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Dialog as interpersonal synergy

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A B S T R A C T

What is the proper unit of analysis in the psycholinguistics of dialog? While classical approaches are largely based on models of individual linguistic processing, recent advances stress the social coordinative nature of dialog. In the influential interactive alignment model, dialogue is thus approached as the progressive entrainment of interlocutors' linguistic behaviors toward the alignment of situation models. Still, the driving mechanisms are attributed to individual cognition in the form of automatic structural priming. Challenging these ideas, we outline a dynamical framework for studying dialog based on the notion of *interpersonal synergy*. Crucial to this synergetic model is the emphasis on dialog as an emergent, self-organizing, interpersonal system capable of functional coordination. A consequence of this model is that linguistic processes cannot be reduced to the workings of individual cognitive systems but must be approached also at the interpersonal level. From the synergy model follows a number of new predictions: beyond simple synchrony, good dialog affords complementary dynamics, constrained by contextual sensitivity and functional specificity. We substantiate our arguments by reference to recent empirical studies supporting the idea of dialog as interpersonal synergy.

1. Dialogical coupling: from synchronies to synergies

Recent studies portray conversation as the progressive entrainment of linguistic behaviors of two or more individuals (Pickering & Garrod, 2004). In other words, interlocutors engaged in dialog spontaneously align their linguistic behaviors on multiple levels from prosody to syntax, thus increasing the coordination of attention, action and conceptualization (Fusaroli & Tylén, 2012). Building on and extending such models, we advance the idea of conversations as *interpersonal, functional synergy*: through context-sensitive alignment and complementary dynamics, interlocutors develop patterns of stable interactions[1] fit to the affordances and goals of the situation, whether good rapport, motor coordination, the solution of a problem, etc.

Inspired by dynamical systems theory, the model of *dialog as synergy* thus reconceptualizes reciprocal imitation as part of a complex process in which interactional patterns are jointly curbed and shaped by situational and task constraints. In order to articulate this conceptual framework, we i) introduce and discuss the model of dialog as alignment, with its theoretical assumptions and limitations, ii) build upon it to develop a more comprehensive model of *dialog as functional synergy*, and iii) introduce preliminary empirical evidence supporting the model as well as suggestions on how to further put it to test. Our examples are mostly taken from contexts of cooperative, task-oriented conversations. However, while the generality of the model is still open for future investigation, initial empirical results point to the applicability of the model to other genres of conversations, such as conflictual ones (Paxton & Dale, submitted for publication).

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[1] As later argued in the paper, 'stable' is intended in the technical sense as implying *dimensional compression* and *resistance to perturbation*, cf. § 3.

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2. From monologue to dialog: the model of synchronization

2.1. Beyond monologue: the model of interactive alignment

The vast majority of existing approaches to the psychology of language focus exclusively on the workings of individual minds and brains (Deacon, 1997; Gallese & Lakoff, 2005; Pinker, 1994). Classical cognitivist approaches such as Generative Grammar are explicitly committed to ideas about the innateness and modularity of language (Fodor, 1984; Hauser, Chomsky, & Fitch, 2002; Pinker, 1994). However, even more functional cognitive approaches (Fauconnier & Turner, 2003; Lakoff & Johnson, 1999; Talmy, 2000) seem implicitly biased toward written monologue as the model-language of study (Linell, 2005). Besides, both generative and cognitive linguistics, although in quite different ways, have favored strong representationalism: The understanding of linguistic behavior is first and foremost a matter of disentangling and mapping abstract cognitive linguistic representations, whether in terms of generative syntactical structure or embodied image schemas (Tylén, Fusaroli, Bundgaard, & Østergaard, 2013). However, studies focusing on the social and dialogical dynamics of language deeply challenge the individualist conceptions of the cognitive mechanisms underlying linguistic interaction and call for new models (Bickhard, 2007; Clark, 1996; Dale, Fusaroli, Duran, & Richardson, in press; Fusaroli, Demuru, & Borghi, 2012; Rączaszek-Leonardi & Kelso, 2008; Tylén, Weed, Wallentin, Roepstorff, & Frith, 2010).

With the recent introduction of dialogical models, such as the *interactive linguistic alignment in conversation* (Pickering & Garrod, 2004), psycholinguistics has made important advances beyond the classical cognitivist assumption that language is primarily a property of individual cognitive systems. The interactive linguistic alignment theory relates to a growing literature characterizing human interaction in terms of reciprocal behavioral and physiological mimicry (Chartrand & Bargh, 1999; Dijksterhuis & Bargh, 2001): Seeing somebody shaking a foot or rubbing the nose makes people unconsciously imitate them (Chartrand & Bargh, 1999), and laughter, smiles, eyebrow movements, headshakes and nods, are more likely to occur if one's interlocutor has just employed them (Louwerse, Dale, Bard, & Jeuniaux, 2012). Analogously, Pickering and Garrod approach dialog as imitation-like coordination of linguistic behaviors. Through an *automatic structural priming* mechanism (Pickering & Ferreira, 2008), interlocutors reciprocally align linguistic behaviors and representations on multiple levels. If one interlocutor speaks in a high tone of voice, the other will start speaking with a higher tone too and if she is calling a car "speedster", the other will have a higher probability of also using the word "speedster" in response. Additionally, structural priming implies that alignment at any given level – say lexical – contaminates and spreads to other levels – say prosodic, syntactic and conceptual. Indeed, the ultimate goal is the alignment of cognitive processes and, in particular, higher-level situation models. This, in turn, enables a deep mutual understanding and thus facilitates fine coordination on collective tasks (Pickering & Garrod, 2004).

2.2. Alignment as synchronization

Focusing on the way participants imitate and simulate each other toward greater alignment of their linguistic behavior (and ultimately conceptual models), the theory of linguistic alignment implicitly rests upon a widespread physical model: *synchronization*. In systems composed of multiple interacting elements, synchronization is defined as a process in which two independent components continuously influence each other toward greater entrainment within a certain lag tolerance (Pikovsky, Rosenblum, & Kurths, 2001). This influence works as a reciprocal imposition of attraction and constraints that allows the synchronizing parties to reduce the overall variance of their joint activity, making them more similar, more regular. Or put more simply, to synchronize means that two entities through mutual influence come to do more or less the same thing within temporal proximity.[2] A prime example of synchronization – as well as the historical origin of the model (Strogatz, 2003) – is the progressive coordination of two swinging pendula. When two pendulum clocks hang side-by-side, they gradually come to swing in synchrony. This happens because subtle vibrations from the clocks pass through the wall, perturbing their individual rhythms until they gradually reach a state of entrainment (Saltzman, 1995). In this case, the entrainment is mediated through purely mechanical means. However, similar phenomena can be observed in biological systems. Numerous observations have been made of people spontaneously synchronizing handheld swinging pendula (Schmidt, Richardson, Arsenault, & Galantucci, 2007), their heart rates (Konvalinka et al., 2011), or the frequencies of their rocking chairs even when these have different weights and momentums (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007). Furthermore, as mentioned, interacting human beings have been observed to make their facial expressions, and gestures more and more similar over time (Dijksterhuis & Bargh, 2001). Such observations have their linguistic analog in the *principle of structural priming* as the underlying mechanism in dialog. In short, structural priming implies that linguistic units presented by one interlocutor are more or less unconsciously and automatically picked up and repeated by the other interlocutor at a short temporal distance (more or less the same thing at more or less the same time). The mechanisms involved are, of course, different from pendulatory oscillations, but the end result is analogous: similar linguistic behavior happening approximately at the same time.

2.3. Limits to the model of mechanistic synchronization

The simplicity of this model and its low-level automaticity are intriguing and, indeed, several aspects of linguistic synchronization are found in corpus studies and

[2] It has to be noted that entrainment and synchronization might entail more complex phenomena than this, where rhythmic cycles are coordinated beyond local proximity and across multiple time scales (cf. Fusaroli, Abney, Bahrami, Kello, & Tylén, submitted for publication). However, we argue, a simplified notion of synchronization underlies the notion of alignment.

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experiments on dialogical interaction (see Dale et al., in press; Fusaroli & Tylén, 2012 for reviews). However, as a comprehensive model of conversation synchronization has serious shortcomings. Brought to its extremes, the assumptions and mechanisms of interactive alignment would predict good dialogical coordination to progress toward obsessive mimicry of each other's lexical and syntactic structure at overlapping pitch-ranges. That does not match any systematic observation of conversation, nor the literature on social interaction. In fact, behavioral mimicry has been shown to be highly context dependent and selective and not necessarily automatic: it can be influenced by a number of pragmatic and cognitive factors such as affiliation, group identities and individualistic/collectivistic priming (cf. van Baaren, Janssen, Chartrand, & Dijksterhuis, 2009 for a review).[3] Just as behavioral mimicry has been argued to serve specific social functions, linguistic alignment seems also to be modulated by the specific functional needs of the interaction (e.g. to coordinate reference and attention, Shockley, Richardson, & Dale, 2009), but not by others. Accordingly, Healey, Howes, & Purver (2010) contested the omnipresence of alignment and Reitter, Moore, & Keller (2006) showed that a task-oriented conversational corpus presents significantly more linguistic alignment than a less constrained corpus of free telephone conversations. Recent experimental work also suggests that good coordination relies on the ability to selectively align relevant aspects of conversation to accommodate the task at hand, while general, indiscriminate alignment seems to have a negative effect on joint task performance (Fusaroli, Bahrami, et al., 2012). In sum, we argue that while a simple mechanism of synchronized imitative behavior seems crucial to explain some of the important processes in dialogs, it is not sufficient. The automatic and unselective process may account for progressive alignment but it is too rigid a mechanism to account for the fact that dialogs are functionally constrained by the situations in which they are immersed.

It is not always advantageous to behave similarly. Imagine a supervisor telling his student "run a repeated measures three-way ANOVA on those data". If he answers by perfectly repeating the sentence "run a repeated measures three-way ANOVA on those data" it is highly probable that he does not really understand the advice. On the other hand, imagine a restaurant kitchen, where the person expediting the orders yells a menu item and the cooks on the line yell the same thing back, like in a perfectly oiled telephone game. Here we would be more likely to interpret repetitions as a sign of good coordination in concordance with the alignment model. However, considering the complementary roles of the interlocutors could capture more: the waiter yelling first conveys a request, and enacts a specific stage of the interactional routine, while had it been a chef yelling first it would have meant "the dish is ready".[4] Progressive alignment is not a goal in itself; the coordinative impact of the interlocutors' alignment can be fully understood only when taking into consideration the complementary functional roles, interactional routines, and affordances of the ongoing task. Complementarity of behaviors and distribution of roles are indeed crucial in most collective tasks: from the highly codified piloting of an airplane and sailing of a battleship (Hutchins, 1995a, 1995b) to telephone conversations (Schegloff, 1986) and collective memory (Peltokorpi, 2008). In these cases, linguistic interactions realize and modify functional coupling among individuals, effectively distributing cognitive processes and actions according to the needs of the tasks at hand (Fusaroli, Gangopadhyay, & Tylén, submitted for publication; Rączaszek-Leonardi & Cowley, 2012; Tylén et al., 2010). It is often by doing, thinking and saying *different* things that interlocutors achieve what an individual alone would not, and it is aligning on specific things, not indiscriminately, that does the job. An adequate model of dialog should therefore specify how local task requirements come to guide and constrain alignment and, even more importantly, distribute *complementary* (rather than identical) actions among interlocutors making them temporally coupled, selectively aligned, and fulfilling different roles in the interaction.[5] Assuming a broader perspective, dialogs are thus conceived as functional coordination of cognitive systems (Clark, 1996; Ochs, Schegloff, & Thompson, 1996). This means that the functional organization has to be sought both at the level of individuals and at the level of conversing dyad.

In the following, by advancing the model of dialog as an interpersonal *synergy* we aim at integrating alignment and synchronization into a more comprehensive theory of linguistic interaction where both imitative and complementary actions are selectively engaged in a functional unit. We highlight the concrete predictions the model makes about the nature of dialog. As preliminary empirical support for it we revisit a number of findings, from turn-taking and lexical-symbolic structure to the emergence of interactional routines.

3. Dialog as synergy

The notion of synergy originates in the study of movement, as a way of describing the functional coordination of multi-element systems (Bernstein, 1967; Turvey, 1977). It has since been adopted by dynamical systems approaches to behavior and cognition (Kelso, 1995; Kugler & Turvey, 1987) as a unifying model for different levels of analysis from motor coordination (Latash, Scholz, & Schöner, 2007) to perception-action coupling (Kelso, 2009) and even to interpersonal coordination (Riley, Richardson, Shockley, & Ramenzoni, 2011; Schmidt, Carello, & Turvey, 1990). In

[3] Some would argue that while mimicry is the default option, there are mechanisms of mimicry inhibition according to context and social cues (Wang & Hamilton, 2012). This supports our claim that alignment alone does not constitute a sufficient mechanism for describing and understanding social interactions, but others should be included and integrated in a more comprehensive model.

[4] We are grateful for those two examples to Patrick Healey and Veronica Ramenzoni, respectively.

[5] It has to be noted that the need for complementarity is mentioned in the linguistic interactive alignment literature (Pickering & Garrod, 2009), but it is not central and its mechanisms are not thoroughly explored.

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the following we extend the model to coordination processes in linguistic dialog.

Bernstein was the first to make the observation that, while having hundreds of muscles and joints is crucial to flexibly perform the many different tasks of everyday life, this also creates a problem of control. Whenever we move a limb to grasp a cup or shake hands, many individual muscles and joints – each with their degrees of freedom – work together in fine concert. He found it unlikely that the central nervous system would be able to finely control all the possible movements (the degrees of freedom) of each single muscle individually to create coherently directed movements. Rather, he suggested that muscles form flexible function-specific self-organizing assemblies, i.e. synergies, by locally coupling and constraining each other's degrees of freedom, greatly reducing the amount of control needed. Since the initial observation, synergies have been identified on multiple levels of individual behavior (Fowler, 1980; Kelso, 1995). Analogously, in interactive, cooperative tasks, individuals have been found to couple and reciprocally constrain their movements reducing the overall control needed to maintain effective cooperation (Ramenzoni, Davis, Riley, Shockley, & Baker, 2011; Ramenzoni, Riley, Shockley, & Baker, 2012; Riley et al., 2011; Schmidt et al., 1990). In effect, individuals' behaviors become increasingly interdependent, so that a higher-level structure of the interaction emerges. This kind of emerging organization has previously been referred to as *soft-assembly* (Kello & Van Orden, 2009): while the individuals preserve a degree of autonomy, they are constrained by the interaction. They can flexibly engage and disengage from it, as well as become part of other soft-assemblies (De Jaegher, Di Paolo, & Gallagher, 2010; Di Paolo & De Jaegher, 2012).

Synergies are identified by their *functional specificity*, *dimensional compression* and *reciprocal compensation*. The need to perform a function (functional specificity) temporarily shapes the coordination of several components into one system (dimensional compression), in which external and internal perturbations are flexibly dealt with via compensatory adjustments of the components (reciprocal compensation), in order to preserve the functionality of the whole system for as long as it is needed.

3.1. Functional specificity

The emphasis on function makes the proposed synergetic model of dialog diverge from the interactive alignment model in a number of interesting ways. The function of a dialog is often assumed to be obvious and is rarely explicitly discussed: people converse in order to *understand* each other. Such a conceptualization assumes an interaction of *independent* and *internally* controlled individuals making the alignment of initially diverging situation models the key step for the success of their interaction. As pointed out above, this is mainly achieved through bottom-up priming. Such priming is context independent, directionless and unselective: everything is aligned irrespective of it actually being beneficial for the specific joint activity at stake. In contrast, the synergetic approach assumes the function of a dialog to be the environmental demands imposed on a dyad, be it a joint task, the establishment or maintenance of social relations, etc. This makes dialogs highly context dependent, constrained, and goal directed. The function is an integral part of the interaction: actions and cognitions of the interlocutors are coordinated toward the goal at hand, selecting relevant dimensions for alignment, distributing roles and compensating for mistakes and perturbations. Two commonly assumed claims have to be rejected in such a view: 1) The ultimate function is not necessarily to reach deep mutual understanding of each other nor to converge internal representations; it is rather to realize an activity together, which might or might not require deep mutual understanding. 2) The function of a conversation cannot be defined on the level of the individual: the role of each individual component in a system cannot be understood separately from the functional organization of a whole; in other words, it makes sense only within the functional organization of a dyad.

Again, we here rely on insights from Bernstein and the movement sciences. To tackle the problem of motor control, Bernstein introduced the functional approach, bringing context sensitivity right down to the atomic details of behavior (Kelso, 2009): If we for instance want to strike a chisel with a hammer, this intention gives direction to and constrains the workings of our body. The exact timing and force of contraction and relaxation of all the individual muscles in our hands, fingers and arm are locally regulated to comply with that overall intention and the unfolding interaction with the environment. The variability of the trajectory of the tip of the hammer across a series of strikes is smaller than the variability of the trajectories of the individual joints on the hammering arm, at least in expert blacksmiths (Bernstein, 1967). The joints are not acting independently, realizing a prescribed action plan, but rather they correct each other's errors at the relevant time scale, in order to preserve function, thus supporting the idea that the function itself is the coordinating principle. Importantly, the very same muscles will flexibly combine in very different synergies for another type of task.

Compared to motor control, dialog seems dauntingly complex, comprising an almost endless number of dimensions from eyebrow movements and gesture to syntax and topicality structure. Needless to say, any analogy to chisel hammering could seem speculative to say the least. But on the other hand, the complexity of dialog forms an important argument in favor of the functional account. How can interlocutors seemingly effortlessly orchestrate all these dimensions (with each their numerous degrees of freedom) in tight intra- and interpersonal coordination? How do they form context-appropriate soft-assemblies? On the one hand, it is unlikely that this happens due to central, executive control processes in the nervous systems of the interlocutors. On the other hand, it is similarly unlikely that processes of unconstrained automatic alignment with no higher-level coordination are driving the dialogical activity. Rather, we suggest that this process is structured by reference to *function*, that is, realizing a specific joint activity. When interlocutors engage in dialog, complexity is reduced by selectively recruiting multiple behaviors and processes, making them interdependent and directing them in ways to best serve the ongoing activity (Louwerse et al., 2012).

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In order to move from simple motor control to dialog as a functionally and inter-individually defined system, one is presented with the difficult task of specifying its functions. Most often people engage in dialog with specific cooperative purposes, e.g. to coordinate in carrying a piano, asking for directions or taking a joint decision. Even a casual chat can be thought of in these functional terms as being about establishing or maintaining affiliation. The function constitutes the overall constraint guiding the collective dialogical behavior and retaining the engagement of the interlocutors *for as long as it serves the overall joint activity*. Whether the context is casual chat, heated argument or collaborative problem solving, a 'good conversation' – qua functional constraints – will be characterized by *stability*, i.e. orderly behavior of the parts of the assembly. Stabilizing the rhythmic and undisrupted flow of the conversation gives the interlocutors a feeling of common rhythm, naturalness and ease. Even in the case of conflictual conversation, where the aim is to persuade or even dominate the interlocutor, reciprocal attunement is needed in order to coordinate the joint activity of conflict (Ashenfelter, 2008; Fusaroli et al., submitted for publication; Mercier & Sperber, 2011; Paxton & Dale, 2011).

Existence of mechanisms for engaging in and sustaining stable interactions finds support in studies on newborns and infants' early sensitivity to the disruption of interaction (Murray & Trevarthen, 1985), as well as the ability to engage in turn taking-like vocal exchanges with caretakers (Gratier & Devouche, 2011). Similar sensitivity is displayed in conversations involving patients with speech impairment. In these contexts, expert interlocutors tend to engage compensatory procedures to keep the conversation fluent despite the impairment (Dressler, Buder, & Cannito, 2009; Goodwin, 2011). Besides, methods sensitive to recurrent patterns in data (Marwan, Carmen Romano, Thiel, & Kurths, 2007; Orsucci, Giuliani, & Webber, 2006; Webber & Zbilut, 1994) have recently been employed to assess the degree to which fluent conversations are characterized by more recurrence and greater order in turn-taking patterns than less fluent ones. Preliminary results suggest that greater recurrence rates correlate with interlocutors' feeling of safety in the conversation (Rączaszek-Leonardi, Rakowski, Kurczych, Radkowska, & Plewczyński, in preparation) and with performance in collaborative task-solving (Fusaroli & Tylén, submitted for publication).

3.1.1. Context sensitive selectivity

Linguistic interactions are always situated: immersed in the flow of actions and co-actions in the environment. Dialogs have to structure themselves according to the joint activities in which they are embedded (Fusaroli & Tylén, 2012). A joint task, for instance, could require the interlocutors to develop a shared vocabulary for jointly guiding attention to and talking about the particularities of the task. Such task-specific linguistic procedures are often stabilized through reciprocal linguistic alignment, enabling interlocutors to effectively optimize their coordination. However, pointing to automatic priming as the main mechanism underlying such alignment is debatable. We have previously indicated that automatic and indiscriminate linguistic alignment may undesirably work against complementary coordination between interlocutors and is insensitive to the crucial contextual aspects for the task at hand. In contrast, the synergetic approach to dialog pursued here emphasizes the functional directionality of interpersonal coordination. In line with this view, a recent study directly contrasted indiscriminate (context-insensitive) and selective (context-sensitive) alignment by correlating them with a measure of cooperative task performance (Fusaroli, Bahrami, et al., 2012). In the experiment, pairs of participants were instructed to individually indicate in which of two brief visual displays they had just been shown a contrast oddball. If their individual decisions disagreed, they were prompted to discuss and reach a joint decision. In order for a dyad 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. By analyzing the videotaped interactions, the researchers analyzed participants' propensity to align their vocabularies during joint decision trials. Indiscriminate alignment was defined as the average transition probability that any given word employed by an interlocutor had been employed by the other interlocutor in their previous joint decision trial. Selective alignment was defined as the average transition probability that any given confidence expression (i.e. pertaining to the dimension relevant for the task, such as 'sure') employed by one interlocutor had been employed by the other interlocutor in the previous trial. Participants generally employed a variety of everyday expressions such as '*I don't know*', '*I saw something*' or '*I think it was …*' when talking about their levels of confidence (see Table 1):

The analysis revealed prominent indiscriminate alignment in all dyads: interlocutors displayed a high probability of picking up and employing words used by the other in the previous interaction. However, the more a dyad indiscriminately repeated each other's words, the lower the collective benefit they gained from cooperation. Automatic linguistic alignment seemed to be deleterious to coordination on the task. In contrast, the participants' reciprocal, selective adaptation to vocabularies of expressing confidence (task motivated selective alignment), turned out to correlate positively with the collective benefit gained from cooperation. However, another process was also observed. While participants initially tended to drift between various ways of expressing confidence – e.g. variations of *to be sure*,

Table 1
Excerpt of transcription from the joint decision experiment reported in Fusaroli, Bahrami, et al. (2012). A and B designate the interlocutors. Confidence expressions are marked by italics.

Original Danish transcription	English translation
B: ((laughs)) *jeg ved det ikke*	B: ((laughs)) *I don't know*
A: *jeg ved det heller ikke. Jeg så* både i venstre hjørne og midt for til højre på dem begge	A: *I don't know either. I saw something* both in the left corner and in the center on the right in both of them
B: okay *jeg synes* det var ovre i venstreside men uhm pas	B: okay, *I think* it was over in the leftside but uhm I'll pass

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to have a feeling, *to see*, etc., over time, particular sets of expressions started to recur forming 'lineage patterns'. These were continuously reinforced and gradually outcompeted others. And as these lineages stabilized, selective alignment was observed to decrease. Since a shared scale was already established, alignment seemed functionally less prominent. In addition to selective alignment, the experimenters calculated the *linguistic convergence*, that is, the dominance of the more frequent set of confidence expressions shared by a dyad. Convergence was measured as the overall percentage of confidence expressions belonging to the most frequent set for each given dyad. Interestingly, convergence was found to be an even stronger predictor of collective task performance than local alignment. This suggests that once the relevant symbolic forms get stabilized, they have a strong coordinative effect not reducible to local alignment.

The results support the dynamical perspective we are endorsing in several ways: On the one hand, throughout the experiment, symbolic forms are shaped and stabilized through interaction in terms of shared sets of vocabulary fit to the task at hand (comparing individual confidence levels). On the other hand, the emergent symbolic forms provide constraints for the interaction, selecting and stabilizing important dimensions of the situation at a systemic level not reducible to individual behaviors nor to simple alignment of behaviors (Fusaroli & Tylén, 2012; Rączaszek-Leonardi, 2009).

Summarizing: while most psycholinguistic approaches to dialog have focused primarily on the individual interlocutors, the model of functional synergy prompts us to take into account also the inter-individual level. Approaching the dyad itself as a functionally soft-assembled unit, we have to consider the way that system copes with specific tasks. Equally important to the question of how the single interlocutor adapts to the other, becomes the question of how the function comes to guide and constrain the linguistic behaviors to form, maintain and dissolve synergies relevant to the situation in which the dyad is embedded. This systemic orientation gives us also new tools to empirically investigate and possibly quantify coordination in dialog. Here we focus on two characteristics that follow from the notion of functional specificity: dimensional compression and reciprocal compensation.

3.2. Dimensional compression

In a synergy, components are structured and constrained by the functionally oriented global dynamics. It is possible to get a quantitative grasp of such global dynamics through the notion of *dimensional compression* (Riley & Turvey, 2002). When a group of components assembles to form a synergy, the variance of their collective behavior displays lower dimensionality than the variance of the individually analyzed independent components. In other words, the number of variables that are needed to account for the variance in the overall behavior of a system is reduced as the system enters the state of synergy (Kelso, 1995; Riley et al., 2011). As mentioned before, the trajectories in hammering a chisel display lower variability than the movement of the single joints, at least in expert blacksmiths (Bernstein, 1967). Along similar lines, Ramenzoni et al., 2011, 2012 showed how this principle applies to interpersonal synergies. Participants involved in a joint coordinative tasks displayed a collective variability lower than the variability of their individual movements. The collective behaviors were more economically and appropriately accounted for when modeled as a single composite system than as two individual systems in interaction. Importantly, this suggests that factors explaining the behavior of the system's elements (interaction participants) would also be attributable to the level of the interpersonal system (Marsh, Richardson, & Schmidt, 2009).

To the authors' knowledge, no study has directly addressed dimensional compression in the context of linguistic dialog. This probably reflects both conceptual and practical difficulties when moving from relatively simple motor behavior to complex interpersonal, multimodal interactions spanning multiple levels of coordination each displaying specific dynamical properties and behaviors. To give an illustrative example: When measuring coordination effects in interlocutors' physiological behavior, e.g. their subtle bodily sway (Shockley, Santana, & Fowler, 2003), it seems appropriate to think in terms of individual, 'parallel' processes moving in and out of sync. The measurements from each of the interlocutors constitute independent time series that potentially can be analyzed on their own. The same holds for other aspects of interactive behavior such as the coordination of visual attention (Dale, Kirkham, & Richardson, 2011; Richardson, Dale, & Kirkham, 2007). However, when we address other, more linguistic aspects of the interaction, the contributions of each individual interlocutor (their respective speech turns) do not seem to form two independent, parallel time series. Rather, there are interesting ways in which a conversation seems to constitute one, single time series shaped by *complementary* conversational moves by the interlocutors.

Complementarity can be defined as the way components doing quite different things come to form a coherent whole. A structure initiated by one component is completed (rather than copied) by the other. In other words – contrary to synchronization – complementary coordination is successful if the components do different things, but in a way that constitutes a coherent structure on a higher level. In dialog, the complementary nature of participants' actions seems evident. On a fundamental plane, we can observe how dialog is most often organized in series of interleaved speech turns. Turn taking is a remarkable ability of humans, and seemingly a universal property of human language (Sidnell & Enfield, 2012; Stivers et al., 2009). It requires the interlocutors *not* to do the same thing at the same time: i.e. stay quiet when the other speaks. Its peculiar timing characteristics do not yield easily to modeling in a reactive fashion: over 50% of the gaps are below the usual threshold for reactions: 300 ms. Still, simultaneous starts are reported to be surprisingly rare in dyadic conversations (Jefferson, 1988). Taking up this challenge, Wilson and Wilson (2005) propose a model of turn-taking that combine synchronization and complementarity. The beginning of an interaction sets up an oscillator in each of the interlocutors' cognitive systems establishing a shared frequency of speech rate (the amount

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of syllables per second). This cyclic pattern governs the potential for initiating speech at any given instant for both interlocutors. The interlocutors, in other words, have to keep the same pace (alignment). However, if the oscillators were simply entrained *in phase*, simultaneous starts would be frequent. Therefore the oscillators must be entrained in *counter-phase*, giving the participants both a common rhythm, constituted by speech rate and length of comfortable pauses, and complementarity: readiness to take the floor must be opposite at any given moment for speaker and hearer. This model assumes internal individual dynamics of the interlocutors that are coupled to create coherence at the level of a dyad. It accounts for the properties of turn-taking behavior in a much simpler and computationally less demanding way than other models.

Complementarity in dialog is evident not only at the level of speech turns. Interlocutors must also locally manage functionally structured sequences of speech turns, such as *adjacency pairs*: Questions are normally responded to with an answer, not with another question; offers and invitations are usually followed by acceptances or declinations, etc. (Schegloff, 1986). Such observations again point to complementary dynamics. A given speech turn, even a given adjacency pair is not a free-floating entity, but often fulfills a role in larger *interactional routines*, locally unfolding routines which scaffold and constrain the possibilities of actions and interpretation in joint activities (Clark, 1996; Levinson, 1983). Interactional patterns are often conceived of as "scripts", normative static phenomena already shared – or assumed to be shared – by interlocutors (Sacks, Schegloff, & Jefferson, 1974; Schank & Abelson, 1977). The synergy approach, however, implies that interactional routines are dynamic, context sensitive structures in continuous evolution: Through dialogic interactions, interlocutors jointly profile relevant contents and distribute complementary (and often flexibly interchangeable) roles to meet the needs of the tasks at hand. Interactional routines vary in formality and flexibility from free and relatively unconstrained conversation over the morning coffee to tightly structured task oriented conversations. We argue that interactional routines work to reduce the overall degrees of freedom of the system and enable a smoother flow of the interaction.[6]

From this perspective follows that as interactional routines stabilize, dialogic interactions become progressively tighter and less negotiation is needed for structuring the interaction itself. Indeed, a number of recent studies show how *ad-hoc* interactional routines emerge and are maintained in task related conversations. In a version of 'the maze game' (Mills & Gregoromichelaki, 2010), pairs of participants cooperated to navigate a virtual maze consisting of boxes connected by paths. The task was construed in such a way that participants had to rely on information from each other using a chat tool (Healey & Mills, 2006). It was observed that, over the course of 12 games, participants radically structured and shortened their linguistic exchanges from more than 150 turns to the brief and efficient exchanges illustrated in Table 2.

Through a shared history, the interaction is given a task-relevant structure, which is progressively stabilized. This enabled participants to smoothly produce and interpret highly elliptical, and fragmentary utterances without much negotiation or clarification.[7] Building on research on similar phenomena by Garrod, Fay, Lee, Oberlander, & MacLeod (2007), Mills (2011) systematically investigated how implicit interactional routines emerge and spread in a small speech community. Again the task involved pairs of participants cooperating to solve a seemingly simple task using a text-based chat tool. However, the solution of the task required participants to establish quite complex implicit, procedural routines. Each participant played a number of games with changing partners within a 'community'. Then, in a critical test trial, unbeknown to the participants, half of the participants were paired with a member from another community. This perturbation seriously disrupted the interaction in the 'cross-community' groups. Participants were found to edit their utterances to a much higher degree, were observed to explicitly acknowledge each other's utterances more often and overall performed less accurately. The findings suggest that interactional routines emerge from a shared history of interaction and come to implicitly constrain actions and perceptions of interlocutors, diminishing ambiguity and supporting a smoother and more effective coordination (cf. also Mills, in this issue).

The emergence of interactional routines has substantial impact on the dynamics of interactions and can become normative to a degree where they do not need to be continuously renegotiated. As an extreme case, consider linguistic coordination in highly structured contexts, such as the piloting of an airplane (Hutchins, 1995b), or the work in a construction site (Perry, 2010). In these cases, highly structured cultural practices and roles support content-oriented minimal communication: technical terms referring to complex aspects of the situation models, short commands to be executed without discussion, even formal codes for emergency situations and responses to them. Symbolic structures deeply shape and constrain the ongoing social interactions in accordance with joint activity in which the interlocutors are immersed (Fowler, 2013). Once they are stabilized, reflecting constraints of a task, they enable even finer coordinative control without the need of continuous linguistic alignment (Fusaroli & Tylén, 2012).

Based on these and other observations, we argue that the presence of interactional routines in dialog is indicative of dimensional compression: Certain levels of coordination are better accounted for as a single time-series, jointly shaped by the interlocutors both continuously, in turns, and by stabilizing routines for the interaction. It seems thus relevant to discriminate purely alignment-based coordination and proper synergetic coordination. When two components are linked by reciprocal priming mechanisms

[6] Just like for turn-taking, certain kinds of routines may happen very early in development, as demonstrated by (Rączaszek-Leonardi, Nomikou, & Rohlfing, submitted for publication).

[7] A routine consisting of: 1. State (and request) location of switches; 2. State (and request) location of goal; 3. Signal accessibility; 4. Move onto switch; 5. Other moves through gate; 6. Move onto goal 1.

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Table 2
Evolution of dialog in the maze game, adapted from (Mills & Gregoromichelaki, 2010). A and B designate the interlocutors.

Dialog from an intermediate stage of the maze game	Dialog for a late stage of the maze game
A: I have switches at 1,2 2,6 1,4	A: 1,2 2,6 1,4
B: Where's your goal?	A: 5,6
A: 5,6	B: 4,5 3,4 7,1
B: mine are at 4,5 3,4 7,1 can you get to any of them	B: 1,4
A: I can get to 4,5 can you get to any of mine?	A: 4,5
B: I can get to 1,2	B: 1,2
A: I'm on 4,5 you can go through now..	A: 4,5
A: go to your goal	
B: Done	

only, they tend to produce increasingly similar overall patterns of activity. This means that the information contained in the behavior of one component becomes redundant with the information contained in the other. Or put in another way, the overall information produced in the interaction of the components is not very different from that produced by either of the individual components: we can retrieve the full information of the interaction by looking only at a single component's contributions. However, in an unfolding complementary structure, information on the overall, systemic level is irreducible to the individual contributions of each of the components. This implies that the amount of significant information at the interpersonal, systemic level is different than at the level of the individual behaviors. While no study – to the authors' knowledge – has yet quantified these informational dimensions of dialog, promising methods of quantifying information both at the individual and collective level are currently explored combining information theory and recurrence plots (Fusaroli & Tylén, submitted for publication; Rączaszek-Leonardi et al., in preparation).

It has to be re-stated that different levels of linguistic coordination might require different types of dynamics. While on the lower physiological levels of dialog (posture, visual attention, speech rate, etc.) good coordination seems to depend mainly on synchronization and alignment, on 'higher' linguistic levels, we observe quite the opposite: here good coordination, while relying on a certain degree of synchronization and alignment, at the systemic level shows complementary dynamics and emergence of interactional routines. More speculatively we can advance at least two related motivations for the different dynamics: The first is that low-level alignment provides a fail-safe coordinative mechanism on which to rely when the more complex complementary dynamics fails or is more uncertain (Louwerse et al., 2012). The second is that conforming behavior on lower levels of coordination provides a stable background on which minimal differences at higher levels can become highly salient and therefore maximize their meaning potential.

3.3. Reciprocal compensation

Another way to identify synergetic properties of systems is by assessing the way they react to perturbations. In the case of motor behavior (e.g. hand movements), it has been shown that if one part of a muscular assembly is interrupted (e.g. the movement of one of the fingers is externally perturbed), the system spontaneously and immediately reorganizes to compensate and thus preserve function. Even remote elements of a synergetic functional assembly have been shown to react almost instantaneously (20–30ms after perturbation) and in strictly task-specific ways (cf. the seminal study on perturbation of articulatory movement, Kelso, Tuller, Vatikiotis-Bateson, & Fowler, 1984). Thus compensation is operationalized as an immediate reaction of the elements of a system to its perturbation in a way that preserves function.

If dialog mainly relied on simple automatic alignment it would be quite sensitive to perturbations. For example, if an interlocutor displays persistent speech impairments as in stuttering, aphasia, or limited vocabulary, alignment implies that the perturbation would potentially propagate through the dialog leading to an overall poor performance. Synergies display different behaviors: the impairment in the speech of one interlocutor can be compensated by the other interlocutor or through other channels. Indeed, aphasic patients have been reported to develop compensatory strategies and speech patterns motivated by the need to effectively interact with others (Goodwin, 2003; Wilkinson, Beeke, & Maxim, 2003). Examples include Goodwin's reports on Chil, who after having suffered a severe stroke can only speak three words: 'yes', 'no' and 'and'. Despite this serious impairment, Chil is able to engage in complex conversations by coordinating other people's utterances. Chil thus relies on different types of reciprocal compensatory moves to restore the dialog: On the one hand, interlocutors have to actively produce utterances completing and supporting Chil's conversational moves. On the other hand, Chil's three words are relational ones: they do not communicate much on their own, but make sense only in a conversational situation. Together with a host of non-verbal means such as facial expressions and gesture, Chil employs his minimal vocabulary to couple with his interlocutors' communicative activity. In this way, he is able to coordinate, support, supplement, and sometimes reject his interlocutors' utterances (Goodwin, 2011). Similarly, Dressler et al. (2009) have quantified prosodic patterns in conversations with aphasic patients. They report that conversation with familiar interlocutors displays overall prosodic rhythms which are much more fluent and regular than conversations with unfamiliar interlocutors. Together, these findings suggest that even in the case of quite extreme impairments (perturbations), the dialog – as a synergetic system – can compensate in order to preserve its functionality.

4. Discussion: a synergetic framework for the investigation of conversation

In this paper, we have proposed a model of dialog as interpersonal synergy, focusing especially on the conceptual implications and the predictions for new studies, which this model generates. We have argued that when studying language in its dialogical and social nature we have to be aware of how the context structures the

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linguistic exchange in a functional way and how systemic constraints emerge as the interlocutors engage with each other. Indeed, the functional context has been shown to affect both the procedural aspects of dialog and its contents, for instance, by selectively driving the attention to specific semantic dimensions: spatial coordinates in the maze game or degrees of confidence in the joint decision task. We have also argued that realizing a function most often implies both selective alignment and complementary dynamics: we take turns in speaking, we contribute to each other's perspectives and we develop routines to effectively structure the interaction without redundancies. From this perspective we predict differential roles for alignment depending on how well important task dimensions are already stabilized in the structure and vocabulary of a conversation.

The model of synergy implies dimensional compression, which can be manifested in different ways. While certain aspects of coordination – postural sway or heart rate synchronization – are dominated by the progressive entrainment of two individual components, other linguistic parameters are better characterized as one behavioral sequence generated by the interpersonal system as a whole. This observation has important consequences for the structure of information we can retrieve from individual behaviors and from the dyad. Finally, the model of dialog as synergy brings us to focus on the temporal dimension of the linguistic interaction. In a scientific study of dialog, we need to develop and apply methods, which are sensitive to the development and change of patterns over time. We have shown some preliminary empirical support for this model: the complex coordination of turn-taking, the development of interactional routines, and of linguistic expressions as symbolic constraints. Finally, by pointing to the existence of the reciprocal compensatory mechanisms in interacting dyads, we hope to have made the case that linguistic behaviors in dialog cannot be accounted for solely by reference to the individuals, but have to be sought also at the level of functionally structured dyadic system.

We have proposed a very general model for the study of dialog and communication. By relying on evidence from situations of cooperative dialogs, we have emphasized dynamics of common timing, smooth complementarity, and flexible context adjustment. It is possible that other types of discourse, such as conflictual dialogs, display slightly different dynamics. We do, however, believe that coordination is at work even in conflict: a certain agreement on what is at stake, a certain complementarity in refuting each other, etc. (on these lines cf. Loan & Dale, 2011; Paxton & Dale, 2011). No doubt more experimental work is needed to further test the predictions of the model and to extend it to other genres of conversations. We hope this article paves the way for such investigations.

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