

# Carving language for social coordination

## A dynamical approach

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Human social coordination is often mediated by language. Through verbal dialogue, people direct each other's attention to properties of their shared environment, they discuss how to jointly solve problems, share their introspections, and distribute roles and assignments. In this article, we propose a dynamical framework for the study of the coordinative role of language. Based on a review of a number of recent experimental studies, we argue that shared symbolic patterns emerge and stabilize through a process of local reciprocal linguistic alignment. Such patterns in turn come to facilitate and refine social coordination by enabling the alignment, joint construction and navigation of conceptual models and actions. Implications of the framework are illustrated and discussed in relation to a case study where dyads of interlocutors interact verbally to reach joint decisions in a perceptual discrimination task.

**Keywords:** social coordination; language; communication; linguistic alignment; symbolic patterns; affordances; emergence; evolution; adaptivity; interaction

### 1. Introduction: Language as social coordination device

*"[Language] is forever changing. It is a complex adaptive system shaped and reshaped by the members of a population in order to satisfy their needs"*

(Steels 2006 p. 349)

Human language plays a pervasive role in almost all facets of our everyday lives. In fact, we are often unaware of how much we rely on language to jointly solve problems and coordinate activities with each other: agreeing on the place and time for a date, discussing a problem to reach a shared solution, reciprocally directing attention, etc. Following Wittgenstein's notion of 'language as a toolbox' (1953), renewed attention has recently been directed at these ways in which language can be considered a tool for cognition (Bermúdez 2003; A. Clark 2006b) and social interaction (H.H. Clark 1996; K. Tylén, Weed, Wallentin, Roepstorff & Frith 2010). Language

is thus seen as enabling particularly efficient means of information sharing (Mesmer-Magnus & Dechurch 2009) and alignment of representations between agents in various kinds of distributed cognitive systems (Hutchins & Hazlehurst 2002). In line with this, studies have indicated that the collective performance of such distributed systems depends on high degrees of linguistic information sharing (Kozlowski & Ilgen 2006). However, in these contexts, language is often implicitly conceptualized as a mere conduit: a pre-existing and neutral medium for transmitting information between subjects (Leezenberg, accepted; Reddy 1979). We argue – on the contrary – that language is a skillful, joint activity through which interlocutors attune to each other and the task at hand co-constructing a shared cognitive niche. Through social interaction, linguistic practices (words, expressions and whole jargons) are continuously evolved and developed to accommodate local coordinative needs. From such perspectives, language does not simply enable information sharing; it is rather the very act of constructing and attuning to shared information in local contexts of coordination.

By bringing together the conceptions of language as a coordination device and a continuously evolving system, we aim at a dynamical framework for the experimental investigation of the reciprocal adaptations of verbal, cognitive and coordinative processes of language. Such a unified framework allows us to systematically map and quantify how different linguistic dynamics and patterns emerge from coordinative interaction and in that process come to facilitate and reshape coordination itself.

The presentation falls in three main parts. The first part will be dedicated to a critical review of literature on the evolution of language through coordinative activity, on how emergent linguistic practices come to constrain coordinative processes, and on how this can be tested and measured. In the second part, we will synthesise the findings in a general dynamical model, tentatively sketching how linguistic activity evolves from, integrates with, and expands upon non-verbal alignment and through evolving symbolic patterns feeds back and constrains coordinative dynamics. Finally, in the third part of the article, we will present a case study investigating how stable symbolic patterns evolve through local linguistic alignment and how their coordinative effects can be measured and quantified. The examples motivate a general discussion of the relation between language and social coordination and point to further directions for research.

## **2. From coordination to language**

What are the basic mechanisms by which human sign systems evolve, develop, stabilize and spread in a community of agents? And how do these sign systems reshape human social interaction? Most traditional approaches have tended to

search for the prerequisites of linguistic behavior at the level of individual biology and cognition, whether in terms of innate language competences (Fodor 1984; Hauser, Chomsky & Fitch 2002; Pinker 1994) or more general cognitive capacities such as ‘theory of mind’ and ‘simulation’ (Stamenov & Gallese 2002; Tomasello 1999; 2008; Tomasello; Carpenter; Call; Behne & Moll 2005). However, there is a growing consensus that the foundational mechanisms of language evolution and change should be sought at the level of local collective dynamics (Elman 1999; Fowler, Richardson, Marsh & Shockley 2008; Loreto & Steels 2007).

From the dynamical perspective we engage, language itself can be considered a kind of joint action (H.H. Clark 1996; Garrod & Pickering 2009). Dialogical utterance activity thus involves a number of cognitive and motor processes resonating *between* agents. But rather than approaching such processes as linear extensions of a number of individual faculties or prerequisites, we need to appreciate how the collective level becomes constitutive of the individual ones (De Jaegher, Di Paolo, & Gallagher 2010; Di Paolo, Rohde & Iizuka 2008). In other words, to capture the inter-agent dynamics underlying language, we must broaden the scope of analysis from the level of the individual to the overall dialogical situation including contextualized interlocutors as the minimal object of study (De Jaegher & Di Paolo 2007; Fowler, et al. 2008). Such perspectives allow us to appreciate how language emerges and unfolds as a distributed activity on an over-individual systemic level, although relying on a number of biological, cultural and material resources.

Already at a non-verbal level, interacting agents have been shown to coordinate low-level aspects of their behaviours in a plurality of ways, involving largely automatic facial, emotional and behavioural mimicry (Chartrand & van Baaren 2009). It has thus been observed how people seated in rocking chairs spontaneously synchronize their rocking frequencies, even if the chairs have different weights and momentums (M.J. Richardson, Marsh, Isenhower, Goodman & Schmidt 2007). Similar effects have been reported for the joint swinging of pendulums (Schmidt, Richardson, Arsenault & Galantucci 2007). Such basic behavioral coordination is also considered essential to early dyadic parent-infant interaction. A number of experiments have thus convincingly shown how even two months-old infants act as competent and responsive interactants when they can rely on the tightly coupled dynamics of the dyad (Murray & Trevarthen 1985; Nadel, Carchon, Kervella, Marcelli & Réserbat-Plantey 1999; Spurrett & Cowley 2004).

Moreover, the seemingly very basic propensity of interlocutors to locally attune to each other’s behaviors has been suggested as one of the central mechanisms by which communicative sign systems (and ultimately verbal language) emerge and stabilize among interacting agents (Loreto & Steels 2007; Hutchins & Johnson, 2009). Following this line of thought, human language evolved – through a series of intermediate stages of mimetic culture – due to a pressure for increasingly

sophisticated means of socio-cultural coordination and cooperation (Galantucci 2005; Tylén, Fusaroli, Bundgaard & Østergaard, accepted; Zlatev 2008). Recent advances in a broad range of disciplines including evolutionary and cognitive anthropology (Hutchins & Hazlehurst 2002; Tomasello 2008; Tomasello, et al. 2005), linguistics (Fay, Garrod, & Roberts 2008; Fay, Garrod & Swoboda 2010; Garrod & Anderson 1987; Garrod & Doherty 1994; Garrod, Fay, Lee, Oberlander & MacLeod 2007; Johansson 2005; Johansson, Zlatev, & Gardenfors 2006; Lupyán & Dale 2010; Zlatev 2008) neuropsychology (Deacon 1997; Donald 1991; 2001), and evolutionary robotics (Baronchelli, Dall'Asta, Barrat & Loreto 2005; Baronchelli, Gong, Puglisi & Loreto 2010; Loreto & Steels 2007; Puglisi, Baronchelli & Loreto 2008) have thus investigated the conditions under which complex social semiotic practices evolve from quite simple local, collective dynamics. In the following, we will discuss some of the central findings.

A fundamental issue in the evolution of signs is how certain aspects of human behavior gain a referential function (Donald 2001; Zlatev 2008). How do some (and not other) of our socially interactive behaviors become invested with ostensive and representational meaning? This question is approached in a recent experiment by Scott-Phillips and colleagues investigating the socially embodied grounding of semiotic behavior (Scott-Phillips, Kirby & Ritchie 2009). Pairs of participants – located in separate rooms – played a simple virtual game consisting of moving stick figures around in a configuration of four colored squares. The colored squares were randomly and differentially distributed on each of the participants' screens. The cooperative task was to place their figures at squares of the same color at the end of each trial. To successfully solve the task, participants thus had to invent shared ways of communicating about colors. Deprived of any other channels of coordination, they could only do so by the movement of their figure. Participants were thus facing the challenge of how jointly to mark and differentiate patterns of movements as communicative 'gestures' referring to shared meanings (the colors and their locations) while other movements would still be simple instrumental displacements (for related discussions, see Noordzij et al. 2009; 2010; Tylén, Philipsen & Weed 2009; Tylén, Wallentin & Roepstorff 2009). Through repeated trials, most pairs were eventually able to solve the task and settle on differentiated movement patterns (e.g. simple repetitions of movement) designating the various colors of the layout and thus solve the task.

The Scott-Phillips study points to important ways in which communicative signs (bodily gestures) emerge from task-oriented collective dynamics. However, a concern might be raised in relation to the experimental design. The task environment is constrained so to afford only purely conventional and arbitrary mappings between signs and their meanings (movement and color). Thereby the study is indifferent to other important aspects of symbol grounding, such as attunement to

iconic and indexical affordances and salient resources of the shared environment (Steels 2008; Tylén, et al. accepted).

These aspects are the focus of another experimental study by Bruno Galantucci (2005). Like the previous study, Galantucci investigated how novel sign systems gradually emerge and stabilize through repeated interactions, when people are deprived of the use of conventional communicational means. In a cooperative virtual game, pairs of participants were to find each other in a maze. The participants were located in separate rooms and could only communicate by means of a special tablet. However, a constant drift on the vertical axis of the tablet prevented the use of any conventional signs such as numbers or letters. While success in the task critically depended on participants sharing information about their location in the maze, the only way to communicate was to negotiate new sign systems from scratch. Despite great variations in the time spend (under twenty minutes to nearly three hours), most pairs eventually converged on shared systems of signs, enabling them to coordinate and thus solve the task.

There were great variations in the behavioral strategies and sign systems developed by different pairs. Some pairs evolved sign systems relying on iconic properties on the rooms. Others rather used the topological make up of the maze or based their signs on numerical systems. Interestingly, the particular choice of strategy did not seem to be predictive of the performance of the pair. However, the degree to which participants align on shared strategies and signs systems for solving the task was found as critical for their performance.

Along the same lines, Garrod and colleagues investigated the social dynamics underlying the emergence of graphical sign systems (Garrod, et al. 2007). Using a moderated version of the Pictionary game, pairs of participants had to cooperatively match a closed set of concepts communicating only through drawings. The experimental conditions varied as to how much the participants of a pair were allowed to interact and give feedback to each other. The authors found that through repeated, interactive trials, graphical representations developed from rich iconic depictions to very schematic, parsimonious symbols. While the participants would initially base their signs on salient iconic features of the referent category (e.g. drawing Bugs Bunny to represent the category “comics”), in the subsequent trials they could increasingly rely on the shared history of the ongoing interaction. Rather than persisting in pointing directly to the referents of a category, their drawings would thus refer back to salient features of previous drawings of the same category in increasingly schematic ways (e.g. sketching only the ears of Bugs Bunny, successfully recognized in previous trials). Towards the final trials, the graphical representations would often have evolved to be so simplified that a naïve newcomer would not retrieve the iconic motivations but would rather experience the drawings as arbitrary signs.

Fay and colleague extended this experimental set-up in two interesting ways (Fay, et al. 2008; Fay, et al. 2010). The experimenters compared the emergence of graphical representations through repeated interactions in isolated pairs versus pairs of alternating participants belonging to a ‘community’. They found that while isolated pairs would develop idiosyncratic sign systems, in the community condition participants would converge on shared sign systems. However, the sign systems developed between communities would show the same idiosyncratic variation. Subsequently, the experimenters found that the sign systems developed in the community condition had a number of beneficial properties compared to the sign systems developed by isolated pairs: generally the community evolved sign systems enhanced individual learning and were easier to understand for naïve overseers. The authors thus conclude that through a process of continuous adaptation and selection, the community condition would evolve more optimized communicative signs systems.

While the preceding studies are largely concerned with the social dynamical mechanisms underlying the evolution of novel communication systems, another series of studies have investigated analogous mechanisms in verbal dialogical interactions, that is, how interlocutors continuously adapt their language to each other in order to accommodate coordination in shared tasks. In their comprehensive account, Pickering & Garrod (2004) thus outline a theory on how interlocutors in dialogues coordinate their linguistic actions and representations on multiple levels. A basic finding is that alignment on lower levels of linguistic behavior facilitates alignment on higher conceptual levels (Garrod & Pickering 2009). Like other spontaneous imitation processes, such low-level alignment largely goes on at an automatic and implicit level and is only rarely subject of conscious attention. Low-level alignment effects have been consistently found in e.g. speech rate, utterance length, gesture, response latency and phonetic profile (see Giles, Coupland, & Coupland 1991 for a review; Nilsenová & Nolting 2011; Pardo 2006). And similar effects are also reported on the level of lexical, sentential completion (Poesio & Rieser 2010) and alignment of syntactical constructions (Branigan, Pickering & Cleland 2000; Branigan, Pickering, McLean & Cleland 2007).

Testing such predictions, Garrod and Anderson thus conducted an experiment where pairs of participants could talk freely to jointly navigate a maze (1987). Again, maze was constructed so that the participants critically depended on each other to navigate to the goal. While participants of a pair would often initially differ in their conceptualizations, the authors observed how the pairs through dialogue gradually adapted to each other’s ways of conceiving and talking about the maze. Some pairs evolved a model of the maze as consisting of lines and rows, and thus navigated the maze with expressions like “second box in the third row”. Other participants developed a ‘path-model’, guiding the other participant by specifying

a path leading to the destination. Again, others used a ‘matrix model’ with expressions like “d4” akin to the one used in chess, etc. While the specifics of the models did not seem to play a big role, the degree of alignment of the pairs turned out to be crucial for their success in the task.

In a ‘community-version’ of the same experimental design (akin to the Fay, et al. 2010 study mentioned above), Garrod & Doherty (1994) found that when participants played with shifting partners belonging to a ‘community’ a particular model (the chess-like matrix model) was favored. This model appeared more fit to transport to new interactions and new mazes and would thus approach a regular social convention (i.e. it would be used even in situations rather affording for one of the other models).

A common finding in the series of studies considered in the preceding section seems to be that the convergence on shared repertoires of communicative practices and signs is driven by simple principles of mutual local adaptivity: the propensity of a participant to pick up and use the semiotic practices used by the other participant in the previous trial when jointly solving a task. The studies are thus suggestive of how – in a community – global linguistic patterns gradually propagate, stabilize and eventually conventionalize through continuous reciprocal linguistic alignment – sensitive to affordances of the shared task environment (Tylén, et al. accepted). Interestingly, even though the outcome is complex and elaborate communication systems, this evolution process proceeds without any central coordination or control (Loreto & Steels 2007).

But one question concerns the nature of the social dynamics facilitating the emergence of sign systems and linguistic practices. Another question is how the coordinative effect of these signs feed back into the very same system and come to constrain and guide collective dynamics on multiple levels (Raczaszek-Leonardi 2009; Raczaszek-Leonardi & Kelso 2008). This is a circular process: Through increasing mutual attunement, interacting agents come to evolve and share new means of communication and coordination. At the same time, these emergent collective resources radically widen the possibilities for and refinement of social interaction and coordination. In the following section, we will thus discuss how language (and semiotic systems broadly) affects non-linguistic socially coordinative action.

### 3. From language to coordination

In Pickering and Garrod’s model cited above, it is shown how alignment on one level of linguistic behavior often spread to other levels. Interestingly, however, alignment on linguistic parameters does not only come to constrain other

linguistic levels, but likewise affects aspects of non-linguistic human behavior. In an experiment, Shockley and colleagues (Shockley, Santana & Fowler 2003) thus measured the continuous bodily synchronization of participants while they engaged in verbal dialogue to jointly solve a cooperative ‘puzzle task’. They found that as participants during conversation aligned various acoustic properties of speech (e.g. stress patterns and speech pace), they came to spontaneously coordinate their subtle postural sway. This happened even when they could not see each other. The findings suggest, that even when deprived from other sensory-motor exposure, interacting agents manage to achieve tight low-level bodily synchronization through the auditory-acoustic dynamics of verbal dialogue (Fowler, et al. 2008; Shockley, Baker, Richardson & Fowler 2007).

Other studies show how linguistic dialogue comes to guide and constrain social coordination at the level of perception. Richardson and colleagues (D.C. Richardson, Dale & Kirkham 2007) thus investigated how agents engaged in conversation mutually coordinate their visual attention. Pairs of participants were located in each their room and communicated via an intercom headset/microphone device. They were instructed to look at pictures of characters from two well-known television shows (*The Simpsons* and *Friends*) and talk freely about their favorite episodes, the characters or their relationships, etc. As they spoke, their eye movements were tracked and their descriptions recorded. The study shows how as conversations unfold the eye movements of the participants become tightly coordinated, fixating on the same images within seconds.

Such coordinative effects on non-linguistic behavior are most likely to facilitate increased collective performance in various kinds of cooperative contexts. Indeed the studies by Scott-Phillips and colleagues (2009); Galantucci (2005) and Garrod and colleagues (2007) cited above are suggestive of such effects. This is most directly shown in the Scott-Phillips study: only as a shared system of semiotic behaviors stabilizes do the pairs gain points in the game. Similarly, the Galantucci study shows how interactively evolved sign systems turn an almost impossible task into a trivial one. And the one pair that did not develop a shared sign system was also the one that did not – through more than two hours of interaction – solve the task. In the Garrod et al. study, collective task performance (identification match) was found to correlate with a number of other parameters of the experimental setup (such as complexity of emergent sign systems, possibilities of feedback, alternate roles, etc.), which again, at least indirectly, points to facilitative feedback effects from the evolved semiotic practices to the quality of the coordinative activity.

Such coordinative effects have been further investigated in a group of studies where the degree of linguistic alignment was used as a predictor of dialogical success in a variety of situations: from speed dating (Ireland et al. 2011) to joint

information search (Gonzales, Hancock & Pennebaker 2010) and even hostage negotiation (Taylor & Thomas 2008). A software package (LIWC, Pennebaker, Booth & Francis 2007) was used to calculate the percentages of occurrence for different linguistic categories (in particular what the authors define as “context-independent function-words” such as adverbs and modal verbs) as well as overall word count and average word count per speech turn. Such measures provided a summary or “profile” of a speaker’s linguistic style that has been shown to be reliable over time (Pennebaker & King 1999) and can be used to measure the match between interlocutors’ linguistic style.

In all linguistic interactions analyzed interlocutors displayed significant matches in linguistic style, although at different degrees. In line with the studies on verbal and non-verbal alignment presented before, the first hypothesis tested was whether the degree of such match would be associated with social cohesion and with a shared way of perceiving the situation and its potential developments. In the case of speed dating, potential partners conversed for 4 minutes in order to decide if to go on a proper date. It was found that 33.3% of the interlocutors presenting a match in linguistic style above the median turned out to desire future contact, as opposed to only 9.1% of the couples matching at pair or below median (Ireland, et al. 2011). Linguistic match among interacting agents was thus predictive of how well they liked one another.

A similar finding was done in relation to the joint information search task (Gonzales, Hancock & Pennebaker 2010). Members of a group were given each a different almanac and the group was asked to search for the answers to 22 questions in them. The group members thus had to coordinate their searches and share the information they yielded. Match in word count and in use of function words was found to correlate with group cohesiveness and performance. In other words, the more the interlocutors shared the same linguistic practices the more they liked each other and the more effectively they interacted and shared information. Higher degrees of linguistic alignment thus resulted in more right answers and thereby success in the task.

While the previous two studies take an overall perspective on the alignment of linguistic styles and the effects of such alignment, a more in depth analysis of the temporal dynamics of linguistic style match is provided in the study of hostage negotiations (Taylor & Thomas 2008). The transcriptions of nine hostage negotiations were divided each into six time-stages and the dialogue of police negotiators and hostage takers analyzed across 18 linguistic categories. As predicted, analyses showed that successful negotiations were correlated with higher inter-speaker matches in the amount of words used and in function words both at a global and at a turn-by-turn level. They were also characterized by high stability in the linguistic style match and by a slow increase in

alignment over time. In contrast, unsuccessful negotiations displayed dramatic fluctuations in the linguistic match between interlocutors and their final level alignment was inferior to their initial level. The authors argue that this was due to recurring attempts of one of the negotiators to impose different agendas, for instance shifting from the assessment of the present situation to past recriminations or future repercussions – thus introducing a higher amount of modal verbs.

While the preceding studies rely upon very generic indices of linguistic style and categorical measures of success (e.g. willingness to date and the release of the hostages), two studies by Reitter and colleagues developed a more fine grained approach both to linguistic alignment and to performance. In the first study, Reitter, Moore & Keller (2006) compared syntactic alignment in a corpus of experimentally elicited, task-oriented dialogues (the HCRC Map Task Corpus, Anderson et al. 1991) and a corpus of spontaneous conversations (the Switchboard corpus, Godfrey, Holliman & McDaniel 1992). They found that the task-oriented conversations displayed a higher recurrence of turn-by-turn syntactic alignment, plausibly due to the more pronounced coordinative needs. A follow-up study (Reitter & Moore 2007) focused on the 128 dialogues constituting the task-oriented corpus only. The authors hypothesized that a higher degree of syntactic alignment would correlate with a higher degree of success in the task. In the task, pairs of subjects were given two slightly different maps depicting the same (imaginary) landscape. One subject had to give directions for a predefined route to another subject, who had to follow them and draw the route on their map. The task thus allowed for a more precise measure of performance than the previously described studies: when comparing the intended path and the actual drawn path on a map, the smaller the area covered in between the paths the higher the success. Syntactic alignment over spans of 10 sec correlated reliably with performance.

The previous studies all point to the possibility of measuring the effects of different levels of linguistic alignment on performance. Indices of generic linguistic alignment predict social cohesion and convergence of conceptual models of the situation, affecting the coordinative process towards improved performance. Additionally, the studies are suggestive of how such alignment could evolve into symbolic patterns fit to the coordinative needs. For example, the syntactic constructions aligned in Reitter and colleagues' study (2007) seem to be related to the co-construction of specific profilings of the situation (Croft 2010; Pickering & Garrod 2004). Interestingly, other aspects of the dialogues such as negative valence, past and future tenses and first person plural pronouns was found to be negatively correlated with performance in some specific situations (Gonzales, et al. 2010; Taylor & Thomas 2008). Together these findings point

to the possibility to further integrate the coordinative conception of language. This is done by directly addressing and quantifying the emergence and stabilization of symbolic patterns, and their fitness (as co-constructed tools and shared representations).

#### 4. On the coordinative role of language: A unified model

The studies presented in the previous section are thus indicative of the way linguistic patterns evolve from local interactive contexts to meet coordinative needs and how the linguistic patterns feed back into and come to guide and constrain the very same coordinative processes towards refinement and optimization. To further extend and elaborate upon these approaches, we will now sketch a unified model of the processes through which language becomes a refined coordination tool.

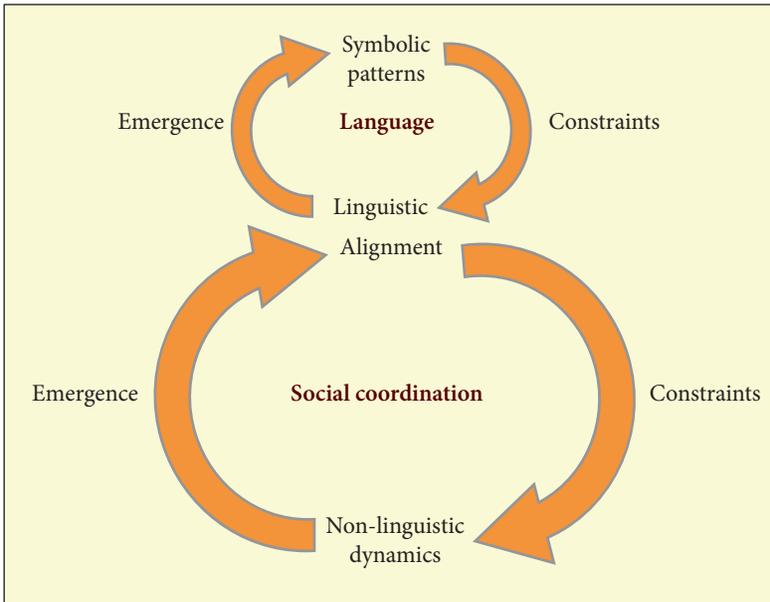
As repeatedly noted in previous sections, human social interactions are characterized by a number of mutual behavioural adaptations at a basic bodily level: postural, gestural and facial mimicry are but examples of this (Chartrand & Bargh 1999; Chartrand & van Baaren 2009). Alignment at any of these levels facilitates alignment at the others as well as social cohesion and sympathy amongst the participants to the interaction (Chartrand & Jefferis 2003; Valdesolo, Ouyang & DeSteno 2010).

As discussed above, verbal dialogue seems to build upon the very same coordinative mechanisms of multi-level alignment (Branigan, et al. 2007; Fowler, et al. 2008; Pickering & Garrod 2004). The main mechanism driving such adaptive alignments is the propensity of interlocutors to pick up and re-use each other's phonetic, lexical syntactic and other linguistic structure after their introduction. This has been referred to as 'the input-output principle' (Garrod & Anderson 1987) or 'the principle of precedence' (Garrod & Doherty 1994). It is this re-use that leads speakers to converge on common conceptual models as seen in many of the studies discussed in the previous paragraph.

However, language is more than just another type of socially coordinative behaviour. While simple embodied joint actions (like swinging pendulums and rocking chairs, etc.) are largely constrained to the here-and-now of face-to-face encounters, language dramatically widens the possibilities for social coordination in time, space and quality (Tylén, et al. 2010). Language thus adds additional channels and modalities for behavioral alignment giving social coordination wider reach, for instance, making coordination possible also in conditions of scarce or no visibility due to darkness, barriers, and distance (Marsh, Richardson, & Schmidt 2009; Shockley, Richardson & Dale 2009). These are

not trivial achievements. Moreover, the local adaptive dynamics of linguistic interaction do not exhaust the mechanisms of linguistic coordination. Through verbal alignment, interacting agents gradually develop stable linguistic (or symbolic) structures. Once signs for colors are established and shared (Scott-Phillips, et al. 2009), once a semiotic system to label categories (Garrod, et al. 2007) or orient and coordinate with each other in a maze is created (Galantucci 2005; Garrod & Anderson 1987), such symbolic structures and practices come to form a shared repertoire, immediately available for further coordination of interactions. These emergent repertoires of shared symbols thus constitute a cognitive niche (A. Clark 2006a; Sinha 2009) that – according to the situation – structures shared situation models, distributes roles in the ongoing activity and generally guides and constrains the possibilities for coordinated action and cognition. Symbolic patterns thus introduce a minimal layer of socio-cultural normativity providing stabilised shared affordances and constraints for linguistic and non-linguistic coordination. These stabilized symbolic patterns can be inherited by successive interactions thus forming cultural constraints. When semiotic systems evolve in a community (Fay, et al. 2008; Garrod & Doherty 1994), we observe how stable symbolic patterns are repeatedly inherited and put to play. This adds a new constraint to their evolution in terms of the need for them to be easily adopted and understood by new users. Such progressions in a community thus lead to more abstract symbolic patterns (Heiser & Tversky 2004; Lupyan & Dale 2010; Schwartz 1995). However, it is important to stress that the constraining properties of symbolic patterns are not absolute (or only quite rarely so, as e.g. in the rigorously scripted verbal interactions in a cockpit, see Hutchins 1995), but will always be partially re-shaped and adapted to meet ever-new local needs, tasks and affordances (Perry 2010).

This interplay between symbolic and dynamic aspects of language has been effectively described in terms of dynamical system theory (Raczaszek-Leonardi 2009; 2010; Raczaszek-Leonardi & Kelso 2008) as the interaction of different time scales. Symbols evolve and stabilize from local dynamics and come to work as constraints for human coordination at different time scales. A social linguistic practice established through a history of interactions, will thus harness dynamics and alignment on shorter scales of ongoing interactions. This way, language widens not only the spatial reach of coordination, but also the temporal reach supporting the construction and evolution of refined cultural systems of coordinative control. Or put in other words: coordinative needs motivate linguistic alignment leading to the emergence of stable symbolic patterns, which in turn guide and constrain the interactive dynamics, in an iterative process (cf. Figure 1).



**Figure 1.** Tentative model of the relation between dynamical and symbolic aspects of social coordination and language. Through processes of social interaction, agents come to synchronize aspects of their behaviours on multiple levels. And through such local adaptive dynamics collective patterns emerge and gradually stabilize. Analogously, multi-level reciprocal alignment of various aspects of linguistic behaviour stabilizes into verbal, symbolic patterns. These, in turn, feed back into the interaction and thus come to structure, guide and constrain coordinative dynamics

## 5. Measuring the coordinative effects of linguistic alignment and symbolic patterns: A case study

As anticipated in the introduction, the purpose of this conceptual model is to structure the discussion about dynamical and symbolic aspects of language towards empirically testable hypotheses. Three main predictions follow from the model: (1) higher degrees of local dynamical adaptivity (alignment) between interlocutors result in higher stability of collectively evolved symbolic patterns, (2) higher degrees of stabilization of symbolic patterns result in better coordination and therefore higher performance in joint tasks, and (3) the stability of emerging symbolic patterns has a higher coordinative efficacy than linguistic alignment alone.

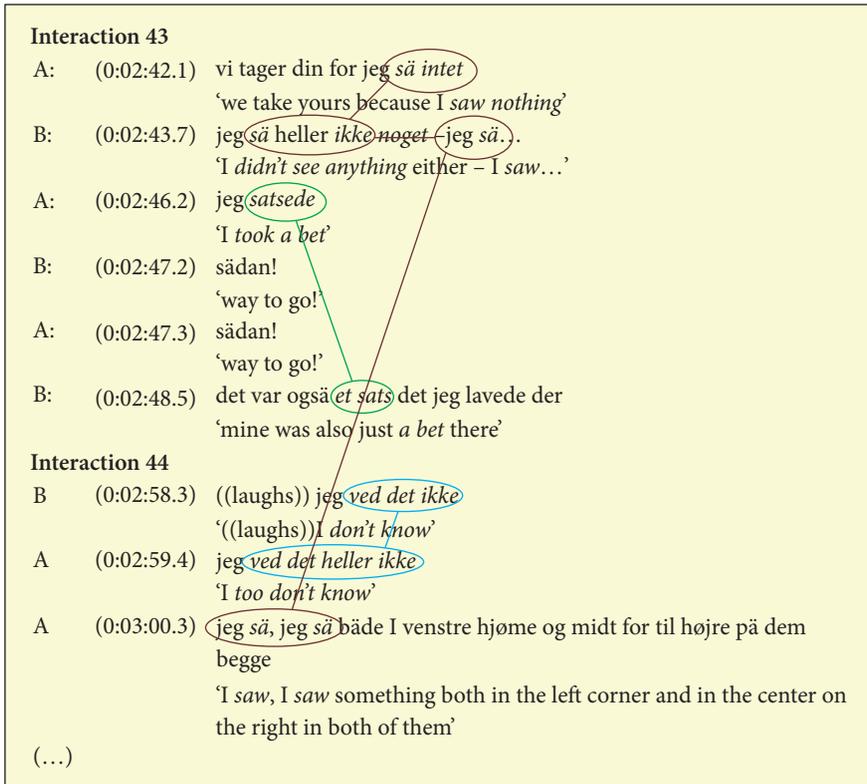
The studies presented in previous sections seem suggestive of such effects though none of them rigorously test the hypotheses. Rather, they tend to focus

on generic linguistic alignment and generally do not present precise and graded measures of cooperative success. Here we will thus present a study attempting to systematically quantify both local linguistic alignment and the stabilization of symbolic patterns and how it affects joint performance in a collaborative task where performance can be precisely measured.

The investigation (Fusaroli et al. accepted) expands upon of a recent experiment by Bahrami and colleagues (2010) testing collective, low-level perceptual decision-making. Pairs of participants had to individually identify a contrast oddball randomly presented in either of two brief visual displays containing Gabor patches. If the individual choices were divergent, the participants were prompted to negotiate, by freely discussing with each other, a joint decision. In order for a pair to achieve a cooperative benefit, that is, to perform better than the best of the individuals, they had to find ways of assessing and comparing their individual levels of confidence so as to choose – on a trial-by-trial basis – the decision of the more confident participant. The main finding reported in Bahrami et al's original study was that pairs generally performed better than individuals, indicating that they – through dialogue – managed to optimally integrate individual visual experiences in their joint decisions. But the experiment also provided a comprehensive corpus of task related dialogues allowing for analysis of differences between better and worse performing pairs. In the follow-up study, Fusaroli, Tylén and colleagues (Fusaroli, et al. accepted) thus investigated properties of the dialogical dynamics facilitating success in the task. While other studies focused on alignment on the level of syntax, speech pace or number of words etc., we found that this task critically afforded participants to stabilize shared linguistic expressions of confidence (Peterson & Pitz 1988). Focusing on specific linguistic expressions of confidence rather than e.g. function words allowed us to better map the way conceptual scales evolved to fit local task affordances.

It was observed how participants would generally use a variety of everyday expressions such as “*I'm not sure*”, “*I'm blank*” or “*I think I saw something ...*” when talking about their levels of confidence. These expressions would tend to organize as shared scales on which participants could compare their levels of confidence to make joint decisions (see Figure 2).

In the analysis, all expressions of confidence were identified and grouped in types: For instance expressions centred around the adjective ‘sure’ (“*I'm not sure*”, “*I'm almost sure*”, “*I'm absolutely sure*”, etc.) would constitute a type, just like expressions with ‘see’ (“*I think I saw ...*”, “*I did not see anything*”, “*I saw something*”), expressions using numeric values, etc. Subsequently, types and tokens were quantitatively assessed for their distributions and frequencies.



**Figure 2.** Example of joint decision dialogue (reproduced from Fusaroli, et al. accepted). The original language of the experiment is Danish. A and B refer to the interlocutors. Expressions of confidence are in italics. It can be noted how interlocutors tend to pick up and reuse each other’s expressions of confidence, such as ‘to see’, ‘to take a bet’, and ‘to know’. Such repetitive patterns of confidence expressions are indicated by coloured circles and lines

In line with the model sketched above, participant pairs generally tended to reciprocally adapt to each other’s way of talking about confidence on a trial-by-trial basis (as measured by the ‘transition probability’ that one interlocutor would reuse expressions introduced by another in the previous trial). But they did so at different degrees, some pairs showing higher and other lower transition probabilities. Interestingly, this measure was found to significantly predict how the pairs would perform in the joint decision task. In other words, the higher the propensity to locally mirror each other’s ways of describing confidence, the higher benefit did the pairs achieve from their cooperation. Moreover, following the predictions from the model, we expected that mutual local adaptivity could lead to a gradual stabilization of more global symbolic patterns. This hypothesis was tested by measuring

the degree to which participants of a dyad converged on a limited functional set of shared expressions of confidence (corresponding to a single ‘type’) rather than indecisively drift between multiple sets of expressions. As in the case of linguistic local alignment, participants were found largely to converge on limited functional sets of expressions of confidence, although again to different degrees. Global linguistic convergence strongly correlated with local adaptivity indicating that these measures was not independent but strongly related. That is, a high degree of mutual local trial-by-trial adaptivity was likely to lead to stabilizations of linguistic patterns at a more global level. Global convergence was also found to correlate significantly with task performance so that the more a dyad converged linguistically the more they benefitted from cooperation in the joint psychophysical task. Crucially, in fact, the role of stable symbolic patterns, that is, shared and recurrent scales for comparing confidence have a much stronger explanatory power than the simple propensity to locally align. In other words, while local linguistic alignment seems to pave the way for the stabilization of shared symbolic patterns, it is these emergent patterns - fit to the local task affordances – that come to facilitate refined coordination and thus increased performance in the joint task.

The study is an example of how research on the coordinative effects of language can advance beyond the prevalent use of generic indices. The experimental and analytical procedures thus allow for the careful analysis of the carving of linguistic tools fit to the specificities of a task environment. The findings thus seem to support the hypotheses generated by our model: Through local linguistic alignment effective linguistic tools are gradually stabilized to facilitate refined social coordination and thus increased performance in cooperative tasks.

## 6. Conclusions

Three general points seem to follow from the ideas discussed in this article. Firstly, language is not a neutral, pre-existing medium enabling information sharing. Rather, we argue, it is a skillful, joint activity drawing upon a number of embodied resources and cognitive processes. On a fundamental level, language thus relies on the same basic dynamics found in a number of other (non-verbal) socially coordinative behaviors, such as the spontaneous mutual alignment characterizing the joint swinging of pendulums or rocking of chairs (Fowler, et al. 2008). In linguistic dialogue, such alignment effects extend on multiple levels from pitch and pace to syntax and conceptual representations (Pickering & Garrod 2004).

But, secondly, language is not *just another* form of socially coordinative behavior. Language plays a unique role in human social life going far beyond such simple behavioral synchronizations. Through repeated linguistic interactions, global

linguistic patterns seem to stabilize from local adaptive dynamics. This happens on multiple time scales from evolutionary time to history, ontogeny and language use. These basic processes are thus thought to underlie how new sign systems evolve and eventually conventionalize, how linguistic structures gradually grammaticalize as well as how shared task specific vocabularies and practices stabilize in local contexts of problem solving (Raczaszek-Leonardi 2009; Raczaszek-Leonardi & Kelso 2008). Interestingly, these linguistic patterns can have a dramatic feedback effect: Once stabilized, they thus come to constitute a cognitive niche for the community of speakers, structuring, guiding and constraining the very same coordinative dynamics from which they evolved. In this sense, language can be considered a tool for social coordination, carved by local needs and social dynamics and at the same time expanding, shaping and refining the possibilities for social interaction (Tylén, et al. 2010).

The third point is rather a lead to further research. In our discussions we have favored various empirical and experimental investigations. A number of existing studies cited in previous parts of the article give us valuable insights in various aspects of the coordinative role of language: its dynamical evolution toward meeting local coordinative needs as well as the effects that language has back on coordination. What remains now is a systematic exploration of the connection between these two sides of the model: the emergence and control. Initial explorations reveal promising connections between linguistic alignment, stabilizing linguistic patterns and cooperative performance conforming to such dynamical models. Further research is now needed to extend those results to a wider variety of situations, to integrate models of cultural transmission (as in the community variations), to take into account both verbal and non-verbal alignment and to further test the causal link.

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