EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Workshop

Linguistic and Cognitive Influences on Numerical Cognition

September 2017

University of Tübingen, Germany

DFG

LEAD
Graduate School & Research Network

IWM
Leibniz-Institut für Wissensmedien

Linguistic and Cognitive Influences on Numerical Cognition

Workshop

8th – 9th September 2017

Tübingen, Germany

Contents

1 Preface

Dear colleagues,

It is our greatest pleasure to welcome you to the Workshop on *Linguistic and Cognitive Influences on Numerical Cognition* that will be held in Tübingen, Germany from 8th to 9th of September 2017.

Numerical cognition is essential in our daily life. It depends on the interaction of many domain-general and domain-specific factors. However, linguistic influences on numerical cognition have been neglected for years and it has been argued that central semantic number processing occurs largely without language. Nevertheless, the last years have seen a surge of studies showing that different linguistic aspects exert major influence on virtually all domains of numerical processing. Moreover, various cognitive, affective and motivational factors have been reported to largely influence numerical processing. Thus, to better understand numerical cognition as well as to develop appropriate educational and interventional approaches, we need to gain a broad perspective on relevant factors. The aim of this workshop is to bring together linguistic and cognitive influences on numerical cognition.

For this year's workshop, we thus invite you to spend two days in Tübingen discussing this timely topic and we are delighted to welcome your many contributions. Keynote talks by ten leading researchers will give a broad overview of current research topics of different disciplines. Participants will also get the opportunity to present their own work within poster sessions and to discuss it with experts.

Besides that, Tübingen offers a wealth of historical sites and cultural highlights, so we are pleased to offer you some of them in an attractive framework program: e.g., a brief sightseeing walk.

Finally, yet importantly, we wish to thank our sponsors for the generous funding that enabled us to invite internationally recognized researchers and to conduct the workshop without collecting registration fees.

This workshop is organized within the project "Linguistic Influences on Numerical Cognition: A cross-cultural investigation using natural specificities of Polish and German languages" (www.lingnumcog.eu) co-funded by Deutsche Forschungsgemeinschaft (DFG) and Narodowe Centrum Nauki (NCN). We are also grateful for the support of the LEAD Graduate School & Research Network and the Leibniz-Institut für Wissensmedien (IWM) in Tübingen.

We look forward to meeting you in Tübingen and hope that you will enjoy the workshop.

The Organizing Committee

2 Organizing Team

Advisory Committee

Hans-Christoph Nuerk

Maciej Haman

Thomas Dresler

Organization

Christina Artemenko

Julia Bahnmueller

Silke M. Bieck

Krzysztof Cipora

Katarzyna Lipowska

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Vesna Milicevic

Philipp A. Schroeder

Mojtaba Soltanlou

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3 General Information

Workshop Venue

Psychologisches Institut
Eberhard Karls Universität Tübingen
Schleichstraße 4
D-72076 Tübingen
Tel. +49 (0)7071 29-78345

Lecture hall 4.329

WiFi

There is a free WiFi access at the venue:

SSID: Guest
User name: neuroscience
Password: Tübingen

Poster sessions

The posters will be presented in a room next to the lecture hall (4.332). The poster walls are numbered from A1 to A27 and from B2 to B26 for the two Poster sessions A and B. Posters with odd numbers will be discussed in Poster Session A on Friday (16:30 - 18:00), and posters with even numbers in Poster Session B on Saturday (11:30 - 13:00). You can find the number of your poster in the overview of posters in the booklet.

Please deliver your poster on Friday. If you want to remove your poster, feel free to collect it on Saturday so that all the posters can be presented during the whole workshop. The presenting authors are asked to be attendant during the respective poster session.

Best poster awards will be presented to the authors of the three best judged posters. The poster committee consists of Professor Annemarie Fritz-Stratmann, Professor Jo van Herwegen and Professor Masahiko Okamoto. The award ceremony will take place on Saturday after the final discussion.

Coffee breaks, lunch and dinner

During the coffee breaks, hot and cold drinks as well as some snacks will be offered in room 4.333 (right next to the room where the poster sessions will take place). Lunch snacks will also be served at the venue, so you don’t need to worry about finding a nearby restaurant for lunch.

On Friday evening all participants of the workshop are invited to join for a dinner at the restaurant “Neckarmüller” (Gartenstraße 4) at their own expense. As we will be a quite large group, the restaurant needs to know the number of guests and the orders in advance. Therefore, please indicate at the reception desk on Friday morning if you want to join us for dinner on Friday and select your dish from the menu.

4 Our Sponsors

Deutsche Forschungsgemeinschaft

Narodowe Centrum Nauki (NCN)

LEAD Graduate School & Research Network

Institut für Wissensmedien (IWM)

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 of 87,000 inhabitants and about 28,000 students combines the flair of a lovingly restored medieval town centre with the colourful 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 6th or 7th century. It was mentioned in writing for the first time in 1078, and achieved town status and civil liberty under the Palatine Counts of Tübingen in the middle of the 13th 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 moulded 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.

To learn more about what Tübingen has to offer visit https://www.Tübingen.de/en.

Famous Personalities linked to Tübingen

ALOIS ALZHEIMER (1864–1915), a German psychiatrist and neuropathologist who first identified Alzheimer's disease, studied medicine partially in Tübingen.

GEORG WILHELM FRIEDRICH HEGEL (1770–1831), a German philosopher, studied theology at the *Tübinger Stift.*

HERMANN HESSE (1877–1962), a German-born Swiss poet, novelist, and painter, apprenticeship with a bookseller in Tübingen, Nobel Prize in Literature in 1946.

JOHANN CHRISTIAN FRIEDRICH HÖLDERLIN (1770–1843), a German lyric poet, studied theology at the *Tübinger Stift*.

JOHANNES KEPLER (1571–1630), a German mathematician, astronomer, and astrologer, studied theology at the *Tübinger Stift.*

WOLFGANG KÖHLER (1887–1967), a German psychologist and phenomenologist, studied psychology partially in Tübingen.

FRIEDRICH MIESCHER (1844–1895), a Swiss physician and biologist, the first to isolate the nucleic acid at the chemistry laboratory of *Schloss Hohentübingen*.

EDUARD MÖRIKE (1804–1875), a German Romantic poet and writer of novellas and novels, studied theology at the *Tübinger Stift,* spent most of his life in Tübingen.

POPE BENEDICT XVI (Joseph Aloisius Ratzinger, *1927), chair in dogmatic theology at the University of Tübingen from 1966 to 1969.

JOHANN LUDWIG UHLAND (1787–1862), a German poet, philologist and literary historian, born and studied in Tübingen.

WILHELM MAXIMILIAN WUNDT (1832–1920), a German physician, physiologist, and philosopher, studied medicine partially in Tübingen.

Sightseeing walk through Tübingen

(*Numbers refer to the map of Tübingen shown on p. 13, adapted from Tourists' city map*)

House of the Nuns (Nonnenhaus) (22)

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 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 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) (11)

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 due to the support of the Duke Eberhard im Bart (*the Bearded*) of Württemberg – the Collegiate Church received an excellent décor.

Goethe (10)

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").

Marketplace (Marktplatz) and City Hall (Rathaus) (7)

The Market place with City Hall and Neptune's Fountain, along with the Neckar waterfront, is one of the 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 still functions, shows the course of the stars, the phases of the moon, and even 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 Schickhardt, who was inspired by a Bolognese archetype.

Protestant Collegiate (Evangelisches Stift) (5)

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, Hermann Kurz as well as Hegel, Hölderlin, and Schelling, who occasionally lived and studied together in the collegiate at the end of the 18th century.

Today it serves as an accommodation and study space for about 120 students. Women have been admitted since 1969.

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 on May 3, 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."

Hölderlin Tower (Hölderlinturm) (*)

In the late 18th century, the *Hölderinturm* was built on the pedestal of the inner ring wall. The wall dates back to the 13th 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.

Neckar Island (Neckarinsel) and Plane Tree Avenue (Platanenallee) (=)

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 elongated *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*.

Additional stop: 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, which he called nuclein (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. Entrance to the cellar of the north wing, where the glorious 850 hl (22,455 gallons) wine barrel is located, dating back to 1546, is unfortunately not currently possible.

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.

6 Map of Tübingen

Map Legend (yellow arrows)

1. Workshop venue, Psychologisches Institut, Schleichstraße 4
2. Restaurant “Neckarmüller”, Gartenstraße 4
3. Hotel Domizil, Wöhrdstraße 5 - 9

7 Eberhard Karls Universität Tübingen

„Tübingen does not have a university, it is a university“, is a common expression for a good reason: With its palm tree symbol and Duke Eberhard’s motto “Attempto!” (“I dare”), the university and its more than 28,000 students certainly shape the city image. Its 517 professors and 4,600 academics make it the second largest university in Baden-Württemberg, following Heidelberg. In total 330 courses are on offer. The 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 Eberhard Karls University 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 12.6% percent of students in Tübingen come from abroad, an 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 *https://www.uni-Tübingen.de/en*.

8 Timetable

Friday, 8th September 2017

08:30 – 09:15	Registration and Placing Posters
09:15 – 09:30	Welcome by Hans-Christoph Nuerk and Maciej Haman
09:30 – 10:15	**Linguistic and Cognitive Influences on Spatial-Numerical Cognition** *Hans-Christoph Nuerk*
10:15 – 11:00	**The Temporary Nature of Number-Space Interactions** *Jean-Philippe van Dijck*
11:00 – 11:30	Coffee Break
11:30 – 12:15	**Numbers, Language, and the Real Preschoolers of Orange County** *Barbara Sarnecka*
12:15 – 13:00	**The Role of Mental Representations of Space and Fingers in Number Processing** *Michael Andres*
13:00 – 14:30	Lunch Break
14:30 – 15:15	**Multitask Study of Numerical Concepts in Transition: From Naïve Numerical Intuitions to Symbolic Representation** *Maciej Haman*
15:15 – 16:00	**Can Language(s) Affect Numerical Cognition? Insights from Different Stages of Bilingual Language Acquisition** *Christine Schiltz*
16:00 – 16:30	Coffee Break
16:30 – 18:00	Poster Session A
18:00 – 18:30	General Discussion
19:45	Dinner

Saturday, 9th September 2017

09:00 – 09:30	Registration Desk open
09:30 – 10:15	**Numbers and Language: What Have We Learned in the Past 25 Years?** *Marc Brysbaert*
10:15 – 11:00	**Semantic Interpretation of Grammatical Number** *Frank Domahs*
11:00 – 11:30	Coffee Break
11:30 – 13:00	Poster Session B
13:00 – 14:30	Lunch Break
14:30 – 15:15	**How Culturally Predominant Reading Direction and Number Word Construction Influence Numerical Cognition and Mathematics Performance** *Silke M. Göbel*
15:15 – 16:00	**What Aspects of Mathematical Development Are – and Are Not – Influenced by the Transparency of the Counting System?** *Ann Dowker*
16:00 – 16:30	Final Discussion and Presentation of Poster Awards
16:30 – 17:30	Coffee Break and Time for Individual Discussion

9 Keynote Lectures

Friday, 8th September 2017

09:30 h – 10:15 h

Linguistic and Cognitive Influences on Spatial-Numerical Cognition

Hans-Christoph Nuerk

Department of Psychology, University of Tübingen, Germany

Leibniz-Institut für Wissensmedien (IWM), Tübingen, Germany

LEAD Graduate School, University of Tübingen, Germany

In this talk, I will first present a taxonomy of linguistic influences on numerical cognition, which may help to categorize different linguistic influences. Besides the more commonly investigated magnitude processing, a particular empirical focus of this talk will be parity processing. I will discuss the linguistic influences (grammatical factors, lexical factors) on multi-digit parity processing and its association with space. I will further show that other cognitive factors like multiplication knowledge and individual factors like handedness can also influence parity processing and its association with space. Finally, I will outline some new determinants of the association of magnitude and space, in particular the SNARC effect. Finally, I summarize which processes and mechanisms may underlie linguistic influences even on basic spatial-numerical properties.

Friday, 8th September 2017

10:15 h – 11:00 h

The Temporary Nature of Number-Space Interactions

Jean-Philippe van Dijck

Department of Experimental Psychology, Ghent University, Belgium

Department of Applied Psychology, University College Thomas More, Belgium

It is commonly accepted that the mental representation and processing of number and space are tightly linked. This is evident from studies showing relations between math ability and visuo-spatial skill. Also, math instruction and education rely strongly on visuo-spatial tools and strategies. The dominant explanation for these number-space interactions is that the mental representation of numbers takes the form of a mental number line with numbers positioned in ascending order according to our reading habits. A long-standing debate is whether the link between numbers and space can be considered as evidence for a spatial number representation in long-term semantic memory, or whether this spatial frame is a temporary representation that emerges in working memory (WM) during task execution. The aim of this talk is twofold. Whereas a pure Mental Number Line account cannot capture the complexity of observations reported in the literature, we here explore if and how a pure working memory account can suffice. Second, we make explicit the potential building blocks of such a working memory account, thereby providing clear and concrete foci for empirical efforts to test the feasibility of the account.

Friday, 8th September 2017

11:30 h – 12:15 h

Numbers, Language and the Real Preschoolers of Orange County

Barbara Sarnecka

University of California, Irvine, USA

Of the many statements we could make about the relation between number and language/culture, at least three are true: (1) Number is unrelated to language/culture; (2) Numbers are a linguistic/cultural invention; and (3) Numbers bear the fingerprints of particular languages. These statements seem contradictory but they can all be true, because they depend on different definitions of ‘number(s)’ and ‘language(s).’ Although all of the statements are true, some of these relations are more important in people’s lives than others. I will discuss which of these relations matter in a practical sense to a particularly important and vulnerable group of American students — young dual-language learners living in poverty.

Friday, 8th September 2017

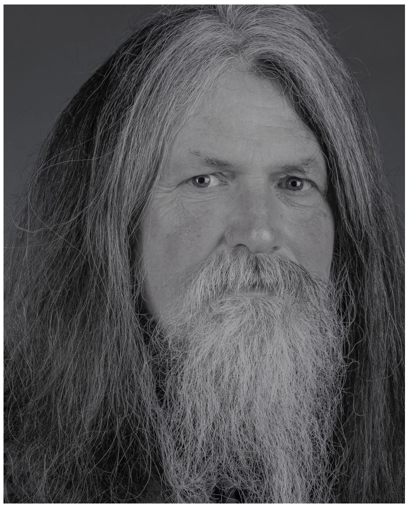
12:15 h – 13:00 h

The Role of Mental Representations of Space and Fingers in Number Processing

Michael Andres

Université catholique de Louvain, Belgium

A core property of number words is that they are organized in sequence and their value is given by their relative position in the sequence. Children often use fingers and spatial cues as external aids for learning the number word sequence and the arithmetic procedures. I will present evidence from psychophysical, eye-tracking and interference studies showing that adults keep on relying on internal representations of space and fingers when they mentally process number words or when they solve arithmetic problems. I will first examine how finger movements interfere with mental arithmetic while looking at the effect of typical parameters of finger counting, such as movement direction and sequentiality. I will then present what spatial judgements and eye movements tell us about the role of spatial attention in number processing and arithmetic problem solving. I will finally confront the results of the reviewed experiments with existing accounts of the interactions between number, space and finger representations. I will propose that these interactions involve working memory mechanisms triggered by linguistic aspects of number processing, including the serial order of number words, their organization in units and decades, and the polarity of arithmetic signs.



Friday, 8th September 2017

14:30 h – 15:15 h

Multitask Study of Numerical Concepts in Transition: From Naïve Numerical Intuitions to Symbolic Representation

Maciej Haman

Faculty of Psychology, University of Warsaw, Poland

More than 200 children aged 3:0-6;3 participated in the study of understanding the numerical concepts. First, participants were assessed for their verbal counting scope, cardinal number scope (Give-a-number task), and knowledge of single-digit Arabic numerals. During the following sessions (up to 5 sessions in total), children were asked to perform several numerical tasks, concerning magnitude processing, numerical ordering, and spatial-numerical associations (magnitude comparison: sets, digits, and cross-notation, non-symbolic and symbolic numerical magnitudes ordering, assessed for correctness and spatial direction, non-symbolic and symbolic number line, non-symbolic and symbolic arithmetic). The main aim of the study was to determine how performance in those tasks changes with cardinality knowledge level, when controlling for the exact age, and number-words and Arabic digits knowledge. The analyses are currently in progress. We expect that the results would significantly contribute to our understanding of the nature of developmental change ongoing in the pre-school age, i.e., during the transition from the stage of acquisition of the first exact numerical concepts to the stage of some established knowledge of the cardinality and the successor principles, and symbolic numbers (including Arabic notation). The role of spatial-numerical associations in this transitional period is among the most important questions in this project.

Friday, 8th September 2017

15:15 h – 16:00 h

Can Language(s) Affect Numerical Cognition? Insights from Different Stages of Bilingual Language Acquisition

Christine Schiltz

Cognitive Science and Assessment Institute, University of Luxembourg

Throughout development number concepts are not only shaped by sensori-motor factors such as visuo-spatial attention (e.g., Hoffmann et al., 2013; 2014; Georges et al., 2017), but the learner's language environment also plays a critical role. Investigations into the relation between *language(s)* and numerical cognition - in particular the question how multi-lingual persons conceive and process numbers - have lately regained interest. Here we present recent findings from studies on the influence of language on numerical cognition in a multilingual context such as Luxembourg (e.g., Van Rinsveld et al., 2015; 2016a; 2016b; 2017). The Luxembourg school system consists in a German-French bilingual setting, which progressively educates pupils to become German-French bilingual adults. Studying numerical cognition in persons going through this school system thus provides an excellent opportunity to investigate how progressively developing bilingualism impacts numerical representations and computations. Our behavioural and neuroimaging results indicate that the language setting of numerical tasks (i.e., the language of in/output) significantly impacts the speed and the quality of numerical computation. In children the structure of number words seems to impact all levels of task complexity, yielding language-related performance differences in transcoding, magnitude comparison and arithmetic. While generally the impact of language becomes more subtle in adults, it is striking that nonetheless brain activation pattern during basic numerical tasks such as simple additions continue to differ when bilingual adults are confronted with this operation in their respective instruction-languages. Taken together, our findings support the view that language(s) significantly influence numerical processing over the lifespan.

Saturday, 9th September 2017

09:30 h – 10:15 h

Numbers and Language: What Have We Learned in the Past 25 Years?

Marc Brysbaert

Ghent University, Belgium

The relationship between mathematical and verbal skills is not a clear one. On the one hand, they seem to be related; on the other hand, many school systems offer pupils the opportunity to choose between a language-oriented education versus a mathematics oriented education, suggesting the two types of skills diverge. In this talk I look at the evidence by analyzing the relationship between verbal and arithmetical skills in intelligence tests and by reviewing the literature on cognitive processes specific to numerical cognition. Finally, I discuss two recent evolutions in psycholinguistics that may be of interest to number researchers.

Saturday, 9th September 2017

10:15 h – 11:00 h

Semantic Interpretation of Grammatical Number

Frank Domahs

Institute of Germanic Linguistics, University of Marburg, Germany

In many languages, including English, German and Polish, the grammatical category number is marked on different word types (e.g., nouns, pronouns, articles, adjectives, and/or verbs). Via agreement relations, it serves to establish co-reference between syntactic elements (e.g., between noun and pronoun or between subject and verb). Grammatical number distinctions (singular vs. plural) typically, although not always, correspond to the actual count of the referents (one vs. many). Therefore, the semantic interpretation of grammatical number basically evokes a quantity meaning. The present talk will try to shed some light on this process. I will present data from studies using behavioral methods, functional magnetic resonance imaging (fMRI) and voxel-based lesion-symptom mapping (VLSM) with healthy participants and brain-damaged patients. Based on these findings, I will come to the following conclusions: Semantic interpretation of grammatical number may occur automatically, but task-dependent (Roettger & Domahs, 2015). In languages with complex morphological paradigms of grammatical number (e.g., German), it may proceed in a probabilistic fashion, using various cues of different validity (Domahs, Bartha-Doering, Domahs, & Delazer, 2017). Neuroanatomically, similar areas (in particular the left inferior parietal lobe) are involved in the interpretation of grammatical number and in numerical tasks (Domahs et al., 2012).

Saturday, 9th September 2017

14:30 h – 15:15 h

How Culturally Predominant Reading Direction and Number Word Construction Influence Numerical Cognition and Mathematics Performance

Silke M. Göbel

University of York, United Kingdom

Linguistic and cultural factors influence even basic Arabic number processing in children and adults. In this talk I will review recent literature and give an overview of our work on how one cultural factor (reading direction) and one linguistic factor (number word construction) influence numerical processing (counting, number generation, number comparison and arithmetic). However, evidence that reading direction and number word construction shape numerical processing does not necessarily mean that these factors are important for individual differences in mathematical performance and development. I will review data showing that the extent to which children and adults are influenced by the culturally predominant reading direction does not seem to be related to their mathematical performance. In contrast, results from our and other longitudinal studies suggest that number word construction and the ability to transcode spoken number words into Arabic digits is a significant predictor of growth in mathematical performance in the first years of primary school.

Saturday, 9th September 2017

15:15 h – 16:00 h

What Aspects of Mathematical Development Are – and Are Not – Influenced by the Transparency of the Counting System?

Ann Dowker

Department of Experimental Psychology, University of Oxford, United Kingdom

Some languages have more transparent counting systems than others. In particular, the counting systems in East Asian languages such as Chinese, Japanese and Korean, correspond closely to the written number system, and make the base ten system particularly explicit. It has sometimes been suggested that this transparency contributes significantly to the fact that children in East Asian countries do well in international comparisons of mathematical skills. As there are many cultural and educational differences between countries, it is difficult to draw firm conclusions about the relative importance of linguistic versus other reasons for cross-national differences in mathematical performance. One way of addressing the issue is to compare children in different language-medium schools in the same country. Studies of this nature have involved comparing children in Chinese and English medium schools in Hong Kong (Mark & Dowker, 2015) and in Welsh and English medium schools in Wales (Dowker, Bala & Lloyd, 2008; Dowker & Roberts, 2015). The Welsh counting system used in schools has similar transparent properties to the East Asian counting systems, and studies of Welsh schools have the advantage that all children are following the same mathematics curriculum, differing only as to language. Results of the studies in both Wales and Hong Kong suggest that the nature of the counting system affects some components of arithmetic, but cannot be the main explanation for overall international differences. In particular, children using a transparent counting system seem to be better at comparing 2-digit numbers, but not at arithmetic as a whole.

10 Poster Sessions

10.1 Poster Session A

A1 - SNARC Effect among Hebrew-Speaking Children

Anat Feldman, Yafit Oscar-Strom, Rotem Sokol, Tal Binjamin, Dana Landau, Joseph Tzelgov & Andrea Berger

Ben Gurion University of the Negev, Israel

Until recently, there was a consensus that the SNARC effect (Dehaene et al., 1993) is dependent on the direction of writing. Consistently, studies have shown that Arabic speakers who write numbers and letters from right to left, were characterized by a reversed SNARC effect, whereas Hebrew speakers who write letters from right to left and numbers from left to right did not show any consistency in the numerical spatial association. However, recent studies by Zohar-Shai, Tzelgov, Karni and Rubinsten (2017) refuted this claim. These researchers showed that existence of the SNARC effect depends on the size of the MARC effect, which masks the SNARC effect. Studies, which reduce the influence of MARC effect allowed the appearance of classic SNARC effect among Hebrew speaker adults (Zohar-Shai et al., 2017; Oscar-Strom & Tzelgov, in preparation). In our experiment, we decided to expand these findings and test whether under the same conditions that reduce the influence of the MARC effect, we will be able to see the presence of the classic SNARC effect among Hebrew-speaking children. Here we report results of our first exploratory experiment with Hebrew-speaking elementary school children. Indeed, by conducting the experiment according to the Zohar-Shai et al. (2017) paradigm, we find first evidence for the mapping of numbers from left to right in Hebrew-speaking children.

A3 - Are Parity and Magnitude Status of Arabic Digits Processed Automatically? An EEG Study Using the Fast Periodic Stimulation Paradigm

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Many studies have shown that humans can easily extract numerical characteristics of single digits such as numerical magnitude and parity status. We investigated whether spontaneous processing of magnitude or parity status can be observed when participants are passively presented with sequences of briefly displayed Arabic digits. We assessed the parity processing by presenting seven odd digit numbers followed by one even digit (and reverse) with a sinusoidal contrast modulation at a frequency of 10 HZ in one-minute sequences. The same paradigm and frequencies were used to investigate magnitude processing (i.e., seven digits smaller than five followed by one digit larger than five; and reverse) and control condition (i.e., sequence of 1-4-6-9 followed by 2-3-7 or 8). We observed a strong EEG activation over right parietal electrodes and a weaker activation over left parietal electrodes in all conditions. Left and right activations were stronger in the parity than in the two other conditions, reflecting an automatic retrieval of parity information conveyed by the Arabic digits. The right-sided activations during the control task might be due to the fact that subjects can quickly learn to categorize numbers, even if the categorization is following arbitrary rules. Overall, these neuronal activation patterns are consistent with the neuro-imaging literature describing the localization of basic numerical processing. Our findings indicate that magnitude and parity status are extracted automatically from Arabic digits, even when numerical stimuli are presented without instructions at a high presentation rate.

A5 - The Role of Methodological Choices when Examining the Integration of Symbolic and Non-symbolic Number Processing

Mila Marinova, Delphine Sasanguie & Bert Reynvoet
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Previous findings provide contradicting evidence for the integration between symbolic and non-symbolic number processing systems, possibly due to methodological differences (Liu et al., 2015; Lyons et al., 2012; Sasanguie et al., 2017). Some report detriment in performance in mixed trials, where participants compare digits and dots, relative to pure trials where two stimuli of the same notation are compared (Lyons et al., 2012). Other studies use matching instructions but do not find such interference (Liu et al., 2015). To investigate this issue, we conducted three behavioral experiments with adults. First, we examined the role of the task instructions, by replicating the study of Lyons et al. (2012), but using both comparison and matching. In the second study, we tested the role of blocked and randomized presentation order of pure and mixed trials. The results of these two experiments suggest that the presence of cost for switching between the two systems is not task- or presentation- dependent. A cost in the mixed conditions was present but can be obscured by large differences in RTs between the two pure conditions: the larger the difference between the pure dots and pure digits, the smaller the switch cost is. We tested this in a third experiment, where we matched the RTs for the mixed and the pure trials by using an audio-visual paradigm, and found a clear switch cost. Overall, our results provide further evidence for the existence of distinct number representations. However, we showed that a switch cost for mixed trials, as it was originally operationalized by Lyons et al. (2012), can be masked by large RT differences between the pure symbolic and non- symbolic, showing the need for alternative paradigms to tackle the issue of distinct representations.

A7 - Exploration of Tasks Involving Numerical Magnitude Processing of Fractions: The Relationships among Immediate Serial Recall, Magnitude Comparison, Number Line Estimation, and Calculation

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Conventional measures to access numerical magnitude representations are not satisfactorily applicable to fractions because their correlations have been inconsistent across fraction studies. In this study, we explore a new measure for fraction magnitude. We conducted three experiments with Japanese university students to investigate (1) whether immediate serial recall involves representations of fraction magnitudes due to semantic number processing, and (2) the relationship between the new and conventional fraction magnitude measures. We consistently found the magnitude similarity effect on recall through the experiments; the recall performance was better for lists of similar magnitude fractions (e.g., 2/7, 4/19, 5/18 and 3/11, representing 0.29, 0.21, 0.28 and 0.27, respectively) than for those of dissimilar magnitude (e.g., 17/18, 4/11, 9/14 and 5/6, representing 094, 0.36, 0.64 and 0.83, respectively), even though the first decimal places of fractions differed in the similar magnitude lists (e.g., 6/19, 5/17, 4/15 and 1/3, representing 0.32, 0.29, 0.27 and 0.33, respectively). These results indicate that immediate serial recall accesses fraction magnitude representations and that 0.1 does not serve as the anchor point, which was also supported by the performance for magnitude comparison. However, we did not obtain consistent correlations in the experiments. The recall performance correlated with calculation scores in only one of the three experiments. Additionally, the performances for number line estimation and magnitude comparison did not correlate with the calculation scores. The correlation result suggests that for mathematically matured participants, performing tasks involving fractions depends more on some complex processes rather than the representations of their magnitudes.

A9 - Spatial Biases in Mental Arithmetic are Independent of Reading Direction Habits

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Studies suggest that numbers are represented in ascending order on a left-to-right oriented continuum in Western cultures. An influential framework attributes the construction of these spatial-numerical associations (SNAs) to cultural factors as SNAs were found to be reduced or inverted in right-to-left reading cultures (e.g., Arabic). Because the representation of numbers is spatially oriented, it has been assumed that solving arithmetic problems involves shifting attention toward the side of the continuum where the answer is represented. In the present study, we used a temporal order judgment task to evidence the spatial biases induced by solving arithmetic operation problems in monolingual French and Arabic speakers. Participants had to determine which of a left or right target appeared first on the screen while solving subtraction and addition problems. We observed that the right target should be presented several milliseconds before the left target to be perceived as simultaneous during subtraction. This finding indicates that attention was biased to the left side of space during subtraction compared to addition. Importantly, this was observed for both French and Arabic participants. Our results thus indicate that the orientation of reading does not determine the direction of SNAs in mental arithmetic.

A11/A12/A13 - Which Factors Affect Response Speed in Two-Digit Number Parity Judgment Task? A Cross-Lingual Study

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Many numerical properties and linguistic factors have been shown to influence reaction times in two-digit number parity decision task. Up till now, however, those factors have not been investigated systematically within a single study. Here we now present the results of such a study. Within one study using a multiple regression approach we tested the influence of numerical properties such as: (1) unit magnitude, (2) decade magnitude, (3) parity, (4) decade parity, (5) parity congruency of unit and decade number, (6) being a prime number, (7) being a square, (8) being a part of a multiplication table, (9) being a tie number, (10) being a decade, (11) being a power of 2, (12) divisibility by 4, (13) and by 5. The influence of these properties was tested separately for Arabic numbers, number words and auditory numbers in three different languages (*P*olish, *G*erman, and *E*nglish). A total of 109 monolingual students were tested. In *Arabic notation* the following number properties had a significant overall effect on RTs: unit magnitude, parity congruency, being a full decade and divisibility by 5. The influence of being a power of 2 was present in *P* speakers only. In *number words* the following number properties had a significant overall effect on RTs: unit magnitude, parity, decade parity, parity congruency, being full decade, as well as divisibility by 4. The influences of unit magnitude (the strongest in *P*), parity congruency (no effect in *P*), and full decade (the strongest in *P*) differed significantly between languages. In *Auditory presentation* the following number properties had a significant overall effect on RTs: decade magnitude, unit magnitude, parity congruency, being a prime number, being part of a multiplication table, being a tie number, being full decade, as well as divisibility by 4 and 5. The influences of decade magnitude (the weakest in *G*, the strongest in *P*), unit magnitude (the weakest in *E*, the

strongest in *G*), parity status (the strongest in *G*), being a prime number (no effect in *G*), being a tie number (no effect in *G*), being full decade (no effect in *G*), being a power of 2 (the strongest in *G*), as well as divisibility by 4 (no effect in *P*) and 5 (no effect in *G*) varied significantly between languages. Significant findings will be discussed with a special consideration of between-language differences.

A15 - (Math) Anxiety Increases When Facing Complex Arithmetic Problems

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Math anxiety as a feeling of anxiety and tension towards math is considered to be a trait which differs between but not within individuals. However, for general anxiety a trait aspect in terms of how anxious one generally feels can be differentiated from a state aspect in terms of how anxious one feels at the moment. Therefore, the current study set out to investigate whether there is a state component in math anxiety, which differs depending on the math-anxiety-provoking situation, for instance, solving simple vs. complex arithmetic problems. The results showed that increased arithmetic complexity was associated with an increase in state anxiety as well as with a decrease in performance. Interestingly, this increase in state anxiety depended on general trait anxiety and not on trait math anxiety in particular, although trait math anxiety predicted state anxiety during the arithmetic task also after controlling for general trait anxiety. This indicates that state anxiety in the math context depends on the difficulty of the arithmetic problem and suggests that it is important to consider the context when assessing the relationship of math anxiety and math performance.

A17 - Embodied Enumeration among the Deaf

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The representations of fingers are embodied in our cognition and influence performance in enumeration tasks. Among the deaf population, fingers are also a tool for communication in sign language, which conveys embodied representations as well. Previous studies in normal hearing (NH) participants have shown behavioral embodied effects such as faster counting of finger counting schemes and an embodied automatic end effect (AEE) using a passive tactile enumeration task. In this study, we examined to what extent the shared use of fingers for counting and sign language manifests in embodied mental representation. In order to do so, we used three enumeration tasks in two ranges (1-5 stimuli, 1-10 stimuli): passive tactile enumeration, dot counting, and comparative dot counting. Preliminary results showed faster counting in the deaf group and stronger AEE compared to the control group in the tactile domain. The exclusiveness of the results in the tactile domain emphasizes the influence of embodied representation in the deaf group, an effect that has not been studied adequately. In addition, the current study provides further evidence for a sensual tactile advantage among the deaf group - a topic that is still controversial.

A19 - Assessing Basic Number Competence Without Language Instruction: Pilot Studies

Max Greisen, Caroline Hornung, Romain Martin & Christine Schiltz
University of Luxembourg

While numerical skills are fundamental in modern societies, some estimated 5-7% of children suffer from a mathematical learning disorder, called developmental dyscalculia (DD). Nevertheless, universally valid diagnostic instruments are still lacking, as all current DD test batteries are based on language instructions. Consequently, their measurements are tightly linked to the specific language context of test administration and thus their results cannot easily be compared across countries. Here we are showing results of the first two pilot studies of a research project that aims to develop a test for basic math abilities that does not rely on language instruction and minimizes language use. To this aim, video and animation based instructions were implemented on touchscreen devices. A first version of the tasks has been tested with two samples of first grade children in Luxembourg's fundamental schools, of which half completed the same tasks with traditional verbal instructions. Our results indicate that performance in the experimental groups was similar or better than the control groups using verbal instructions. Relationships between linguistic background and the sample's performance on one hand and qualitative usability aspects of nonverbal task instruction and tablet-pc use with young children will be discussed.

A21 - Language x Working Memory = Numeracy Development? Investigating Numerical Knowledge among Emergent Bilingual Kindergartners

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Acquiring or developing numerical knowledge requires not only domain specific (i.e., numeracy) skills, but also domain general (e.g., working memory) skills (e.g., Geary & Hoard, 2005). Additionally, skills from other domains, particularly language, can affect math learning and numerical cognition development directly through transparency of number word structure (e.g., Dowker & Roberts, 2015) or indirectly through executive function skills (e.g., Bialystok, 2011, Nicolay & Poncelet, 2015). The present study aims to connect language, working memory, and early numerical skills among emergent bilinguals. We collected data from over 100 kindergartners enrolled in English instruction (N = 87) or Mandarin instruction classes (N = 34) in Southern California. Preliminary analysis indicates that the level of bilingualism is highly variable; however, those individual differences do not seem to have any effect on their numerical cognition. Among native English speakers, though, being enrolled in Mandarin instruction classes is associated with better number line estimation and magnitude comparison skills after accounting for maternal education. Interestingly, we find that the verbal working memory skills seem to correlate very little with children's number line estimation or magnitude comparison skills. In contrast, visuo-spatial working memory skills appear to positively predict these skills after controlling for language instruction and maternal education; this trend approaches significance. Additional regression and SEM analyses are forthcoming.

A23 - Improving Mathematical Abilities by Training Numerical Cognition in Children

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Our intuitive sense of number, the Approximate Number System (ANS), is the basis for a non-linguistic ability to estimate and compare quantities and approximate basic arithmetic operations. We share such system with non-linguistic animals and preverbal infants. Several lines of research suggest that ANS performance relates with formal mathematical performance. However, the existence of a number sense is not sufficient to explain our ability to understand and compute exact operations with numbers and follow exact calculation algorithms. These and other more advanced mathematical abilities require a symbolic and accurate mathematical language. Arabic digits are a precise representation of quantities. Understanding the exact cardinality that digits refer to is crucial for the improvement of arithmetic skills. Here, we independently train the ANS and the Digit-Quantity Relation (DQR), in a three-week computer-trained regime. We find that training the ANS has positive effects on math abilities in low-performing children when an exact answer is not required. Furthermore, strengthening the DQR results in a generalized improvement of 7-year-olds' math competence. Such improvement adds to those that a regime based on training ANS can provide. We propose that training the DQR helps children to become more proficient in exact mathematics. We submit that the educational systems overestimate 7-8-year-olds' comprehension of this basic aspect of mathematical language. An appropriate training of this relation may complement standard school teaching, potentially generating long-lasting benefits in children's mathematical abilities and self-confidence.

A25 - Spatial Skills First: The Importance of Mental Rotation for Arithmetic Skill Acquisition

Carrie Georges, Véronique Cornu & Christine Schiltz
University of Luxembourg

Considering the importance of arithmetic in school curricula, it is crucial to understand the cognitive processes underlying its successful acquisition. Spatial skills seem to play an important role in arithmetic skill development. Nonetheless, only a few intervention studies could observe gains in arithmetic following spatial training, suggesting a causal link. These inconsistencies might be explained by developmental stage (Mix et al., 2016) and/or the componential nature of arithmetic, with developmental shifts from procedural calculation to verbally-mediated fact retrieval mainly occurring for simple additions, subtractions, and multiplications, as opposed to divisions (Campbell & Xue, 2001). To better understand the importance of spatial skills for arithmetic, we assessed the predictive effect of spatial skills, namely mental rotation and visuo-spatial memory, on different arithmetic components (addition, subtraction, multiplication, division, completion and comparison) in 3rd-4th graders. At this stage, additions and subtractions are already well mastered, while multiplications and divisions are newly acquired. Although spatial skills positively correlated with arithmetic regardless of operation (all $ps<.05$), mental rotation (but not visuo-spatial memory) only significantly predicted multiplication ($\beta=.28$, $p=.01$), division ($\beta=.29$, $p=.01$) and completion performances ($\beta=.24$, $p=.05$) when controlling for age and basic numerical abilities in a stepwise multiple linear regression analyses. This highlights the differential effects of spatial skills on arithmetic, with a particular importance of mental rotation for newly acquired arithmetic material. These findings extend previous research on the relation between spatial skills and arithmetic and yield practical information for mathematical education and instruction.

A27 - Influences of Fast Mapping on Counting Skills in Kindergartners

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The development of early counting concepts has been aim of empirical research for several years. Besides domain-specific numerical factors the contributions of both general and specific language factors like vocabulary, phonemic awareness, mathematical language or grammatical skills showed significant effects on early numerical development (Purpura & Reid, 2017; Sarnecka et al., 2015). In this pilot study we aim to investigate the influence of fast mapping in 3-year-old kindergartners. We assessed conceptual counting (Give-N and How-many following Wynn, 1992), subitizing and fast mapping skills (following Gray & Brinkley, 2011) of 104 kindergartners (*M*age=42,60 months, range 34,8-54,0; 55 girls). In total four hierarchal regression models were created, two for the Give-N and How-many task as dependent variable each. The models used in given order (a) subitizing, fast mapping, phonological working memory, age and bilingualism and (b) fast mapping, subitizing, phonological working memory, age and bilingualism as independent variables. The results differ between the Give-N and the How-many task. Regarding the How-many task subitizing and fast mapping appeared as most important factors, while phonological working memory showed less influence and age and bilingualism were not significant factors. Regarding the Give-N task subitizing, phonological working memory and age were the most important factors, while fast mapping and bilingualism were no significant factors. These results suggest that the Give-N and How-many task involve different skills. Fast mapping seems to be important for the latter, while the first-mentioned task requires other skills. Further research in this project will focus visual-spatial working memory and central executive influences.

10.2 Poster Session B

B2 - The Parity Congruency Effect Depends on the Target: Evidence for Automatic Place-Value Processing

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The parity of any integer is indicated by its unit digit. However, in parity judgment for two-digit numbers, responses are facilitated if the parity status of the decade and the unit number are equal (parity congruency effect; e.g., 62: both decade and unit are even). This effect already supports the idea of the automatic processing of single components in multi-digit numbers. Previous studies provided evidence for automatic place-value processing regarding the magnitude representation. In this study, we examined if automatic place-value processing extends to parity representation: Participants assessed the parity of either the unit (unit-parity condition, for 54 the response is even, because 4 is even) or the decade digit (decade-parity condition, for 54 the response is odd, because 5 is odd). A group of 48 students was tested in a within-subject design. The parity congruency effect was stronger in the decade-parity condition. Differences between parity congruent (e.g., 68) and incongruent (e.g., 67) trials were larger if the task was to assess the parity of decade digit than the unit digit. Interestingly, the interaction of parity congruency and condition was significant only for right hand responses, but not for left hand responses. These outcomes suggest that place value is automatically processed in parity decision, even if it is irrelevant for the task at hand, because the unit parity is the same as the parity of the place-value integrated numbers. Importantly, this place-value integration occurs automatically, because the identity of the two-digit number was task-irrelevant throughout the experiment.

B4 - Is Order Judgment Driven by Associations Between Digits?

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Over the past few years there has been a growing interest in the relation between digit order processing and mathematical ability. Several studies have shown that the performance on a digit order judgment task (measuring the ability to indicate whether a sequence of digits is presented in an order or not) is strongly related to individual differences in calculation. However, it is unclear how the processing of ordered sequences occurs. One explanation is a serial scanning mechanism, suggesting that participants scan the number list, either spatially or verbally, and decide on the basis of congruency with this list that the triplet is in the correct order. We (Vos et al., 2017) recently proposed an alternative explanation that assumes that ordered sequences are in part processed through lexical associations between the items. To further verify this claim, we examined whether the lexical association strength between number words (e.g., what is the first word that comes into your mind when you hear “2”) could predict order processing ability. Preliminary regression results showed that overall RTs of digit order judgments can be predicted by association strength between numbers. In further analyses we will examine whether association strength is a better predictor than numerical distance in some (or all types) of triplets (ascending, descending, non-ordered) that are typically presented during a digit order judgment task.

B6 - Eye Position Reflects the Spatial Coding of Numbers and Arithmetic Operations

Samuel Salvaggio, Nicolas Masson & Michael Andres
Université Catholique de Louvain, Belgium

Behavioural studies have suggested that number manipulation involves shifting attention along a left-to-right oriented continuum. However, most of these studies do not inform us about the time course of attention shifts during number processing. In this study, we used an eye-tracker with high spatio-temporal resolution to study horizontal gaze patterns in two experiments that combined the free exploration of visual scenes with a verbal numerical task. The first experiment required participants to compare numbers (from 20 to 70) to a reference (45). Results showed that eye position deviated relatively to the magnitude of numbers: a rightward shift was observed when the number was larger than the reference compared to smaller, starting after hearing the number decade and lasting until response production. The second experiment investigated the mental solving of addition (43+4) and subtraction problems (53-6). A first difference in eye position was observed just after hearing the operator: the plus sign shifted the eye rightward compared to the minus sign. A second difference was observed later between problem offset and response onset: addition shifted the eye rightward compared to subtraction, but only in problems requiring carrying or borrowing procedures. These findings provide unique evidence about the time course of attention shifts during number comparison and support a two-stage model of mental arithmetic where the operator first triggers the setting of a spatial frame to help situating the response relative to the first operand, and the calculation then proceeds with a re-calibration of the frame reflecting the computational constraints.

B8 - Inversion Effects on Mental Arithmetic in English-Speaking Participants

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Detrimental effects on basic numerical tasks (e.g., magnitude comparison), but also on mental arithmetic (e.g., addition), have been observed for languages with an inverted number word system. In German, for example, the order of tens and units of two-digit numbers larger than twelve is consistently inverted [e.g., 23 = "dreiundzwanzig" (literally: "three-and-twenty")], whereas in English only teen numbers from 13 to 19 are inverted [e.g., 16 = "sixteen" (meaning six-and-ten)]. While previous studies focused on between group comparisons of inverted and non-inverted languages, in the current study we investigated whether number word inversion at item level affects arithmetic performance within an otherwise non-inverted language (i.e., English). We used a symbolic addition verification task, including carry and no-carry problems, with sums ranging between 13 and 29. In particular, we focused on the influence of inverted (I; teen numbers ≥ 13) and non-inverted summands (N). Based on this differentiation, three categories of addition problems were created: N+N (e.g., 6+21), N+I (e.g., 12+15), and I+I (e.g., 13+14) with problem size matched across categories. Overall, we found a significant carry effect: responses for no-carry problems were faster than for carry problems. Most importantly, we observed that RTs for the three categories of no-carry problems differed significantly with increasing RT the more summands within a problem were inverted (i.e., I+I > N+I > N+N). This clearly indicates that inverted number word formation influenced place-value processing of Arabic digits even in an otherwise non-inverted language.

B10 - Strategies in Negative Fraction Comparison

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Aspects of processing fractions and negative numbers were considered separately so far. However, the question remains open whether theoretical mechanisms postulated in multi-digit number processing models for negative integers and fractions (e.g., sign flip, whole number bias) also apply for the processing of negative fractions. A fraction magnitude comparison task was used to investigate fraction processing with differing polarities (i.e., positive (+ +) vs. negative (- -) vs. mixed polarity (+ - / - +)) and containing one common component (numerator vs. denominator). Similar to positive fraction comparison, fraction pairs with common denominators were processed faster than fraction pairs with common numerators indicating added response costs of the denominator flip. Moreover, heterogeneous pairs (+-) were solved faster and more accurately than homogeneous pairs (++ and --) replicating the previously observed sign-shortcut strategy for integer numbers. Additionally, positive homogeneous fraction pairs were responded to faster than negative homogeneous pairs indicating added response costs of the sign flip. Finally, processing costs were largest for negative homogeneous fraction pairs with common numerators indicating that both the denominator flip and the sign flip uniquely contribute to the complexity of negative fraction comparison. Thus, results suggest that the denominator and sign flip mechanism postulated for positive fractions and negative integer numbers, respectively, generalize to negative fractions. The findings seem inconsistent with the whole number bias account. Instead, strategies in negative fraction comparison refer to the components of a fraction (i.e., nominator and denominator) and their regular or inverse relation to (negative) fraction magnitude.

B14 - Mathematical Anxiety and Altered Brain Structures in Children With and Without Developmental Dyscalculia

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Adequate mathematical competences are nowadays indispensable in professional and social life. However, mathematics is often associated with stress and frustration and the confrontation with tasks that require mathematical knowledge triggers anxiety in many children. We asked if there is a relationship between math anxiety and changes in brain structures in children with and without developmental dyscalculia (DD). Behavioral and magnetic resonance imaging (MRI) examination of 43 children (23 with DD, 20 without DD) revealed that children with DD suffer more often from math anxiety. In general, boys and girls were equally affected, and math anxiety was independent from age or general cognitive abilities like IQ. Interestingly, math anxiety affected specifically arithmetical performance negatively, probably because arithmetic and math anxiety are both thought to be a learned mathematical feature. Most importantly, our results showed that math anxiety is also related to altered brain structure. In particular, the right amygdala volume was reduced in children with stronger math anxiety. In conclusion, math anxiety does not only hinder children in arithmetic, but it goes along with changes in brain structure of fear processing. Hence, math anxiety is a serious factor to be considered especially in children with DD.

B16 - Endorsing Math-Gender Stereotype Relates to Math Anxiety and Math Self-Concept in Females But Not in Males

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Math anxiety and math self-concept are known to influence math performance. Math anxiety refers to negative feelings towards math, whereas math self-concept refers to self-evaluation as being skilled in math. Studies consistently show that even though there are no gender differences in actual math performance, females are characterized by higher anxiety and lower math self-concept than males. One reason for that might be a prevalent math-gender stereotype (i.e., “females are bad in math”). In the presented large-scale online study ($N = 1051$, 734 females), we aimed at investigating the relationship of math-gender stereotype endorsement with math anxiety and math self-concept. Math performance measures (speeded arithmetic and school grade) as well as perceived daily math usage were also considered. In general, math-gender stereotype endorsement correlated very weakly with math anxiety (positively) and math self-concept (negatively). It did not correlate with any other variable. When females and males were analyzed separately, math-gender stereotype endorsement correlated with math anxiety and math self-concept only in females. Furthermore, in females math-gender stereotype endorsement correlated very weakly with school math grades (stronger endorsement corresponded to worse grades) and perceived math usage (stronger endorsement corresponded to smaller perceived math usage). These results suggest that math-gender stereotype endorsement relates to higher math anxiety and lower math self-concept in females. On the other hand, the lack of correlation in males shows that endorsing stereotype (while being in the advantaged group) does not relate to reduced owns math anxiety. The possible underlying reasons for this correlation patterns will be discussed.

B18 - Mathematical Development in Neurodevelopmental Disorders

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Number abilities are impaired in both individuals with Williams syndrome (WS) and Down syndrome (DS). Recent research in typically developing (TD) children has shown that mathematical difficulties can be caused by a number of factors, including impaired domain specific abilities such as ANS abilities, number line, counting and digit knowledge and domain general difficulties such as visuo-spatial deficits. To date, the development and interdependent relationships between these different factors have not been assessed in DS and WS. Cross-syndrome comparisons of neurodevelopmental disorders that have similar overall intellectual abilities but different cognitive profiles, allow further insight into what abilities are not only related, but also which ones are necessary for the development of mathematical abilities. The current study examined the relationship between ANS, number line abilities, visuo-spatial abilities, counting, and general mathematical performance in 30 participants with WS and 30 with DS aged 8 to 40 years. Performance was compared against 3 groups of TD children (each group N=15): aged 4-5, 7-8, and 10-11. Participants were administered an ANS task in which they had to indicate which of two sets contained the larger quantity. In the number line task, participants had to indicate the position of numbers 1-9 on a 0-10 scale and the numbers 3, 4, 6, 8, 12, 14, 17 on a 0-20 scale. Numerical Operations from Wechsler Individual Achievement Test were used to measure formal mathematical abilities. Finally, participants completed the Pattern Construction task (BAS-II), a digit recognition task, and counting task. Preliminary analysis yields different developmental trajectories for individuals with WS and DS.

B20 - No Difference in the Neural Representation of Number and Letter Symbols in Children: An fNIRS Study

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The relation between the neural representations of number and letter symbols has not been fully explored yet, especially in children. It is under debate whether and in which tasks the processing of numbers and letters might rely on distinct neural substrates, or on a mostly shared brain network. In the present study, a total of 47 children from fifth and sixth grades participated in two separate experiments. While they copied number and letter strings, brain activation changes were recorded by means of functional near-infrared spectroscopy (fNIRS). FNIRS data of both experiments revealed that a shared fronto-temporo-parietal network was activated in response to both copying numbers and letters in these ages. No difference was observed in the brain activation patterns between these processes in each experiment or in the more strongly-powered joint analyses. Moreover, these null differences were corroborated by Bayesian analyses. Our findings indicate that at these ages in development, copying numbers and copying letters rely on mostly similar brain networks. In an ecologically valid setting, namely dealing with numbers and letters via written production in the academic setting, the underlying neural processes might not differ. This is an important foundation for studies using number or letter copying as control tasks in children. However, number and letter activations could still differ in more semantic tasks. The similarity of the findings in two different samples of children additionally highlights the reliability of fNIRS as a neuroimaging method in children.

B22 - Impact of Phonology and Rule Knowledge beyond Domains

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During literacy acquisition children learn orthography based on phonological principles (e.g., short vowels are followed by a double consonant) as well as word-related rules (e.g., nouns refer to persons or objects). Interestingly, basic numerical operations also draw on either phonological/verbal (e.g., single-digit multiplication) or rule knowledge (e.g., carry effect). However, it has not yet been clarified if or to what extent specific knowledge of one domain predicts competencies in the other domain. Overall, N = 989 (463 female) German-speaking fifth-, sixth- and seventh grade children completed a computerised assessment of spelling and basic arithmetic competencies. Spelling was assessed separately for different spelling rules (i.e., capitalisation, gemination, lengthening, rule words) while arithmetic was differentiated by operation (i.e., addition, subtraction, multiplication, division). Rasch analysis was conducted using the statistical environment R (R Core Team, 2016) to assess individual person abilities and detect differential item functioning (DIF) in subgroups of the sample (i.e., sex, grade). Second, nested (hierarchical) random effects models were specified to analyse the association of spelling abilities with basic arithmetic. In both spelling and arithmetic tasks DIF was identified for only a few items. After excluding these items, random-effects analysis indicated that person ability for correct spelling of rule-words and doubling consonants was a significant predictor for subtraction and multiplication, but not for addition and division. In sum, findings suggest an association of phonology and rule knowledge in linguistic and arithmetic, at least for tasks sharing similar cognitive processes as germination and multiplication as well as orthographic rule knowledge and subtraction.

B24 - When 'One' and 'A' Are the Same: How Do German-Speaking Children Interpret the Indefinite Determiner and Numeral ‘Eine’?

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Children treat quantifiers and cardinal numbers differently with respect to pragmatic principles. In particular, English-speaking children draw a distinction between the indefinite determiner *a* and the numeral *one*. While children do not accept two strawberries as a correct response to the question “Is there one strawberry in the red circle?”, they do if the question includes *a* instead of *one* strawberry, thus assigning an upper bounded interpretation to *one* but not to *a* (Barner et al., 2009). Unlike English, however, many languages do not draw a distinction between the indefinite determiner *a* and the numeral *one* (e.g., Sarnecka et al., 2007). In German, for instance, *eine* serves both functions. To find out how German-speaking children and adults interpret the ambiguous term *eine*, we tested them in a truth-value-judgment task (TVJT, based on Barner et al., 2009). While German-speaking adults predominantly showed an exact interpretation of *eine*, the majority of children considered two strawberries a proper response (= vague interpretation). Thus, unlike English-speaking children who benefit from a distinction between *one* and *a*, German-speaking children seem to interpret *eine* as the determiner *a* and not yet in an upper bounded way (i.e., exactly one). However, when introducing a numerical context to the same TVJT, German-speaking children were more prone to assign an upper bounded interpretation to *eine*, suggesting that they can also switch to a more numerical interpretation depending on context. In sum, our findings shed light on the acquisition of linguistic determiners, numbers, and possible links between the two.

B26 - The Relevance of Verbal and Visuo-spatial Abilities for Verbal Number Skills – What Matters in 5 to 6 Year Olds?

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The acquisition of verbal number skills, as defined by the meaningful use of number words, marks a milestone in numerical development. In the present study, we were particularly interested in the question, whether verbal number skills are primarily verbal in nature, or if they call upon visuo-spatial processes, reflecting a spatial grounding of verbal number skills. 141 five- to six-year old children were tested on a range of verbal (i.e., vocabulary, phonological awareness and verbal working memory) and visuo-spatial abilities (i.e., spatial perception, visuo-motor integration and visuo-spatial working memory). We were particularly interested in the predictive role of these abilities for children's verbal number skills (as measured by different counting and number naming tasks). In a latent regression model, basic visuo-spatial abilities, measured by spatial perception and visuo-motor integration, emerge as the most important predictor of verbal number skills. This gives raise to the assumption, that verbal number skills are, despite their verbal nature, spatially grounded in young children.

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12 Notes