EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Diagnostics and Cognitive Neuropsychology,

Department of Psychology, University of Tübingen

Workshop: Relations between space, language, and numbers

April 10th to 12th 2024

Federal Ministry of Education and Research

Baden-Württemberg MINISTRY OF SCIENCE, RESEARCH AND ARTS

DFG Deutsche Forschungsgemeinschaft German Research Foundation

Contents

1. **Welcome**

Dear participants, dear speakers, dear colleagues,

It is our greatest pleasure to welcome you to our workshop “Relations between space, language, and numbers” at the Department of Psychology at the University of Tübingen from April 10th to 12th, 2024.

Space, language, and numbers are highly relevant to our everyday lives. Research in the disciplines of Psychology, Cognitive Science, and Linguistics investigates how humans perceive, process, and mentally represent these three dimensions. However, the relation between space, language, and numbers is still unclear most likely because these three dimensions have often only been looked at from the perspective of one discipline. Hence, this workshop aims at providing new insights into the relation between space, language, and numbers and at developing methodological skills and experimental paradigms that may be instrumental for future investigations. Both early-career researchers and established experts from Psychology, Cognitive Science, and Linguistics are invited to contribute and enrich our understanding of the relation between space, language, and numbers.
During the three days, we welcome you to attend keynote talks, interactive methodological talks with Q&A, two poster sessions, a podium discussion, a meet-the-expert-session, and a social networking event in Tübingen! In addition, the city of Tübingen offers many historical sites and cultural highlights, which you can visit. More information can be found in this booklet.

We are very grateful that so many experienced international speakers accepted our invitation to give talks and conduct hands-on sessions during the workshop. We greatly appreciate their willingness to share their knowledge with us. Also, we are happy that an unexpectedly high number of researchers have registered and will take part in the workshop. This confirms the importance and relevance of the topic as well as the timeliness of our event. Thanks to all of you for your interest and support! Finally, we would like to thank our sponsors who make it possible to host this workshop without asking for any registration fees: the *German Research Foundation* (DFG) and the *Excellence Strategy* (i.e., Federal Ministry of Education and Research and Baden-Württemberg Ministry of Science, Research and Arts).

We are looking forward to interesting sessions, important insights, constructive discussions, new project ideas, and - most importantly - to getting to know you and your research interests. We are very happy to have you on board! We hope that you can gain new knowledge about the relation between space, language, and numbers, and make new connections within different disciplines in the research community.
If you have questions or need help with anything related to the workshop, please do not hesitate to talk to us.

The organization team

2. **Scientific organization**

Organization team

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3. **General information**

Website

https://uni-tuebingen.de/de/256925

Workshop Venue

Department of Psychology
University of Tübingen
Schleichstraße 4
72076 Tübingen (Germany)
Phone: +49 (0)7071 29-78345

Rooms:

Lecture hall:	4.329
Seminar room:	4.332, 4.333

All keynote talks, interactive methodological sessions, and the podium discussion take place in the lecture hall. Lunch breaks, coffee breaks, meet-the-expert session, as well as both poster sessions take place in the seminar rooms.

WiFi

Participants and speakers can use their eduroam login to access the wifi provided by the University of Tübingen. Participants and speakers who do not have their own eduroam login can use the following login:

SSID:	Guest
User name:	siirlg01
Password:	lp2lp8

Materials and Networking

In order to share workshop materials and to stay in touch with other speakers/participants/organizers in the future, we have created an OSF project as an exchange platform: https://osf.io/apwj9/

To access the content, please log in with your OSF account and send us a request to be added to the project. If this does not work, just write us an e-mail with your OSF name and we will add you. Feel free to share whatever might be useful for other speakers/participants/organizers. Like this, we can all benefit from this workshop in a more sustainable way.

4. Acknowledgements

Excellence Strategy

Our workshop is sponsored and supported by the Excellence Strategy of the University of Tübingen. The Excellence Strategy itself is a funding program of the Federal Government and the Länder to strengthen cutting-edge research at universities in two funding lines: Clusters of Excellence and Universities of Excellence.

As part of this program, the University of Tübingen has been heralded as one of Germany's excellent research locations since 2012. It holds its excellence status for its attempts *Research – Relevance – Responsibility* as well as *Open to New Challenges* and *A Global Scope of Action*. In the context of this excellence status, the University of Tübingen strives for five goals: strengthening research excellence, (further) developing a collaborative research environment, changing ability, promoting global awareness in research and teaching, and expanding social commitment.

Further information about the Excellence Strategy of the University of Tübingen can be found here:
https://uni-tübingen.de/en/163957

Further information about the Excellence Strategy funding program of the Federal Government can be found here:
https://www.bmbf.de/bmbf/en/academia/excellence-strategy/excellence-strategy_node.html

German Research Foundation (DFG)

The German Research Foundation is a major research funding organization in Germany, responsible for promoting and supporting academic research and scientific cooperation across various disciplines. Its primary goal is to fund and facilitate high-quality research projects, promote the training of young researchers, and foster international collaboration in science and academia. It plays a crucial role in shaping the research landscape in Germany and promoting scientific excellence both nationally and internationally.

Further information about the German Research Foundation can be found here:
https://www.dfg.de/en

5. **About Tübingen**

Small steps, narrow alleys, and pointed gables shape the silhouette of old Tübingen on the way up to its castle. The Swabian university town, with 28,000 of its 90,000 inhabitants being students, combines the flair of a lovingly restored medieval town center with the colorful bustle and typical atmosphere of a young and cosmopolitan students' town. Tübingen has witnessed almost a millennium of history. The area was likely first settled in the 12th millennium BC; Tübingen itself dates to the 6^{th} or 7^{th} century AD. It was first mentioned in writing in 1078 and achieved town status and civil liberty under the Palatine Counts of Tübingen in the middle of the 13^{th} century.

Many well-known personalities have resided in Tübingen over the past few centuries. They came to teach, to study, or to find space for their artistic, scientific, or political goals. The University became the cornerstone for numerous great careers and has itself been molded and enriched by the subsequent activities and events.

Discover the treasures of the historic old town: The Protestant seminary, in which Hölderlin, Schelling, and Hegel once shared a study; or the town hall in the marketplace, which is more than 500 years old. The Hölderlin Tower by the Neckar River invites you to linger with a line of "*Stocherkähne,*" punting boats unique to Tübingen ready for a ride. Numerous sidewalk cafes, wine taverns, restaurants, and boutiques invite visitors to stroll around and to pause here and there.

Sightseeing walk through Tübingen

(Numbers refer to the map of Tübingen "Highlights" below)

House of the Nuns (Nonnenhaus) (1)

The House of the Nuns dates back to the second half of the 15th century and owes its name to the Beguine or hermit women who lived here in a fellowship similar to nuns and who devoted their lives to charity. The stairs on the exterior of the building lead to the second floor, and to the left you will see to the so-called Speaking House, a medieval toilet directly over the Ammer Canal. Leonhard Fuchs, professor of medicine in Tübingen and known as the Father of Botany, moved into the house in 1535 and planted an herb garden next to the building, which he used for his experiments on the medicinal use of plants. In the 18th century, a newly discovered plant family, Fuchsia, was named after him. The stone book in front of the House of the Nuns commemorates his work.

Collegiate Church (Stiftskirche) (2)

In the context of the foundation of the University in 1477, the former parish church, which was mentioned for the first time in 1191, was transformed into a Gothic Collegiate Church. It was one of the first churches to convert to Martin Luther's protestant church after the Reformation in 1534. The top of the tower was added only at the end of the 16th century. As one of the most important churches in Württemberg – and thanks to the support of Duke Eberhard im Bart (the Bearded) of Württemberg – the Collegiate Church received an excellent décor.

Goethe (3)

Across from the *Stiftskirche* (Collegiate Church), number 15 in the Münzgasse lane, you will find the *Cotta-Haus* (House of Cotta), the former address of the famous publishing house that released the works of Schiller and Goethe. A plaque on the *Cotta-Haus* commemorates Goethe's stay of a few weeks while visiting his publisher (*Hier wohnte Goethe*). This is parodied on the building next door – once a dormitory, which features a plain sign with the words *Hier kotzte Goethe* (*"Goethe puked here"*).

Burse (4)

The Burse was built from 1478 to 1482 as a students' home and study shortly after the founding of the University. From 1803 to 1805, the building was transformed into the first medical clinic in Tübingen. One of the first patients was the poet Friedrich Hölderlin, who was released as incurable after 231 days of therapy in 1807. With the advancing medical development, the clinical center became too small. In 1972 – after a thorough reconstruction of the building – students and professors of philosophy and art history returned to this place of the "free arts".

Marketplace (Marktplatz) and City Hall (Rathaus) (5)

The Market Square with the City Hall and Neptune's Fountain, along with the Neckar waterfront, is one of Tübingen's favorite photography locations. The visually dominating City Hall – the oldest house at the marketplace – was built with three stories in 1435, in 1508 heightened by a fourth level, and in 1511 decorated with an artfully made astronomical clock by Johannes

Stöffler. The clock, which is still functioning, shows the course of the stars, the phases of the moon, and even such celestial events as eclipses of the sun and the moon. The Renaissance Neptune's fountain gives a certain touch to the marketplace and dates back to the beginning of the 17th century. It is the work of the master builder Georg Müller based on the design by Heinrich Schickard, who was inspired by a Bolognese archetype.

Hohentübingen Castle (Schloss Hohentübingen) (6)

In 1078, the castle of the Counts of Tübingen was mentioned for the first time. The current castle, which hosts numerous institutes and collections of the University, derives mainly from the 16th century. The Hohentübingen Castle is a mighty renaissance construction with four wings and a round tower. Its most beautiful decoration is the Renaissance portal built around 1606 in the style of a Roman triumphal arch, whose center shows the emblem of the Duchy of Württemberg. Beginning in the mid-18th century, the University acquired its first rooms in the castle, and in 1816, the King of Württemberg, Wilhelm I, transferred ownership of the castle to the University. The University library of nearly 60,000 volumes was temporarily housed in the hall of knights, an astronomical observatory was housed in the northeast tower, and a chemistry laboratory was set up in the kitchen. There, in 1869, Miescher was the first researcher to isolate various phosphate-rich chemicals (nucleic acid) in a laboratory, paving the way for the identification of DNA as the carrier of inheritance. After the complex restoration of the castle from 1979 to 1994, some of the University's cultural and academic institutions were relocated there, the collections of which are open to the public. Parts of the highlights are numerous archeological findings and replicas, such as a complete ancient Egyptian burial chamber. From the castle, the visitor has views to the city, as well as to the Neckar and Ammer valleys and the extended region up to the horizon of the Swabian Alb in the south.

Protestant Collegiate (Evangelisches Stift) (7)

The *Evangelisches Stift* was a former monastery of the Augustinians. In 1534, after the implementation of the reformation in Württemberg, it was reconstructed and enlarged in order to serve as a ducal stipend, a scholarship for students of Protestant Theology. A great amount of European intellectual history has been written within its walls. Among the scholars who studied there were Johannes Kepler, Gustav Schwab, Eduard Mörike, and Hermann Kurz as well as Georg Wilhelm Friedrich Hegel, Friedrich Hölderlin, and Friedrich Schelling, who occasionally lived and studied together in the collegiate at the end of the 18^{th} century. Today it serves as an accommodation and study space for about 140 students. Women have been admitted since 1969.

Hölderlin Tower (Hölderlinturm) (8)

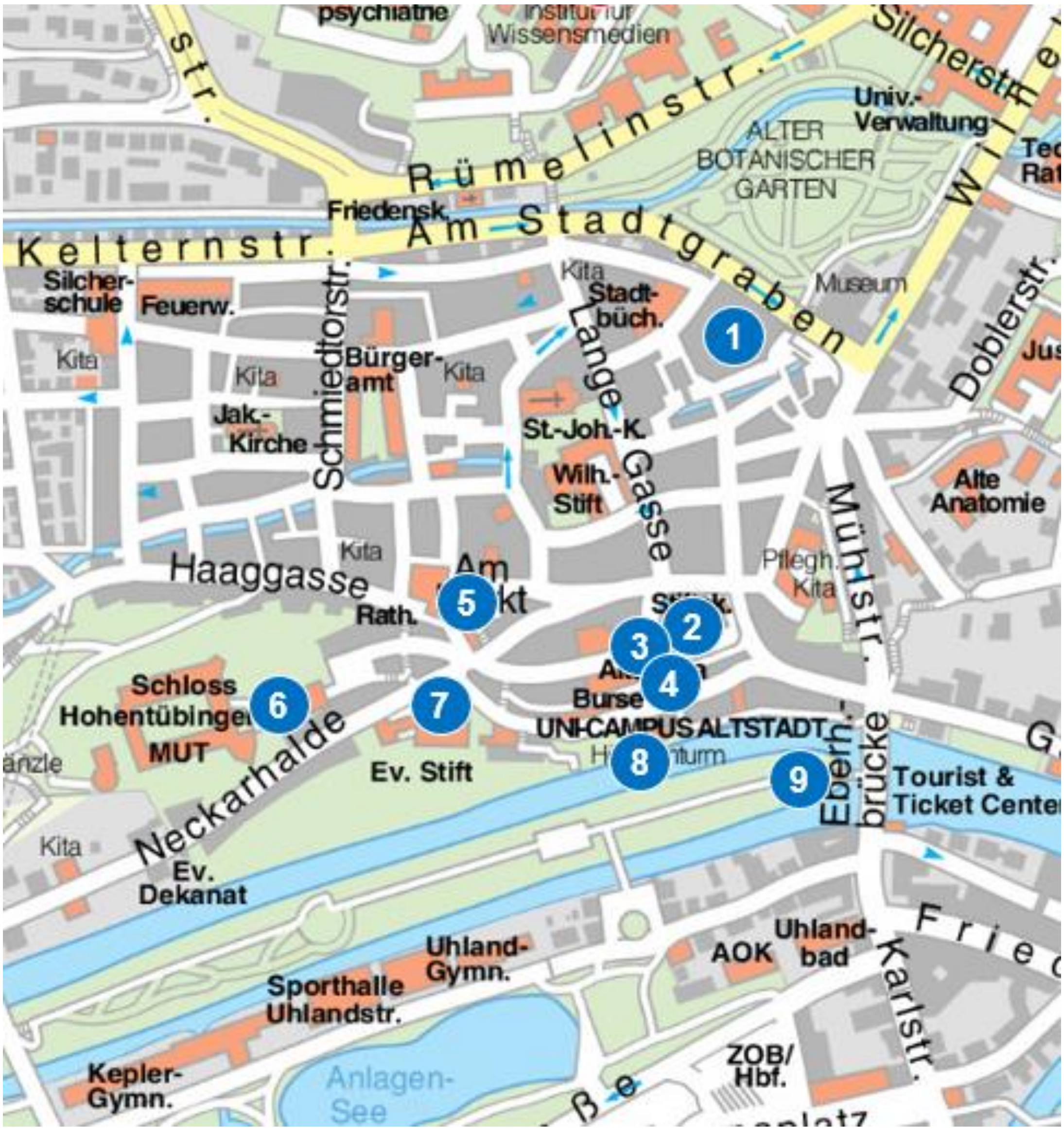
In the late 18^{th} century, the *Hölderlinturm* was built on the pedestal of the inner ring wall. The wall dates back to the 13^{th} century. The poet Friedrich Hölderlin (born in 1770) lived here from 1807 until his death in 1843. The family of a carpenter, Zimmer, accommodated him in this building for the last 36 years of his life as he struggled with mental instability. Today, the *Hölderlinturm* is a literary memorial place and museum.

Eberhards Bridge (Eberhardsbrücke), Neckar Island (Neckarinsel), Plane Tree Avenue (Platanenallee) (9)

In central Tübingen, the Neckar River divides briefly into two streams, forming the elongated *Neckarinsel*, famous for its *Platanenallee* with high plane trees, some of which are more than 200 years old. During the summer, the *Neckarinsel* is occasionally the venue for concerts, plays, and literary readings. The row of historical houses across one side of the *Neckarinsel* is called the *Neckarfront*. Houses were built even upon the city wall above the Neckar River during the Middle Ages, which created this distinctive waterfront, including the *Hölderlinturm*. The *Eberhardsbrücke*, which was formerly the only bridge in the city center and is therefore also called *Neckarbrücke*, is dominated by pedestrians. The railings and lanterns are decorated with brightly blossoming flower baskets during the summer months.

To learn more about what Tübingen has to offer, please visit www.tuebingen.de/en.

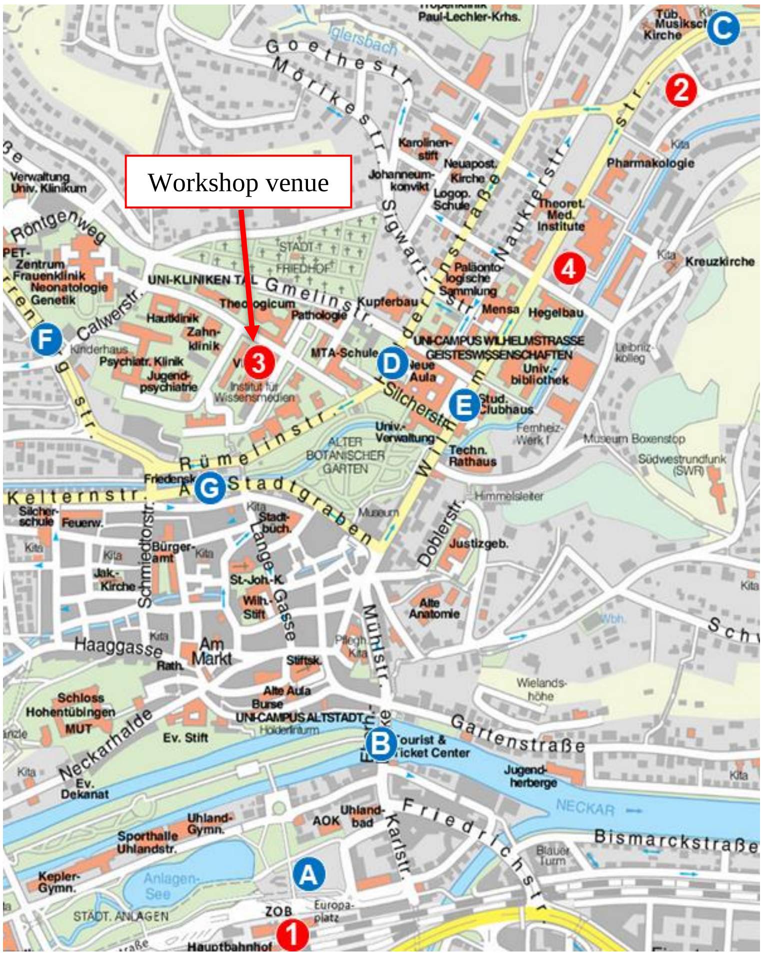
Highlights



https://www.tuebingen.de/stadtplan/

6. **Map of Tübingen**

Important locations and relevant bus stops



https://www.tuebingen.de/stadtplan/

Important locations

1: Main train station
2: Hotel Meteora
3: Department of Psychology
4: "Saints and Scholars" Irish Pub

Relevant bus stops

A: Tübingen Hbf
B: Neckarbrücke
C: Pauline-Krone-Heim
D: Hölderlinstraße
E: Uni/Neue Aula
F: Calwer Straße
G: Stadtgraben

Hauptbahnhof → Hotel Meteora

Walking from Tübingen Hauptbahnhof (= main train station) to the Hotel Meteora (Weizsäckerstraße 1) takes around 30 minutes. You can also take bus number 1 or 7 from *Hauptbahnhof C* to *Pauline-Krone-Heim*, which takes around 15 minutes.

Hotel Meteora → Hauptbahnhof

To get back from Hotel Meteora to the main train station, you can take bus number 1, 2, 7 or 21 from *Pauline-Krone-Heim* to *Hauptbahnhof*.

Hotel Meteora → Institute of Psychology

Walking from Hotel Meteora (Weizsäckerstraße 1) to the Institute of Psychology (Schleichstraße 4) takes around 15-20 minutes. You can also take bus number 1, 2, or 7 from *Pauline-Krone-Heim* to *Hölderlinstraße*.

Institute of Psychology → Hotel Meteora

To get back from the Institute of Psychology to Hotel Meteora, you can take bus number 1, 7 or 21 from *Uni/Neue Aula* to *Pauline-Krone-Heim*.

Hauptbahnhof → Institute of Psychology

Walking from Hauptbahnhof to the Institute of Psychology takes around 15-20 minutes. You can also take a bus instead, which takes around 10 minutes. Numbers 9, 11, 12 *(Hauptbahnhof K);* 13, 18, 19 (*Hauptbahnhof B); 8, 16 (Hauptbahnhof K)* go to *Hölderlinstraße.* Numbers 1, 7

(Hauptbahnhof C) and numbers 2, 3, 4, 6, 17, or 21 go from *Tübingen Hbf* to *Uni/Neue Aula*.

Institute of Psychology → Hauptbahnhof

To get back from the Institute of Psychology to Hauptbahnhof, you can take bus numbers 1, 2, 4, 5, 7, 17, or 21 from *Hölderlinstraße* to *Tübingen Hbf*.

Hotel Meteora → "Saints and Scholars" Irish Pub

Walking from Hotel Meteora to the Irish Pub "Saints and Scholars" (Wilhelmstraße 44), where our event dinner takes place on Thursday, takes about 7 minutes.

Institute of Psychology → "Saints and Scholars" Irish Pub

Walking from the Institute of Psychology to the Irish Pub "Saints and Scholars" (Wilhelmstraße 44) takes about 10 minutes.

All bus connections (as well as train connections) can be found in the phone apps *Naldo* or *DB Navigator* as well as on *Google Maps*. Bus tickets can be bought online in the app *Naldo* or at a ticket machine in each bus. One ride (*Einzelfahrschein Kurzstrecke*) costs 2.70€, and a one-day ticket (*Tagesticket*) costs 5.40€.

7. **University of Tübingen**

“Tübingen does not have a university, it is a university,“ is a common expression and for good reason: With its palm tree symbol and Duke Eberhard’s motto “*Attempto*!” (“*Dare!*”), the university and its 28,000 students certainly shape the city image. Its over 500 professors and nearly 5,000 academics make it the second largest university in Baden-Württemberg, following Heidelberg. Its seven institutes are spread throughout the city. In the old town, there is hardly a single building or location not associated with a famous scholar – Hegel, Hölderlin and Schelling, Mörike and Uhland, Kepler and Schickard among them. Furthermore, nine Nobel laureates are associated with the University of Tübingen.

The University of Tübingen is one of Europe’s oldest universities. Several hundred years of history in the sciences and humanities have been written here. The University’s history began back in 1477, when Count Eberhard “the Bearded” of Württemberg founded the University. The latest chapter of the University’s history is marked by its success in the Excellence Initiative of the German federal and state governments. One Graduate School, one Excellence Cluster, and the University’s Institutional Strategy were successful in the major funding program – also making Tübingen one of Germany’s eleven universities in the top “Excellent” class. The University has partnerships with more than 150 educational institutions in 45 countries, particularly in North America, Asia, and Latin America as well as with all countries in Europe. Moreover, together with 6 partner institutions, the University of Tübingen promotes excellence in research-led education within the Matariki Network of Universities (MNU). Some 13 percent of students in Tübingen come from abroad, and many of the University's German students pursue part of their studies in other countries.

To learn more about the University of Tübingen, please visit the University's Website: www.uni-tuebingen.de/en.

8. **Timetable**

Wednesday, April 10th, 2024

Time	**Title**	**Speakers**
12:00 pm – 1:30 pm	Reception and lunch	
1:30 pm – 1:45 pm	Welcome	Lilly Roth & Elena Albu
1:45 pm – 3:00 pm	Keynote talks: **Numbers, actions, language, & space: How do they interact in the brain?**	Roi Cohen Kadosh (online) & Rocco Chiou (in-person)
3:00 pm – 3:30 pm	Coffee break	
3:30 pm – 4:30 pm	Keynote talk: **Psychological Markedness as integrating principle for human cognition: The case of numerical cognition**	Hans-Christoph Nürk
4:30 pm – 5:30 pm	Keynote talk: **What language can tell us about space and spatial cognition, and numbers and numerical cognition**	Max Louwerse

Thursday, April 11th, 2024

Time	Title	Speakers
9:00 am – 10:15 am	Keynote talk: cancelled	
10:15 am – 10:45 am	Coffee break	
10:45 am – 11:45 am	Keynote talk: **The evolution of cognitive tools for quantification**	Andrea Bender
12:00 pm – 2:30 pm	**Poster session 1** and lunch	Participants
2:30 pm – 3:45 pm 3:45 pm – 4:15 pm 4:15 pm – 5:00 pm	Interactive methodological talk: **iScience Part I: Methods, Best Practice & WEXTOR** Coffee break Interactive methodological talk: **iScience Part II: Samply – A Web and Smartphone Application for Conducting Experience Sampling Studies**	Ulf-Dietrich Reips, Yury Shevchenko & Annika Tave Overlander
7:00 pm – open end	Social networking event at “Saints & Scholars” Irish Pub	https://www.saints-and-scholars.de/

Friday, April 12th, 2024

Time	Title	Speakers
9:00 am – 10:30 am	Talks and interactive debate: **The role of order and magnitude in Spatial Numerical Associations**	Valter Prpic (in-person) & Benjamin Pitt (online)
10:30 am – 11:00 am	Coffee break	
11:00 am – 12:00 pm	Podium discussion	*Moderator:* Elena Albu *Invited Guests:* Krzysztof Cipora, Max Louwerse, Barbara Kaup
12:00 pm – 2:00 pm	Meet-the-experts session, and lunch	Participants and speakers
2:00 pm – 3:30 pm	Interactive methodological talk: **Time after time: what can we learn about cognitive phenomena by looking into their temporal stability with the Ironman paradigm?**	Krzysztof Cipora, Jean-Philippe van Dijck, & Lilly Roth
3:30 pm – 4:30 pm	**Poster session 2** and coffee break	Participants
4:30 pm – 5:30 pm	Developing collaboration projects	Participants & speakers

9. **Speakers**

Elena Albu
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(Post-Doc at the Department of Psychology at University of Tübingen, Germany)

Elena is a postdoctoral researcher in the DFG Research Unit "Modal and Amodal Cognition". Her research focuses on the interplay between modal and amodal encodings underlying space-metric associations. She is particularly interested in the nature of the SNARC and SNARC-like effects and the factors triggering them. With a background in linguistics, she is equally interested in language and negation processing.

Andrea Bender
Andrea.Bender@uib.no
(Professor at the Department of Psychosocial Science at University of Bergen, Norway)

Andrea is a PI in the NFR-funded Centre for Early Sapiens Behaviour (SapienCE) at the University of Bergen, and one of four PIs of the project "Evolution of Cognitive Tools for Quantification (QUANTA)", funded by the European Research Council with a Synergy Grant. As a cognitive scientist with background in anthropology, she studies the relationship between cognition, language, and culture, and their (co-)evolution.

Rocco Chiou
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(Lecturer in Cognitive Neuroscience at University of Surrey, UK)

Rocco is a cognitive neuroscientist interested in how the brain represents conceptual knowledge. He uses methods such as fMRI, psychophysics, and brain stimulation to investigate cognitive control, perception, semantic memory, & numerical cognition. He is a lecturer of cognitive neuroscience at the University of Surrey.

Krzysztof Cipora

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(Lecturer at the Centre for Mathematical Cognition at Loughborough University, UK)

Krzysztof investigates Spatial-Numerical Associations: how they are influenced by language, culture, and how they are linked to mathematical skills. Moreover, he explores the individual prevalence of cognitive effects and their intraindividual stability over time. Krzysztof also works on mathematics anxiety and its links to mathematics achievement in different groups.

Roi Cohen Kadosh

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(Head of the School of Psychology and professor of Cognitive Neuroscience at University of Surrey, UK)

Roi is the Head of School of Psychology and professor of Cognitive Neuroscience at the University of Surrey. His research delves into the intricate interplay between psychological and biological factors shaping mathematical learning and cognition. Leveraging different methods such as brain stimulation, cognitive training, and artificial intelligence, his research explores ways to optimise these functions in various populations, including those with mathematical learning difficulties and those exceeding in mathematical abilities.

Barbara Kaup

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(Full professor and head of the Department of Psychology at University of Tübingen, Germany)

Barbara is currently the head of the Department of Psychology at the University of Tübingen and the leader of the DFG research group on Modal and Amodal Cognition. Her research addresses the processes and representations involved in language comprehension, with a particular focus on the way in which semantic and pragmatic factors affect the processing of negative sentences.

Max Louwerse

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(Professor of Cognitive Psychology and Artificial Intelligence at Tilburg University, and Professor by Special Appointment at Maastricht University, the Netherlands)

Max is Professor of Cognitive Psychology and Artificial Intelligence at Tilburg University, and Professor by Special Appointment at Maastricht University, the Netherlands. He has published extensively on symbolic and embodied cognition, neurophysiology, and virtual, mixed and augmented reality.

Hans-Christoph Nürk

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(Full professor at the Department of Psychology at University of Tübingen, Germany)

Hans-Christoph is heading the lab Diagnostics and Cognitive Neuropsychology and the Tübingen Brain and Number Group. His research focusses mainly on the (neuro)-cognitive underpinnings, the development and the impairment of numerical cognition as well as its diagnostics, possible interventions and educational impact. He is also exploring the relation of numerical cognition and spatial processing in various, frequently cooperative projects.

Annika Tave Overlander

annika-tave.overlander@uni-konstanz.de

(PhD student at the Department of Psychology at University of Konstanz, Germany)

Anni is a first-year PhD student in psychological methods. Her interests mostly lie in online research and statistics as well as decision making. She also works on several online studies on the SNARC effect, specifically on the technical side of experimental coding. With her background in psychology as well as neuroscience, she plans to tackle statistical and methodological challenges by developing tools for research and data analysis to make proper research techniques more accessible.

Benjamin Pitt

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(Research fellow at the Institute for Advanced Study in Toulouse, France)

Benjamin studies how people conceptualize abstract domains like time and number. His work across cultures, contexts, and age groups shows how even these fundamental aspects of cognition are shaped by language and culture, at multiple timescales. By studying conceptual diversity, he seeks to clarify the mechanisms that underlie human's extraordinary cognitive abilities.

Valter Prpic

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(Assistant professor at the Department of Philosophy and Communication Studies at University of Bologna, Italy)

Valter’s main research interest is in Spatial-Numerical Associations, and in particular in the role of order and magnitude in determining the origins of these effects. Additionally, Valter is also interested in perception, attention and music cognition.

Lilly Roth
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(PhD student at the Department of Psychology at University of Tübingen, Germany)
Lilly is a third-year PhD student investigating spatial mental representations of numbers and automatic number processing. She runs large-sample online studies to investigate the replicability of basic findings on the SNARC effect ("Spatial Numerical Associations of Response Codes"). Moreover, Lilly is interested in research methodology and statistical data analysis and strongly commits to Open Science practices.

Ulf-Dietrich Reips
reips@uni-konstanz.de
(Full professor at the Department of Psychology at University of Konstanz, Germany)
He focuses on Internet-based research methodologies, the psychology of the Internet, measurement, experimental methods, personality, privacy, data science, and mobile experience sampling. Ulf was a founder of the German Society for Online Research and has published more than 180 scientific articles and book chapters, six books and four special journal issues. Serving the research community, Ulf and his iScience team develop and provide free Web tools and apps for researchers, teachers, students, and the public that are available from the iScience Server.

Yury Shevchenko

yury.shevchenko@uni-konstanz.de

(Post-Doc at the Department of Psychology at University of Konstanz, Germany)

Yury did his PhD at the Chair of Experimental Psychology at the University of Mannheim, Germany. His interests lie in the intersection of psychology and computer science with a focus on methods and programming. Yury has developed Open Lab, a web platform for conducting online experiments, and Samply, web and mobile application for experience sampling studies. Since 2019 he has been working as a Post-Doc at the University of Konstanz.

Jean-Philippe van Dijck

jean-philippe.vandijck@thomasmore.be

(Lecturer and researcher at Thomas More University, and visiting research professor at Ghent University, Belgium)

In his scholarly investigations, Jean-Philippe utilizes insights from the domains of numerical and mathematical cognition to elucidate variations in mathematical proficiency among individuals in educational settings. In addition, he aims to develop tests for the (early) detection of mathematical learning difficulties. His research particularly concentrates on the associations between numbers, serial order in working memory and space, as well as the psychological aspects of math anxiety and psychometry. In addition to conducting research, Jean-Philippe instructs in the courses of General Psychology, Neuropsychology, and Research Methods.

10. Session abstracts

Numbers, actions, language, & space:
How do they interact in the brain?

Roi Cohen Kadosh

This talk delves into the critical, yet under-explored, role of visuospatial abilities in mathematical expertise. While research often focuses on children and intervention programs, this presentation shifts the lens to mathematicians themselves. Key areas I will address in this talk include:

- Neuroimaging insights: Examining structural changes in the brains of mathematical experts, particularly in regions associated with visuospatial processing.
- Influence on number processing: Utilizing a comprehensive battery of tasks, we will explore how the type of number and expertise level impact the processing of numbers on the number line.
- Cognitive styles and expertise: We will investigate whether specific cognitive styles employed for solving arithmetic problems, including visuospatial style, such as visualising numbers/equation in the mind's eye, predict mathematical expertise.

These findings illuminate the strong connection between visuospatial abilities and mathematical proficiency; however, a crucial question remains – is spatial involvement necessary for developing mathematical expertise? By addressing this critical gap, we can gain a deeper understanding of the underlying mechanisms at play. Moreover, we can develop more effective educational programs to enhance mathematical abilities. This presentation invites discussion and paves the way for further research into this essential aspect of mathematical cognition.

Rocco Chiou

Decades of neuroimaging research have shown that different lobes of the human brain exhibit distinct modality-specific preferences owing the differential sensory input they receive. The occipital lobe receives direct visual input and prefers visual processing. The temporal lobe receives direct auditory input and prefers auditory/linguistic processing (particularly the superior temporal areas). The frontal lobe contains the motor cortex and is closely involved in motor planning and execution. Interestingly, the parietal lobe is the functionally most heterogeneous lobe amongst all - it is widely involved in visual, linguistic, sensorimotor, and numerical processing. In my talk, I will discuss why there is such functional heterogeneity in the parietal lobe and how this affects different aspects of numerical cognition so that in neuroimaging research we see different types of number processing engage different subregions of the parietal lobe, resulting in a unique cortical topography that shows a multisensory centroid and modality-related periphery.

Psychological Markedness as integrating principle for human cognition: The case of numerical cognition

Hans-Christoph Nürk

In this talk, we introduce the concept of Psychological Markedness into human cognition and elaborate the account by the example of numerical cognition. After defining Psychological Markedness, we clarify previous misconceptions about linguistic markedness effects. Next, we give an overview over the most important effects in numerical cognition that can be conceptualized as markedness effects. We develop a new taxonomy categorizing these effects by delineating stimulus attributes, relations, and response codes.

Then we develop a model framework of psychological markedness. We provide multiple lines of evidence that the psychological representation of markedness goes beyond common accounts of linguistic markedness. For instance, it is embodied, graded and extends to non-linguistic attributes. We show that markedness is both influenced (i) by the individual experiences an individual is exposed to (e.g. body- specificity: handedness) and (ii) by the context, such as a task, paradigm, stimulus specificity, or other experimental manipulations. We shortly elaborate how this model framework differs from other competing accounts like the polarity correspondence account and what the advantages of the new concept are. We suggest that the Psychological Markedness account can provide an integrated guideline for future research endeavors of the numerical cognition field and possibly beyond.

What language can tell us about space, spatial cognition, numbers and numerical cognition

Max Louwerse

Many studies have argued that space and numbers have little to do with the symbolic system called language. After all, no meaning can be extracted from an abstract, arbitrary amodal symbol system. Instead, according to these embodied cognition theories the only answer to the symbol grounding problem in language processing is the activation of perceptual simulations. This poses worthwhile discussions on the nature of cognition, but yields fundamental problems with natural language processing (NLP) solutions, including Large Language Models (LLMs) such as ChatGPT.

An increasing amount of evidence has however accumulated showing that meaning extracted from the language itself. The Symbol Interdependency Hypothesis (Louwerse, 2011; 2018; 2021) has even posed that language encodes perceptual information. Language users can rely on patterns in the linguistic system itself to bootstrap meaning. Stated simply, language creates meaning.

This presentation gives an overview of various studies showing that findings that have been attributed to the activation of a perceptual system ought to be attributed to the language system itself. These studies for instance suggest that we need to be careful attributing the Spatial Numerical Association to Response Codes (SNARC) effect to perceptual information because its findings can also be explained by word frequency. Similarly, comprehenders may not always need to activate perceptual information for spatial cognitive tasks, but can also rely on the language system itself.

If language encodes perceptual information, it has important implications for the way we understand language processing both in human and artificial minds.

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The evolution of cognitive tools for quantification

Andrea Bender

A variety of cognitive processes concerned with numbers (including the discrimination and comparison of different quantities, their exact enumeration, and mental arithmetic) depend on the availability of cognitive tools such as numeral systems. Such systems vary across cultures and languages, and their distinct properties affect how numbers are represented and processed (Bender & Beller, 2018). Numeral systems are thus a prime example of the close dovetailing of culture, language, and cognition, and a paradigmatic case of both distributed and embodied cognition (Bender & Beller, 2012). This talk will present QUANTA, a highly interdisciplinary project aiming to investigate how these systems evolved, developed, and diversified, and which cognitive implications arise from their specific properties. The talk begins by outlining the diversity of numeral systems and the challenges that this diversity poses for any comparative investigation. It then details some of those system properties on which QUANTA is focusing: how numerical information is represented in a system (e.g., in an explicit or implicit manner; Zhang & Norman, 1995), how this is organized (e.g., by structural elements that allow for compositionality; Bender & Beller, 2014), and how it affects the processing of numerical information (e.g., by affordance/constraints or representational effects; Beller & Bender, 2011; Bender, Schlimm, & Beller, 2015).

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iScience Part I:
Methods, Best Practice & WEXTOR

Ulf-Dietrich Reips, Annika Tave Overlander

We will introduce and discuss methods, pitfalls, and best practices of Internet-based research (Reips, 2021). Noting a “fundamental asymmetry of accessibility” in data collection (most experiments programmed for the lab cannot be conducted online, but any online experiment can also be conducted in the lab), Reips (2002) recommends to always set up an experiment as an online experiment, if possible. Published in *Behavior Research Methods* in 2002, WEXTOR was the first online experiment generator (Reips & Neuhaus, 2002), its newest version is available from https://wextor.eu. It follows a “good methods by design” philosophy and can be used to design laboratory and web experiments in a guided step-by-step process. It dynamically creates customized web pages for the experiment and provides experimenters with visualizations of their experimental design and previews of appearance on different devices. WEXTOR flexibly supports complete and incomplete factorial designs with between-subjects, within-subjects, and quasi-experimental factors, as well as mixed designs. Randomization and counterbalancing are included and any JavaScript codes (e.g. SNARC routines) can flexibly be added via WEXTOR’s plugins or by editing the html pages created. WEXTOR is responsive (i.e. adapts to any device, such as mobile phones, tablets, laptops, and desktop computers), implements both server- and client-side exact response time measurement and includes a content wizard for creating interactive items such as Likert-type scales, visual analogue scales or multiple-choice items, on the experiment’s pages. Experiments can be shared with other experimenters, and can be duplicated and adapted easily. WEXTOR is a powerful practical tool for both creating and hosting well-designed online and lab experiments that are easily replicable.

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Samply – A Web and Smartphone Application for Conducting Experience Sampling Studies

Yury Shevchenko

Samply supports the way researchers conduct experience sampling, ambulatory assessment, and diary studies (Shevchenko, Kuhlmann, & Reips, 2021). As a researcher, you have the flexibility to craft online surveys or experiments using your preferred tools. Samply enhances this process by sending mobile notifications via its app, directing participants straight to your online study in their mobile web browsers.
In this tutorial, we'll explore Samply's core functionalities: setting up a study, scheduling notifications, and managing participants. We'll delve into the versatility of Samply in supporting various experience sampling designs and discuss its advanced features like geofencing (Shevchenko & Reips, 2023) and the Samply API, demonstrating how these features can enhance behavioral research. Additionally, we will address practical tips on preparing and executing an experience sampling study efficiently via mobile phones (Shevchenko & Reips, 2022). Stay informed about the latest updates with our online step-by-step guide to Samply (Shevchenko, 2023).

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The role of order and magnitude in Spatial Numerical Associations

Valter Prpic

Spatial Numerical Association (SNA) is a tendency to associate small numbers with the left space, and large numbers with the right space. In particular, a well-known demonstration of this tendency is the Spatial Numerical Association of Response Codes (SNARC) effect, which consists in faster left key responses to small numbers and faster right key responses to large numbers (Dehaene et al., 1993). Traditionally, this phenomenon has been attributed to numerical magnitude, however evidence shows that purely ordinal information can elicit similar effects (e.g., letters of the alphabet and months of the year; Gevers et al., 2003). The working memory account (van Dijck and Fias, 2011) provides further support to the idea that ordinal information is responsible for this phenomenon, suggesting that the order of items in WM can be responsible for the SNARC effect (early items in a WM sequence are associated to the left, late items to the right). Currently, the debate is not settled and several theoretical papers discussed about the role of order and magnitude in SNARC and SNARC-like effects (see Prpic et al., 2021; Pitt and Casasanto, 2022). In this contribution I argue that, although much evidence in the field can be explained by the ordinal properties of the stimuli, there is clear evidence that also magnitude plays a relevant role in these phenomena. I will present evidence from behavioural experiments in humans and animals, and discuss the contribution of recent theoretical accounts (Brain's Asymmetric Frequency Tuning, Felisatti et al., 2020) in this debate. Finally, I will discuss some promising experimental manipulations with the aim to disambiguate the role of order and magnitude in SNARC and SNARC-like effects.

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All in order: The mental number line reflects associations between spatial and numerical position

Benjamin Pitt

Studies have long attributed the mental number line to implicit associations between numerical magnitude and left-right space. Here I argue that this mental mapping – and the SNARC effect often used to measure it – reflects associations between spatial position and numerical order, not magnitude. This account is supported by empirical findings showing for example that SNARC effects (a) obtain when stimuli do not vary in magnitude, (a) follow ordinality even when it contradicts cardinality, and (c) do not scale with numerical magnitude. I also argue that SNARC effects cannot in principle be explained by magnitude alone because magnitude does not have direction. Rather, mental mappings of number and many other domains appear to be associations between spatial and ordinal position, whether that position is determined by relative magnitude or other stimulus features.

Podium discussion:
Relations between space, language, and numbers

Moderator: Elena Albu

Guests: Krzysztof Cipora, Barbara Kaup, Max Louwerse

In the podium discussion the relation between space, language, numbers will be further discussed, with a special focus on:

- how linguistic factors affect spatial associations in general and spatial numerical associations in particular
- representations of quantity words and numerals in numerical cognition and everyday language use
- cultural effects on spatial numeric associations: cross-cultural comparisons (and how they often are confounded with language)
- how new developments in methods may provide new insights into the relation between space, language, and numbers

Time after time: What can we learn about cognitive phenomena by looking into their temporal stability with the Ironman paradigm?

Krzysztof Cipora, Jean-Philippe van Dijck, Lilly Roth

Most of the studies in experimental psychology investigate cognitive phenomena by collecting data from participants for a task at one time point. The obtained results are then generalized over the population (typical statistical inference), but two other implicit generalizations follow: (1) that a group-level effect is present among all participants and (2) that this effect is stable over time. Our recent work has explored whether these two generalizations hold. Firstly, we tested them for the SNARC effect (i.e., left-/right-side advantage in responding to small/large number magnitudes, respectively). We developed bootstrapping methods to test whether the effect is reliably present at the individual level. We found that robust group-level effects are not necessarily reflected in all participants (speaking against generalization 1). Even more surprisingly, an easily replicable, robust group-level SNARC effect seems to be driven by a minority of participants (Cipora et al., 2019; Roth et al., 2023). In the next step, using the bootstrapping toolkit we tested whether the effects were stable within participants across extended periods of time . Using this, as we called it, *Ironman paradigm*, we found that even though the SNARC effect was robust at the group level, and the proportion of participants revealing a reliable effect across 30 sessions was similar to proportions observed in other studies (4 out of 10 participants), only one participant revealed a reliable effect in more than half of the sessions (speaking against generalization 2). This observation has important implications for cognitive psychology, namely that the two generalizations are not always valid. It calls for testing the presence of other robust cognitive group-level phenomena and their temporal stability. We will also present preliminary results of a follow-up Ironman study testing intra-individual stability of other cognitive phenomena (Cipora et al., 2023).

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11. Poster abstracts

a. Preregistration posters

Common mechanisms for spatialization of short and long-term information?

Lucie Attout[1,2], Suzanne Lefèvre[2], & Pom Charras[2]
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Numerous studies have demonstrated our ability to link short or long-term information with mental spatial codes during various cognitive tasks. Participants exhibit quicker responses when associating small numbers or the initial items encoded in working memory (WM) with their left hand and larger numbers (SNARC) or the final items of a WM sequence (SPoARC) with their right hand. However, despite these shared characteristics, the two effects are not necessarily rooted in the same cognitive processes as they manifest differently depending on the context. While the SNARC effect can be observed along all three Cartesian axes, suggesting a sensori-motor explanation (see Sixtus et al., 2023 for a recent review), the SPoARC effect appears to be more broadly influenced by cultural practices (see for example Abrahamse et al., 2017). Hence, the objective of this study is to contrast both spatial effects on two axis, one easily explained by the cultural assumption, namely the horizontal axis and another, importantly, not readily explained by the cultural assumption, specifically the mid-sagittal axis. To achieve this, we will use distinct paradigms that have been highly validated and yielding to reliable spatialization effects for both SNARC and SPoARC. For the SNARC effect, we will use a go/no-go procedure requiring an explicit magnitude judgment (Shaki & Fischer, 2018). On the other hand, for the SPoARC effect, we will employ a three-phase paradigm (inspired by van Dijck & Fias, 2011) encompassing an encoding, maintaining, and serial order recognition phase, including letter stimuli. For each effect, both axes will be assessed by manipulating the orientation of an Azerty response keyboard, positioned either in a horizontal plane (left-right lateralised keys), or in a mid-sagittal plane (close-far lateralised keys) on the table between the participant and the computer screen. A sample size of 30 French participants per group will be required (estimation based on the BayesFactor package for R, Brysbaert, 2019), showing a power of .87 for the main effect of compatibility. Given the theoretical framework and the findings from previous studies, we anticipate robust SNARC effects on both dimensions and a strong SPoARC effect on the horizontal axis. Importantly, the absence of a SPoARC effect on the mid-sagittal axis is expected if the SPoARC effect is influenced solely by reading/writing direction. However, the presence of a SPoARC effect on this axis would suggest a potential involvement of sensorimotor experience in this phenomenon, akin to what has been observed for the SNARC effect. Furthermore, in this latter scenario, the magnitude of the SPoARC in both horizontal and mid-sagittal dimensions is expected to correlate with the strength of the SNARC effect on their respective dimension. Additionally, we will investigate the impact of reading expertise and spatial imagery abilities on the magnitude of the SPoARC effect in the different dimensions by including a Fluency reading test and a spatial imagery questionnaire.

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The social side of the STEARC effect: Spatial representation of face age in explicit and implicit tasks

Mario Dalmaso[1], Stefano Pileggi[2], Mauro Murgia[2], & Michele Vicovaro[1]
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Time can be conceptualized in spatial dimensions, as evidenced by the STEARC effect (Bonato et al., 2012; Ishihara et al., 2008). Recent work by Dalmaso et al. (2023; see also Dalmaso & Vicovaro, 2021) tasked Western participants with categorizing the age of a central target face (depicting a man) as either younger or older than a reference face. The findings revealed that the perceived age was mapped from left to right (Dalmaso et al., 2023). In our ongoing project, we aim to delve deeper into this phenomenon by examining whether a comparable spatial representation emerges when face age is implicit. Unlike our initial study, we will utilize two face identities, one male and one female, analysing data through linear mixed effects models, with sample size determined in accordance with dedicated guidelines for such models (Brysbaert & Stevens, 2018). In Experiment 1, participants will explicitly categorize facial age as younger or older, aiming to replicate our earlier results with a left-to-right spatial representation of face age. In Experiment 2, a new set of participants will categorize the sex of faces (male vs. female), making face age an implicit dimension. Here, we anticipate the spatial representation of face age to disappear, aligning with research demonstrating the cancellation of the STEARC effect for implicit time dimensions (Dalmaso et al., 2023; Mariconda et al., 2022).

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The effectiveness of different action plans and their impact on modal to amodal representation shifts in response to food stimuli

Rabia Dilawar & Caterina Gawrilow
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This study examines how quickly and accurately we can recognise and categorise things we see, focusing on food items. It explores how different 'if-then' plans affect our ability to recognise these foods and how our brain shifts from seeing and thinking about something as an image (modal representation) to thinking about it in words (amodal representation). We are testing if more straightforward 'if-then' plans, where seeing something immediately leads to a physical response, are quicker than more complex plans that involve thinking in words before responding. Based on direct sight, the more straightforward plan (Modal)will be faster, while the word-based plan (amodal) might be slower because switching from images to words takes extra mental effort.
In our experiment, we'll ask participants to identify 15 food items shown as pictures randomly quickly. We'll measure how long it takes them to press a key from the moment the food item starts becoming clear to see. Depending on their assigned group, they also need to verbalise the word in their mind and then press the key. Furthermore, conditions will be the same for both groups depending on their modal (if I see a food picture, then I will respond by pressing a key as quickly as possible) or amodal (in this, then part entails an alternative action- e.g., if I see a food picture, then I will imagine spelling it out) representation. Reaction time (measured by the moment the image will be displayed on the screen) will be measured to test our hypotheses: H1 states that the modal if-then plan will result in faster RTs due to direct visual processing. Whereas, H2 hypothesised that the modal if-then plan will lead to slower RTs, requiring an additional cognitive step of shifting the visual stimuli to verbal processing. A mixed design ANOVA will be used treating type of plan as between subject and food stimuli as with subject factor. Depending on the results of ANOVA, Post hoc analysis will be applied to see the differences between groups and individual factors.
Our findings will help us understand how planning in specific ways can make us better at quickly identifying things we see. This could be useful in many areas, like helping people control unhealthy eating habits. We aim to uncover more about how our brains process different types of plans and add to the conversation about making cognitive tasks more efficient.

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Investigating colexification of number words and body parts through finger counting practices

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Introduction: The study of colexification, where one word represents multiple concepts, reveals global patterns in languages, reflecting universal aspects of human perception and conceptualization (Youn, et al., 2016). The relationship between number words and terms for body parts (e.g., using the same word for "hand" and "five") is a particularly intriguing colexification example. This connection has been extensively recorded across different language families and linked to the prevalence of quinary, decimal, and vigesimal counting systems. The study of colexification patterns and dominance of particular numeral structures could help us understand the early phases in the development of numerical concepts (Wiese, 2007). However, prior discussions have mainly concentrated (quite reasonably) on the linguistic dimensions of colexifying number words and body parts, often neglecting their link to finger-counting customs in various cultures. I posit that an examination of how colexification of these two notions intertwines with bodily representations of numbers (through finger counting, body tallies, etc.) could deepen our insights into the evolution of numeral systems.

I propose two primary research questions: RQ1) Is there an association between the specific body parts used in colexified number words and those employed in body-based counting systems (e.g., do groups that use toes for counting colexify numbers with "toe" more frequently)? RQ2) Does the base (and perhaps sub-base) of a body-based numeral system influence its colexification patterns (e.g., are groups with a quinary system more likely to colexify body parts with the number 5)?

My hypotheses are twofold: H1) Groups utilizing specific body parts for counting (e.g., toes) will show a higher frequency of colexification with corresponding parts as opposed to groups counting on other body parts. H2) Groups with body-based systems with a specific base size (e.g., base-10) will tend to more often colexify body parts with number words corresponding to that element (10).

Methodology: The data will be collected from descriptions, such as dictionaries, fieldwork notes, research studies, and reports. Groups will be distinguished by names and Glottolog identifiers (https://glottolog.org/). Key variables will include:

- base and subbase sizes of the body-based numeral systems (given as integers)
- body part used for counting (fingers, toes, other body parts, finger segments, space between fingers, etc.)
- colexified concepts: values for numbers (given as integers) and body parts (digit, thumb, hand, toe, foot, etc.). e.g., "5hand", "10fingers", "15toe".

Approach for statistical analysis: Given the nature of the data (categorical), the statistical method for testing H1 and H2 could be a Chi-Square Test of Independence. Additionally, to test H2, Logistic Regression Analysis could be implemented to test the probability of a specific colexification pattern given the base size. The relatedness between language families should be accounted for.

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Generalization and exploration in semantic conceptual search spaces

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When writing a research proposal, you can exploit ideas that immediately come to mind, or try and explore new, uncertain, or random thoughts. Either way, you are searching in a rich space with seemingly endless options, be it in the actual physical world (e.g., a library, a city, a forest) or your own mind (e.g., filled with large associative networks of acquired information). Many studies that investigate exploration strategies look at value-based decision-making using multi-armed bandit paradigms, offering participants two or three visible and clearly defined choice options (Cogliati Dezza et al., 2017; Dubois et al., 2021; Wilson et al., 2014). By doing so, they may underappreciate the vast, and often invisible and more abstract search spaces agents are typically faced with. Instead, this project studies value-based decision-making in unbounded cognitive semantic search domains.

The project's primary objective is to explore how individuals generalize rewards and guide exploration strategies within cognitive, semantic associative networks. The paradigm we work from has been extensively used in spatial search domains (Wu et al., 2018), which will allow us to identify the differences and similarities between spatial and semantic search.

We will conduct an experiment where participants (80 typically developed adults) navigate a semantic space (of animals) to learn reward distributions based on semantic similarity. Concretely, participants are, per round, asked to sell pictures of 20 animals (with replacement) to an unknown customer. We will not provide them with visible and well-defined choice options, but they rather will have to sample from their own memory. The price the customer is willing to pay follows such a reward distribution (a mixture of Gaussians), in which animals that are semantically similar yield similar rewards. Utilizing a similarity matrix derived from word co-occurrence data, we will quantify the semantic distance between animal names (Hills et al., 2012). Participants are informed about the relationship between reward and (semantic) similarity, which allows them to generalize prior rewards to make predictions about novel choice options (animals). Behaviorally, we will study the semantic distances of their decision-making as a measure of exploration. Further, we will apply a computational model of generalization and exploration to the behavioral data to analyze how participants utilize their cognitive representations of semantic similarity to inform decision-making. It remains an open question whether people (can) use similar generalization and search strategies in semantic networks, and what the cost is of navigating in them.

Through this interdisciplinary approach, integrating cognitive psychology, computational modeling, and semantic analysis, this project aims to advance our understanding of exploration and generalization in semantic space. By elucidating how individuals navigate complex decision spaces characterized by semantic similarity and systematically comparing those to spatial search, we can glean insights into the cognitive mechanisms driving human decision-making across diverse domains.

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Error detection in preschoolers: An fNIRS study of numerical vs semantic incongruence

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Introduction. Symbolic numerical knowledge is the basis of mathematical learning. Studies in adults and children propose the frontoparietal network as the basis of mathematical thinking, with left parietal involvement for processing number words, right parietal involvement for processing non-symbolic magnitudes and cognitive support from the frontal regions (Bugden, et al., 2021; Hyde, 2021; Pinhas et al., 2014; Vogel et al.,2017). One of the most often used tasks to investigate symbolic numerical knowledge in preschoolers is a numerical incongruency task (Bugden et al., 2021; Pinhas et al., 2014). Despite many insights, no study has investigated the extent to which numerical error detection relies on semantic error detection in preschoolers. Furthermore, this knowledge could clarify the role of executive function in mathematical learning in early childhood. We hypothesize that the bilateral parietal, but not frontal, engagement will be different in response to numerical error detection vs. semantic error detection.

Methods: 44 typically-developing children (aged 3-4.6 years) took part. Behavioral tasks included the Give-a-Number task (Krajcsi, 2021) to assess cardinality understanding and the Preschool Early Numeracy Screener (PENS; Purpura et al., 2015) to measure overall numeracy competency. In the neuroimaging part, participants' bilateral frontoparietal activity was recorded using functional near-infrared spectroscopy (fNIRS) while they were completing a numerical congruency task. The task consisted of 3 conditions (small number, large number and semantic control), each with 3 blocks of 4 trials. In each condition, children were presented with a picture (e.g., 3 apples in a small number condition). Once a picture was shown, audio played (e.g., either "one"/"two"/"three" in a small number condition), and the child had 6 seconds to say whether the audio matched the picture.

Analysis plan. NIRS Brain AnalyzIR toolbox is used for data preprocessing, and systemic artefact correction is applied using a general linear model (GLM). For the analysis, we will first compare the two numerical conditions with the semantic condition to test for domain-specific magnitude processing. We will include both congruent and incongruent trials and expect higher bilateral parietal activation in the numerical conditions when compared to the semantic condition. Second, we will compare large and small number conditions to test for the difficulty of calculation and cardinality knowledge. We expect higher frontoparietal activation in the small number condition.

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Will it take long, or a lot?
When language-specific metaphors change the way we calculate durations

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Introduction – Background: This project intends to tackle whether the language we speak influences the way we think – also known as the Sapir-Whorf hypothesis of linguistic relativism (Whorf, 1939). More specifically, we aim to contribute to a line of works suggesting that time perception may differ depending on the language spoken (Casasanto et al., 2004, 2007). Building on previous findings according to which English and Indonesian speakers tend to use distance-related expressions to talk about time (e.g. "a long time"), while Spanish and Greek speakers tend to use amount-related expressions instead (e.g. "much time"), we intend to evaluate whether those differences impact the way that individuals calculate durations. We propose to contrast the performance of native speakers of 4 different languages on arithmetic word problems involving durations. Those problems are meant to elicit different solving strategies based on the mental encodings constructed by the participants (Gros et al., 2021). In previous studies in French and in English, it was shown that duration problems elicit an ordinal encoding, compatible with a 1-step solving strategy. However, this effect might not replicate in languages using amount-related expressions to talk about time. We aim to investigate whether the use of distance-related or amount-related expressions in one's native language influences the way they think about time and solve duration problems.
Hypotheses: We intend to evaluate whether participants speaking languages predominantly using 'distance-related' phrases about time will be more likely to construct an ordinal encoding of situations involving durations, compared to those speaking languages using 'amount-related' phrases to talk about time, resulting in different solving strategies being used.
Methods - Linguistic Analysis: Following the methods described in existing literature (Casasanto et al., 2004, 2007) and incorporating recent criticism of using Google as a corpus (Carrion & Valenzuela, 2021), we used Sketch Engine to classify languages into two categories. We observed that English and French primarily use "distance-related" time expressions, while Spanish and Portuguese predominantly use "amount-related" phrases for time. **Participants:** A total of 1200 participants will be recruited online, using Prolific, on the basis of their native language. All participants will be compensated for their time. Our target sample size is 300 participants per language.
Design: Each participant will be asked to solve 12 mathematical word problems in their native language, comprising 6 ordinal (duration & height) and 6 cardinal (collections & price) problems. All problems are adapted from former studies (Gros et al., 2019, 2021) and share a common mathematical structure.
Procedure: The experiments will be executed simultaneously in 4 languages on Qualtrics: English, French, Spanish and Portuguese. Each participant will be provided with the mathematical word problems and necessary instructions in their native language. Problem order will be controlled across participants.
Statistical Analysis: We will use a generalized linear mixed model with a binomial distribution to evaluate inter-languages differences in solving strategies on durations problems. We will include participants as well as problem statements as random effects, to account for the repeated measures in the design. plan to explore how the two independent variables may interact with each other and also influence the way participants construct mental encodings of different problems and solve them using specific problem-solving strategies.

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Comparing spatial conceptualizations: Collective versus regular numerals in Hebrew

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Introduction: Alongside the conventional number system, Hebrew can express numerosities of objects using collective nouns based on numbers (henceforth collective numerals)**.** For example, *three birds* can be expressed by *ʃaloʃ tsiporim* 'three birds' or *ʃliʃiyat tsiporim* 'a trio of birds'. This collective system is applicable to numbers ranging from 3 to 10. All collective nouns have a dual conceptual nature: (i) they reference a multiplicity, which is (ii) conceived as a unity (Joosten et al., 2007). Hebrew, as a case study, allows a direct comparison of collective numerals with regular numerals, which merely enumerate objects, and with nonnumeric collective nouns (e.g., 'a crew').

We investigate whether the distinct ways of conceptualizing objects result in different spatial construals. Specifically, we aim to determine whether the group-level conceptualization induced by the collective systems prompts a grouped spatial conceptualization. We compare collective numerals with regular numerals, on one hand, and with standard collective nouns, on the other.

Method: Participants: 40 native Hebrew speakers.

Materials and procedure: Participants read a sentence and then viewed two pictures. In one, objects were grouped closely, while in the other, they were spread out. Participants were asked to choose the picture that matched the sentence description best. Sentences included Hebrew numerals from 3 to 10 in both collective and regular forms. Each participant saw 12 experimental items, with each number appearing only once in each form, alongside four sentences containing collective nouns.

Results and analysis: Collective numerals in the stimulus sentences led to the highest proportion of choice for the grouped image (72.3%), followed by collective nouns (68.91%), and regular numerals (59.46%). We conducted a mixed-effects binomial regression, with the choice of grouped image as a function of the NP type (reference level: collective numerals), and random intercepts for participants and items. Regular numerals significantly decreased the likelihood of choosing a grouped image compared to collective numerals (β = -.8, *SE* = .29, $p < .01$), but collective nouns did not (β = -.27, *SE* = .74, p = .72, *n.s.*). We conducted a post-hoc analysis focusing only on collective and regular numerals. We fitted the same model with the additional continuous predictor of number size. The model revealed that the higher the number, the more likely it is for the ungrouped image to be chosen (β = .41, *SE* = .12, $p < .001$). The type of numeral remained a significant predictor even after considering the effect of number size (β = .8, *SE* = .29, $p < .001$).

Discussion. The results indicate that collective numerals, like collective nouns, prompt a more grouped spatial arrangement compared to regular numerals. Additionally, smaller numbers were more strongly associated with a grouped image, possibly due to the ease of counting them. Further research could explore whether the effect of number size extends beyond spatial grouping to group cohesion in general.

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Trying to kill musicians' SPoARC

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Introduction: Recent studies on the spatial positional associated response codes (SPoARC) effect have shown that when Western adults are asked to keep in mind sequences of verbal items, they mentally spatialize these items along a horizontal axis, with the initial items being associated with the left-hand side and the last items being associated with the right. The origin of this mental line is still debated, but it has been theorized that it requires specific spatial cognitive structures to emerge, which could be built through expertise. Results by Guida and Porret (2022) seem to confirm this hypothesis, as they observed that only musicians spatialize melodies in comparison to non-musicians. Guida and Porret (2022) proposed that such spatialization is made possible via a mental musical stave built through expertise, which would rely on visuo-spatial processes. This contrasts with Baddeley, Allen and Hitch's (2011) proposal that music and sounds are processed and rehearsed through the phonological loop in working memory. In this study, we will test both the effect of a visuo-spatial and a verbal concurrent task on the SPoARC effect. Based on Guida and Porret (2022), we expect that the visuo- spatial concurrent task should hinder the SPoARC effect.

Planned Method: A group of forty professional/expert musicians will be tested. With the exception of the concurrent tasks, we will use the same procedure and stimuli as in Guida and Porret (2022). Participants will be asked to memorize sequences of four musical notes and to indicate if a subsequent probe was part of the sequence by pressing a "yes" key or a "no" key using the left or right index finger. Left/right-hand key assignment will be reversed at mid-experiment. Stimuli will be two sets of 42 sequences of four different musical notes synthesized with piano timbre and comprised in a fifth interval. Two concurrent tasks will be used: a concurrent repetition task (pronouncing continually 'BA-BE-BI-BO- BU') and a spatial tapping task. Participants' spatialization will be tested on three separate occasions, using i) no concurrent task, ii) a vocal concurrent task, and iii) a tapping concurrent task (the order will be pseudo-randomized).

Targeted statistical analysis: A 3 × 4 × 2 ANOVA will be carried out using "*Concurrent task*" (three levels: absent, vocal, tapping), "*Position in the sequence*" (four positions: 1 to 4), and "*Hand assignment*" (two levels: left for "yes" answers *vs*. right for "yes" answers) as within-subjects variables. In order to investigate spatialization, a regression analysis for repeated measures (Lorch & Myers, 1990) will be performed on the dRT obtained when subtracting the left-hand reaction times from the right- hand reaction times for each sequence position. Participants' dRT values will be entered in the regression analysis using *Position in the sequence* and *Concurrent task* as fixed factors and participants as a random factor.

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Why numerical quantifiers do not trigger strong presuppositions? Spatial and event knowledge

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Introduction:
In the domain of presupposition theory, it has been posited that definite quantifiers trigger strong presuppositions (i.e., contents which are not cancellable under any circumstances), while indefinite quantifiers give rise to weak presuppositions. In many languages, like German, French or Spanish, some indefinite quantifiers bear resemblance to their equivalents in the numeral paradigm (e.g., "ein" and "eins", "un" and "un", "un" and "uno"). The present research endeavours to investigate the correlation between this phenomenon and the weaker semantic fact that these triggers produce, attending to two types of knowledge that we believe this distinction demonstrates: spatial knowledge and event knowledge, the latter being a revision of the notion of language knowledge by refining the terminology with event semantics.
Hypothesis:
Indefinite numerical quantifiers trigger weak presuppositions because they leverage a vocabulary we will refer to as material or spatial, which is anchored to the contingencies of experience. Meanwhile, definite quantifiers exploit strictly formal logical operators to represent the event.
Analysis:
We plan to prepare surveys for a total of 20 speakers of German, French, and Spanish, respectively. In these surveys, we will collect data through two major blocks of questions regarding the naturalness of certain statements:
(i) acceptance tests around strong and weak quantifier triggered presuppositions (e.g., welchen Satz finden Sie zweifelhafter, „es gibt eine Katze dort" oder „die Katze steht dort")
(ii) acceptance tests regarding spatial, causal, and psychological propositions (e.g., welchen Satz finden Sie zweifelhafter, „es gibt einen Hausmeister" oder „der Hausmeister stört Martha")
The tests are framed in some apparatuses that help to control the salience of the phenomena. We will establish a context that permits that the speaker cannot get distracted with common ground doubts or intentional related issues of communication, but with the particular judgment around how much the existence of the quantified object is presupposed.
Research questions:
(1) How does the numerical nature of these quantifiers influence the sort of knowledge they can codify?
(2) What relationship do numbers, spaces, and presuppositions maintain?
(3) Why do the most common indefinite numerical quantifiers imitate the number one?

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The anticipatory Cross-Modal Congruency Effect: Modeling of event-predictive crossmodal interactions

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While we experience everything around us continuously in time, our brains appear to segment our experience into events to help process, structure and interpret it. According to predictive coding and related theories, our brain consistently tries to predict what happens next. This includes anticipating next event boundaries and following events (Butz, 2016).

We also gain sensory information from several modalities, which are integrated into a cohesive whole for our brain's generative model and used to anticipate upcoming events. Because of this, the existence and dynamics of event anticipations and how our brain projects sensory observations into the future can also be seen in cross-model interactions.

This is specifically shown by the anticipatory Cross-Modal Congruency Effect (aCCE), which we have previously found in Virtual Reality (VR) paradigms (Lohmann et al. 2019) and are now studying in a real-world setting. Study participants are asked to reach for an object and place it in a new position, but during their reach, encounter both a flash of light from the side of the object and tactile stimulation at their index finger or thumb. Simultaneously, they are required to respond verbally by saying which finger is stimulated as quickly as possible. Depending on the orientation of the object, overhand or underhand grasp may be required, and the position of the light compared to which finger is stimulated may be congruent or incongruent.

We anticipate that, in accordance with previous findings (Belardinelli et al. 2018), this verbal response of the participants takes longer in incongruent trials rather than when the stimulation is congruent. This shows that visual and tactile information are integrated and the position of the hand and fingers in space are projected into the future, to the boundary of the current event ('reaching') to the next ('grasping'). In addition, the effect on the onset of verbal responses shows the connection of the sensorimotor activity and feedback to language and how the event anticipations are expressed. This effect has also been shown to depend on the consistency of the sensory information our brain can receive, so this event-anticipatory processing is dynamic and flexible (Lohmann et al. 2019).

In order to better understand this effect and the underlying event structures and processes, we also develop a model based on Bayesian inference and event schemata. This variational model shows how event anticipations depending on the currently occurring events unfold to develop this effect, particularly given limited cognitive resources. It may also give insight into the dynamics of resource-efficient event-predictive cognition beyond the aCCE.

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How important is transparent number naming for children with & without Developmental Language Disorder?

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Children with Developmental Language Disorder (DLD) often have numeracy problems that are probably rooted in their language deficit. Numeracy problems associated with DLD predominantly concern verbal skills (such as counting and arithmetic –Cross et al., 2019), and language is generally thought to play an important role in typically developing (TD) children's numeral acquisition. Previous studies have argued that the transparency of number naming systems can affect when and how children learn cardinals and ordinals (e.g., Meyer, 2019; Yang, 2016), suggesting that transparent morphological rules aid numeral acquisition. To better understand DLD-related numeracy deficits, it is thus important to examine how children with and without DLD learn numerals cross-linguistically. The present study aims to do so by investigating whether children with DLD are able to use the same linguistic rules when learning numerals as typically developing children, and to which extent the timing and pattern of acquisition depend on the transparency of such rules in their native language Czech (which has many irregular ordinals but more transparent cardinal derivation) or Dutch (which has more unpredictable cardinals but a transparent ordinal system)? We will answer these questions by assessing the ordinal and cardinal knowledge of Czech-speaking children with and without DLD, using a Give Me task (e.g., Wynn, 1992), Tell Me task (e.g., Meyer, 2019), Next Number Task (e.g., Schneider et al., 2021)) and a counting out loud task. These outcomes will be compared to previously collected data of Dutch-speaking peers (matched on age and gender) (De Vries et al., 2023). We propose to use Linear Mixed-Effects Models for all four tasks to assess whether there is a significant interaction effect of learner groups (DLD vs TD) and native language (Dutch or Czech) on children's highest counts and response accuracies for cardinals and ordinals This will answer whether numeracy difficulties associated with DLD depend on the numerical transparency. Subsequently, we plan to compare the knower-level distributions between the four groups as well as their error patterns on all four tasks to determine whether children use different learning strategies across languages. This analysis will shed light on the role of numeral transparency in early numerical acquisition in children with and without DLD, thereby contributing to the existing debate on the interaction between language and numeracy.

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b. Traditional posters

Command of natural language quantification in speakers with Williams Syndrome

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Individuals with Williams Syndrome display an unusual cognitive profile characterized by a moderate intellectual disability (mean IQ around 60), as well as severe deficits in spatial and numerical cognition (Landau & Hoffman, 2005). At the same time, they appear to show a sophisticated understanding of scalar terms—words that denote number and quantity (Musolino, Chunyo, & Landau, 2010). In this work, we focus on the logical meaning of scalar terms as a way to tap into the knowledge of set relations captured in the semantics of quantifiers and other scalar expressions, as well as their entailment patterns.

Theoretical background: Scalar implicature constitutes a phenomenon where the use of a weaker term on a scale, for example, the use of some, typically invites the inference that the stronger term on the same scale, such as all, does not hold (Horn, 1972). Since weaker terms rarely appear in contexts where the stronger term can be used, the ability to access the semantic reading of the scalar terms might be views as a sign of abstract lexical and grammatical knowledge that develops in speakers through understanding of set relations and entailment patterns.

Design: Using a Truth-Value-Judgement-Task, we investigated whether adolescents with WS show preserved knowledge of (a) the set-theoretic properties associated with basic English quantifiers, numerals, and connectives; (b) the entailment relations that follow from these properties; and (c) the pragmatic consequences of these properties. We evaluated 4 scales: not all - none, some - all, two - three, and or - and. Participants included three groups of 12 individuals: WS (mean age = 16,4 (year, month)), typically developing children matched to the WS group on the basis of mental age (MA), and a control group of neurotypical adults.

Results: The analysis revealed that in trials testing the knowledge of basic truth-conditions participants with WS did not differ from MA children in their rate of correct responses ($\beta = 0.8287$, $p = 0.3716$) but were less accurate than adults ($\beta = 2.2902$, $p = 0.0278$). In entailment trials, individuals with WS did not differ from adults in their rate of logical interpretations of scalar terms (64.4% vs. 69.3 %, $\beta = 0.4356$, $p = 0.4017$). Interestingly, they gave more logical responses than MA children in this task (63.4% vs. 44.8%, $\beta = 1.1275$, $p = 0.0284$). Overall, the rates of logical interpretations differed for different scales, confirming the scalar diversity hypothesis.

Discussion: The analysis of responses in all three groups revealed a) scalar diversity: rates of semantic interpretations for different scales are non-uniform; b) between-speaker variability: some speakers primarily chose semantic interpretations while others opted for pragmatic ones; and c) within-speaker variability for some participants: they alternated between two readings of a scalar term in the course of 4 trials. In truthconditional trials, individuals with WS produced more than 90% of correct responses revealing knowledge of the semantics of scalar terms. Statistically, they were less accurate than adults but indistinguishable from typically-developing children matched by MA. In entailment trials, we saw that at least half of the individuals with WS consistently accepted statements containing some and not all in situations which verify the semantic content of stronger terms on the relevant scales, all and none. Our results suggest that core components of quantifier logic and its expression in language are mastered not only by typically developing individuals from age 6 and up, but also by individuals with WS. Furthermore, we have demonstrated that the individuals with WS perform more adult-like by demonstrating an understanding of set relations and intricate entailment patterns.

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Translating numerical motion: Prices skyrocket in English but increase in Spanish

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Languages vary in how they encode motion events. Some languages, like English, express motion with verbs that incorporate the manner of motion. Other languages, like Spanish, tend to incorporate the path of motion in the verb. These distinctions inspired Slobin's *Thinking for Speaking Hypothesis* (1991), suggesting that languages typology may direct the attention to different facets of the motion event. These typological differences also extend to metaphorical uses (Özçaliskan, 2003), with typology having an influence in how space-based metaphors are encoded across languages, like English and Spanish. (Valenzuela and Alcaraz-Carrión, 2020). If typology influences how speakers encode space metaphors, we should also observe similar differences in other spatial mappings.

This study investigates the differences in the expression of numerical motion metaphors in English and Spanish. We evaluated 1472 English-to-Spanish translations in which a manner of motion verb was used to metaphorically express numerical change (e.g., *unemployment is skyrocketing*). These translations were extracted from English-to-Spanish parallel corpora. We annotated 1) the metaphor used in Spanish, 2) presence of manner of motion and path, and 3) where the information was located. There were three main findings. First, Spanish translations shifted from to the size domain in 48% of the cases. Second, Spanish translations omitted manner of motion in 50% of cases. Third, path of motion was always present in the Spanish translations. This analysis suggests that language typology may influence the choice of numerical metaphorical mappings.

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Cultural aspects of the Mental Number Line beyond reading/writing direction

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The SNARC (Spatial-Numerical Association of Response Codes) effect (Dehaene et al., 1993) refers to the faster left/right responses to smaller/larger numbers, respectively. It is suggested to be a result of the Mental Number Line (MNL) on which the mental representation of magnitudes is mapped on a horizontal continuum from left to right. Several studies suggest that the direction of the MNL could be influenced by individuals' reading/writing habits (i.e., direction: left-to-right vs. right-to-left;). We aimed to find out whether it is also influenced by culture (Western vs. Middle-Eastern).

We tested the SNARC effect in three samples: German (left-to-right reading, Western culture; N = 130), Turkish (left-to-right reading, Middle-Eastern culture; N = 112), and Iranian (right-to-left reading, Middle-Eastern culture; N = 75) with parity judgment (PJ) and magnitude classification (MC) tasks. To measure the directional habits of individuals and compare them across samples, we developed a Cultural Directionality Questionnaire (CDQ) in which participants are required to e.g., name horizontally aligned objects to see whether they start with the left/right object, put pictures showing scenes into the correct temporal order on a horizontal timeline, indicate whether they preferred pictures of objects facing leftward/rightward, and report some drawing preferences for objects.

To investigate the SNARC effect, individual regression analysis was used. dRTs (right hand RT - left hand RT) for each number were calculated and regressed on number magnitude (continuous in PJ and categorical in MC) and parity (only in PJ as categorical). Resulting negative magnitude slopes were interpreted as the SNARC effect and negative parity slopes as the MARC (Linguistic Markedness Associations of Response Codes; Nuerk et al., 2004) effect which indicates faster-left responses for odd and faster right responses for even numbers. For the CDQ, we calculated a total score between -7 (strong left-to-right preferences) and +7 (strong right-to-left preferences).

There was a significant SNARC effect in each sample in PJ. As expected, the SNARC effect was stronger in the German compared to the Turkish sample and in the Turkish compared to the Iranian sample. In MC, the group-level SNARC effect was only significant in the German and Turkish samples but not in the Iranian. No differences were observed between samples in MC. Compatible with PJ-SNARC findings, German<Turkish<Iranian order was significant for CDQ total scores which suggests that left-to-right preferences in directionalities were most prominent in the German (-3.65), least prominent in the Iranian (0.07) and intermediate in the Turkish sample (-2.96). No significant MARC effects were found.

With the current design, we were able to separate the influence of reading direction and culture. The differences observed between Turkish and Iranian samples suggest that the right-to-left reading direction weakens the SNARC effect even though both samples are strongly influenced by Middle-Eastern culture. On the other hand, the differences observed between German and Turkish samples suggest that the Middle-Eastern culture itself can weaken the SNARC effect although both samples have a left-to-right reading/writing habit. The similar pattern observed in the CDQ supports the notion that cultural directionalities might be involved in spatial-numerical associations. For the first time, the influence of cultural habits other than reading/writing direction on the SNARC effect was systematically demonstrated.

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A nonverbal representation of multiplication-like arithmetic facts

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Numerous studies showed that certain arithmetic facts, specifically multiplication, are stored in long-term memory using a verbal representation (Campbell, 1995; Dehaene et al., 2003). However, we do not yet know whether this reliance on verbal representations arises from an intrinsic property of arithmetic facts, or merely from how the facts were learned (e.g., in school).

To address this question, we examined whether multiplication-like arithmetic facts can be memorized nonverbally, by relying on the two other representations of numbers: a magnitude representation, which overlaps a spatial representation via the so-called mental number line, and a visual representation as digits (Dehaene, 1992). The participants were adults, who already knew the multiplication table, so we used multiplication-like arithmetic facts – interest rates (e.g., "5% during 4 years is 22%"). Based on studies indicating that multi-sensory learning can be effective (Brunyé et al., 2008; Mayer, 2014), we reasoned that if the multiplication-like facts can be represented nonverbally, presenting them in a multi-modal manner (verbal + digits + magnitude/spatial) would give rise to better learning than in a verbal-only baseline condition.

We asked 20 adults to memorize two sets of multiplication-like facts, with 4 facts in each set. Each participant learned both sets of facts, each set in a separate week. In the baseline-condition week, learning was purely verbal: the participants repeated each fact several times. In the multimodal learning week, the participants repeated each fact in the same manner, but simultaneously, they also saw each fact's result printed as digits (i.e., digit representation), and these digits were placed in the correct position on a number line (which presumably recruits the quantity representation via the mental number line).

A subsequent testing session, in which the participants were asked orally about each fact once, showed significantly higher accuracy in multimodal learning than in the baseline (~80% vs. ~60%, respectively). A linear mixed model (random factors: participant, fact; within-participant factor: baseline/multimodal learning mode) showed that this effect was significant (p = .007). We conclude that the participants memorized the facts using a nonverbal representation – digits, spatial/magnitude, or both. Our follow-up experiments aim to discover which precise representation they used.

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Development of spatial-positional associations in working memory in school-aged children

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The interplay between culture and cognition has been a growing topic since the discovery of the SNARC (Spatial-Numerical Association of Response Codes, Dehaene et al., 1993) thirty years ago. Studies conducted in the domain suggest that individuals organize numerical information onto a Mental Number Line according to the direction of their reading and writing habits (e.g., from left to right in Westerners *vs.* from right to left in Arabic readers, Dehaene et al., 1993; Shaki et al., 2009; Zebian, 2005). A mental line has also been observed when random information is presented serially in the short term. When memorizing novel sequences of items, individuals tend to mentally map their order onto a spatial array. This phenomenon known as the SPoARC (Spatial-Positional Association of Response Codes, Guida & Lavielle-Guida, 2014) refers to the use of spatial information to code non-spatial information entering working memory. While the SPoARC has been widely investigated in adults (for a review, see Guida & Campitelli, 2019), too few studies have focused on the development of this effect (e.g., Guida et al., 2020; van Dijck et al., 2020). In the current study, one hundred participants aged between 6 and 11 years old were asked to memorize sequences of three and four colored drawings of fruits presented sequentially in the middle of a screen. To detect a horizontal mapping, participants were subsequently prompted to decide whether a probe belonged to the memorized sequence using two lateralized response keys (left *vs.* right). Data were analyzed using generalized linear mixed models. Results showed a significant SPoARC for sequences of three items, whereas no SPoARC was detected with four items. We also found that the SPoARC was only observable in children from 8 years old, which coincides with the development of reading and writing abilities. Still, correlational analyses showed that spatialization was linked to participants' working memory capacity, but not to literacy. Overall, our findings indicate that the SPoARC can be detected in children using experimental designs akin to those implemented in adults. However, our study also suggests that the effect is facilitated in children using shorter sequences than with adults, for whom the SPoARC is usually detected with four items. We discuss the idea that spatial-positional associations are best detected when the size of the memorandum fits working memory capacity in children.

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Covert attention shifts induced by serial position in working memory

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Theoretical background: Increasing evidence suggests that spatial attention may support the mental manipulation of numerical magnitude and mental arithmetic (e.g., Salvaggio et al., 2022). Indeed, assigning abstract concepts on a mental whiteboard with internal markers could help at alleviating the workload of their manipulation. The precise nature of these attentional mechanisms and whether they are specific to numerical magnitude has long remained debated (e.g., van Dijck & Fias, 2011). It has been suggested that the inherent ordinal value of a number, instead of its magnitude, would be the key determinant of how the mental space is organized. This is now supported by the investigation of lateral eye movements showing that both number manipulation and retaining serial order of verbal items elicit similar spatial biases (Sahan et al., 2022). The first items would be located on the left and last items on the right. However, the oculomotor system is not a prerequisite to shift attention. Indeed, the focus of attention can also be shifted covertly (i.e., without the execution of eye movements). The present study aimed to track the covert attention shifts elicited by the serial position of items retrieved from verbal working memory, taking advantage of the pupil light response.

Method: Participants (n=40) had to memorize sequences of 5 letters presented auditorily. A probe letter was then presented, and participants had to indicate verbally whether the letter was present or not in the memorized sequence while fixating the center of a horizontally split screen (bright *vs*. dark part). Covert shifts of attention were quantified from the pupillary response to luminance differences between the left and right sides of the screen.

Results: Pupil size for "Congruent to Dark" trials (i.e., begin item and dark left; end item and dark right) was compared to "Congruent to Bright" trials (i.e., begin item and bright left; end item and bright right). Pupil analysis revealed a spatial coding of order oriented from left to right: retrieving a begin item (i.e., position 1 or 2) accentuated pupil dilation when the dark part was on the left side while retrieving an ending item (i.e., position 4 or 5) accentuated pupil dilation when the dark part was on the right side.

Conclusions: These observations indicate that serial order processing in verbal working memory involves shifts in spatial attention beyond those revealed by oculomotor behavior. Future studies will investigate whether these attentional biases are restricted to the horizontal plane of if they extend to the vertical plane. The investigation of intra and inter-individual variability of these biases should also clarify if the function of the spatial coding of mental concepts is to reduce the mental workload of the manipulation of abstract complex concepts.

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Linguisitic influences on number processing in a two-digit number comparison task

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Which impact does language have on multi-digit number processing? Processing multi-digit Arabic numerals has been shown to be influenced by linguistic irregularities of number naming systems. At the behavioral level, for instance, German speakers tend to display a larger unit-decade compatibility effect (Nuerk et al., 2002) when comparing two-digit numbers than speakers of other non-inverted languages, because Germans read the units in two-digit numbers first (72 = "2 70"; Zuber et al., 2009). To date, studies have mainly focused on inversion-related effects. The effects of the number word syntax in non-inverted but still intransparent number word systems such as French have not yet received similar research interest. Using electroencephalography, Salillas and Carreiras (2014) have shown that the base-20 number word system in the Basque language influences the speakers' processing of Arabic numbers. In French, only numbers above 60 are spoken in a base-20 manner (72 = "60 12"). We investigated how this mixed number word system influences number processing in native speakers.

We conducted a web-based study in native French speakers ($N = 60$, $M_{age} = 28.69$ years) consisting of two magnitude comparison tasks: a symbolic two-digit number magnitude comparison task and a non-symbolic bar magnitude comparison task. In the bar magnitude comparison task, we presented two bars whose length represented the magnitude of a digit in place of digits. In other words, we represented digits as bars to evade linguistic processing. We expected to find a unit decade-compatibility effect in both tasks and an additional effect of base 20 compatibility only in the symbolic numerical task.

Linear-mixed models revealed significant base-10 and base-20 compatibility effects in both tasks. When controlling for decade distance, the base-20 compatibility effect disappeared in the non-symbolic task. However, when considering other difficulties of balancing the design, the base-20 compatibility effect also disappears in the symbolic task. We discuss possible improvements in follow-up experiments as well as potential differences between the hypothesized base-20 effect and the regular unit-decade compatibility effect.

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Early automatic detection of symbolic numbers as a category: A visual mismatch negativity (vMMN) study

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Introduction: Number representations are assumed to be automatically activated whenever we encounter numbers in our environment. This assumption seems to be supported by behavioural and electrophysiological studies (e.g. Dehaene & Akhavein, 1995; Hsu & Szűcs, 2012). However, numbers were usually task-relevant stimuli presented in the centre of attention. The visual mismatch negativity (vMMN) (Stefanics et al., 2014) could be useful for investigating automatic representation activation. VMMN is an event-related potential (ERP) correlate of violations of regularity in unattended, usually task-irrelevant stimuli in the visual modality, and has been shown to be sensitive to categories (Czigler, 2014).

In a 'vanishing' oddball paradigm (Sulykos et al., 2017), we showed frequent (standard) and rare (deviant) within-category (number-to-number), between-category (number-to-letter, number-to-character), and simple physical features changes, while the participants performed an unrelated task. The automatic activation of number representations should lead to category recognition and modify the vMMN. Absent or smaller vMMN to within-category changes was expected compared to vMMN to between-category changes.

Methods and applied statistical analysis: In two experiments, participants (Exp 1: *N*=22, Exp 2: *N*=18 (ongoing)) performed a continuous tracking task in the centre of the screen, while oddball stimulus sequences were presented around the task field. A categorization task preceded the oddball sequences. Consecutive one-sample *t*-tests to 0 on the deviant-minus-standard difference potential determined the elicitation of vMMN.

Results: VMMN was elicited for the physical features in Exp 2 within the expected early (110-140 ms) post-stimulus time window. VMMN emerged for within-category (number-to-number) changes: in Exp 1, for the smaller number when the standard change was also number-to-number (140-170 ms), and in Exp 2, in the 140-180 ms and 220-300 ms as well as 160-200 ms time windows when the standard change was number-to-letter or number-to-character, and in the 170-200 ms for the larger number with number-to-number standards.

Discussion and conclusions: Category-related VMMN was observed for within-category changes after being explicitly invoked in a categorization task. Possible explanations include certain physical features of the stimuli, stronger ERP reduction for the frequent within-category change as well as stronger emphasis on the number category. The interim results tentatively suggest automatic but context-dependent number representation activation.

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The meaning contributions of Akan's plural morphemes

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This research tests Ahenkora's (2022) claim that Akan (Niger-Congo: Kwa, spoken in Ghana and Côte d'Ivoire) has exclusive plurals through experimental means and seeks to provide a more comprehensive picture of Akan's plural semantics. In most languages, similarly to English, plurals in an upward-entailing context (i.e., the subset entails the superset) (1a) refer only to a plurality, making them exclusive of the atomic reading. However, plurals in a downward-entailing context (i.e., the superset entails the subset) (1b) refer to both atoms and pluralities, meaning they are inclusive of the atomic reading.

(1) a. John planted trees.
#'John planted one or more trees.' [Inclusive]
'John planted more than one tree.' [Exclusive]
b. John didn't plant trees.
'John didn't plant one or more trees.' [Inclusive]
#'John didn't plant more than one tree.' [Exclusive]

However, Ahenkora (2022) claims that the plural circumfix, which marks kinship terms, is inclusive, similarly to English, but that the plural prefix, which marks most Akan nominals, is exclusive. The present experiments test these two plural morphemes in multiple downward-entailing contexts. One experiment for each morpheme was run, using the same design: The two-level factor CONTEXT [0, 1] (i.e., how many of each object occurs in the context) was fully crossed with the four-level factor SENTENCE_TYPE [positive, negative, question, universal_quantifier]. Using auditory stimuli, 24 test items were interspersed with 12 filler items and shown in random order. Using auditory stimuli, native Akan speakers rated the acceptability of each test item within the given context on a scale from 1 to 5, with 1 being the least acceptable, and 5 being the most acceptable. Results were analyzed using a linear mixed model analysis in R. *P* values were obtained through likelihood ratio tests.

Both morphemes were found to be inclusive (have the reading of 'one or more') in all three downward-entailing contexts. These results are contrary to Ahenkora's claim for the plural prefix, but in line with her claim concerning the plural circumfix. In Ahenkora's original analysis, she suggests each morpheme has a different meaning contribution. However, to account for the results of the experiments, I claim that the prefix is the only morpheme that contributes plural meaning to nominals in Akan. The circumfix, in turn, is comprised of the plural prefix, and a kinship suffix that adds no additional plural meaning to the noun. These results, furthermore, give credence to the idea that multiplicity inferences are equal to scalar implicatures.

The results of this study support the idea of inclusive plurals in downward-entailing contexts as a semantic universal. Therefore, this analysis augments the understanding of plurality cross-linguistically. Additionally, it also contributes to the growing body of experimental semantic research done with non-WEIRD (Western, Educated, Industrialized, Rich, and Democratic) research participants.

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Mid-sagittal expression of the SPoARC effect?

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Spatialization has been a subject of significant interest in cognitive psychology for several decades, with separate examinations in numerical cognition (SNARC effect) and working memory (SPoARC effect). Although the cultural explanation for the SNARC effect, associating quicker responses with the left hand for small numbers and the right hand for large numbers, is currently under scrutiny, the SPoARC effect, which aligns items from the beginning of a sequence in working memory to the left side of space and items from the end to the right side, is elucidated by the 'whiteboard hypothesis' (Abrahamse et al., 2014). This concept finds support in the highly flexible directionality of spatialization in the SPoARC effect, which is influenced by reading experience (Guida et al., 2018). Recent evidence for a vertical SPoARC, running from up to down (Hartmann, 2021) is still consistent with a cultural grounding. The present study aims to challenge the cultural account of spatialization in working memory, by testing whether the SPoARC effect can manifest along the mid-sagittal axis (organization from close to far space), as observed with the SNARC effect.

We developed a single paradigm (adapted from Huber et al., 2016) that concurrently assesses both the SNARC and SPoARC effects on the horizontal and mid-sagittal axes. Participants had to memorize a sequence of five numbers, and subsequently required, during the maintenance phase, to engage in a magnitude comparison task, indicating whether a target number was small (1–5) or large (6–10). In half of the trials, participants were instructed to use their left hand to respond to small numbers and their right hand for large numbers; this mapping of response hands was reversed for the remaining half of the trials. Importantly, for assessing the SPoARC effect, participants only provided responses for the number items included in the memory list. Participants were then tested on recognizing the correct memory sequence among four different sequences, each composed of a mixed order of the numbers presented in the initial memory list.

In our study involving, 32 French native participants, as anticipated, we noted the presence of both horizontal and mid-sagittal SNARC effects, along with a SPoARC effect on the horizontal axis, replicating the effects documented in existing literature. Notably, we also identified a SPoARC effect on the mid-sagittal axis, evident in both raw reaction times (RTs) and differential reaction times (dRTs) – the differences in RTs between right and left responses. The statistical analyses revealed a significant main effect related to magnitude/position, while no effect associated with Axis or their interaction was observed. This outcome suggests the existence of both SNARC and SPoARC effects on the two axes. Crucially, our results challenge the conventional notion of the cultural influence on the SPoARC effect, as it becomes difficult to attribute a mid-sagittal representation solely to cultural influences or practices. Instead, this novel finding implies a more cohesive theoretical basis with the SNARC effect, particularly along the mid-sagittal axis.

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Interaction between magnitude and space in a writing version of the random number generation task

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Introduction: Existing research suggests that processing of numerical magnitude is accompanied by sensorimotor activation. For example, participants' response reaction times are faster if smaller numbers (from 1 to 4) are presented in leftward space (or are judged with the left key), and if larger numbers (from 6 to 9) are presented in rightward space (or are judged with the right key) (Dehaene et al., 1993, inter alia). Furthermore, several studies show that number processing can also be influenced by the physical size of presented stimuli (Huang et al., 2021). While the interaction between magnitude and space has been investigated in a wide range of tasks, no studies used a random number generation (RNG) task involving motor activity, e.g., writing. If magnitude-space interaction can be observed in such complex motor acts, this may provide further evidence for the robustness and polymodality of sensorimotor activation in number processing.

Method: In this online study, 70 participants (45 females, aged 25±5 years) were asked to write any random number from 1 to 30 into a blank square of varying Size (small / large) and location on the screen (left / center / right Space). Since responses were provided by finger, only devices with a touchpad were allowed for this study. We hypothesized that participants would write smaller/larger numbers in squares of smaller/larger size + presented on the left/right sides of the screen.

Statistical analysis: A Linear Mixed Effects Model (LMM) analysis was performed on the data using the lme4 package (R software version 4.1.3 76).

Results: The analysis revealed that participants generated larger numbers in larger squares (Size). Moreover, produced magnitude increased if large square appeared on the right side of the screen (interaction between Size and Space). To control for possible correlation between number magnitude and the space in the square, we conducted an additional analysis using only two-digit numbers (from 10 to 30). Again, we found an interaction between Size and Space: participants generated larger numbers when a larger square was presented on the right side of the screen.

Discussion and conclusion: In this study, we demonstrated the interaction between physical size and space reflecting in the magnitude of randomly produced numbers. To our best knowledge, this is the first investigation of magnitude-space association using writing version of RNG task. Our findings (1) are consistent with embodied theories of cognition suggesting the key role of sensorimotor experience in number processing;(2) provide further support for the robustness and polymodality of sensorimotor activation accompanying number processing; (3) offer new opportunities for conducting online research in the field of numerical cognition.

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Minding the gap in primary school: examining the interplay between working memory, math anxiety, spatial anxiety, and mathematical ability

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A growing corpus of studies demonstrates a complex interplay between cognitive (e.g., working memory) and affective factors (e.g., anxiety) contributing to sex-based differences in mathematics performance and abilities). Most of this research, however, is conducted with adult populations, while children and adolescents are largely understudied. In the current study, 211 primary school children (aged between 9 and 13 years) performed a verbal working memory task (Monkey game; Van der Weijer-Bergsma et al., 2015), visuo-spatial working memory task (Lion Game; Van der weijer-bergsma et al., 2016) and mathematical performance task (tempo test arithmetic and scores obtained from the national school testing. In addition, children completed a math anxiety questionnaire (CMAQ; Ramirez et al., 2013) and spatial anxiety questionnaire (CSAQ; Ramirez et al., 2012). Hierarchical regression analysis showed that visual-spatial working memory uniquely explained math performance. Additionally, sex-based differences were found for mathematical performance, math anxiety and spatial anxiety but not for arithmetic fluency and working memory. Mediation analyses further showed that math anxiety fully explained the relation between sex and math performance. suggesting that sex differences in math perfomance are fully explained by math anxiety. These outcomes further emphasise the importance of monitoring math anxiety and its potential impact on math abilities already in primary school.

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Horizontal eye movements as an indicator of the strategies recruited to solve arithmetic

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Theoretical Background: Mental arithmetic is a challenging exercise. To resolve this difficulty, it has been assumed that the cognitive system relies both on memory retrieval and procedural strategies. Hence, the answer of small problems (e.g., 3+2) can be retrieved directly from memory whereas large problems (e.g., 62-17) typically require calculation procedures. A large body of evidence suggest that these procedural strategies involve attention shifts reminiscent of increments (or decrements) along a mental continuum (e.g., Mathieu et al., 2016). Attention is shifted rightward/upward or leftward/downward when participants solve additions and subtractions, respectively (e.g., Masson et al., 2023; Salvaggio et al., 2022). While attentional shifts in both the vertical and horizontal axes co-exist, it is unknown whether the two axes are rooted into identical cognitive mechanisms and mental representations.

Methods: To investigate the role of horizontal and vertical attentional shifts in mental arithmetic, we monitored horizontal and vertical eye movements, as a proxy for attentional shifts, using an eye-tracker. Adult participants (n=40), while looking at a blank screen, had to solve orally subtractions presented auditorily that are either typically solved directly (e.g., 78 - 32 = ?) or solved with a strategy consisting in transforming a subtraction into an addition (e.g., 71 - 68 = ? → 68 + ? = 71).

Results: We compared the mean gaze position for “Direct Subtraction” and “Subtraction by Addition” trials in the horizontal and vertical axes. Gaze patterns revealed a dissociation between horizontal and vertical shifts. Horizontal shifts reflected the strategy that was employed to solve the problem as “subtraction by addition” elicited horizontal shifts more to the right than “direct subtractions”. Vertical eye movements were driven by the absolute magnitude of the answers as small answers were associated to more downward shifts.

Discussion: Altogether, this suggests attentional shifts are part of the solving procedure but that shifts along horizontal and vertical axes reflect distinct cognitive mechanisms. The study provides direct evidence that spatial attention shifts are functionally related to the strategies used during mental arithmetic and that adult calculators preferentially use the horizontal dimension for implementing such strategies. The vertical axis is merely associated to the magnitude of the answer, irrespective of how it is accessed.

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Spatial associations in short-term memory vanish as memory consolidates using repeated sequences

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Studies on the SPoARC (Spatial-Positional Association of Response Codes) have shown that serial information is spatially processed in working memory (Abrahamse et al., 2014; Van Dijck & Fias, 2011). However, it remains unclear whether or not these spatial-positional associations remain when memory is consolidated (see Guida & Campitelli, 2019, for explanations of the potential implication of long-term memory structures). Our study thus investigated whether spatialization would persist when a sequence is presented repeatedly enough to be learned. Thirty-seven adult participants performed a spatialization task in which a unique sequence of four stimuli was repeated (as in the Hebb-repetition paradigm --but not using filler sequences --; e.g., Page & Norris, 2009), for a given hand assignment (there was two different sequences per participant, one for each yes-no assignment to two lateralized response keys). After each presentation of the sequence, participants were prompted to indicate whether a probe (one of the four items, versus a lure) belonged to the presented sequence using one of the two keys (assigned to yes versus no responses respectively, with the assignment switched half-way of the task for each participant, and counterbalanced between participants). We used the difference of response times between the two hands as the principal measure of spatialization. Separate analyses per block revealed that the SPoARC was only detectable during the first quarter of the task, suggesting that spatialization was no longer used after the sequence was learned. This finding shows that (horizontal) spatial-positional associations in working memory vanish with memory consolidation. Our interpretation is that the formation of a chunk with learning unifies its constituent items, thus resulting in a parallel unification of their spatial associations. We conclude that the SPoARC supports the encoding of ordinal information only temporary to increase the likelihood of retrieving novel information in working memory.

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The interplay of order and magnitude in the SNARC effect: Using playing cards as stimuli to disentangle their contributions

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The SNARC effect (Dehaene at al., 1993) is believed to reflect a left-to-right mapping of numbers resembling a mental number line (Restle, 1970). However, disentangling the roles played by numbers' magnitude and order in the SNARC effect remains a challenge due to their inherent correlation (Prpic et al., 2016). This study focused into the impact of order and magnitude in the SNARC effect, utilizing playing cards as stimuli. While most people organize cards in ascending order (AO), we observed that a subset of individuals arranges them in descending order (DO). For individuals in the DO category, there is a stable tendency to associate low-magnitude cards (e.g., 2) to the right and high-magnitude cards (e.g., 6) to the left, creating conflicting spatial mappings for cards' order and magnitude. In our first lab experiment, DO participants (N = 31) engaged in a magnitude classification task involving both simple numerals and playing cards as stimuli. A one-sample t-test conducted on mean regression weighs showed that they deviated significantly from zero in the simple-numerals condition, in line with the SNARC effect. However, no difference emerged when classifying cards. To further explore this null effect, we performed an online experiment employing a larger sample of DO participants (N = 59) to replicate Experiment 1 and clarify spatial associations in card classification. Surprisingly, results indicated that DO participants exhibited consistent SNARC effects in both number and card classification tasks, suggesting that magnitude played a decisive role, regardless of cards order. This finding appears to challenge the notion that specific experiences with ordered stimuli should dictate the direction of an association.

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Are the mental number line and spatialization in working memory related in preschoolers?

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Theoretical background: Studies in adults suggest that the manipulation of numbers would rely on spatial representation. Numbers would be mentally organized from left-to-right, in Western cultures, as attested by the well-established Spatial Numerical Association of Response Codes (SNARC[1]). The main theoretical account suggests that the SNARC, measured during the processing of numbers, could reflect a spatial representation specific to numbers, the so-called mental number line. However, it has been suggested that the ordinal information carried by numbers, instead of their magnitude, would elicit the SNARC. Accordingly, tasks requiring the storage of items in short-term memory showed that serial order also elicited left-to-right associations (Ordinal Position Effect – OPE[3]). Yet, despite the resemblance of these effects at the group level, the nature of their underlying mechanisms is debated, and the similarity of their developmental roots remains poorly investigated. Both effects are robustly observed in adults, but their occurrence is less clear in young children. Determining when they arise in young children would help elucidate their underlying cognitive mechanisms since different onset times of both effects would provide support for distinct underlying mechanisms. Therefore, we investigated the SNARC and the OPE in preschoolers, their prevalence, and whether they dissociate from each other at the individual level.

Methods: 123 kindergartens (mean age: 6.3 years) completed two tasks: a magnitude judgment task[2] to index their SNARC and an ordinal position short-term memory task to measure their OPE[3].

Results: At the group level, linear regressions revealed the presence of the SNARC, but no systematic OPE. Moreover, no significant correlation was found between the two effects (r=-.154).

Conclusion: Our findings show that SNARC is present in kindergarten children and precedes OPE. Our study further suggests that both: spatial coding of numbers and serial position are two independent mechanisms.

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The common spatial representation of deictic time, numerosity, and emotional valence on the lateral axis.

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Some theories suggest that our mental representation of abstract concepts is based on mapping them metaphorically to experiential domains such as space. Previous studies have indicated that concepts like time, numerosity, and emotional valence are linked to space. It has been observed that past events, small numerosity, and negative emotions (in right-handed individuals) lead to quicker responses on the left side. In contrast, future events, large numerosity, and positive emotions (also in right-handed individuals) lead to faster responses on the right side. Two reaction time experiments explored the common representation of these concepts on the lateral axis in an implicit association test. Experiment 1 asked subjects to judge time words (past vs. future) and dot numerosity (more vs. less than a reference count) in four experimental blocks using right and left key presses (e.g., "Press 'I' for 'less' and 'past' "). Time and numerosity items were randomly intermixed across trials in each of the four blocks. Experiment 2 investigated the common representation of dot numerosity and emotional valence. For this, dot images were mixed with positive vs. negative valence words. Error rates and reaction times were analyzed with mixed effect models to assess a potential time-numerosity association and a potential valence-numerosity association. Moreover, standard spatial congruency effects (i.e., the association of numerosity, time, and valence with space) were also analyzed. In line with the hypothesis, subjects in both experiments responded faster in the *match* condition (less/past and more/future; less/negative and more/positive) than in the *mismatch* condition (less/future and more/past; less/positive and more/negative) indicating an association between time and numerosity and between numerosity and valence. The expected congruency effect was evident in Experiment 1 for time words but not for dot sets. In Experiment 2, this effect also seemed evident for valence words, but not for dot sets. The results suggest a common representation of time and numerosity and also for valence and numerosity. Still, the role of space as a common base is unclear due to the inconsistent congruency effect.

Language-Space Associations in children under four years

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Look at the moon! Even young children experience referents in a specific spatial context, thus early on these experiential traces might already relate to the corresponding label. In adults' language-space associations are reflected in faster up responses, when presented with a noun referring to an object that is typically experienced in an up location ("up word" such as "moon") compared to a noun referring to an object typically experienced in a down location (and vice versa for "down words" such as "stone, [1]). Such language-space associations have already been shown for manual responses of preschoolers aged between 4 to 7 years [2]. In a previous study we showed evidence of language-space associations in eye fixation data of even younger children, namely children aged between 2 to 4 years. In our newly developed language-space task, participants fixated the upper part of the screen more than the lower part while listening to an "up word" (and vice versa for "down words"). We could not find a similar pattern for the tested infants aged between 11 to 14 months. Our previous failure to show language-space association in infants might be due to the sparse word knowledge of the tested infants. Within this planned preregistered follow-up study, we test whether looks of 18- to 24-month-old children are already biased during word processing of "up words" and "down words". So far we tested 10 children (M = 20 months, SD = 1.34) out of the planned 30 toddlers. On average these infants were faster to detect the target following an incompatible (M = 571.55 ms) rather than compatible cue (M = 566.61 ms). Within this preliminary data we find evidence for a developmental trend: The language-space compatibility effect (Target detection in incompatible trials – Target detection in compatible trials) is positively associated to children's age in months, $r(9) = .52$. Thus, older children were as expected faster in compatible (over incompatible) trials, while younger children showed the reversed effect. This could hint to a development of language-space associations within children close to their second birthday. Prospectively, we intend to draw a more conclusive picture about developing language-space associations in relation to vocabulary acquisition.

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The complexity of number representation in Ukrainian nouns: A distributive analysis

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The study delves into intricate dynamics of the number category in the Ukrainian noun system through a distributive analysis. In Ukrainian the category of number is viewed as morphological category with a semantic dominant (Vykhovanecj, 2004). This perspective suggests that some forms are semantically motivated, and some express number only formally.

So, the research questions put in the study are: (1) How do Ukrainian nouns exhibit distribution patterns in terms of number, syntactic features, and semantic classes? And (2) To what extent does the choice between singular and plural forms in Ukrainian nouns depend on semantic factors such as semantic class, lexical plural, or collective nouns.

Addressing the research questions, we utilized the extensive dataset from the General Regionally Annotated Corpus of Ukrainian (Shvedova et al., 2022). Applying semantic tags, our study encompasses 282,822 nouns distributed across 23 semantic classes. Next, we conducted morphological analyses using pymorphy2, unraveling subtle characteristics, including syncretic forms, within Ukrainian nouns. To visualize and comprehend the intricate relationships within the dataset, we employ t-Distributed Stochastic Neighbor Embeddings (t-SNE) (Maaten and Hinton, 2008).

First, we applied t-SNE to a large set of nouns, including many low-frequency words, and observed a more global but probabilistic separation of singular and plural forms. Overlapping arised from semantic factors such as lexical plurals, collective nouns, paucal forms, and semantic associations. Next, we moved away from the singularity and plurality tantum and exclusively focused on nouns with grammatical number. The analysis highlighted a clear separation based on number, emphasizing the syntactic influence of grammatical number in Ukrainian. Third, we considered the Ukranian shift vectors for number.

The outcomes found that the embeddings of plural nouns are positioned differently as in Russian, Polish, and Finnish in semantic space, depending on case. Given that Ukrainian, Russian, and Polish are closely related languages, we expected to find a similar pattern for Ukrainian.

The observed patterns in the usage of singular and plural forms in Ukrainian nouns are fully align with the heterogeneity of the number category. Thus, the distribution of singular and plural forms may not strictly adhere to grammatical patterns and that semantic considerations significantly influence the choice between singular and plural forms in Ukrainian nouns, with countable, lexical plural, and collective nouns impacting the decision. In Ukrainian the ability of the nouns in singular express plurality is largely similar to that noted by authors (Chierchia, 2021; Landman, 2011). The specific patterns observed in the Ukrainian language suggest a nuanced relationship between linguistic expressions of number and the cognitive and perceptual characteristics of the concepts represented by those expressions.

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Comparative analysis of SNARC effect reliability: Insights from parity judgment and magnitude comparison tasks

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Recent studies have indicated a notable inconsistency in the correlation between the magnitude of the Spatial Numerical Association of Response Codes (SNARC) effect observed at distinct time points (Hedge et al., 2018; Roth et al., 2023). Specifically, individuals demonstrating a pronounced left-to-right SNARC effect at one instance may display a nearly negligible or even a reversed SNARC effect at another, and vice versa. This challenges prevailing theories positing the SNARC effect as an outcome of a stable spatial representation of numbers along a horizontal axis. A stable representation, by definition, should remain impervious to short-term temporal fluctuations reported for the SNARC effect. Beyond theoretical implications, the lack of reliability in the SNARC effect poses challenges for studies exploring its correlation with independent constructs, such as mathematical skills. Notably, existing investigations into the reliability of the SNARC effect have been confined to the parity judgment task, one of the two conventional methods for its measurement. To our knowledge, there has been no exploration of the reliability of the SNARC effect using the alternative task, namely the magnitude comparison task.
This study seeks to address this gap by comparing the reliability of the SNARC effect as measured by each task. Two large groups of participants ($N \approx 150$ each) engaged in either a magnitude comparison task or a parity judgment task across two sessions, separated by at least two weeks. Preliminary results confirm the previously noted low reliability of the SNARC effect in the parity judgment task. However, a marked increase in reliability emerges in the case of the magnitude comparison task.
These unexpected results suggest the existence of intrinsic, yet largely unexplored, differences between the two traditionally employed tasks for SNARC effect measurement. Moreover, these findings hold practical implications for task selection in studies investigating the correlation between SNARC and other constructs.

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The association between fingers' usage and early numerical skills in toddlers

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Introduction: Most preschoolers spontaneously use their fingers for counting and calculating [1]. Finger counting is recognized as a valuable tool for fostering the development of numerical skills [e.g., 2-3]. However, the relationship between fingers' usage and numerical skills has primarily been explored in preschoolers, leaving the question of when this association first emerges. This study addresses this gap by examining the associations between fingers' usage and numerical skills in toddlers. We hypothesize that a correlation between these abilities can already be observed at this early age.

Methods: During two testing sessions, 94 Italian toddlers (45 males, age range = 17-43 months, mean age = 29.83 ± 6.93) completed a total of 12 tasks aimed at assessing their fingers' usage and numerical skills. Specifically, tasks related to fingers' usage included: (1) finger configuration (i.e., reproducing a finger configuration seen in a photo), (2) finger montring (i.e., displaying the number of dots on a dice using fingers), (3) finger counting (i.e., counting the number of their fingers), (4) representation of age on fingers. On the other hand, tasks related to numerical skills included: (1) enumeration, (2) one-to-one correspondence, (3) size-based one-to-one correspondence (e.g., assigning the biggest t-shirt to the biggest child), (4) size seriation, (5) magnitude seriation, (6) proto-arithmetical skills (performing non-symbolic sums), (7) counting, (8) point-X. We examined the strength of the association between the scores achieved by participants in the various tasks using Pearson's r coefficient.

Results: We found that children's performance in finger configuration was correlated with their performance in several different numerical skills, including enumeration (r=.282, p=.011), one-to-one correspondence (r=.429, p<.001), size-based one-to-one correspondence (r=.241, p=.021), size seriation (r=.291, p=.005), magnitude seriation (r=.290, p=.005), and proto-arithmetic (r=.209, p=.046). Similarly, finger montring was associated with counting (r=.373, p<.001), one-to-one correspondence (r=.341, p <.001), enumeration (r=.276, p =.013), size seriation (r=.221, p=.038), magnitude seriation (r=.213, p=.045). Finger counting, instead, was associated only with counting (r=.369, p<.001), and magnitude seriation (r=.339, p<.001). Finally, showing the age with fingers was associated with counting (r=.289, p=.008), and size-based one-to one correspondence (r=.238, p=.031).

Discussion and conclusions: Our findings suggest that correlations between fingers' usage and certain basic numerical skills are present already by the second year of life. While our study design cannot establish causality, it underscores the necessity for longitudinal studies to explore how this association evolves over time and its potential educational implications.

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Spatialization and its link to working memory capacity

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The SPoARC (Spatial Positional Association of Response Codes) is a phenomenon in which information that does not have inherent ordinal property (e.g., a list of fruits) is mentally spatialized from left to right in working memory. This phenomenon, driven by cultural habits such as the reading and writing direction, is thought to support working memory by facilitating order encoding (Abrahamse et al., 2014; Guida & Lavielle-Guida, 2014), although this hypothesis has never been directly tested. To address this issue, our objective was to show a relationship between spatialization and working memory capacity. In the present study, we investigated *i)* whether spatialization could vary as a function of working memory load and *ii)* which component of the cognitive system (verbal *vs.* visual) could modulate the effect. We hypothesized that spatialization should be sensitive to capacity limits because anchoring ordinal information spatially may alleviate difficulties to retain information. We also predicted that verbal abilities would support spatialization more than visual abilities because spatialization has been shown to be preferentially linked to semantics (Ginsburg et al., 2017).

In Experiment 1, 139 participants performed a spatialization task with sequences of either two, three, four, or five items. Verbal working memory capacity was assessed using a forward and backward digit span task. Using generalized linear mixed models, results showed a significant spatialization effect for all sequence lengths except for sequences of 5 items. However, no direct relationship was found between individual verbal spans and spatialization. In Experiment 2, 96 participants performed the same task for sequences of three, four, and five items, but using a within-subject design. Several abilities were measured, including verbal, spatial, and visual working memory capacity, as well as visuospatial ability, mental imagery, and spatial orientation ability. The absence of spatialization persisted for sequences of five items, whereas a significant effect was found for sequences of three and four items. Notably, this significant spatialization was related to the participants' verbal span. Additionally, larger spatialization was associated with lower spatial orientation abilities.

The working memory capacity limit hypothesis is thus supported by our findings that spatialization can be best detected for sequences of four items and that participants with lower verbal spans spatialize more. The more surprising results concerning the low spatial orientation skills are discussed in relation to Bottini and Doeller's (2020) review on spatial representation of conceptual knowledge.

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Modality and stimulus effects on Distributional Statistical Learning: Sound vs. sight, time vs. space

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Statistical learning (SL), the ability to implicitly extract regularities from the environment was found for various types of sequential patterns across sensory modalities. Following the seminal finding of Saffran et al. (1996), many studies have identified participants' sensitivity to transitional probability between auditory syllables or visual objects in artificial sequences, allowing them to learn discrete representations without any additional cues of item boundaries. In contrast, despite its equal importance in processing sensory information, such as phoneme categories (Maye et al., 2002) or face shapes (Altvater-Mackensen et al., 2017), few studies have focused on distributional SL (DSL), which involves learning the frequency distribution of individual exemplars. Additionally, even fewer studies have examined DSL across modalities using comparable tasks. Therefore, the current study investigated DSL's modality- and stimulus-specificity using a within-subject design to compare individuals' performance in auditory and visual modalities (N = 118 adults). Two stimulus types were used for each modality: linguistic vs. non-linguistic auditory stimuli and temporal vs. spatial visual stimuli. Stimuli varied in their lengths as they were distributed into two categories (short vs. long). DSL was assessed using a passive categorization task (accuracy score) and an active production task (deviation from mode). Results showed that learners' performance was correlated only for tasks in the same sensory modality or with the same type of stimuli, supporting the modality- and stimulus-sensitivity of DSL. In addition, participants were better at categorizing the temporal signals in the auditory conditions than in the visual condition, where in turn an advantage of the spatial condition was observed. Linear mixed-effects models also showed significantly more exaggeration in reproduced signal length for linguistic than non-linguistic signals. Considering both production and categorization results, we suggest that SL, if a unitary mechanism, faces constraints at multiple levels while learning and processing distributional patterns.

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