Minds, Mechanisms and Interaction in the Evolution of Language
Poster Abstracts

Poster 1
Convexity and expressivity in the simplicity–informativeness tradeoff
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Language is shaped by competing pressures from learning and communication: The pressure from learning favours simplicity, while the pressure from communication favours informativeness. This leads to the simplicity–informativeness tradeoff, which has been demonstrated in typological (e.g., Kemp & Regier, 2012) and empirical (e.g., Kirby, Tamariz, Cornish, & Smith, 2015) studies. However, a recent experiment by Carstensen, Xu, Smith, and Regier (2015) has suggested that iterated learning alone can give rise to informative languages.

One explanation for this result lies in how the pressures for simplicity and informativeness affect two key properties of semantic categorization systems: expressivity (the number of categories a space is partitioned into) and convexity (approximately, how effectively the space is organized; Gärdenfors, 2000). In the case of expressivity, the two pressures work against each other: Learning prefers few categories; communication prefers many. While in the case of convexity, the two pressures are aligned: Learning and communication both prefer convexity. This leads to a situation in which expressivity is subject to the tradeoff, while convexity is not and can only increase.

We first demonstrate this in a Bayesian model of the tradeoff. The language user has a prior bias for simplicity, but once the language user derives sufficient experience from communicative interaction, the prior bias may be overpowered by a preference for informative languages. We support this with an iterated category learning experiment, in which chains converge on inexpressive but convex systems.

A measure of informativeness that is sensitive to convexity may reveal that languages become increasingly informative over time, but it cannot reveal the causal mechanism if an explanation from simplicity is also possible. We suggest that future experiments should be careful to control for these two semantic properties in ascertaining the mechanisms involved in the cultural evolution of language.

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Poster 2

Unifying horizontal and vertical interactions in the Bayesian Language Game

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Background

Agent-based models of language emergence have primarily explored two modes of interaction: horizontal interactions within generations in the Naming Game (NG; Steels, 1995) and vertical interactions between generations in Iterated Learning (IL; Smith et al., 2003). Although combinations of these modes of interaction have been studied (e.g. Kirby et al., 2015; Whalen & Griffiths, 2017) little work has been directed at unifying the two paradigms. We present our first results in precisely that direction.

Main contribution

Our contribution is twofold. First, we extend the model in De Vylder & Tuyls (2006) to a *Bayesian Naming Game* (BNG), using Bayesian updating as a lateral inhibition strategy. The innate learning biases of the agents are modeled explicitly with a prior (Griffiths & Kalish, 2007). Second, we change the population model of the BNG by introducing (1) a life expectancy parameter and (2) a random walk as transmission model. The resulting *Bayesian Language Game* (BLG) interpolates between the BNG and a Bayesian IL model by changing the life expectancy. The BLG moreover incorporates MAP and sampling strategies (cf. response function in De Vylder & Tuyls, 2006) and therefore gives a unified view of a continuum of mechanisms for cultural language evolution.

Findings

We find a that the BNG converges to a stable language that reflects innate biases, while deviating slightly from it (see figure 1). Different lineages thus develop different languages, but still reflect the same biases. This behaviour is not exhibited by NG's and Bayesian IL models and suggests that plausible models of language emergence lie in between those extremes. The BLG further characterises the possible outcomes of a process of cultural evolution in an abstract fashion, but we also consider its relevance for deriving concrete predictions in the domain of music and number systems.
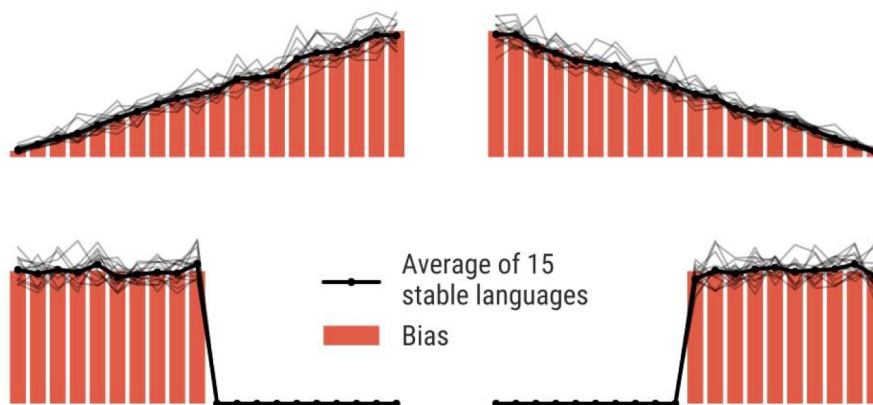
Figure 1: In the BNG, different lineages result in different languages (thin lines), but on average (thick line) they reflect the agents' biases (orange).

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Poster 3
The emergence of verse templates through iterated learning
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Every language produces some type of verse in the form of songs, poems or nursery rhymes. Verse sets words to abstract templates, absent in everyday speech, such as melodies or poetic metres. Templates typically consist of hierarchically organised sections: e.g. songs are made up of stanzas, divided into lines, containing bars, etc. We hypothesise that this kind of patterns may emerge in the process of cultural transmission; unstructured sound sequences impose a challenge to short-term memory, but chunking the input makes it easier to parse and reproduce the sequences accurately.

In order to test this hypothesis, we have run an iterated learning experiment where random sequences of syllables are evolved across four transmission chains with ten generations of subjects each (all native Dutch speakers), following the sequence-wise imitation procedure used in Cornish et al. (2013). The initial random sequences are generated by concatenating twelve tokens of the set {ban, bi, ta, tin}, as a way to materialise the abstract verse templates without using content-words. More precisely, the experiment aims to model the sequences of nonsense syllables used in many traditions to communicate the rhythmic patterns underlying songs (e.g. bols in Hindustani music (Clayton 2000), lalay patterns in Berber verse (Dell & Elmedlaoui 2008)). Participants listened to the sequences of syllables using headphones, and tried to reproduce them using four computer keys. When transmitting a participant's response to the following participant, we normalised the relative timing between syllables to create completely isochronous sequences. Hence, we focus on emerging combinations of syllables and syllabic features rather than the timing patterns produced by the participants (cf. Ravignani et al. 2016).

Sequences become shorter, easier to recall and more structured in the transmission process. Some regularities can be related to a global tendency to chunk the input and increase the popularity of a handful of ngrams. Besides, sequences increasingly tend to be opened by a heavy syllable (e.g. ban) and closed by a light syllable (e.g. ta), which can derive from a Dutch-specific bias.

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Poster 4

Underdetermination, recipient design and interaction

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In this poster I use features of communicative interaction to challenge two arguments for mind-reading being a pre-requisite for communication (Clark 1996; Levinson 2006; Wilson & Sperber 2012; Scott-Phillips 2014).

First, pragmatists often conflate two versions of the code model of communication. In the 'narrow' code model of communication the 'literal' and context-insensitive contents of an utterance strongly underdetermines speaker's intended meaning. This motivates accounts of ostensive communication in which mind-reading is essential. However, a broader concept of the code model is needed to account for non-ostensive animal communication, in which codes can be complex, non-deterministic, and be used in a context-sensitive manner.

The problem is that the broader code model only suffers from a weak underdetermination problem, where the signal plus context provides some non-deterministic evidence for speakers meaning. Weak underdetermination problems such as this are routine in cognition (e.g. visual input weakly underdetermines visual representations). In the context of communication, mind-reading is simply not required to resolve a non-existent strong underdetermination problem.

Second, mind-reading is claimed to be necessary for recipient design: tailoring an utterance for a particular audience requires reasoning about their mental states. However, this argument assumes that speakers have only one chance to successfully communicate their meaning. Instead, all that matters is that a recipient understands a speaker's meaning over the course of an extended conversation.

Distinguish then between deliberate recipient design, which may demand mind-reading, from interactive 'recipient refined' communication, where recipients use repair mechanisms (Dingemanse et al. 2015) to demand signals to understand speakers meaning. In this case, interaction and repair replaces mind-reading. In this way interactive repair mechanisms can also help resolve the weak underdetermination problem of the broad code model.

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Poster 5
Gesture, sign and beyond - Negation across three generations of signers
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Across signed languages, negation is typically expressed by combining a negative handwave and a negative headshake. Speakers may use both gestures in spontaneous interaction (Wilcox 2009). Sign languages vary as to which marker functions as the obligatory negator and as of the timing and the scope of the headshake (Zeshan 2004, 2006). The present study investigates negation in Kata Kolok (KK), a signing variety that newly emerged in a Balinese village due to exceptionally high incidences of congenital deafness and is shared by the deaf and many hearing villagers alike (de Vos 2012; Winata et al. 1995). Adopting a corpus-based approach, I analyzed naturalistic data from six deaf native KK signers from generations III through V (KK Corpus; de Vos 2016). Findings show that KK negation features three markers: a manual handwave, a negative headshake, and tongue protrusion. The handwave and the headshake have probably entered the grammar of KK from a gestural root as both occur in the gesture repertoire of hearing villagers (Marsaja 2008). Yet, KK negation does not entirely fit the established typological dichotomy since it remains unclear which marker is obligatory. Moreover, signers from different generations show disparate tendencies: the use of the handwave develops slightly over time, and headshake spreading, i.e. co-articulating the headshake with multiple signs rather than just the manual negator, increases significantly in signers from the youngest generation (Figure 1).
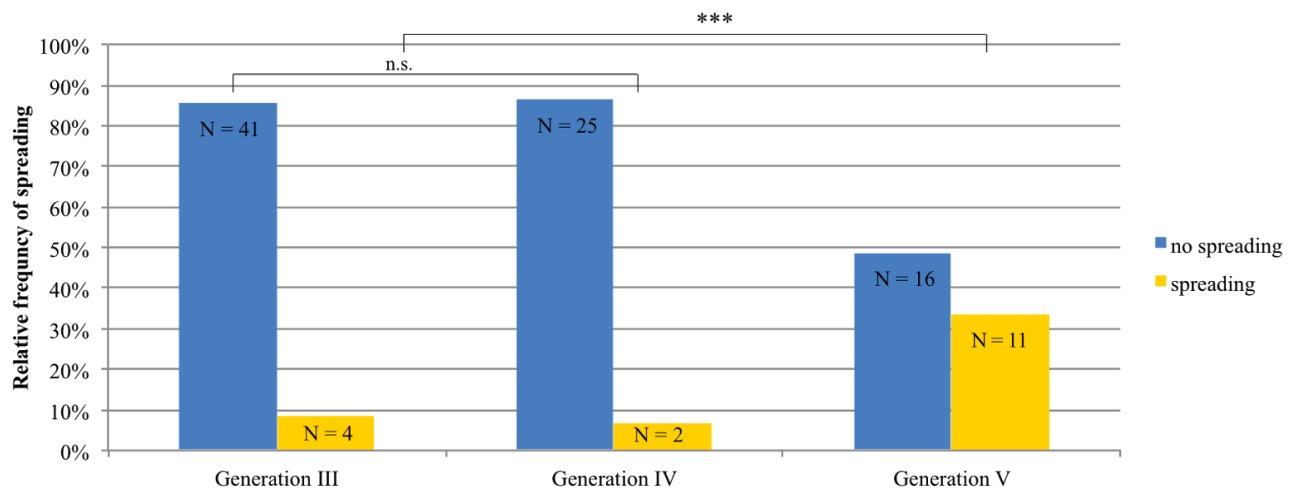

Figure 1. Emergence of headshake spreading in generation V.

The headshake spreading in KK does not co-occur alongside a decrease in using the manual negator. Thus, the KK pattern seems to represent a typologically unusual pattern or an intermediate stage in the established dichotomy. This study suggests that KK negation is a case in point for language evolution throughout three generations of signers. Even with a relatively short time-frame, emergent signed languages like KK may evolve to have unique and previously unattested linguistic features.

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Poster 6

The Cognitive Architecture of Recursion: Behavioral and fMRI Evidence from the Visual, Musical and Motor Domains

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The ability to perform recursive hierarchical embedding is thought to be an essential pre-requisite for the evolution of language. This ability is present in linguistic syntax but it has also been argued to underlie human multiply-nested mind-reading abilities, essential for communication and coordination in general.

To investigate the cognitive underpinnings of this capacity, and to draw a broader picture regarding its cognitive architecture and evolutionary history, we devised a research program aiming to investigate the representation of recursive hierarchical embedding in a variety of non-linguistic domains. This broad comparative work is essential to inform theories on the specificity of recursion to language, and how it can be instantiated in human cognition and the human brain.

After conducting a series of behavioral and fMRI experiments in the visual, musical and motor domains, we found that, behaviorally, the acquisition of recursive rules seems supported by cognitive resources that are general across domains (Martins et al., 2015; Martins, Gingras, et al., 2017). However, when we explicitly instruct participants on recursive rules, train them for 2 hours and then test them in the fMRI (Martins, 2014; Martins, Bianco, et al., 2017; Martins, in prep.), we find that their representation of recursion seems supported by activating schemas stored in (visual, musical and motor) domain-specific repositories. However, in all these domains, recursive representation of hierarchies seemed to be associated with increased top-down processing in comparison with simple iteration (Fischmeister et al., 2016; Martins, Bianco, et al., 2017; Martins, in prep.).

Together, these findings suggest that 1) the resources necessary to acquire recursive rules are different from those necessary to utilize these rules after extensive training, and 2) despite differences in implementation across domains, recursive cognition provides specific processing advantages to represent hierarchies in comparison with other strategies.

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Poster 7

The emergence of conventions for coordinating on timing: No evidence is better than negative evidence

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When participants use dialogue in joint activities, they rapidly converge on idiosyncratic referring conventions. Convergence is inherently interactive, relying on participants providing each other with both positive and negative evidence of understanding (Clark, 1996; Healey, 2007; Pickering and Garrod, 2009).

In addition to securing reference, participants in joint activities need to coordinate on the timing and sequencing of their contributions. Dialogue is replete with procedural expressions that establish who performs which action, when it should be performed, and how initiation and completion of the action should be signaled, e.g. "*when I've done x, do y*", "*wait a moment before doing y*", "*let's start again, but this time you do y*", "*do x and then tell me when you're done*". Recent work has demonstrated that, similarly to referring expressions, participants rapidly establish idiosyncratic procedural expressions, which then become conventionalized in new adjacency pairs (Mills, 2011; Mills, 2014, Fusaroli et al, 2014).

To investigate how procedural coordination develops, we report a computer-mediated "alien language" task which presents dyads with the recurrent coordination problem of performing their contributions in a single sequence. All turns are intercepted automatically by the server, which detects and selectively blocks participants' displays of positive and negative evidence of understanding. Dyads were assigned to one of 4 conditions: (1)Positive evidence blocked; (2)Negative evidence blocked; (3)Positive evidence and Negative evidence blocked; (4) No blocking.

Dyads whose signals of positive evidence were blocked completed fewer trials, made more errors and exhibited more effortful interaction, confirming the basic predictions of the grounding model (Clark, 1996). Surprisingly, participants who had both positive and negative signals blocked performed at the same level as non-blocked participants. We argue this is due to the doubly-blocked participants being forced to develop new, and consequently more robust, routines for establishing and sustaining procedural coordination.

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Poster 8
Misalignment increases abstraction of referring expressions
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A central finding in dialogue research is that interlocutors rapidly converge on referring expressions which become progressively contracted and abstract. For example, in the maze task (Pickering and Garrod, 2004) participants initially use descriptions that identify salient features of the maze, e.g. "the sticking out square", "the topmost box", "the middle square". Over the course of the experiment (~30 mins), the most coordinated pairs increasingly use abstract Cartesian descriptions, e.g. "2,4" or "A5". Crucially, the semantics of these abstract descriptions are interactively negotiated by the participants (Healey, 2004; Mills, 2014; Larsson, 2017). However there is currently no consensus on which interactive mechanisms underpin convergence: The interactive alignment model (Pickering and Garrod, 2004) favours alignment processes, the grounding model (Clark, 1996) prioritizes positive feedback, while Healey (2004) demonstrates the importance of miscommunication in identifying differences of interpretation.

To investigate convergence, we report a variant of the "maze-task" in which members dyads are given misaligned, incommensurable instructions: One participant is primed with instructions that conceptualize the maze as consisting of horizontal vectors (e.g. "4th row, 2nd square") while the other is primed with instructions that conceptualize the maze as consisting of vertical vectors (e.g. "3rd column, 2nd square"). 16 dyads were compared with an identical number of baseline dyads who were not primed with any spatial instructions. Compared with the baseline dyads, misaligned dyads produced more abstract, Cartesian descriptions.

We argue that this pattern is due to misalignment having a beneficial effect of inducing miscommunication and its resolution via repair (Schegloff, 2007): Misaligned dyads are forced to expend more effort in identifying and diagnosing differences between their conceptualizations, which when resolved, ultimately give rise to enhanced coordination.

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Poster 9

Biases in the improvisation of basic word order are not modality specific

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Languages vary in their basic word order (the order of Subject, Object and Verb). Strikingly, despite this variation, hearing participants who are asked to improvise ways of communicating motion events using only their hands consistently employ SOV order (Goldin-Meadow et al., 2008). In contrast, participants communicating about another class of events (e.g. creation events) use SVO order (Schouwstra & de Swart, 2014). These experiments appear to reveal fundamental cognitive biases in the way we organise information into sequences. Thus far they have been conducted only using gesture, leaving open the question whether the findings generalise to other modalities.

We use a vocal analog of the silent gesture paradigm to test whether biases in improvisation are modality specific. In experiment 1, participants describe pictures of extensional events (e.g. motion events) and intensional events (e.g. psychological events) using non-linguistic vocalisations. Similarly to the findings in silent gesture, we find SVO and SOV to be the dominant orders, and we observe a greater proportion of SOV for extensional events than for intensional events, confirming that this bias is not modality specific.

In experiment 2, we build on work by Marno et al. (2015) who show an increase in SVO order in silent gesture if participants are trained on individual items prior to complex meanings. We ask participants to produce vocalisations for individual items, before going on to complete scenes. Again, our results in the vocal modality reflect those in the manual modality by demonstrating an increase in SVO overall.

These findings provide the first evidence that gestural and vocal improvisation yield similar results for basic word order. Whatever the modality, by bypassing the word order of participants' native language, improvisation tasks provide access to the cognitive drivers of language emergence.

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Poster 10

Social and cognitive factors together shape the typology of kinship categories

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Kinship systems group family in different ways. For instance, they can group together siblings and cousins, make a distinction between siblings, parallel-cousins and cross-cousins, or further distinguish maternal and paternal parallel- and cross-cousins. They show cognitive economy: no kinship systems distinguishes maternal and paternal but not parallel- and cross-cousins.

In this regard, kinship is similar to other universal semantic categories such as colour terms (Kemp & Regier 2012). However, whereas colour terms broadly fit into one typological hierarchy, kinship systems comprise a diverse typology. Cultural traditions and social practices (particularly marriage and transfer of resources) place functional pressures on the shape of kinship systems. This helps explain the structured variation that they show (Jordan & Dunn 2010).

Using mixed-effects regression modelling -- controlling for the effect of lateral transmission and phylogeny -- and a global ethnographic database of over a thousand societies (Kirby et al. 2016) we show that marriage rules and ancestry have a significant influence on the type of kinship system found in a society. For instance, a language is more likely to distinguish cousins and siblings if cousin marriage is prevalent in the society.

As such, kinship demonstrates the link between the evolution of categorical linguistic systems and social and cultural mechanisms that belie them. It constitutes a further example of the effect of social use on category structure (Bybee & Hopper 2001).

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Poster 11

Compositional structure can emerge without generational transmission

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Experimental work in the field of language evolution has shown that novel signal systems become more structured over time. In a recent paper, Kirby et al. (2015) argued that compositionality, one of the hallmarks of natural language, arises as a trade-off between compressibility and expressivity pressures, operating at different and independent time scales: intra-generational communication and cross-generational transmission, respectively. Importantly, a compressibility pressure, which leads languages to become simpler and more systematic over time, has been argued to be imposed only when languages are transmitted across multiple generations, and stems from cognitive biases on memory and learning.

In the current study, we argue that compressibility pressures can also be imposed during communication within a single generation. We show that compositional languages can emerge in a closed community without generation turnover, when the communication includes two real-world aspects of language use that give rise to compressibility pressures: interacting with multiple partners and an expanding meaning space, which requires referring to more items over time.

We conducted an artificial language experiment in which we tested the emergence of linguistic structure in six closed micro-societies of four participants. Participants interacted in alternating dyads for several rounds, and needed to refer to an increasing number of novel meanings (four shapes moving in different directions). We measured the compositionality of the languages as the correlation between string distances and meaning distances. Our results show that languages became more structured over time, with participants converging on shared, stable, and compositional lexicons, where similar shapes and angles were systematically represented using similar strings. This study is the first to show that compositionality reliably emerges without generational turnover, indicating that new learners are not necessary for the formation of linguistic structure within a community. Our findings have implications for cross-cultural differences and for developing sign languages and Creoles.

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Mind the Generation Gap: Differences between Young and Old in Everyday Lexical Categories

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Individual differences in word use, originating from differences in interaction between individuals and their environment, can act as a driver for language evolution. We presented four sets of 40 pictures of common household containers, such as bottles, to samples of monolingual Dutch- (N≈400) and French-speaking (N≈300) Belgian adults. Participants made a binary acceptability judgment of one category label in their native language for each object in a given set. We evaluated whether there were systematic differences in judgments across speakers of each language as a function of age, education level, and gender. Additionally, we aimed to identify any differences within language groups in the features used in judging category membership.

Mixture Item Response Theory (IRT) analyses revealed the presence of latent groups of categorizers related to age in each language. Age, but not gender or education level, influenced the category membership judgments in latent groups of categorizers in a significant and systematic way. The group-specific dimensions underlying the acceptability judgments were regressed upon item features using Bayesian multiple linear regression (BMLR). These feature analyses showed that these subtle but consistent categorization differences between young and old participants were connected to a different weighting of traditional versus newer materials. Older adults relied more on classic materials such as glass or cardboard in their judgments, whereas younger adults emphasized relatively new materials such as plastics. Younger adults are for example more inclined to consider a plastic bottle as a good example of the bottle category than older adults.

The different weighting of classic versus relatively new materials by age suggests that there is a subtle change in meaning attached to labels for everyday household containers between generations. The systematic variability in categorization judgements and feature use reflects age related differences across participants in exposure and experience with objects made from plastic versus classic materials. Such variability contributes to larger scale language evolution over historic time and can co-exist with relatively stable representations within individuals and largely shared representations across individuals.

Poster 13
Information Transfer constrains the emergence of graphic codes
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Humans commit information to graphic symbols for three basic reasons: as a memory aid, as a tool for thinking, and as a means of communication. Yet, despite the benefits of transmitting information graphically, we still know very little about the biases and constraints acting on the emergence of stable, powerful and accurate graphic codes (such as writing). Using a referential communication task, where participants play as Messengers and Recipients, we experimentally manipulate both the mode (synchronous or asynchronous) and type of information transfer (solo or dyad) to generate four conditions: Recall (synchronous + solo), Mnemonic (asynchronous + solo), Dialogue (synchronous + dyad), and Correspondence (asynchronous + dyad). Only in the Dialogue condition, where Messengers and Recipients are two different persons interacting within the same timeframe, do we consistently observe the emergence of stable, powerful and accurate graphic codes. In the Mnemonic condition, where Messenger and Recipient are the same person at different points in time, participants produce accurate codes that are comparatively less stable and powerful than those in Dialogue. By contrast, in the Recall condition, where Messenger and Recipient are the same person at the same in time, and the Correspondence condition, where Messenger and Recipient are two different persons communicating across timeframes, stable and powerful codes fail to emerge. These results suggest that the paucity and late-arrival of stable, powerful, and accurate graphic codes in human history is due to strong constraints on information transfer.

Poster 14

A model of cultural co-evolution of language and mindreading

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Language relies on mindreading skills, as language users have to entertain and recognise communicative intentions (e.g. Moore, 2015; Scott-Phillips, 2014). Mindreading in turn profits from language, as language provides a means for expressing mental states explicitly (e.g. Bar-On, 2013), and for communicating one's understanding of minds to others (e.g. younger members of the population) (Heyes & Frith, 2014). Given this interdependence, it has been hypothesised that language and mindreading have co-evolved (e.g. Malle, 2002).

We present an agent-based model to formalise this hypothesis, in which referential signalling is combined with mental states. In this model, each agent has a perspective on the world which determines the salience of potential topics to them (given a particular context). A topic is then chosen probabilistically from the speaker's saliency distribution. Because all objects in the world are considered potential topics, learners have no other way of inferring the intended referent of an utterance than by gaining knowledge of the speaker's perspective or lexicon. However, neither of these are directly observable. Learners therefore have to simultaneously infer a speaker's perspective and lexicon (through Bayesian inference). Simulation results show that they can solve this task by bootstrapping one with the other, but only if the speaker uses a language that is at least somewhat informative.

We will present results of an iterated learning version of this model (where languages are passed on from generation to generation), and explore under which circumstances populations can build a fully informative language from scratch. We show that without any additional learning bias or selection pressure, populations do not establish any linguistic conventions. In contrast, under a selection pressure for communicative success, populations do evolve a fully informative language. Interestingly however, selection on perspective-taking alone also results in the emergence of partially-informative lexicons, which is sufficient for inferring others' perspectives.

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Poster 15

A place for ideophones within language evolution

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We illustrate in this poster our hypothesis on the relationship between a particular type of sound-symbolic words, ideophones (Hinton et al. 1994, Voeltz and Kilian-Hatz 2001), and the question of the origin and evolution of language (Imai and Kita 2014). We find ideophones in several languages that are used in daily life for example, Japanese (Hamano 1998, Kita 1997, Akita 2009), Korean (Diffloth 1972, Lee 1992, Lee 1993), African languages (Samarin 1965 et 1971, Childs 1994, Dingemanse 2011) and Turkish (Zülfikar 1995, Demircan 1996, Ido 1999 et 2011, Jendraschek 2001, Karahan 2008). The reason why we find thousands of ideophones in Turkish and in Japanese is linked to the evolution of language. A common feature of Turkish and Japanese is that their written forms are both attested lately. Japanese is attested since the 7th - 8th century A.D (Ciancaglini 2009:292), and we may find the oldest written traces of Turkish « the Orkhon inscriptions », in current Mongolia, in the same century. These two populations had nomadic and oral cultures up to a recent era (Diamond 1997). Their written literary culture is more recent than Indo-European languages which are attested since the second millennium BC. By the influence of the oral culture, they express their environment by ideophones, where we find an analogy between the phonological signifier and the semantic value of the reference (Kita 2008). On the contrary, it seems that civilizations with ancient written culture make larger use of constatives statements and we may easily notice the absence of motivated words like ideophones. In conclusion, we suggest that in language evolution it is possible to observe a correlation between the cultural opposition {oral vs written} and linguistic oppositions such as {iconicity vs conventionalism} and {expressivity vs constatation}.

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