Arbitrariness. In WP Phylo we combine data on genetic and linguistic evolution in tracing the history of human language and engage with the ongoing debate of these two modes of evolution and the methods to explore it.

**WP Arbitrariness**

**Team:**

**PIs:** Marta Manser, Paul Widmer. **NCCR-funded researchers:** Nicole Tamer, Nikola Falk, Stuart K Watson. **Internal collaborators:** Aitana Garcia, Eloise Deaux, Guanghao You, Hans-Johann Glock, Maxime Garcia, Piera Filippi. **External collaborator:** Luca Gasparri (U Lilles).

**Goals:**

The goal is to explore the evolutionary origins and the diversification of arbitrary form-meaning mapping in language and how it relates to systematic form-category mappings. We explore this from a cross-species perspective to better understand the nature of observable constraints on arbitrary mappings in the animal kingdom which seem to limit diversification processes.

**Work during the reporting period:**

The WP is now at a stage where much of the data necessary for its major empirical outputs have been gathered and formal analysis is either underway or will be carried out over the next 6-12 months. We carried out research in three principle domains:

(i) We continued to work on a comparative analysis of systematicity patterns in word-initial segments across Indo-European languages (in collaboration with TTF Concepts and TTF Data Science). For this we have started to team up with an associated SNSF project, where we investigate how phonological, phonotactic, and syntactic properties determine semantic and linguistic units and how they scaffold language learning. 

(ii) We completed an analysis of the variability of vocalizations occurring within and between behavioral contexts in meerkats (in collaboration with WP Reception and TTF Data Science), a mongoose species we selected for its complex vocal and social behavior and on which we have long-standing expertise. 

(iii) We performed a cross-species acoustic analysis of vocal repertoires, shedding light on whether (and if so, what) universal properties are shared by similar call-types across different species (with input from TTF Data Science and WP Reception). For this we have built a database of cut and ‘analysis-ready’ audio files of four different mongoose species (~50,000 audio files and associated metadata).

We will present preliminary results at the *Joint Conference on Language Evolution* in September 2022.

**Findings and interim conclusion:**

In a review (14) we propose a novel conceptual framework for examining the evolutionary origins of linguistic arbitrariness. Specifically, we determined that a fundamental feature of arbitrariness is the capacity to associate alternative functions to a given signal-form (and vice versa) based on the current body of animal communication
literature. We found ample evidence in diverse non-human species, to greater and lesser extents, across five dimensions of communication. We conclude that this fundamental building block of linguistic arbitrariness exists on a phylogenetic continuum, and may relate to domain-general causal reasoning abilities rather than being a unique feature of human cognition or language.

Further exploring the relationship between signal forms and functions in animals, we have applied a novel method to tease apart alternative hypotheses for so-called ‘functionally referential’ signal production in meerkats, demonstrating that their aerial alarm calls are indeed referential, and not driven by internal arousal states or acting as an ‘imperative’ to other group members (MS submitted).

Using propagation experiments in three closely related mongoose species, we found that while native habitat type strongly affected sound transmission, each species’ vocalizations were not systematically better adapted to transmit in their native habitat, raising important further questions about the factors that may drive the diversification of signal-forms (33).

Expanding this examination of the relationship between signal forms and their functions to language itself, we have preliminary results from an investigation of systematicity in Indo-European languages indicating that phonological cues in the first word segment help distinguish between open and closed word classes, but not, as formerly claimed, within the open class (presentation at the International Max Planck Research School (IMPRS) Conference Series on Interdisciplinary Approaches in the Language Sciences). In all languages of our sample systematic mappings are amply represented. This hints at functional biases based on learnability, processing, and planning playing an important role in diversification processes.

WP Phylo

Team:

*PIs:* Kentaro Shimizu, Paul Widmer, Robert Weibel; *NCCR-funded researchers:* Chiara Barbieri, Chundra Cathcart, Gereon Kaiping, Marc Lischka (shared with WP Statistics), Nico Neureiter, Peter Ranacher; *Internal collaborators:* Anna Graff, Balthasar Bickel, Borja Herce, Christian Ebert, Epifanía Arango-Isaza, Carmen Saldana, Marcelo Sánchez-Villagrà, Nour Efrat-Kowalsky, Reinhard Furrer. *External collaborators:* Damián Blasi (Harvard U), Harald Hammarström (U Uppsala), Hiromi Matsumae (U Tokai), Remco Bouckaert (U Auckland), Robert Forkel, Russell Gray, Simon Greenhill (MPI for Evolutionary Anthropology, Leipzig), Sören Wichmann (U Kiel).

Goals:

The WP addresses the evolutionary dynamics of language diversification in a historical and geographical framework and evaluates the demographic and ecological impact of cultural and biological transmission along and across phylogenies. The goal is to anchor the evolutionary dynamics to a time scale in human history and evolution. Human linguistic and cultural evolutionary trajectories are studied on a global scale using explicit evolutionary tools and concepts borrowed and adapted from the biological and ecological domain and further developed by our team. Additionally, we extend available methods to processes of diversification in animal communication systems.

Work during the reporting period:

In method and toolbox development, we worked on the refinement of phylogenetic inference and analysis: (i) We further developed *sBayes*, a novel method for inferring spatial traces of contact effects in evolutionary data, by systematically exploring parameter settings and enhancing speed and performance in combination with a worldwide case study on linguistic data; (ii) we developed distributional phylogenetic methods, a flexible type of phylogenetic comparative method inspired by distributional regression models (which allow both the location and scale of a response variable to vary as a function of one or more predictors); (iii) introduced *contacTrees*, a Bayesian phylogenetic model with horizontal transfer for detecting language contact while inferring phylogenies; (iv) we performed spatio-temporal simulations of language diversification for specifying baseline expectation; and (v) we started *Glottography*, a web atlas and collection of language ranges, for tracing the geographies of languages.
In a second axis of our WP we applied dataset screening, targeting genetic, linguistic, and cultural diversity in human groups and testing the correspondence between genetic and linguistic diversity and relationship on a global scale. To do so, we curated a dataset of genetic diversity that was updated with recent publications, filtered and analyzed on different dimensions of variation. Before linking the genetic dataset with quantitative linguistic data, we focused on the optimization of linguistic datasets with sparse data coverage; (ii) we worked on exploring the dynamics behind the formation of linguistic isolates; (iii) we adapted linguistic methodologies to other species by assembling call data from meerkat and performing spatial analyses; and (iv) carried out several case studies. In an associated SNSF Sinergia project we collaborate on building language phylogenies (Arawak, Maweti-Guarani, Sal branch of Sino-Tibetan) and on exploring correlated patterns of genetic and linguistic diversification in Eurasia and the Americas.

Findings and interim conclusion:

In the first (methodological) axis of our WP we published a new phylogenetic model (contacTrees) that implements a principled way of integrating horizontal transmission in phylogenetic methods (17). The model shows that ignoring contact can lead to systematic errors in the estimated tree height, rate of change and tree topology, which can be avoided with contacTrees. This work complements our earlier work using mixture models (sBayes) to quantify signals of contact from those of shared inheritance and universal probabilities (16). Furthermore, we developed distributional phylogenetic methods, a flexible type of phylogenetic comparative method inspired by distributional regression models, allowing both the speed of change and long-term preference (i.e., stationary probability) to vary according to predictor variables. Applying this the evolution of meaningless morphological alterations (“morphomes”) in Romance as a test case, we find that frequency and simplicity impact long-term preferences, but not speed of change or stability (18), in line with results from artificial language learning experiments we conducted to confirm these preferences for regularization (34). Our new approach will make it possible to model branch-level variation in speeds and preferences, and can be expanded to explicitly model spatiotemporal autocorrelation in branch-level variation.

In the second axis of research, we explored evolutionary patterns in material culture by assembling and analyzing a large dataset of musical instruments in South America, a region characterized by a high cultural and linguistic diversity. We observed phylogenetic signals of cultural evolution corresponding to broad macro regions, and in some cases, to similar linguistic backgrounds (35). In a global scale survey (20), we found that vertical transmission of languages overlaps with genetic and demographic trajectories for most populations and a few genetically cohesive language families (i.e. Indo-European and Sino-Tibetan). Nevertheless, cases of horizontal transmission of languages are a regular outcome in all continents, reflecting different cultural scenarios. Similarly, there is no uniform pattern to the demographic history of linguistic isolates, which only in some cases correspond to genetic isolates.

Assessing the linguistic typological landscape in the Near East, as transmitted in the first written remains, suggests a massive transformation in the last few millennia (MS under review in Scientific Reports). This finding challenges the notion that present-day frequency distributions of typological features are representative long-term preferences. Another case study takes Indo-European as an example that we have massive corpus data on and shows that phylogenetic distance predicts more word order variation than geographical distance, but the most important predictor is the shared fraction where phylogeny and area overlap. We conclude that word order in Indo-European has evolved along both dimensions and cannot be reduced to a single one (MS under review in Journal of Linguistic Geography).

Overall, we learn that the steadily growing amount of available linguistic data and novel methodologies profoundly transform the way we understand diversification processes in human language. Progress with animal call data, on the other hand, is still hampered by the lack of standardized data formats and data preparation pipelines: this challenge will be addressed in the second half of Phase 1.

Our results furthermore show that for the inference of linguistic history at the family level, more realistic models — in particular models that explicitly co-estimate horizontal transfer — substantially increase the accuracy of the models, painting a more realistic picture of evolutionary history. Moreover, linguistic diversity is possibly still heavily underestimated because the linguistic landscape may have been transformed time and again.
Computation Project (Coordinator: Van De Ville)

Any account of the biological evolution of language must start from an adequate characterization of the language phenotype, and a central aspect of this is how language’s computational system is implemented in the human brain. In this project we take up the prospect for biologically plausible models of language, fully embracing the temporal deployment and probabilistic information flow that characterizes how language works. We take neurobiologically detectable mechanisms as a starting point and work our way to the corresponding computations (instead of starting from linguistic theory, as is more commonly done). In WP NeuroComp we focus on overall computations, while WP SignalRec targets a series of more specific issues in signal processing and learning.

WP NeuroComp

Team:

PIs: Anne-Lise Giraud, Dimitri van de Ville; NCCR-funded researchers: Raphaël Liégeois (shared with WP Statistics), Sevada Hovsepyan, Itsaso Olasagasti; Internal collaborators: Yaqing Su.

Goals:

The WP NeuroComp tackles evolutionary dynamics at the frontier between the structure and the biological substrates of language. By modeling the neural underpinnings of language we explore its biological roots and seek to unravel the structural processes on which it evolved. At the same time the WP offers novel perspectives for the evolution of natural language processing systems. Current language models, based on high-resource statistical learning by artificial neural networks, target short range predictions (next word or next sentence), disregarding how they are implemented in the human brain, hence also the important constraints of maximizing efficiency given limited energy resources. The goal of this WP is to model the neurobiological underpinnings of the language function, emphasizing different computational aspects, e.g. the notions of on-line temporal processing, hierarchy, neural oscillatory processes, predictions, and multiplexing.

Work during the reporting period:

We created two computational models of speech perception that combine the notion of hierarchical inference and that of neural oscillations, one (Task 1) exploring the temporal control of bottom-up versus top-down driving inference; the other (Task 2) exploring the role of hierarchical and nested predictions that include explicit world knowledge to extract the meaning of an utterance from the continuous speech signal. Additionally (Task 3), we have been using experimental data to compare inference mechanisms in brain activations (EEG, fMRI data), relying on recent causal inference techniques for time series data.

Findings and interim conclusion:

Results of Task 1 suggest a new mechanical role for cortical beta oscillations during speech perception (4): alternation of the influence of top-down and bottom-up information on the inference process by rhythmic modulation of state precisions. Such an alternation provides periods in which inference is driven by internal expectations (deployment of strong predictions) and periods in which inference is dominated by bottom-up prediction errors (incorporation of external evidence into the internal model that will be deployed as revised strong predictions in the next round of inference dominated by internal expectations). This finding highlights the necessity of modeling language processing in its real temporal deployment, which current natural language processing models do not yet do.

Findings in Task 2 emphasize the importance of nonlinguistic knowledge in speech comprehension and provide a plausible mechanism for the brain to exploit such knowledge in real time (36). It also highlights the importance of the interplay between internal models and sensory processing in language comprehension. The human brain might be able to build internal models of the world and of other agents based on representations and operations that afford higher levels of abstraction and richer mental models than nonhuman animals. A next step in this project will be to determine the depth of hierarchy that could be sufficient to emulate complex language tasks, such as solving a semantic ambiguity or detecting a grammatical mistake.
In Task 3, we published a new method to characterize the nature of brain functional dynamics (37). This work is being used in the current analyses of brain dynamics elicited by mother speech in preterm and full-term newborns.

**WP SignalRec**

*Team:*


*Goals:*

WP SignalRec investigates the computations underlying language by investigating three specific phenomena of evolutionary significance:

**Task 1:** Vocal learning is shared by humans and songbirds. The way zebra finches learn a song from a tutor has been likened to speech learning in infants in their first year of life. In a comparative approach encompassing both infants and zebra finches, we study interactions between the tutor and the learner and the influence they have on learning progress. We are particularly interested in phonology learning, the emergence of speech sound patterns and how the first words/units emerge and are copied from the surrounding speech environment.

**Task 2:** The human ear and auditory mechanism have presumably evolved to be close to optimal for understanding human speech (although clearly humans are sensitive to other sounds too). We aim to take the best understanding of the human auditory system and evaluate whether it can improve speech technology such as speech recognition. Reciprocally, we aim to analyze deep learning solutions to speech recognition to find what they can tell us about the biological system and its evolution.

**Task 3:** Human language understanding requires more complex structure prediction than seems to be required for non-human communication. The success of attention-based deep neural network models of language structure indicates what kinds of computational models this ability requires. We investigate fundamental computational mechanisms and how they relate to current models of speech processing and to our understanding of the neural mechanisms of computation and learning.

*Work during the reporting period:*

**Task 1:** We have started to use the nearest neighbor method developed for the analysis of bird song (38) to human infants babbling. A major challenge was to segment vocal sounds from background noise and to look for recurrence of stereotypical vocal sound patterns, to study the adult contexts in which they occur.

**Task 2:** Traditional speech recognition solutions have always used rough models of the human cochlea, notably the logarithmic frequency spacing and sensitivity. However, current end-to-end trained solutions are able to improve upon this in terms of speech recognition metrics such as word error rate. A key thread in our work has been to analyze what such end-to-end systems learn in order to achieve such improvements. Furthermore, we have built a framework that allows the traditional sigmoid-like activations of neural networks to be replaced with biologically plausible spiking units. These are enabled using surrogate gradients in the backward training pass.

**Task 3:** We are developing Bayesian models of representation learning (variational auto-encoders) for the unboundedly large bag-of-vector representations used by attention-based models such as Transformers. Our proposed models regularize the number of vectors in the latent bag-of-vectors, which will provide a principled approach to discovering syntactic constituents from the statistics of word sequences.

*Findings and interim conclusion:*

**Task 1:** We found that the vocal units discovered using the nearest neighbor (NN) approach did not correspond well with our expectations formed using the transcriptions of the data. For most of the vocal units examined, the number of NN-retrieved units per file did not correlate with the number of units transcribed from that file. The main reason for the disagreement is the large background noise inherent in the recordings. To better deal with this challenge, in future experiments, we will use LENA portable recording devices (www.leona.org) and separately record background noise, in addition to making use of speech segmentation approaches.
Task 2: End-to-end systems appear to learn wider-bandwidth filters in addition to the usual narrow-bandwidth responses associated with cochlear models; this supports a hypothesis that the mid-brain has evolved to favor voiced speech. Evaluations of spiking neuron models on a speech command task suggest that such models are able to out-perform artificial solutions (7). This will allow us to better understand the evolutionary significance of spiking for auditory processing.

Task 3: We have developed the theory and initial experiments for the first variational auto-encoder (VAE) for Transformer encoder-decoder models, which regularizes the information in the unboundedly large bag-of-vectors output by the encoder. This theory shows that such state-of-the-art attention-based models closely approximate non-parametric Bayesian inference, which provides an essential insight into the unbounded nature of human language. This result plus the empirical success of such deep learning models suggests that non-parametric Bayesian inference is adequate for linguistic structure prediction, opening up new avenues for exploring an evolutionary trajectory towards human brain computation.

Reception Project (Coordinator: Giraud)

The Reception Project explores the biological roots of language in humans and other species, focussing on key neural processes enabling the transformation of a continuous acoustic sequence into meaning. This Project has two WPs: TemporalHierarchies and ProsodyToMeaning tackling two fundamental issues of continuous speech reception: (i) how to chunk continuous speech into basic linguistic elements, and encode these elements while maintaining sequentiality and hierarchical relationships and (ii) how prosodic cues (including rhythm) contribute to meaning and syntax extraction in speech.

WP TemporalHierarchies

Team:

PIs: Anne-Lise Giraud, Didier Grandjean, Martin Meyer. NCCR-funded researchers: Eloise Déaux, Sandrien Van Ommen, Théophane Prette. Internal collaborators: Balthasar Bickel, Chiara Barbieri, Chundra Cathcart, Pierre Megevand; External collaborators: Adrien Meguerditchian (U Aix-Marseille, Marseille, France), Lina Oberlißen (Wolf Science Center, Ernstbrunn, Austria), Marianne Herberlein (Wolf Science Center, Ernstbrunn, Austria), Trang Phan (Vietnamese National U, Languages and International Studies, Hanoi).

Goals:

Neural oscillations are key components of speech perception, as they allow linguistic hierarchies to be deployed in time. However, since they are present in the neural system of most animals, their mere presence cannot explain our evolved ability to perceive and produce speech. The goal of this WP is hence to determine what distinguishes us from other species with regards to neural oscillations and their hierarchical coupling. We hypothesize that the emergence of language-relevant procedures is related to neural oscillations, their interactions, and the order of their hierarchical nesting. By delineating the key auditory processing neural tools that other animals do and do not share with us, this project contributes to the fundamental question of human language evolution.

Work during the reporting period:

Task 1: While dogs are not our closest genetic relatives, they are arguably the species that is most exposed to human speech and able to consistently respond to it. During the reporting period we finished acquiring EEG and behavioral data and began analyzing them.

Task 2: Here we investigate whether the theta/delta rhythm is a recent adaptation or widespread across animal vocal productions. During the reporting period we continued compiling the animal call database and began assembling the phylogenetic tree required to perform the analyses. We explore the presence of this and other rhythms in bird, mammal, reptile and fish vocal sequences in order to determine the prevalence of the 3-7hz rhythm across the animal kingdom and of its possible causal constraints (mechanical articulation constraints vs. neural production/reception. Preliminary results have been presented at the 15th Ecology and Behavior Meeting in March 2022, and will be presented in their final form at the Joint Conference on Language Evolution in September 2022.
Task 3: Using a cross-species EEG approach on dogs, baboons, pigeons, pigs, and rabbits, we plan to explore whether the ability of the neural theta rhythm to track conspecific vocalization modulations, and the presence of nested cortical oscillations are shared features of acoustic communication. During the reporting period we conducted pilot tests on rabbits and pigeons (U Geneva) to refine the experimental protocol and started collecting data in wolves (U Vienna).

Task 4: How universal are organized cortical oscillations when comparing across languages? We are currently collecting data to investigate cortical entrainment and nested oscillations during the perception of Vietnamese, a language for which there is little evidence of the existence of a prosodic level between the syllable and the phrase (39,40). This research is done in the framework of a new collaboration with the Vietnamese National University in Hanoi (MoU signed in June 2022).

Findings and interim conclusions:
The results from Tasks 1 and 2 concur to suggest that there are marked commonalities and differences between human and animals speech/vocal communication both in terms of rhythm production and perception. Particularly, results from Task 2 suggest that mastication may not have been a primary factor in influencing vocal rhythms across species, as the delta/theta rhythm was found across species, including those that do not masticate. Instead, we propose that this evolutionary ancient rhythm may be the result of shared neural constraints deriving from brain architectures (41).

Furthermore, results from Task 1 show that dogs track speech at the word level (delta range) and that delta tracking predicts behavioral response accuracy. Conversely, while increasing speech rate decreases theta tracking, this does not influence behavioral outcomes. From Task 2 we know that dogs’ vocal sequences fall within the delta range.

Together, our current findings suggest that while auditory tracking in the theta domain may pre-date speech production as it is shared with dogs, its recruitment in speech processing required input from production processes that affected syllabification processes.

WP ProsodyToMeaning

Team:
PIs: Martin Meyer, Narly Golestani. NCCR-funded researchers: Chantal Oderbolz, Giulio Degano. Internal collaborators: Paola Merlo, Sandrien Van Ommen, Sebastian Sauppe, Volker Dellwo. External collaborators: David Poeppel (New York U), Elisabeth Stark (U Zurich), Laura Gwilliams (UCSF), Peter Donhauser (Ernst Strüngmann Institute, MPI, Germany).

Goals:
Between the speech signal entering the human ear and abstract representations in the cortex lie a series of neural computations. This WP aims to shed light on the steps involved in this complex process, which unfolds over different time scales and levels of abstraction. Specifically, we seek to explore how prosody – the rhythm and melody of an utterance – might be integral for facilitating the neural mapping of the incoming speech signal onto syntactic structure, providing a physical nexus to the abstract (42). From an evolutionary viewpoint, prosody was likely a vital feature for allowing humans to identify recurring speech patterns and to facilitate the processing of compositionality, and to thus generate complex meaning.

Work during the reporting period:
Task 1 is concerned with disentangling the relative contributions of different features subsumed under the umbrella term prosody (specifically rhythm [stress] and intonation) and to clarify their functions in speech processing using EEG data and phase-based synchronization measures. To this end, in the last year we collected data from 30 participants and are in the final stages of data analysis and are beginning to write the manuscript. In Task 2 we apply a combination of encoding and decoding models on EEG data, to tackle how these features interact with syntactic structure and ultimately result in successful speech comprehension. Here, we are now creating appropriate stimuli and testing out analysis pipelines.
In Task 3, we investigate how a different prosodic measure – prosodic boundary strength – modulates the neural encoding of syntactic information in MEG data during naturalistic speech perception. For this, we used existing MEG data, and probed whether the decoding of syntactic information (i.e. dependency relations within spoken sentences) is stronger when prosodic information is more prominent. Results show that the presence of prosodic information ‘boosts’ (i.e. improves the decoding of) syntactic information in the brain, thus demonstrating an interaction between prosody and syntax.

Findings and interim conclusions:
The results of Task 1 suggest that different prosodic features are used to fulfill different functions in speech processing such that rhythm aids in the perceptual structuring of the speech signal, while intonation comes into play for higher-level linguistic operations such as syntactic parsing (43).

The results of Task 3 show that prosodic information is associated with stronger encoding of syntactic dependency relations in the brain, suggesting that prosodic information improves the temporal specificity of the brain’s ability to process functional closures between words during dynamic and naturalistic speech processing (44).

Our WP results point to potentially different evolutionary trajectories of how the brain processes speech rhythm and melody, and of their relative roles in the perceptual structuring and linguistic processing of speech input. This would be consistent with prosody being a potential evolutionary precursor of, or having evolved with higher-level language, acting as a physical link to syntax and meaning. Prosody interacts with higher-order linguistic information to generate meaning. An intriguing question arising from this is how stable this link is across languages, including languages with radically different prosodic organization, such as Vietnamese (cf. WP TemporalHierarchies).

Production Project (Coordinator: Meyer)
The Production Project addresses the neural bases of speech planning from abstract syntax to articulation. It seeks to understand both the nature of structural and computational hierarchies as cardinal mechanisms in language (planning) and cognition at large, as well as the origins of speech motor control. WP StructurePlanning focuses on syntax and WP SpeechArticulation on speech.

WP StructurePlanning
Team:
PIs: Anne-Lise Giraud, Balthasar Bickel, Martin Meyer; NCCR-funded researchers: Alec Shaw, Piermatteo Morucci; Internal collaborators: Aitor Egurtzegi, Caroline Andrews, Sebastian Sauppe, Timothée Proix; External collaborators: Elisabeth Norcliffe (Oxford U), Ina Bornkessel-Schlesewsky (U South Australia, Adelaide), Itziar Laka (U Basque Country, Vitoria-Gasteiz), Kamal K. Choudhary, Mahima Gulati, Shikha Bhattamishra (IIT Ropar, Rupnagar, India); Associate Investigator: Nathalie Giroud.

Goals:
We tackle the question of how hierarchical syntactic structures are deployed in speaking and what comprises the neural underpinnings of these processes. Hierarchical syntactic structures, i.e., structural asymmetries between heads and dependents, are a fundamental feature of human languages and are at best marginally found in animal communication systems. By studying the processing of sentences with different types of hierarchical dependencies in factorial experiments and in free, naturalistic speech, we explore whether different structures are deployed and implemented by identical or different neural networks and functions (as instantiated by oscillatory activity and functional connectivity). This will provide the foundations for understanding the neural bases of the production of hierarchical syntactic structures, a prerequisite for exploring their evolution.

We begin by exploiting a minimal contrast in Swiss German between crossing, nested and adjoineded dependencies, structures that are freely exchanged with no impact on meaning or context. We will extend our experiment plans to Vietnamese serial verb constructions in the next two years because they allow minimal and entirely unmarked contrasts between hierarchical (e.g. causal) and conjunctive (‘and’) structures. Meanwhile, intracranial recordings...
from free speech (at the HUG hospital in Geneva, hence in French) will give insights on how hierarchical
representations arise during planning in a naturalistic context.

Work during the reporting period:

On the experimental side, we studied the production of crossed dependencies, a syntactic phenomenon only
attested in three languages worldwide. In Swiss German, the order of verbs in the sentence-final verbal complex
of subordinate clauses is free, so that structures with crossed, nested (center-embedded) and adjoined
dependencies occur without any differences in semantic or pragmatic meaning. We have now completed analysis
of a first behavioral experiment (online) and demonstrated that the preparation of nested dependencies is
associated with less planning effort than the preparation of either crossed or adjoined dependencies, leading to
significant differences in speech onset latencies. This goes against self-reports by participants, and native speakers
more generally prefer crossed dependencies as the most natural choice — we will corroborate this difference with
usage frequency analyses of corpora of spoken Swiss German. Our result also shows that speakers already prepare
the word order of the whole sentence before starting to speak, suggesting that an atemporal preparation phase
could at best be very short. To further explore these initial observations we have started data collection in an EEG
study contrasting the different Swiss German dependency types. This will provide more fine-grained temporal
detail on the planning processes as well as show which neural frequency bands are functionally involved in
hierarchy preparation.

During the reporting period we also started to collect intracranial recordings during free speech episodes (6
patients so far). The postdoctoral fellow who will analyze these data will start in October 2022. Data analysis will
take information-theoretical measures during the recorded speech periods and correlate them to the neural
dynamics in relevant brain regions.

Since neural activity during sentence planning is vastly unexplored territory, making our EEG findings hard to
interpret, we complement our research with EEG studies differentiating the planning of sentences that start with
versus those without an explicitly marked dependency to something later (e.g., an early ergative marker that points
to a transitive verb at the end of the sentence). In an associated SNSF project carried out together with WP
SemanticRoles, we published new findings on Hindi (5) and Basque (6), suggesting that event-related power
synchronization in the theta band reflects syntactic choices, while desynchronisation in the alpha and beta bands
reflects the way competing structures are accessed and manipulated before speech articulation begins.

Findings and interim conclusions:

Our preliminary results suggest that nested dependencies are preferred over both crossed and adjoined
dependencies even though they come with longer dependencies and have been argued to be computationally more
demanding than adjoined dependencies during comprehension. This preference for nesting in sentence planning
might have evolved from the intrinsic nesting in action planning (with hierarchically embedded sub-routines), a
possibility we are currently exploring in the new SIG Cultures and Action Structures.

WP SpeechArticulation

Team:

PIs: Marina Laganaro, Volker Dellwo; NCCR-funded researchers: Daniel Friedrichs, Monica Lancheros, Tanja
Atanasova; Internal collaborators: Balthasar Bickel, Chiara Barbieri, Lei He, Martin Meyer.

Goals:

We investigate the ontogeny and phylogeny of speech production, specifically: (i) how and when the production
of speech relies on efficient/stored motor speech routines, and (ii) how changes in the anatomical properties of the
articulators throughout time contributed to speech evolution. Understanding the ontogeny of expert speech
production and the conditions of practice and cognitive control underlying it contributes to the key issue of the
conditions which allowed the evolution of humans to transform an (abstract) linguistic message into efficient
articulated speech. Further, the investigation of changes in the anatomical properties relates to the fact that human
jaw shrinkage has been observed since the transition to softer diets among food-producing societies (45).
Work during the reporting period:
We ran a behavioral, acoustic, and neurophysiological (EEG/ERP) study on the production of speech (syllables) and matched non-speech gestures in a group of 18 children (7-9 years old) and 18 adults. In addition, we studied the effect of mandible size on temporal properties of speech in 14 adult talkers producing speech (syllables) using electromagnetic articulography (EMA) and speech amplitude envelope analyses.

Findings and interim conclusions:
ERP data revealed activation of the same global electrophysiological patterns preceding the production of speech and non-speech sequences in children, indicating the recruitment of the same neural networks. At the same time, adults showed different brain activation patterns for speech and non-speech, which supports the hypothesis that speech motor plans are not routinised in 7-9-year-old children and adult-like speech is only reached in adolescence (46). Further results from behavioral and acoustic analyses underline this and suggest that speech routinization is costful, and several years of speech practice are needed to build efficient motor speech routines (47). Overall, the results are puzzling in terms of the efficiency of speech and the amount and variety of speech gestures within and across languages. Acoustic analyses are currently being run to yield converging results on the same population and speech material.

The results of the articulatory study (48) showed that talkers with shorter mandibles produced syllables at a significantly higher rate than those with longer mandibles under certain controlled conditions (fast repetition of consonant-vowel sequences). Reconstruction of jaw kinematics revealed that talkers with longer mandibles needed considerably more time to raise their mandibles (mouth closure), which resulted in an extended fall-time of the speech signal’s amplitude. In such cases, raising the mandible is likely influenced by other factors such as its natural resonant frequency (49). Because these findings suggest that temporal dynamics may have been affected by human jaw shrinkage since the transition to agriculture, further research on the encoding of anatomical properties in the speech signal is essential to understand how segmental timing evolved in the world's languages. Another challenge is how to reconcile our findings with those of WP TemporalHierarchies, which suggests that anatomy has very limited consequences for rhythmic structure in communication. We will zoom in on these questions in the next few months.

Variability Project (Coordinator: Golestani)
The Variability Project addresses an essential issue of language as a biological product, namely the variability in its expression, spanning from physiology to pathology. While WP Aptitude focuses on variation ranging from language disorder (dyslexia) to multilingualism and polyglottism, WPs NeuroModulation and DigitalForDisorders assess the extent to which (neuro- and digital-)technological evolution can assess and remediate the biological capacity for language. Together, these WPs shed light on the genetic and environmental foundations upon which the biological evolution of language must have operated in the past, and on how this foundation might interact with future evolution in technology, in particular with regard to its plasticity.

WP Aptitude
Team:
PIs: Narly Golestani, Raphael Berthele. NCCR-funded researchers: Alessandra Rampinini, Irene Balboni. Internal collaborators: Aspasia Sfakaki, Olga Kepinska, Sevil Maghsadhagh. External collaborators: Cathy Price (UCL), Christian Doeller (MPI Leipzig), Clyde Francks (MPI Nijmegen), Evelina Fedorenko (MIT), Isabelle Udry (Institute of Multilingualism, Fribourg), Jutta Mueller (U Vienna), Laurent Cohen (INSERM UMRS 975), Maaike Vandermosten (KU Leuven), Michael Ullman (Georgetown U), Peter Schneider (U Heidelberg), Robert Zatorre (McGill U), Simon Fisher (MPI Nijmegen), Susanna Reiterer (U Vienna), Véronique Bohbot (McGill U).

Goals:
Language learning and skills arise from an interplay between domain-general and domain-specific cognitive factors, which are in turn modulated by the complex interaction of predisposition and experience. Language use in phylogeny and ontogeny evolves dynamically and often multilingually as individuals draw on cognitive abilities
to construct social and cultural realities. The variability in our study population and the in-depth investigation of the participants’ linguistic and non-linguistic abilities, previous language and related experiences, brain function and structure, and polygenic profiles allow us not only to characterize the broad and multidimensional contributors to individual differences in language skills, but also to model the relative contributions of evolving experience-dependent abilities (plasticity) versus innate predispositions to these. Our participants span a wide continuum of language skill and experience, from monolinguals, bi- and multilinguals to polyglots (i.e. speaking 10 or more languages), as well as dyslexic readers. The sample characteristics will maximize variability and will thus optimize the study of the aforementioned dimensions and their interplay.

Work during the reporting period:

A broad behavioral and brain imaging battery has been developed during the first two years, via access to established tests through international experts in the respective subdomains. Through collaboration with WPs DigitalForDisorders and WP EduGame, the programming of the test material and tasks has resulted in a comprehensive battery of 7 questionnaires and 24 tasks for online, large-scale testing, also shareable beyond the present WP.

The WP is currently in the data acquisition stage. Participants are now tested on an extended battery of questionnaires and behavioral tests, online and in person. Domains tested include general cognition (attention, inhibition, different memory systems), linguistic processing including phonology, rote/vocabulary learning, morphology and syntax, as well as non-linguistic domain-specific skills including musical, arithmetic and motor skills. Participants will be invited back for functional and structural neuroimaging and for saliva collection (for genetic analyses) starting in September 2022.

Findings and interim conclusions:

Our work has led us to a reconceptualization of language aptitude as a broader spectrum of skills to which general cognition, language-specific skills, brain function and structure contribute, likely via experience-based plasticity and predisposition. Preliminary results in a smaller existing collaborative data-set suggest that linguistic skills and general cognitive abilities are strongly interrelated in adults, consistent with what has previously been shown in children. This remains to be corroborated in the data to be obtained in our WP.

For now, results suggest that individual differences in linguistic skill may have co-evolved with individual differences in non-linguistic cognitive domains. The results have implications for foreign language learning as well as for our general conception of language skills; they suggest that the overlap between language aptitude and general cognition is stable across age, and also that it’s independent of the language learning context. A finer assessment of a wider range of domains in a larger sample will shed further light on this. In addition, analysis of the genetic data will more directly clarify the contribution of gene sets in determining how individual differences in language skill, aptitude, and relevant aspects of general cognition may have evolved (through polygenic risk score assessment).

WP NeuroModulation

Team:

PIs: Adrian Guggisberg, Anne-Lise Giraud, Silvia Brem; NCCR-funded researchers: Amelie Haugg, Camille Farcy, Kinkini Bhadra, Nada Frei, Silvia Marchesotti; Internal collaborators: Iliana Karipidis, Léa Chauvigné, Martina Röthlisberger, Martin Meyer, Narly Golestani, Shizhe Wu; External Collaborators: EEG-BCI facility staff at Campus Biotech (U Geneva).

Goals:

Human brains have evolved into specialized neural networks supporting, among others, the evolutionary ancient oral and the very recent written language functions. The overall aim of this WP is to examine how advanced neuromodulation approaches can help to restore or improve such diverse language functions in the future with a special emphasis on clinical populations (aphasia and dyslexia). In Task 1, we aim at testing if we can enhance neural processes related to naming with non-invasive brain stimulation methods. In Task 2 we develop a non-invasive Brain–Computer interface (BCI) that allows decoding imagined speech units from non-invasive (EEG)
and intracranial (ECoG and SEEG) neural features (50) to learn about the neural mechanisms of covert speech. Finally, in Task 3 we use neurofeedback to target the function of a brain network in the occipito-temporal cortex (OT) that shows impressive plasticity during ontogeny in the phase of literacy acquisition and becomes crucial for fluent reading.

Work during the reporting period:

We completed an experiment on healthy adult human subjects (Task 1), where we showed that non-invasive brain stimulation with transcranial direct current stimulation (tDCS) can facilitate learning new action verbs by enhancing neural communication of language areas of the brain. In addition, we report the neural effects of an alternative form of brain stimulation, transcranial alternating current stimulation. In Task 2, we are extending our pool of healthy participants (+6) and analyze preliminary EEG and behavioral data. We are adapting our BCI loop to intracranial signals for patients undergoing pre-surgical evaluation for epilepsy. Together with TTF Tech we are developing adaptive decoding algorithms to improve the classification of our BCI system. In Task 3 we finished our first proof-of-concept study with 40 healthy adults who learned to either up- or downregulate the activation in the left OT with real-time fMRI neurofeedback.

Findings and interim conclusions:

Two original (Tasks 1 and 3) and one review article (Task 2) are in preparation. In Task 2 we completed a first intracranial EEG recording and were able to technically improve the BCI loops with adaptive decoding algorithms. In Task 3 our data show the feasibility to volitionally regulate OT activation. Neuromodulation approaches do not only make use of the brain's plasticity to improve performance, but, importantly, also provide valuable insights into the causality of brain signal changes and behavior. Thus, the three neuromodulation tasks targeting very different aspects of language processing allow for gaining a better understanding of how both dysfunctional and normalized brain signals are associated with language-related behavior in a causal fashion. To summarize, our first results show that both evolutionary ancient and very recent human language functions can be targeted successfully with neuromodulation techniques and, thus, have a great potential for improved, individualized treatments in various language disorders.

WP DigitalForDisorders

Team:


Goals:

We explore the future of diagnostics and interventions for language disorders in a cross-methodological approach, including new digital (e.g. VR/AR/App-based) tools and to characterize the brain plasticity underpinning changes following language treatments.

Task 1 investigates the behavioral and neural plasticity effects of immersive Virtual Reality (iVR) based language treatment tools in close to real-life communication contexts in adults. At first, iVR-based lexical learning (new word learning in neurotypical adults) has been evaluated against standard digital learning/recovery to assess whether iVR induces faster learning and better lexical-semantic integration than standard approaches. In a second step recovery (from anomia in participants with aphasia) following iVR-based treatment will be evaluated against standard treatment approaches behaviourally and electrophysiologically.

Task 2 examines future avenues for screening literacy skills in children and supporting patients with reading disorders. First, we develop and evaluate app-based literacy screeners for alphabetic languages of different orthographic depths (in collaboration with WP EduGame: German, Italian, French and most likely also English to cover the full transparency range). Second, we characterize plastic changes in the brain during the learning of letter-speech sound correspondences in a large group of school children of varying reading skills from very poor to good readers. This will help us better understand how such learning differs and where problems arise. These
findings will be important for leveraging digital or neuroscience-informed technologies (i.e. real-time neurofeedback, see WP NeuroModulation) to improve the support for struggling readers, contributing to the interaction between future evolution of language and technology.

Work during the reporting period:

Task 1: Our study on 30 neurotypical adults showed that new-word learning with iVR does not lead to better short-term learning relative to a matched standard approach on tablet, but it leads to better consolidation and lexical-semantic integration of the newly learnt words. We are currently analyzing the EEG/ERP results.

Task 2: We analyzed data for preparing a first publication on the plastic brain changes during letter-speech sound learning in more than 70 children and for comparing paper-pencil and app-based literacy screeners. Based on these results we are now developing a new paradigm and study design for fMRI-based neurofeedback to support such learning (with WP Neuromodulation). Together with WP Neuromodulation we finished a pilot study including 18 adults with dyslexia on the regulation of the ventral occipito-temporal cortex. We have prepared the German contents for the literacy screener to be used in a training study in WP EduGame.

Findings and interim conclusions:

We showed an advantage of iVR on lexical-semantic integration of newly learnt words (51), the comparability of paper-pencil and App-based literacy screeners in 284 children of 2nd and 3rd grade is (MS under revision), and brain plasticity during character-speech sound learning and marked differences in brain connectivity during learning in >70 children with and without dyslexia (MS in preparation). App-based screeners are easy to apply and can be made available for the public. This will allow a fast and low threshold identification of potential problems during reading acquisition. Learning with iVR favors lexical-semantic integration of new words probably through enhanced interaction/communication relative to standard/static word learning. The amazing plasticity of our brain which we see e.g. during learning processes, is an important prerequisite to develop more targeted neurotherapeutic approaches for patients in the domain of written and spoken language.

Sociality Project (Coordinator: Stoll)

The central goal of the Sociality Project is to shed light on the role of social interactions in driving the ontogeny and biological evolution of communicative competence across species. The project explores the role of directed and surrounding acts of communication in human and nonhuman primate infants to find out whether, how and which features (joint attention, contextual cues etc.) of directed communication are necessary for language learning. To tackle the evolutionary question of these features we compare learning in human infants with our closest relatives, the bonobos and chimpanzees. To understand how meaning gets extracted from the environment we focus on extralinguistic cues and their integration into meaning development with two WPs, EarlySurround and SocialContext.

WP EarlySurround

Team:

PIs: Carel van Schaik, Klaus Zuberbühler, Sabine Stoll; NCCR-funded researchers: Caroline Fryns, Franziska Wegdell, Johanna Schick; Internal collaborators: Eklavya Sarkar, Guanghao You, Mathew Magimai Doss, Simon W. Townsend; External collaborator: Marion Laporte (Sorbonne, Paris)

Goals:

Our goal is to understand the role of communicative input (both directed and surrounding) in humans and nonhuman primates (chimpanzees and bonobos) to shed light on its relative importance in the ontogeny and biological evolution of language. We test current theories regarding the importance of child-directed communication (CDC) compared to child-surrounding communication (CSC) in the evolution of language. We aim to, first, assess the presence of CDC in great-apes and, second, we disentangle the relative importance of CDC and CSC in language learning in the Hominin lineage. We apply a comparable data collection and analysis framework across all 3 species (humans, chimpanzees and bonobos) to assess the types and amounts of vocal
inputs in both infant-directed and infant-surrounding communication in human infants and immature apes to find out whether child-directed communication is an ancestral feature or has newly evolved in humans.

*Work during the reporting period:*

We have developed a comparable recording and coding scheme for human, chimpanzee and bonobo data collection, which consists of day-long recordings of immatures and their surroundings. We also initiated fieldwork across all three species by quantitatively and qualitatively documenting and comparing child-directed and child-surrounding vocal behavior. To facilitate unambiguous identification of call types produced during child-directed or child-surrounding communication in bonobos, we have revisited their vocal repertoire to apply a more objective, non-linear dimensionality reduction approach.

During the reporting period we have furthermore analyzed the state-of-the-art and significance of child-directed communication from both an ontogenetic and phylogenetic perspective in the form of an opinion paper (cf below). For human speech, we have developed a machine learning algorithm to automatically distinguish child-directed from adult-directed communication. So far, this algorithm has been applied successfully to Chintang and English, but we plan to further develop it to automatically annotate and quantify child-directed and child-surrounding speech in a number of ACQDIV languages.

*Findings and interim conclusions:*

In an opinion paper (8) we suggest that child-directed speech is a specific teaching device and a crucial part of natural pedagogy. We demonstrate that CDS is a universal feature of human communication but also that there is enormous cross-cultural variation both in the amount and the features of CDS, which is relevant for theories of linguistic evolution. Based on existing data, we suggest that directed communication is nearly absent in our closest relatives, the great apes, but present to some degree in other species that are less closely related to humans, such as marmosets, suggesting convergent evolution. We also disentangled structural from acoustic features showing that some of them are uniquely human (but not necessarily present in all cultures) and others are shared with animals. Given the enormous cross-cultural variation of CDS, we propose that child-surrounding speech represents an important focus for future research.

Initial analysis and comparisons of our day-long, comparative data sets suggest that great apes engage in far less child-directed communication compared to humans. This tentatively supports our proposal that, at least within the primate lineage, child-directed communication may have evolved de novo and that vocal learning in apes must be fostered by infant-surrounding communication.

Through applying machine learning models to naturalistic data, we have shown that features of child-directed speech can be detected from features of adult-directed speech. Specifically, we demonstrate that structural features alone are sufficient to distinguish the two genres. Acoustic features, even though prevalent, are less important for automatic differentiation. This finding sheds light on the importance of structure as a main characterizing feature of child-directed speech.

We will present these results at the *Cognitive Science Conference* in July 2022 and at the *Joint Conference on Language Evolution* in September 2022.

**WP SocialContext**

**Team:**

*PIs:* James Henderson, Sabine Stoll, Simon Townsend; *NCCR-funded researchers:* Joseph Mine, Melika Behjat, Miranda Dickerman; *Internal collaborators:* Anshul Gupta, Jean-Marc Odobez. *External collaborators:* Claudia Wilke (U York, UK), Katie Slocombe (U York, UK) and Zarin Machanda (Tufts U, USA).

**Goals:**

We investigate how the social environment impacts meaning disambiguation in humans and primates, by combining methodological approaches from linguistics, primatology and natural language processing. We analyze how meaning is derived from both signals and extra-linguistic cues, such as gaze, facial expressions, gestures and
the surrounding environment. This is important to detect the evolutionary balance between on-the-spot interpretation and sign-mediated ritualization of meaning.

Our analyses also have an impact for the development of new technologies. We design machine learning approaches for the induction of meaningful units from sequences of text and we investigate how to improve this via grounding including cues from the environment into our algorithms. This sheds light on how artificial communicators might evolve in the future.

Work during the reporting period:

We focus on the question of how meaning can be detected by human infants, chimpanzees and machines. In human infants, we focus on the role of joint attention in naturalistic contexts. We ask how much and what kind of joint attention is present in interactions with children in diverse cultures in their daily lives. In collaboration with internal collaborators at IDIAP, we have created a testing dataset and a semi-automated data preparation pipeline for machine learning-based annotation of joint attention in naturalistic data. In parallel, in studying meaning disambiguation in chimpanzees we go beyond alarm calls to better understand the meaning transferred in other communicative acts. We have developed a coding scheme for an existing chimpanzee data set focussing on extralinguistic cues deployed during vocal events. We apply collocation analysis (24) to the data to detect correlations between these cues and the accompanying vocalizations. To allow for automatic meaning detection and automatic analysis of human data in an unsupervised way, we have also developed new models for inducing meaningful units from text. We have developed a new evaluation framework for showing the one-to-one correspondence between the units identified and the real morphemes. Lastly, to unite these three strands of research together, we have been working on the draft of a review paper on the role of contextual information in the process of meaning disambiguation.

Findings and interim conclusions:

We have shown that joint attention can be automatically detected with a visual algorithm adapted for our purpose and demonstrated that joint attention is a main feature of child-directed communication in natural settings. We have tested the algorithm in two culturally diverse settings (Tuatschin and Shipibo).

We have also made progress in reconstructing an effective multi-modal repertoire of communicative signals in chimpanzees. Using collocation analysis, we have shown upwards of 30 distinct extra-linguistic-like cues, ranging from body movements to postures and orientation, which reliably co-occur with specific vocalizations. Preliminary analyses suggest that there is a considerable range of extra-linguistic-like cues accompanying calls. Especially less context-specific calls and potentially also vocal events where precision of information transfer is critical (such as during dominance interactions) correlate with extralinguistic cues.

In a paper (52) on detecting meaningful units, we proposed the first unsupervised unit discovery method. This is a viable alternative to hand-coded tokenizers.

Finally, in a collaborative opinion paper (8) we have been presenting a common approach to meaning that unites the three disciplines of our WP, language acquisition, primatology and NLP. We argue that distributional (statistical) approaches to meaning disambiguation are useful in all three disciplines. Together, our observations suggest that our last common ancestor with chimpanzees combined gestures and vocalizations into a vast repertoire of multi-component communicative signals, a capacity that is at the heart of the biological evolution of the language faculty.

Cooperation Project (Coordinator: Zuberbühler)

The Cooperation Project explores the relation between human hyper-cooperation and the origins of language. It investigates this relationship at three different levels of analysis - cognitive (WP MentalState), behavioral (WP JointAction), and communicative (WP Accommodation) processes.
WP MentalState

Team:
PIs: Fabrice Clément, Hans-Johann Glock, Klaus Zuberbühler; NCCR-funded researchers: Cameron Alexander, Derry Taylor; Internal Collaborator: Gökhan Gönül. External Collaborator: Zanna Clay (U Durham)

Goals:
Our main goal is to articulate and test a novel theoretical framework concerning the socio-cognitive foundations of language. Mainstream accounts of social cognition, in particular the Theory-of-Mind account (53), are beset by unresolved conceptual and empirical problems. With adapt script theory to provide an alternative account of social cognition that resolves these issues and makes novel predictions. We further aim to test these predictions using experimental techniques designed to evaluate socio-cognitive processes in pre-linguistic subjects, great apes and human infants, and linguistic subjects, children, from different cultures, which is relevant for both linguistic and biological evolution. The results of these studies will shed new light on the evolutionary roots of language by (i) establishing whether script theory provides a scientifically useful account of social cognition in pre-linguistic and linguistic subjects, and (ii) illustrating the extent to which socio-cognitive processes resemble one another in humans and other great apes.

Work during the reporting period:
We designed and started to conduct observational and experimental fieldwork into the socio-cognitive abilities of wild chimpanzees at Budongo, Uganda. The field experiment involves human demonstrators modifying routine behaviors to test whether wild chimpanzees use social scripts to understand human behavior. Data collection is currently ongoing.

We are also conducting an eye-tracking study in Basel Zoo to test script-use in captive great apes, which has produced encouraging pilot results. This zoo study also feeds into a comparative eye-tracking study with human infants, to be conducted at the Baby Lab (U Neuchâtel). We are also preparing a comparative study between children in Switzerland and Uganda, to investigate whether scripts are subject to cultural variation.

Findings and interim conclusions:
We have submitted a theoretical paper, which summarizes the script perspective on social cognition and illustrates its ability to resolve outstanding issues within the literature (54). In this paper, we reinterpret a classic false-belief task used in eye-tracking studies and show that infants can pass such tasks without having to refer to a Theory of Mind account, provided they can learn a script during the familiarization phase of the experiment. We have developed hypotheses from script theory, which can be tested in infants and nonhuman primates. Script theory is not dependent on linguistic abilities and as such accessible for research with non-human animals, providing a toolkit for reconstructing the biological evolution of language. For instance, we suggest a ‘second try’ condition for the implicit false-belief task to test whether an observing subject uses a script to make sense of an agent’s behavior which violates the subject’s expectations in incongruent conditions.

We have also submitted a registered report (MS under review), which promises to reveal developmental patterns in children’s acquisition of scripted patterns by using some social cues (affective and dominance cues) in a social rule learning scenario.

Observations of wild chimpanzees in Budongo in 2021 and 2022 have fed into experiments to be conducted with wild chimpanzees, and captive great apes (for which we have conducted pilot testing). Wild chimpanzees respond to (deviations from) regular human activities in their ecological niche. Human demonstrator experiments piloted in April - June 2022 test how stable wild chimpanzee representations of regular human activities are. Our observational evidence of wild chimpanzee script-use suggests measurable ontogenetic differences between juveniles and adults when attending to humans. Juveniles visually attend to human followers more frequently and for longer periods than adults, and adults tend to move away from human followers when the human deviates from the script of a regular activity. Initial analysis of eye-tracking data from Basel zoo suggests that captive chimpanzees also use scripts to understand human behavior.

These findings indicate that pre-linguistic subjects use scripts to understand others in social contexts. Overall, our achievements to date suggest that a de-intellectualized account of important forms of social cognition is possible.
Moreover, complex communication, long thought restricted to ‘mind-readers’, may have its phylogenetic and ontogenetic basis in scripted behavioral sequences. This suggests that the evolutionary origins of sophisticated social cognition and communicative abilities in humans is grounded in a shared cognitive ability to organize reality in terms of a collection of social scripts, of how events typically unfold, an account that makes references to mental states as principle drivers of behavioral decision-making obsolete.

**WP JointAction**

**Team:**
Adrian Bangerter, Judith Burkart; NCCR-funded researchers: Emilie Genty, Jessie Adriaensen, Natalia Morozova; Internal collaborators: Fabia Miss, Sabine Stoll, Sébastien Quigley, Sidney Maffini, Théo Schöpfer; External collaborator: Federico Rossano (UCSD).

**Goals:**
We explore the assumption that one of the motors for the biological evolution of language is joint action, which is intricately linked to prominent concepts like shared intentionality, joint commitment, and co-representation. To address this assumption empirically, we assess the cross-cultural ontogeny of joint action coordination in three maximally diverse languages: Vietnamese, Swiss French, and Shipibo-Konibo (Peru). To investigate the evolutionary origin, we study on the one hand our closest relatives, the great apes, to pinpoint which elements of joint action in humans can be explained by common descent from the last shared ancestor. On the other hand, we study cooperatively breeding marmoset monkeys, who are less closely related to humans but have convergently evolved systematic reliance on joint action. Since humans are cooperative breeders too, marmosets help us identify the role of cooperative breeding during language evolution. Since the prominent concepts we investigate are difficult to define and operationalize, we also aim at unifying this research in conceptual analyses.

**Work during the reporting period:**
Several strands of research are ongoing. The first is ontogeny where we collected the data from Vietnamese adults in Vietnam and currently coordinate the study of 4- to 7-year-old children and adults in Neuchâtel. (This work is done within a new collaboration framework that we established with the Vietnamese National University in Hanoi; cf WP TemporalHierarchies). The second is on signaling transitions in joint actions in great apes and marmosets. We code communicative signals in apes during grooming and play, as a means to study joint commitment. The statistical analyses are in progress. We furthermore analyze social play and infant transfers in marmosets, and investigate how marmosets signal joint action transitions, how this may functionally affect the joint action itself, and which role joint commitment may play. So far, we completed the data collection for both projects and are working on coding and statistical analyses. First results have been presented at the EFP/GfP conference in Utrecht. Finally, in a comparative study, we have quantified co-representation in marmosets, capuchin monkeys, macaques and human children (55–57). To bring these strands together, we have been working on several review papers and comments which integrate different strands of research on joint action ranging from co-representation during joint action to shared intentionality and joint commitment (11,57,58). Together with WP Mental States and TTF Concepts, we have organized a joint seminar Biology and Philosophy at the University of Zurich to scrutinize joint action from different fields.

**Findings and interim conclusions:**
We find that joint commitment can be best viewed as an interactive process, which critically enables its empirical assessment in nonhuman primates (57). The interim conclusion of this comparative work is that several precursors like rudimentary forms of joint commitment are present in nonhuman primates and therefore can not be the result of language.

Our findings also suggest that co-representation per se is automatic and widespread in primates and young children, but that only more cooperative species (marmosets and human children) use mutual gaze as a coordination marker to flexibly adjust it, suggesting both evolutionary convergence and homology (55,56). These findings also suggest that cooperative breeding indeed played a prominent role in language evolution (11).
WP Accommodation

Team:
PIs: Judith Burkart, Volker Dellwo; NCCR-funded researchers: Elisa Pellegrino; Kaja Wierucka; Internal collaborators: Andrea Froehlich, Debora da Cruz, Claudia Roswandowitz, SilvaNikhil Phaniraj, Yvonne Zürcher. External collaborators: Thayabaran Kathiresan (Telepathy Labs GmbH, Zurich).

Goals:
Similarity generally facilitates cooperation, and one means to achieve similarity in communication is vocal accommodation. Otherwise rare in primates, vocal accommodation is relevant to understand language evolution. The overall goal of this project is to elaborate similarities and differences in vocal accommodation in humans and marmosets, to understand what elements were precursors, rather than consequences of human language, and perhaps evolved convergently in humans and marmosets as a result of cooperative breeding. In both humans and marmosets, we are in particular interested in elaborating how the different needs of signaling similarity and closeness through accommodation vs maintaining individuality produce tradeoffs that predict when individuals should be more likely to converge and when to diverge. Disentangling vocal features that are more prone to convergence from those who tend to remain stable within and between speakers in interactions also contribute to make the development of language patterns somewhat more predictable.

Work during the reporting period:
We examined the flexibility of human vocal modulation dynamics by studying vocal accommodation and voice individualization in an experiment where the need to signal individual identity by voice varied, by varying group size. We collected speech production and speaker recognition data in ludic cooperative situations with groups of three and five players. Between-speaker acoustic similarity across group size was calculated using the i-Vetor/PLDA speaker verification system VOCALIZE (59), and compared the speaker verification performance of the same system with voices obtained in groups of 3 and 5 speakers. To investigate how the need to signal identity influences vocal accommodation in marmosets, we compared vocal accommodation in closed distance contact calls (signaling identity not important because transmitted visually) and long distance contact calls (vocal identity is crucial, (13)). We have developed new machine learning (ML) approaches to analyze marmoset vocalizations and compared the robustness and consistency of various data processing and ML approaches in classifying marmoset vocalizations. Based on these approaches, we are currently synthesizing calls of conspecifics to sound more or less similar to the caller for playback experiments that examine whether higher similarity elicits more cooperative vocal turn-taking exchanges. In addition to this long-term accommodation in captivity, we are currently collecting long-term accommodation data in the wild (Brazil) and short-term accommodation data in captivity.

Findings and interim conclusions:
We have found that in humans (i) acoustic similarity between speakers increases, rather than decreases in a larger group, and (ii) the system verification performance deteriorates when the testing conditions involve speech collected in a larger group. These results show the prevalence of convergent accommodation in larger groups with negative effects on voice discriminability. This suggests that interactions in larger groups of unacquainted speakers are the type of communicative settings in which signaling in-group cooperation and social cohesion through convergence has priority over individualization.

For the marmosets, we managed to develop a new, highly accurate (over 95%) hierarchical classifier of calls, which will enable setting up automated recordings and thus a much larger body of data. We found that vocal accommodation in marmosets is robust and consistent across data extraction and processing methods and that as predicted, they accommodate more and faster in short than long distance calls. Overall, we find substantial overlap in patterns of vocal accommodation in humans and marmosets, in line with evolutionary convergence. In both species, the need to signal individuality critically changes the extent and pace of accommodation in a way that supports the function of signaling social closeness and cooperativeness. This social function can thus not be the result of language. Rather it is a likely mechanism on which language evolution could eventually build. Future
work will allow us to also pin down under what conditions – for example, cooperative breeding (11) – this social function of vocal accommodation is most likely to emerge among primates.

**Digitisation Project (Coordinator: Bavelier)**

The Digitisation Project focuses on the future evolution of language. It explores the impact of language technology and artificial languages on human linguistic intuitions, mental representations and speech output. WP CompuLang focuses on how we interact with artificial communicators while WP EduGames probes the impact of digital technology in language.

**WP CompuLang**

*Team:*

*PIs:* Christian Lovis, Martin Volk; NCCR-funded researchers: Anastassia Shaitarova, Jamil Zaghir; *Internal collaborators:* Anne Göhring, Christophe Gaudet-Blavigac, Jean-Philippe Goldman, Julien Ehram, Mina Bjelogrlic; *External collaborator:* Pierrette Bouillon (U Geneva, Department of Translation Technology).

*Goals:*

The WP CompuLang, concerned with questions of linguistic evolution, investigates how the increased exposure to machine-generated language might impact human linguistic intuition and natural language production. We work with the output of commercial machine translation systems, specialized auto-completion tools, and generative language models such as GPT2. Considering that the state of the art in the field of Natural Language Processing advances rapidly, our evaluation is dynamic and multifaceted. Aside from retrospective studies, we prepare a thorough lexico-syntactic analysis of machine-produced texts and compare the results to human writing. Additionally, we conduct psycholinguistic experiments in order to investigate the correlation between machine-produced language and human language production.

*Work during the reporting period:*

We have pursued our retrospective study on the HUG autocompletion tool usage by gathering temporality information to make the study feasible. We designed experiments with the hypothesis that humans optimize their conduct using this autocompletion tool with experience, that is, they reduce the time spent on the technology by typing fewer characters to select labels. The experiments consist in monitoring the user’s typing over his working time, quantitatively and qualitatively. In our work on machine translation effects, we completed a pilot study with five language learners which provided insights into the development of the psycholinguistic experiments. Currently, the group is finalizing and automating the setup, and moving the experiments online. Additionally, we are concluding our corpus linguistics investigation of commercial machine translation output.

*Findings and interim conclusions:*

Physicians using auto-completion tools to report patients’ health problems and drug prescriptions are in a precarious situation that needs to be monitored. Our preliminary findings (60) show that, with experience, physicians type fewer characters to find the corresponding item. At the same time, they type fewer prefixes per item, showing that they found more appropriate prefixes for each item. While health professionals are under constant pressure, they seem to intuitively reduce the time spent typing to find the correct item.

On the other hand, despite the rapid improvement of commercial MT engines, their output continues to exhibit lexical and syntactic homogenization and simplification. Our experiments confirmed this for German texts produced by three under-researched MT engines frequently used in the context of German (a language we chose for its societal relevance in our context). Depending on the textual domain however, one system in our experiment outperformed the human translation in terms of morphological variability. Another system’s homogenization is partially due to avoidance of borrowings in favor of “native” German words. Since the scope of human exposure to MT output is vast and often underestimated, these findings provide an insight into potential near-future linguistic evolution. Text generation tools are designed to mimic natural language and currently produce fluent and grammatically correct output (which still has issues with regard to text coherence and logical entailments).
Inductive and algorithmic biases, carried by the algorithms, create an almost imperceptible yet undeniable shift in the produced language. Continuous exposure to these tools makes human language susceptible to this shift, affecting the evolution of language in the long run. We observe a high interest in our research due to societal concerns about the potential impact of computer-generated language.

**WP EduGame**

**Team:**

*PIs:* Daphne Bavelier, Pascal Zesiger, Silvia Brem; *NCCR-funded researchers:* Angela Pasqualotto, Martina Roethlisberger, Timothy Piton; *Internal collaborators:* Enno Hermann, Iliana Karipidis, Mathew Magimai; *External collaborators:* Irene Altarelli (LaPsyDE, U Paris)

**Goals:**

The process of literacy acquisition is effortful and compared to spoken first language acquisition requires explicit teaching and guidance of the culturally defined links between written and spoken information, as done in our school system. We study the factors that facilitate literacy acquisition. One such factor appears to be executive functions, and in particular attentional control, core components of the biologically evolved language faculty. We will evaluate the role of attentional control in the plasticity of literacy acquisition through video game-based training that targets attentional control and is predicted to lift several of the barriers to literacy acquisition, both in typically developing children and in poor readers.

**Work during the reporting period:**

Our proposed work extends a recently published study in Italian children using domain-general skill training via video game and documenting improvements in lab-tasks of reading shortly after the training ended, as well as and notably a protracted improvement in Italian school grades 12 and 18 months after the end of training (10). We are improving on our existing child-friendly video games, both experimental and control games, as well as developing an app-based, gamified battery to evaluate the impact of our planned digital intervention. Currently, we are focusing on the design, implementation and execution of an at-home, tablet-based domain-specific (reading, possibly production) and domain-general assessment battery (Computer-based Reading-related Assessment Battery - CRAB) in four different languages (German, French, Italian and English). A specific challenge is to include Automatic Speech Recognition so as to give feedback in the various reading or production tasks in real-time.

**Findings and interim conclusions:**

Pilot tests and focus groups recently carried in Italian and French-speaking schools show that our new battery of tasks and the upgraded game version is well received by children. We have implemented short instruction videos with one trial feedback in a way that children find helpful and playful. At the ASR level, comparison of existing commercial solutions show very satisfactory results for word and sentence level recognition, but still poor performance for tasks that entail phoneme substitution. This latter issue is being addressed by working with a speech recognition (ASR) system developed at IDIAP. Literacy can arguably be considered as the most recent large-scale change in the evolution of language. Maybe one day, youngsters by being immersed from a very young age in a world of words will effortlessly develop reading abilities, as they do for speech. Understanding the common mechanisms that facilitate or constrain trajectories of literacy development is key to advance our understanding of this recent aspect of language evolution. Our work already shows how attentional abilities act as a key cornerstone of such development.

**Transversal Task Forces (TTF)**

The TTFs address fundamental issues that are of concern to all projects. TTF PIs and staff collaborate with project members on jointly developed solutions for specific problems (relying on a common ticketing system), publications, and outreach events, thus fostering interdisciplinary collaboration and knowledge transfer within and outside of our large network.
TTF DataScience (Coordinator: Hahnloser)

Team:
TTF DataScience team consists of 6 PIs (Richard Hahnloser, Paola Merlo, Sabine Stoll, Dimitri Van De Ville, Reinhard Furrer and Ce Zhang) supervising 3 data science service specialists (Nianlong Gu, Guanghao You and Sumit Kumar Ram, in the NCCR@LiRI unit; cf Chapter 3) and 3 research postdocs and collaborators (Raphael Liegeois, Marc Lischka and Viviane Nastase) in 2 WPs, namely WP MachineLearning, and WP Statistics.

Research done and/or service offered:
The 3 WPs in TTF Data Science Team jointly offer the service of developing solutions for data-related issues to support the research efforts of the NCCR Evolving Language. In addition, WP Databases oversees the data management of NCCR and develops and maintains the infrastructure for data management. Due to the lack of personnel, in the past year, WP Statistics mainly focused on research development.

Research achievements of the WPs:
The WP Statistics has made contributions to the following research tasks:
(i) Finding a dense submatrix with a lower proportion of NAs given a data-frame with a substantial number of NAs while maximizing phylogenetic diversity.
(ii) Establishing an interface between the output of sBayes (16) and the input of leave-one-out cross-validation using Pareto-smoothed importance sampling.
(iii) Proposing optimal null models to best describe the complex spatio-temporal structure of brain functional dynamics to help exploit the rich information in neuroimaging data. This work is currently being used to describe brain dynamics during mother speech processing using data from WPs EmotionIntegration and TemporalHierarchies.
(iv) Defining a new metric that exploits the asymmetric nature of the passage of time to quantify causal effects in multivariate time series. This method is applied to a dataset from the WP NeuroComp to identify causal triggers of brain function during speech processing and word disambiguation.
(v) Modeling the morpheme/POS burstiness of word usage in first language acquisition.
(vi) Quantifying the geographical isolation of languages based on various features and computing the association of such isolation with linguistic attributes, taking Sino-Tibetan as a test case (WP Phylo).

Service achievements of the WPs:
The WP Databases and the WP MachineLearning have together completed the following tasks: (i) Setup of the NCCR-internal Wiki (https://evolvinglanguage.linguistik.uzh.ch/start; with the assistance of LiRI) for all WPs and TTFs to internally disseminate up-to-date information of the research, the services, and the important concepts (especially from the work of the TTF Concepts) in NCCR. This is particularly important for internal knowledge transfer. On April 7, 2022, the first tutorial on the Wiki was carried out. (ii) Setup of the Google cloud space with abundant computing resources, thanks to the collaboration with the Google Research and Machine Intelligence team. The WP Databases has developed a robust and secure data management pipeline with an established backend and frontend framework for the smooth integration and management of the large-scale data in NCCR (Figure 6).

With this pipeline, we adhere to the FAIR principles and implement our management strategy as regulated in our research data management plan (RDM). Highlights of the pipeline include:
(i) The deployment of the openBIS (open Biology Information System) platform (61) developed by ETH Zurich Scientific IT Services (ETH SIS), which is a free "open platform for managing scientific information ... [designed] to support research data workflows from bench to publication" (https://openbis-evolvinglanguage.ethz.ch/). The openBIS platform provides a frontend with sharable personal spaces for researchers to manage their research data, while allowing platform administrators to predefined data/metadata submission schemes to ensure proper data
documentation and deposition. The platform administrators, thus use the openBIS platform as the interface to manage the up-to-date research data from the researchers.

(ii) Code development of data aggregation pipeline to gather research data/metadata from openBIS to MongoDB on the backend, with proper dataset indexation.

(iii) An NCCR data platform consisting of (iiia) a navigation platform rendered with Meilisearch (https://dataplatform.evolvinglanguage.ch/; accessible with authorization) for researchers to explore both ongoing and published research of NCCR and (iiib) API interfaces indexed on the navigation platform for datasets centrally managed by the TTF DataScience.

(iv) Automatic generation of an open dataset index from the backend database, which is published on https://evolvinglanguage.ch/dataset-index/.

(v) Secure Ngrok tunnels and an Nginx reverse proxy to facilitate data sharing.

(vi) Real-time data integration and fluid archiving pipelines into recognized scientific data repositories such as Zenodo or into long-term tape archives. We thereby not only facilitate the internal knowledge exchange in the NCCR (e.g., with openBIS and NCCR data platform), but also maximally enable public access to the research outcome of the NCCR (e.g., the open dataset index), thus ensuring the knowledge transfer from the NCCR to the scientific community.

We gave the first presentation about the data management pipeline and infrastructures at the 4th project meetings in Neuchâtel on February 23-25, 2022. More recently we also started the biweekly tutorials on data management with the openBIS platform.

Meanwhile, in an effort to enhance the interoperability of data generated in the NCCR, we provide database solutions (e.g. database design, data restructuring, facilitation of data storage and sharing), especially for large datasets. We have developed standardized procedures to transform data from different disciplines into JSON-based databases and create APIs with comprehensive documentation and designed endpoints to ease the data interaction. We manage these databases via the above-mentioned data management pipeline. Currently, we are maintaining three main large databases (ACQDIV, Songbird, AUTOTYP) in our central infrastructure, and have set up respective API interfaces that are indexed in the backend database and accessible via the data navigation platform. Besides, upon request, the WP Databases has offered data processing services for WPs (e.g. SemanticRoles, Arbitrariness) and the larger NCCR community. We furthermore host and maintain the AUTOTYP database with the Cross-Linguistic Data Formats (CLDF) (AUTOTYP with CLDF is accessible via https://github.com/autotyp/autotyp-data/tree/cldf-export), a framework designed to encode cross-linguistic data to enhance data interoperability and reusability. This framework will be incorporated in future database aggregation depending on the demand and use of the international community.

The WP MachineLearning has provided machine learning solutions for tasks from various work packages. These include:

![Figure 6: Illustration of the data management pipeline](image-url)
(i) implementing a state-of-the-art vocal segmentation system based on VoxSeg, which utilizes a CNN+biLSTM deep neural network to predict the label (vocal or non-vocal) of each column in the spectrogram of the sound signal. This system can be generally applied to animal call/human voice segmentation;

(ii) in collaboration with google we conducted a preliminary analysis for metaphor detection in child speech by first comparing the word embeddings of child-directed speech with adult-directed speech, where the word embeddings are computed via unsupervised methods close to word2vec; further machine learning approaches for detecting metaphors in phylogenetic data were tested;

(iii) universal dependency parsing with UDify for low-resource languages with minimally annotated data.

In the meantime, the WP MachineLearning is also in discussion with NCCR groups on the protocols of how to further develop and maintain existing machine learning pipelines and statistical procedures that are related to linguistic evolution, such as sBayes. An important challenge we are working on is to improve computational efficiency. (Currently, sBayes’s MCMC takes several weeks to converge when performing estimates on datasets with global coverage.)

TTF Technology (Coordinator: Magimai-Doss)

Team:

PIs: Anne-Lise Giraud, Mathew Magimai-Doss; NCCR-funded researchers: Eklavya Sarkar and Shizhe Wu; External collaborators: Enno Hermann (IDIAP), Julian Fritsch (IDIAP).

Research done and/or service offered:

In WP ASR (Automated Speech Recognition) we focused on the following lines of research and development: We contributed to WP EarlySurround in the development of auditory segmentation technologies relating to distinguishing adult and infant speech. To that end, we have worked on the development of unsupervised signal-processing based methods for vocalization detection (audio/speech segmentation). We focused on applying the methods to data collected in uncontrolled scenarios, such as in the Shipibo-Konibo subset of the ACQDIV corpus, to test its robustness to noise. We also extended these techniques to segment animal vocalizations in order to develop audio segmentation technologies specific to animal call-signs. In addition to that, we also developed and tested speaker diarization systems. Currently, the performances of the developed speech segmentation methods are not up to the level where they can be utilized in a fully automatic manner to segment speech data collected in uncontrolled scenarios. Our current development work is therefore focusing on addressing this challenge by combining the developed unsupervised methods with neural-based supervised learning methods. We contributed to the development of speech recognition and related services for the DigitalForDisorders and EduGame WPs in the three main languages of Switzerland (French, German, Italian). This included development of grapheme-to-phoneme conversion, keyword spotting, speech recognition and pronunciation assessment systems. Besides that, we provided advice to DigitalForDisorders and EduGame WPs on the use and integration of commercially available cloud speech technologies, such as IBM Watson. Our upcoming research will focus on evaluation of the children's speech data that will be collected in the EduGame WP.

WP Neurofeedback focuses on the development of a closed-loop brain-computer interface (BCI) system for decoding speech-related brain signals in tight collaboration with the WP NeuroModulation. More specifically, we have worked on integrating an adaptive classifier in the existing BCI system currently in use in the above-mentioned project. This approach is expected to achieve better decoding accuracy as compared to static decoders currently in use in most BCIs by compensating for the non-stationarity of the electroencephalography (EEG) signal. We implemented an adaptive linear discriminant analysis (LDA) classifier and performed different simulations on a pre-recorded dataset whereby participants control an EEG-based BCI system through syllables imagery. We have found that optimizing parameters with which to update the classifiers in real-time improves decoding accuracy. The improvement occurs not only when the parameters are computed separately for each subject, but also when applied at the group level, thus reducing the experimental time. Further, decoding accuracy could be improved also by the incremental inclusion of data from the previous days throughout the training week. The next steps will consist in bringing the adaptive classifier from simulations on pre-recorded data to real-time classification of brain signals and testing its efficacy to other kinds of speech units. In parallel, we are working on
a review paper in the domain of speech-BCI. Finally, we are working on extending the pool of healthy participants in an ongoing study in the WP Neuromodulation.

**Research Achievements of the TTF WPs:**

In **WP ASR**, a part of the work on signal processing-based unsupervised vocalization detection method was communicated to the ‘Interspeech 2022’ conference and has been accepted. In this paper, we demonstrated that voice source information and vocal tract system information can be effectively modeled for voice activity detection through zero frequency filtering without making any explicit model assumptions about speech signal production, as source-system decomposition methods such as linear prediction analysis and cepstral analysis do (62). We are currently working on merging the research on human and animal vocalization detection and segmentation into a journal paper.

In **WP Neurofeedback**, a paper related to the work on adaptive classifiers is in preparation. The review paper is at the stage of conceptualization.

**Service achievements:**

(i) Development of a pipeline for automatic speech and audio segmentation, where an end-user can feed an audio file as input and get segmented audio file at the output.

(ii) Provision of a server for the EduGame WP that does speech recognition for all tasks of their CRAB speech assessment battery. Integration of a keyword spotting service into an Android app for the DigitalForDisorders WP.

(iii) The adaptive classifier is ready to be included in the online BCI loop. In addition to the R&D activities TTF Technology also supported the development of virtual reality systems for WP DigitalForDisorders through services offered by the Foundation Campus Biotech Geneva.

**TTF Concepts (Coordinator: Glock)**

**Team:**

*PIs:* Hans-Johann Glock, Markus Wild (until the end of 2021), Marcel Weber (since 2022); *NCCR-funded researchers:* Luca Gasparri (until September 2021), Piera Filippi, William Bausman (since 2022).

**Research done and/or service offered:**

The general aim of the TTF Concepts is “Conceptual Integration”: it tries to make the conceptual and methodological frameworks of the different disciplines of the NCCR commensurable, so that fruitful collaborative research is not hampered by terminological ambiguity and/or conceptual opacity. The TTF also conducts its own research. It combines conceptual analysis and conceptual engineering. So far the main topics have been the concept of arbitrariness (with WP Arbitrariness) and semantics (with members of WP Arbitrariness and WP JointAction), both with a view to pinpointing the phylogenetic steps that separate animal communication from human language. The TTF has also returned to the topic of evolution in general, aided by the recruitment of two renowned experts (Marcel Weber and Wiliam Bausman).

The services offered by the TTF are threefold. First, we provide expert assistance to members of the NCCR seeking conceptual clarification or pointers to the literature on specific topics. One example is advice on how to identify premises and conclusions of arguments in scientific publications for purposes of data mining (for the TTF Data Science). Another example is input on meaning and on the notions of joint attention, shared intentionality and cooperative activity to the WP JointAction. Secondly, we run a special Concepts Wiki which lists key notions of NCCR research that are contested or understood differently in various disciplines, paradigms and WPs. Thirdly, the TTF Concepts organizes specialist workshops on topics of shared interest across the NCCR and participates in outreach events for the general public.

**Research Achievements of the TTF:**

We have addressed the concept of arbitrariness, a feature of human language that has traditionally been deemed to be absent from animal communication systems (63). Specifically, we distinguished four notions of semiotic
arbitrariness to enable terminological and conceptual clarity and consistency in cross-species and cross-disciplinary research on this topic (64) and formulated a new conceptual framework for tracing the evolutionary origins of arbitrariness through cross-species investigation (14). In addition, another paper discussing two of the methods employed by the TTF Concepts argues that conceptual engineering presupposes rather than replaces conceptual analysis (65). Finally, in recent work which will be presented at the Society for the Philosophy of Science in Practice in July 2022 in Ghent (66) we argue that rational reconstruction remains an important tool for the epistemology of science and shows this through a case study on using paleoclimate proxies based on natural selection.

In order to advance foundational work on evolution within the NCCR, we have updated ourselves on the classic and current literature addressing evolution in biology, language and culture, engaging in regular discussion groups with members of the WP Phylo. This resulted in the organization of four interdisciplinary workshops:

(i) “Thinking about Evolution” in Neuchatel on April 29th, 2022. Each WP spelled out in what sense their work contributed to evolution; in addition, we discussed the opinion paper by Bickel et al. (1) on how linguistic evolution relates to and interacts with biological and technological evolution.


(iii) Within the same summer school, building on their work on arbitrariness, the TTF Concepts has organized a minisymposium integrating theoretical and empirical approaches to the concept of meaning, featuring Hans-Johann Glock, Luca Gasparri, Piera Filippi, Stuart Watson, Judith Burkart and Carel van Schaik. As a result, a successful application for an SIG Meaning was submitted.

(iv) We are organizing a workshop on “The evolution of arbitrariness” at the Joint Conference on Language Evolution (Kanazawa, Japan, September 2022).

Service achievements:
The TTF Concepts, with help from TTF Data Science, has set up the Concepts WiKi. A survey of concepts that NCCR members across various WPs would like to be clarified and discussed is currently being conducted. The TTF Concepts has contributed two Science Cafés “Animal culture” & “Urban environment” and a divulgative video on language evolution to Scientifica 2021. It has organized and conducted a very successful workshop ‘Thinking about Evolution’ designed to bring out evolutionary themes in the run-up to Phase II of the NCCR.

TTF Ethics (Coordinator: Hurst)

Team:

PIs: Markus Wild, Samia Hurst; NCCR-funded researchers: Elodie Malbois, Nico Müller.

Research done and/or service offered:

The main aims of the TTF Ethics is to provide ethics consultations to the researchers of the NCCR and to conduct research on topics relevant to them. Research has been conducted on the topics of empathy and sympathy and on the ethics of using social robots in healthcare. Further research topics included the applicability of ethical theory to particular circumstances and the notion of ethical duties towards animals. The TTF Ethics has been offering ethics consultations to researchers and participating in other meetings to offer ethics support. The TTF has also established brown bag lunch discussions to invite researchers to discuss issues that are especially relevant to them. Lastly, the TTF Ethics has been organizing the collection of ethics proposals within the NCCR to help junior researchers write their own proposals and learn how to address ethical issues.

Research Achievements of the TTF:

The TTF Ethics has inquired into the topic of technology transfer, particularly the relation of public funding to universities. We have held several meetings with experts in the field in Switzerland. We have decided however, that we would not contribute to the topic with a publication because we lack more specific expertise on the subject. We have updated ourselves on the current literature in different topics including open science ethics, patents and...
public funding and racial justice in language research in order to be best able to serve the NCCR. Through publications and talks, the TTF Ethics has also addressed several research questions and has:

(i) Proposed a new and more precise understanding of sympathy (empathic concern) which is thought to play an essential role in altruism (67);

(ii) presented ethical considerations related to a robotic cup designed to remind people with dementia to drink (68);

(iii) argued that robots like the PARO seal robot are not necessarily a threat to the dignity of elderly people with dementia (69);

(iv) criticized the empathy-based argument against robots in healthcare for being based on two problematic assumptions (70);

(v) defended the view that blame is more closely related to interpersonal (mis)-understanding than moral judgements (71);

(vi) presented a novel account of ethical responsibility vis-à-vis animals (72);

(vii) Discussed difficulties with recent Kantian accounts of moral obligations to animals (72,73) and (viii) developed a model to connect animal ethical Utopias with real-life action-guidance (74).

Service achievements:
The TTF Ethics has developed an Animal Ethics Charter and a Human Research Ethics Roadmap. We have finalized our ethics consultation process and have presented it at the Annual Summer School and Retreat 2021. We have conducted consultations and have participated in other meetings to offer ethics support. We also offered an introduction to animal and human research ethics at the summer school. In addition, we have been planning the collection of ethics proposals for researchers upon suggestion by a panel member and will soon inform members of the NCCR on the project and on how to contribute and benefit from it. Lastly, the TTF Ethics has established a “Brown Bag Lunch” discussion series on emerging ethical issues in research (six sessions held thus far with 7 to 15 participants each).

Special Interest Groups Reporting

Special Interest Groups (SIGs)
The SIGs serve to enlarge the research scope of our NCCR by developing and strengthening new research foci. SIGs can potentially develop into full-fledged projects in the future phases of the NCCR.

SIG Metaphors

Team:
PIs: Paul Widmer, Sabine Stoll, Srinir Narayanan (Google Research, Zurich); Researchers: Kim Gfeller, Ljudmila Feurstein (both financed by Gerda Zeltner Fellowships at UZH); Iulia Comsa (financed by Google Research). Internal collaborator: Oliver Hellwig, Nianlong Gu

SIG goals:
How does meaning develop and how is it transmitted in human language? There are at least three mechanisms responsible for the creation of new meaning: duality of patterning, compositional structure, and metaphors. Metaphors are a key mechanism allowing for creativity in meaning interpretation based on cross-modal mappings grounded in experience (75–77). Metaphors primarily make use of already existing experiential and linguistic units applying them in new contexts to express a new meaning. We are interested in the underlying mechanisms that create meaning through metaphors and in processes related to the evolution of metaphors. We focus on the development of metaphors and colexification patterns in phylogeny and the use and understanding of metaphors in human ontogeny to tap into the underlying cognitive mechanisms that make the use of metaphors possible. We
combine cross-linguistic corpus study and analysis with machine learning techniques to arrive at concrete proposals for such mechanisms. We will first try to work out the relevant mechanisms underlying such mappings and subsequently in a later step relate them to the communication systems of other species.

**Current research:**

We continued the computational work started by Narayanan in Berkeley (78) on Spiking Network models of metaphor acquisition using modulated Spike Timing Dependent Plasticity (STDP), a widely prevalent learning mechanism found in many areas of the brain. This model allows us to model a wide range of phenomena and open problems in the metaphor literature, including the lifecycle of metaphors, initial conflation and conventionalization, target domain overrides, and formation of structured mappings between source and target frames. Work is underway to extend the model to more realistic settings and scale culling data from the human connectome data.

In a more applied line of work, we have initial results on the performance of the current deep learning models and techniques trained on web data to interpret metaphoric language. This is a purely data driven approach to knowledge acquisition and will contribute to the scientific exchange between machine learning/AI and the creativity in language. We have just started on a project comparing the role of metaphors in child-directed speech (CDS), adult-directed speech and written language. We hypothesize that child-directed speech is simpler in how meaning is presented (more repetitive and less complex constructions) to support children in understanding. We will use existing algorithms (word embeddings) to compare the three genres and then in a second step we will analyze the development of meaning in children in the ACQDIV corpus. We are currently in the process of coding and will proceed to the analysis as soon as this is completed.

In linguistic evolution, we currently concentrate on two approaches. First, we use NLP methods to explore gradually changing contexts of occurrence of lexical items in longitudinal language corpora (Icelandic and Sanskrit) starting from the assumption that changing contexts are indicative of progressive metaphorization and/or semantic shift. Second, we investigate recurrent colexification in the history of the IE language family. In particular, we are interested in colexifications that are attested in etymologically unrelated lexical items or can be shown to have reemerged with novel lexical material after the loss of a formerly attested lexical item with the same colexification.

**Achievements of the SIG:**

We presented a poster on Spiking Network modeling of metaphor learning at the Cortical Microcircuits and Consciousness Symposium in April 2022 (79). We performed an inter-annotator agreement test on three language modalities (child-directed speech, spoken corpus, written corpus) in terms of metaphor identification by two coders. There was a moderate agreement between the two raters (Cohen's $\kappa = 0.724$; $95\%\text{CI} = [0.71, 0.74]$). We will use this ground truth coding in order to compare the human ratings to the automatic metaphor identification and annotations by MelBERTa.

Expanding on extant collections, we compiled a large set of colexifications in the Indo-European languages and added etymological information. This will serve as a starting point to investigate the evolution of colexifications in a language family, especially in cases where lexical material is replaced by new forms. We have conducted a pilot study looking at semantic change in a diachronic corpus of Icelandic. Despite the small size of the corpus the interim results were promising and we set up a collaboration with Oliver Hellwig to apply and test the methodology on the much larger Sanskrit corpus.

**SIG Cetacean Communication**

**Team:**

*PIs:* Klaus Zuberbühler, Michael Krützen, Richard Hahnloser, Stephanie King (U Bristol), Jörg Rychen (ETHZ).
*Researchers:* Kaja Wierucka (U Zurich), Chérine Baumgartner (ETHZ).

**Goals:**

*Language and joint action:* Develop a research programme on understanding the relationship between physically coordinated joint action and flexible vocal communication in cetaceans, with comparisons between humans and
non-human primates. Vocal production learning and syntax: Determine what linguistic features are present in cetacean communication systems and compare communication structures with species under similar and different social and ecological pressures.

**Technological development:** Develop technological advancements that enable us to process large amounts of high-quality acoustic data, to collect high-resolution tracking data of wild cetaceans, and to conduct field-based experiments to test the function of cetacean communication signals in the wild.

**Current research:**

We are constantly evaluating new technology for array recording of cetaceans. For cognitive experiments with cetaceans, we are developing an underwater telecommunication system similar to what some of us have proposed for controlling vocal communication networks in zebra finches (80). Together with experts from seismology and acoustic signal processing we are evaluating algorithms to separate sound sources. Our intermediate goal is still to automatically process large datasets to extract the pitch contours of each call, localize them in real space, and categorize the stereotyped calls according to the norwegian call type catalog. We recorded orcas and humpback whales in Norway with our self developed hydrophone arrays. We are preparing this dataset for publication and started analyzing these data. We have two Master’s students starting projects with us. One will work towards classifying killer whale calls in an attempt to define the vocal repertoire of the population and preparing data for further analysis of communication structures. The other will be assisting with developing signal processing methods (using machine learning algorithms) for the localisation and separation of calls collected using hydrophone arrays.

**Achievements of the SIG:**

We presented a poster underwater call localisation at the NCCR summer school 2021 and have recruited Master students to analyze the already recorded orca dataset to develop an automated call classification and vocal repertoire, the basis for future work on coordinated group hunting. Some of us submitted papers (81) for a special issue in “Interaction Studies | Social Behaviour and Communication in Biological and Artificial Systems” on a new full-duplex underwater acoustic communication system and to present the results of a pilot experiment (82) on vocal interactions of humans with orcas and humpback whales. We performed an experiment (83) in Lake Zurich in collaboration with seismologists of ETH Zurich to test fiber optical cables as sensors for acoustic signals, potentially revolutionizing underwater array recording for animal communication studies. A publication of the dataset and about the performance evaluation is in preparation. We have been successful in obtaining the NCCR Innovation grant, with which we aim to acquire a ground-truth dataset in Lake Zurich to further develop separation algorithms for group level communication.

**SIG Cross-linguistic Studies of Reading and Reading-related Disorders**

**Team:**

 **PIs:** Anne-Lise Giraud, Daphne Bavelier, Pascal Zesiger, Silvia Brem.  **Researchers:** Angela Pasqualotto, Iliana Karipidis, Martina Roethlisberger, Timothy Piton.  **External Collaborators:** Irene Altreli (U Paris), Johannes Ziegler (U Aix-Marseille), Pier-Luigi Zoccolotti (La Sapienza U Rome), Sendy Caffarra (U Modena), Sophie Bouton (CNRS/Institut de l’Audition, Paris), Zeno Menestrina (Game developer contractor).

**Goals:**

This SIG will pave the way for the NCCR in Phase 2 to become the leader of an international, cross-linguistic effort around digital interventions targeting reading acquisition, with or without neuromodulation.

**Current research:**

Working together with other groups including those of Golestani, Laganaro, and Stoll, the SIG has identified a common need across NCCR members when it comes to developing task batteries for the evaluation of language but also cognitive, emotional and social skills. We are working on a blueprint for a new TTF that would curate a database of computer-based tasks that is dynamically searchable, and would provide a user-friendly map of
available task assets within the NCCR. Putting together a cross-linguistic research group, at least in the languages of the Swiss educational system (Italian, German and French), we conducted a video-game based intervention study on reading acquisition in these languages, allowing cross-linguistic comparison.

**Achievements of the SIG:**

(i) Organisation and funding (via an SNSF project grant) of a workshop to take place Fall 2022 in Geneva with international partners to pre-register the planned video-game based intervention study on reading acquisition.

(ii) Submission of a SNF “Scientific Exchanges” scheme to support this meeting to come. International collaborators include, by alphabetical order, Altarelli, Bouton, Cañarre, Karipidis, Menestrina, Mirault, Pizzicannella, Ziegler, and Zoccolotti.

(iii) Submission of a letter of intent for a project titled “Supercharging literacy and Dene language use by bringing together Indigenous bilingual education, cognitive research, video games and traditional knowledge” by Dagmar Jung (LiRI staff collaborating with Stoll on language acquisition data) and her local collaborators, pertaining to the UN post-pandemic goal of “5.5 How can digital technologies be harnessed to promote social cohesion while ensuring no one is excluded?”

**New Developments in Research Structure**

During the reporting period we issued again calls for application as Associate Investigator (AI) and Special Interest Groups (SIG). These found again great resonance. Likewise, we launched a call for Innovation Grants and selected one.

**Associate Investigator (AI)**

In autumn 2021 and spring 2022, the NCCR issued its biannual calls for Associate Investigator (AI) status. We received eight applications for the autumn call and one application for the spring call. The Steering Committee accepted the following applications (cf our website for the full list of AIs):

- Andrea Migliano, professor in evolutionary anthropology, U Zurich
- Diana Mazzarella, assistant professor in information and communication sciences, U Neuchatel
- Pierre Mégévand, associate physician, Geneva University Hospitals
- Thibaud Gruber, assistant professor, U Geneva
- Timothée Proix, SNSF Ambizione fellow in neuroscience, U Geneva

**Special Interest Groups (SIG)**

Following a new call, the Steering Committee received five SIG applications, of which three were granted:

The **SIG Mechanisms of Vocal Learning in Ovo and Utero** consists of AI Alexis Hervais-Adelman, PIs Simon Townsend and Richard Hahnloser and external collaborator Andras Jakab (U Zurich). This SIG combines interdisciplinary expertise to investigate in ovo and in utero mechanisms that underpin the development of vocal learning capacity in songbirds and humans. Their departure point are theories of language evolution that usually consider only selection pressures after hatching or birth but ignore factors that may affect development prior to that point. More precisely, these dominant theories neglect the potentially crucial role of in ovo or in utero experience, which are likely instrumental in brain development. The SIG’s focus is to elucidate the developing mechanisms of vocal learning and how ultra-precocious exposure to (conspecific) vocal stimuli shapes the neural and genetic foundations of vocal learning.

The **SIG Meaning** consists of PIs Judith Burkart, Hans-Johann Glock, NCCR researchers Piera Filippi, Stuart Watson and external collaborator Luca Gasparri (CNRS, France). The SIG focuses on the concept of meaning from a cross-species and evolutionary perspective. Although much progress has recently been made in our knowledge of animal vocal and gestural communication, comparative research focusing specifically on the concepts of meaning remains sparse.
The SIG Cultures and Action Structures consists of Al Thibaud Gruber and PIs Balthasar Bickel, Anne-Lise Giraud, Martin Meyer and Didier Grandjean. It combines research from comparative and developmental psychology with neuroscience, linguistic and cultural evolution studies to better understand the relevance of social life for the evolution of language. The goal of this SIG is to broaden the discussions on the origin of language but with a particular focus on how structured actions are processed and socially shared. It aims at a holistic approach to the social transmission of hierarchically structured phenomena.

Innovation Grants

We introduced this funding instrument to encourage innovative research projects by the members of the NCCR. Initially, this instrument was tied to SIGs, allowing only approved SIGs to apply for the grant of CHF 50’000 but the Steering Committee recently decided to open the grant to all members of the NCCR so that we can expect more applications in the future. This year, the Steering Committee reviewed and approved one application submitted by the SIG Cetacean Communication on “Sound Source Separation and Localization: Toward Analyzing Group-Level Communication”.

Chapter 4 - Structure-related aspects

Education

Doctoral School in Biology of Language

Course catalog

We have continued and updated the course catalog of the Doctoral School Biology of Language. This catalog contains a list of courses at the MA/MSc and PhD level offered by our senior staff and PIs that are of particular interest to our junior researchers. The catalog is regularly updated and sent to our research staff at the beginning of each semester. It is further complemented with courses that we organize on demand (cf. below, under “synergy-related measures”, for a list).

Our ultimate goal is to raise a new generation of scholars, trained in interdisciplinary research, to overcome the compartmentalization of language studies, which we can still see today. To this end, our catalog gathers courses from different fields scattered around across universities and departments, including linguistics, neuroscience, animal and social sciences, psychology, neuropsychology, computer science, statistics and mathematics.

We are currently also working towards expanding the existing MA in Evolutionary Language Science into a cross-faculty MA/MSc research program at UZH, leveraging the interdisciplinary spirit of our course catalog and growing integration of our consortium at UZH. We initiated talks with the Rectorate and the Dean’s Offices (Faculty of Science and Faculty of Arts and Social Sciences) in spring 2022. We received highly encouraging feedback and will follow up with a first draft of a possible course scheme later this year.

Regular educational activities

NCCR Evolving Language Colloquium Series

We have continued the NCCR Evolving Language Colloquium Series, organized jointly between the Center for Interdisciplinary Study of Language Evolution (ISLE) in Zurich (directed by PIs Stoll and Manser) and the B&C (Brain & Cognition) Seminar of the Campus Biotech in Geneva (cf. Chapter 3). The colloquium offers a platform for the NCCR to invite internationally renowned scientists for talks as well as to invite NCCR members to present their research to the NCCR community. Presenters are given 45 minutes for their talk, which is followed by a Q&A session. For our junior research staff we offer additional Q&A time (ca. 30 min) in order to enable a more direct interaction with guest speakers, without PIs. In addition, we organize smaller-scale meetings with guests before or after their presentation, opportunities that are extensively made use of by our researchers, including PhD students.

Synergy-related measures

The NCCR comprises researchers from many disciplines and specializations. It can thus be a challenge to bring everyone into a fruitful conversation and enable exchanges across different areas of knowledge and methodologies. We have taken active measures to familiarize especially our junior researchers with the basics of other disciplines represented in the NCCR and organized a series of introductory theoretical lectures on five major NCCR research fields (linguistics, animal behavior/cognition, computational modeling of language, phylogenetics and neuroscience). Please consult the tables 6 and 7 below for the courses.

Table 6: Introductory courses to major NCCR disciplines (February 23, 2022)

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chundra Cathcart</td>
<td>Linguistics and Phylogenetics</td>
</tr>
<tr>
<td>Alexis Hervais-Adelman</td>
<td>Introducing the Brain and Language</td>
</tr>
<tr>
<td>Eloise Deaux</td>
<td>Animal Behavior</td>
</tr>
</tbody>
</table>
These workshops were partly integrated into the NCCR-wide project meetings (which took place on 24-26 February, 2022 in Neuchatel) and made available to our researchers as recordings for later consultation. Another part of the workshops, organized by junior researchers themselves, stretched over the fall and spring terms (Nov 2021 - Jan 2022) and covered particularly important issues in greater depth. All workshops were given in hybrid format (Table 7).

Table 7: NCCR-wide courses and workshops offered by early-career researchers

<table>
<thead>
<tr>
<th>Date</th>
<th>Instructor</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/02/22</td>
<td>Derry Taylor</td>
<td>Intentional communication in animals</td>
</tr>
<tr>
<td>24/03/22</td>
<td>Nicole Tamer</td>
<td>Linguistic history, change and diversity</td>
</tr>
<tr>
<td>19/05/22</td>
<td>Aixiu An</td>
<td>Predictive modeling in linguistics</td>
</tr>
<tr>
<td>12/05/22</td>
<td>Chiara Barbieri</td>
<td>Phylogenetic thinking</td>
</tr>
<tr>
<td>09/06/22</td>
<td>Coralie Debracque</td>
<td>Comparative neuroscience</td>
</tr>
<tr>
<td>mid-Nov 2021 – mid-Jan 2022</td>
<td>Jessica Ivani</td>
<td>Linguistic diversity and typological data</td>
</tr>
<tr>
<td>7/4/22</td>
<td>Viviane Nastase</td>
<td>NCCR internal wiki tutorial</td>
</tr>
<tr>
<td>28/8/21</td>
<td>Guanghao You</td>
<td>NCCR data management plan and open science</td>
</tr>
<tr>
<td>23/6/22</td>
<td>Guanghao You</td>
<td>openBIS tutorial</td>
</tr>
</tbody>
</table>

Workshops
The NCCR Office has continued to organize workshops on critical methodological and theoretical issues during the second year. In November 2021, together with researchers from PI Marta Manser’s research group we organized a two-day online seminar entitled “Exploring methods for analyzing bioacoustic data”. The event was attended by approximately 50 researchers, who were introduced to various softwares for analyzing acoustic data by experts. In April 2022, we organized a one-day workshop on “Thinking about Evolution” at the University of Neuchâtel. The event, which was attended by roughly 60 NCCR members (with at least one representative per WP), discussed the relevance of an evolutionary perspective in each WP.

NCCR Women campaign
On the occasion of the International Women’s Day (March 8, 2022), the NCCR participated in a joint NCCR initiative and relaunched the videos produced for the NCCR Women campaign in 2021 on its social media platforms.

Mobility grants
We launched the NCCR mobility grant scheme in April 2022. The grants offer financial support for early-career researchers so that they can spend a period of one to three months at the department of another NCCR PI. In this way, our internal grants complement existing SNSF grants, which are intended for research stays abroad. However, we received one application for the spring call, which was granted by the Steering Committee, and we are currently evaluating the current setup to make sure that the program is tailored to our researchers’ needs. One issue is that the travel distance in Switzerland easily allows for spontaneous short visits and does not need much support beyond train tickets. At the same time this decreases chances of extended involvement, which are only partially compensated for by our social events.

Annual Summer School and Retreat
Every year in the weeks preceding the autumn term, we organize the Annual Summer School and Retreat. The event offers the opportunity to bring together our vast network of researchers and to organize lectures and
workshops on various topics related to the NCCR. The second NCCR Summer School and Retreat took place in Engelberg from August 24–28, 2021. The event consisted of:

- three minisymposia (see Table 8)
- a workshop on comparative approaches to evolution, organized by Chiara Barbieri and Piera Filippi
- informations by the TTF DataScience
- introduction to KTT and specific support by the Translational Accelerator at UNIGE
- an extended poster session for early-career researchers (ca. 50 posters)

### Table 8: Minisymposia lectures

<table>
<thead>
<tr>
<th>Organizers</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hans-Johann Glock (TTF Concepts), Stuart Watson (WP Arbitrariness) and Carel van Schaik (WP EarlySurround)</td>
<td>The concept of meaning in animal communication and theories of language evolution</td>
</tr>
<tr>
<td>Marina Laganaro and Volker Dellwo (WP SpeechArticulation) and Miren Olasagasti (WP NeuroComp)</td>
<td>Syllables in speech production and perception</td>
</tr>
<tr>
<td>Adrian Bangerter, Judith Burkart and Jessie Adrianse (WP JointAction), Cameron Alexander (TTF Concepts), Volker Dellwo WP (SpeechArticulation)</td>
<td>Language, cognition and action</td>
</tr>
</tbody>
</table>

Due to the COVID-19 pandemic, all presentations (with the exception of the poster session) were streamed online to enable remote participation. The event was attended by more than 100 people onsite and followed by an online audience that on average comprised about 25 people. The Summer School thus was a great success, both scientifically in aligning our members to the NCCR’s interdisciplinary research mission and by creating a sense of community among our researchers. The organization of the next Summer School, which will take place from 24-28 August 2022 in Champéry, is currently in full progress.

### Knowledge and Technology Transfer

In Year 1 we conducted an analysis of our KTT situation to better understand the current needs of our PIs. We noticed that most of our PIs do not know their IP rights and what to take into account if they start to collaborate with external partners. Capitalizing on this and with the help of the Translational Accelerator of the Faculty of Medicine (ATFM) of the University of Geneva, we have started to raise awareness on technology transfer topics in year 2. For this purpose, we invited Dr. Vincent Wagner to come to our annual retreat where he gave a joint presentation with our KTT Officer. During this presentation, our KTT officer introduced the guidelines in collaboration with the technology transfer offices of our home institutions (UNITECTRA for U Zurich and UNITEC for U Geneva) and added them to our NCCR shared drive. Furthermore, we asked our researchers to highlight potential KTT projects during the January project meetings to be able to accompany them during the process. In the same vein, we coordinated meetings between the ATFM and inteestd NCCR researchers. Finally, we communicated about the Bench2biz event, a workshop for young and aspiring entrepreneurs in science and technology, which was organized jointly by several NCCRs. We were not official partners in the event, but this may change if we notice sufficient interest from our own research community.

Within the NCCR, the TTFs are tasked with fostering interdisciplinarity and promoting knowledge transfer between disciplines. It is therefore important for the TTFs to share data, tools and knowledge on a common platform, accessible for all members. To this end, our TTFs set up a data management platform openBIS to facilitate data sharing, a unified wiki system to support WPs in knowledge transfer, and a ticketing system for handling incoming requests from our researchers. Furthermore, they are implementing a data platform that is already linked to our website (https://dataplatform.evolvinglanguage.ch/). See the report of the TTF DataScience in Chapter 4 for more details.
Our researchers also gave talks for the interested lay public. For instance, we started to collaborate with popular, senior and children universities, which are always eager to invite researchers for their programmes. For year 2, we had lectures in Zurich at the Children's University and in Solothurn at the Senior University. Furthermore, we have secured lectures for Senior Universities at Neuchâtel and Zurich for year 3. We have also started a collaboration with the Swiss Youth in Science organization and, as a first step, they invited one of our PhD students (Andrea Grütter) as a keynote speaker for their annual assembly in August 2021. Finally, four members of the NCCR participated in the Brain Awareness Week in Geneva.

Last but not least, many of our researchers are active with regards to knowledge transfer to the professional sector. One example is Silvia Marchesotti (postdoc in the lab of PI Anne-Lise Giraud), who received the Swiss Dyslexia Association Research Award 2021 for her work “Selective enhancement of low-gamma activity by tACS improves phonemic processing and reading accuracy in dyslexia”. Our PIs are furthermore involved in several committees. To mention only a few examples, PI Silvia Brem is a member of the Swiss Dyslexia Association, PI Samia Hurst recently joined the Assembly of the International Committee of the Red Cross, and PI Volker Dellwo is executive and research committee member of the International Association for Forensic Phonetics and Acoustics.

The aforementioned activities are completed by active public engagement, which aims at raising the public’s interest in our research (see Section on Communication below).

Equal Opportunity

Due to a job vacancy and long medical leave of one of our staff members, we were not able to advance our equal opportunity measures at the pace that we had originally envisaged. Given these limitations, we decided to put a strategic focus on maintaining formats that had already been established during Year 1 (Diversity and Inclusivity Roundtables and the NCCR Woman Campaign) while further expanding the NCCR childcare support scheme.

Diversity and inclusivity

The Diversity and Inclusivity Roundtable Series was launched in 2021 with the goal of raising awareness for hidden and unconscious discriminative structures that our members may be confronted with in their work life. A major area of action concerned the risks researchers with an LGBTQ+ identity face when conducting fieldwork in countries and societies with anti-LGBTQ+ legislation or negative attitudes. We elaborated on this topic by (i) encouraging our members to get in touch with an experienced LGBTQ+ researcher within our own network, who volunteered to offer informal consulting and (ii) raising awareness with testimonials from LGBTQ+ researchers who have been exposed discrimination during fieldwork.

Gender equality

The second strategic focus is on advancing the NCCR’s family support schemes, a central aspect of our strategy to create an equal-opportunity and family-friendly working environment. A survey has been sent to review if parents of the NCCR were in need of childcare support during specific events that last beyond normal working hours. Upon its review, it was clear that some parents would benefit from such family-friendly measures. So far and for the first time, we are organizing a childcare solution on-site for our third annual retreat in Champéry, where at least three children will be attended to throughout the entire week.

We also are in the process of launching several all-year measures: (i) short-term childcare support, (ii) emergency child-care support, and (iii) extended paternity leave grants. Short-term child care support is designed to relieve our members from childcare duties for a short time so they can attend scientific events. Emergency child-care support, in turn, is designed to relieve members from childcare duties during family emergencies (e.g. sickness or accident) that clash with submission deadlines, experiment schedules, or other work-related time-sensitive obligations. Extended paternity leave grants, finally, offer four additional weeks of paid paternity leave to male members of the NCCR. These grants complement the existing SNSF Flexibility grants and SNSF Gender Equality grants. The SNSF Flexibility grant aims at helping PhD students and post-doctoral researchers to cover the
external child care costs by financing a support person. The Gender Equality grant is aimed at young female researchers and offers individualized and flexible support for career development.

**Bottom-up EO measures**

Within the domain of equal opportunity measures, it is not always easy to anticipate relevant needs and appropriate areas of interventions. Therefore, we have reserved a budget of CHF 30,000 for bottom-up EO measures. The idea is to offer our members the opportunity to actively participate in the development of EO measures of our NCCR. A first call for bottom-up EO measures in spring 2021 did not lead to any proposals. In reaction to this, the EO Officer got in touch with the community and initiated the establishment of a peer-mentoring group. The EO Officer and the peer-mentoring group have now started to collaborate on proposals for further mentoring and diversity measures, which eventually will require funding through this grant.

**NCCR Women Campaign**

In 2021, we participated in the NCCR Women Campaign, an initiative supported by 32 NCCRs. The goal was to promote female role models in academia through short video portraits of female researchers from different disciplines and career stages. The videos were posted on Youtube and Instagram and advertised through our own social media outlets (Twitter, LinkedIn). On the occasion of the International Women’s Day (March 8, 2022), the videos were relaunched through social media. We will expand the NCCR Women Campaign under the label “NCCR Women go to school”, an initiative originally planned for autumn 2021 but now implemented in 2023 (see Education strategy in Annex 3 for more information).

**Communication and Outreach**

With our communication strategy we continue to pursue two goals. First, we ensure the internal communication with and between the members of our network and, second, we engage in communication activities to target the external public, especially the lay public and other academics, with continuous information about relevant news and events. In doing so, we continue to guarantee the SNSF communication standards. For instance, we have implemented a multilingual version of our website (French, German, English) and, we send internal newsletters (2-3 per semester) and one subscription-based external newsletter (once a year) to present main highlights. We continue to be active on social media, as demonstrated by our Twitter account, with now over 1,000 followers, and our growing LinkedIn network. In terms of social identity, we regularly remind our researchers to use the NCCR templates (logos, paper letters, slides), while all researchers are explicitly named on our website with links to their personal home institution web pages. Furthermore, we plan on creating a keyworded database where NCCR members will be able to quickly find visual and/or auditory material for effective presentations.

In terms of public communication initiatives, we issued six press releases in collaboration with different media offices (U Zurich, U Geneva, U Neuchatel) and published one of our own, in addition to one blog entry (for the lay public) and several news items on our website. Concerning the arrival of the MEG platform at HNP (U Geneva), we are working on a joint communication strategy involving videos, interviews, and social media news outlets. In other outreach efforts, we have continued our art-science collaboration with the sound artist and performer Julie Semoroz, who started different collaborations within the NCCR (workshops, performances, concerts) in Geneva (Théâtre de la Comédie & Spielact Festival), Montreux (Montreux Jazz Festival), Zurich (Scienifica), Engelberg (annual retreat), Sierre (Symposium “Être à l’écoute”) and Lausanne (Pavillons de l’EPFL). Furthermore, we participated in Scientifica (science fair by U Zurich and ETH Zurich) on September 4-5 with 13 researchers from four different WPs. We organized three workshops and a Science Café on ‘animal culture’ and were part of the SciFilmIt hackathons (Zurich in June; Geneva in September), a three-day science filmmaking event. Here, researchers and artists combined their expertise to create short science films on language-related topics. Finally, we launched several Citizen Science projects (e.g., PI Aris Xanthos in partnership with the Citizen Science Center Zurich), including for example a call for the public to annotate emojis on Whatsapp conversations, supported by a blog that explained the relevance of the research.

Our NCCR has been often covered by various media during the first year, with hundreds of appearances in print and online media. Around 70 of those have been identified by us as high visibility appearance in Switzerland (major media, such as in the Tamedia Group, Le Temps, Heidi.News, SRF, RTS) or internationally (CNN, die Welt,
Furthermore, we have continued our collaboration with SRF Einstein, which plans to present the past, present, and future of language in one or two issues of their TV show. We have regular contacts with one of the producers of SRF Einstein, and we invited him during our project meeting in Neuchâtel. This was the opportunity for him to learn more about the NCCR and to meet several of our researchers.

**Open Science**

**Presentations and workshops**

At the annual NCCR retreat (Engelberg August 24–28, 2021), the TTF DataScience gave a two-hour introduction to its services and explained the NCCR data management plan, including issues of Open Science. At the 4th project meetings (Neuchâtel, February 23-25, 2022), the TTF DataScience presented the further development of the framework and the established infrastructures for implementing the data management plan. This presentation encouraged researchers to contribute to open science over the course of data management and explained how the infrastructures established by the TTF DataScience will help them in this regard.

**Promotion of open access publications**

In compliance with the open access strategy of swissuniversities and SNSF, we encouraged our members to publish their results in open access journals, whenever possible. To this end, the NCCR Office regularly raises awareness for the SNSF open access policies and the possibility of obtaining funding for APCs via the platform mySNF (ChronosHub).

**Promotion of data archiving and open research data**

The TTF DataScience has taken measures to promote and facilitate the implementation of open science standards (cf Chapter 4). Particular focus has been put on the establishment of data management infrastructures and the development of these policies regarding transparency, reproducibility, and accessibility of research data. To achieve this goal, the TTF has (i) developed a data management pipeline, which includes openBIS (https://openbis.ch/), which complies with the FAIR principles, (ii) launched a server that aggregates up-to-date research data (essential metadata) from ongoing and published studies into a centralized database with indexation, (iii) published an open dataset index, (iv) generated an NCCR data platform with the centralized database on the backend, allowing NCCR members to navigate and access research metadata, (v) secured data transmission tunnels to facilitate data communication between the central server and other data servers distributed in different institutions/institutes within NCCR, (vi) deployed an NCCR-Wiki for disseminating the research/service information of individual projects/WPs in NCCR.
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Note: We highlight the names of PIs and their lab members.


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