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ORIGINAL RESEARCH REPORT

Procedural Coordination in the Matching Task

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Participants in conversation who recurrently discuss the same targets require fewer and fewer words to identify them. This has been attributed to the collaborative elaboration of conceptual pacts, that is, semantic coordination. But participants do not only coordinate on the semantics of referring expressions; they also coordinate on how to do the task, that is, on procedural coordination. In a matching task experiment (n = 22 dyads), we examined the development of four aspects of procedural coordination: Card placement (CP), implicit generic coordination (IGC), explicit generic coordination (EGC) and general procedural coordination (GPC) in two conditions (the classic condition where targets remain the same over trials, and a new cards condition, where they change at each trial, thus increasing the difficulty of semantic coordination). Procedural coordination constituted almost 30% of the total amount of talk in the matching task. Procedural coordination was more effortful when semantic coordination was more difficult and the four aspects of procedural coordination developed differently depending on participant roles.

Keywords: collaborative referring; dialogue; conversation; matching task; conceptual pact; procedural coordination

1. Introduction

Dialogue is a species of joint activity during which two or more people collaborate to make themselves understood to one another. While dialogue can be studied in its own right, it is often produced in the context of other joint activities, which it serves to coordinate (Bangerter & Clark, 2003; Clark, 1996; Gambi & Pickering, 2011). For example, participants may engage in dialogue to reach a common goal such as planning a trip, or deciding on how to move a bench. The fundamental unit of dialogue is a contribution (Clark & Wilkes-Gibbs, 1986; Clark & Schaefer, 1989; Clark & Brennan, 1991), which is composed of two phases, a presentation phase and an acceptance phase. In the presentation phase, a speaker produces an utterance. During the acceptance phase, the addressee either accepts the utterance as understood well enough for current purposes, for instance by saying *okay* or by nodding, or initiates a repair sequence (Drew, 1997), during which both partners attempt to determine what the meaning of the initial presentation was. Contributions to dialogue become part of participants' common ground, or mutual knowledge (Brown-Schmidt, 2012; Clark, 1996; Clark & Marshall, 1981). As successive contributions to dialogue accumulate, then, participants' common ground base is enlarged, and it becomes easier to engage in subsequent dialogue. This is most notably evidenced in a process called lexical entrainment (Garrod & Anderson, 1987; Van der Wege, 2009), whereby interaction partners progressively come to use the same words to refer to recurrent objects (e.g., tools in a manual task or patients in a hospital). On some accounts, lexical entrainment occurs because participants infer from their common ground that their current partner is capable of understanding these words. Lexical entrainment is a key phenomenon used to support prominent models of dialogue, although in different ways. In the interactive alignment model (Pickering & Garrod, 2004), it is evidence for priming mechanisms that serve to align representations of conversational partners. In the grounding model (Clark & Brennan, 1991), it corresponds to the establishment of conceptual pacts: Partners negotiate conventional agreements about how to refer to recurrent objects in a task. These conventions are normative; partners are expected to continue to use them, even when they may be overly informative in a novel context (Brennan & Clark, 1996).

Lexical entrainment has mainly been examined in experiments involving the *matching task* (or some kind of variation of it, e.g., Clark & Wilkes-Gibbs, 1986; Horton & Gerrig, 2005; Hupet, Seron, & Chantraine, 1991; Knutsen, Ros, & Le Bigot, 2018; Krauss & Weinheimer, 1966; Schober & Clark, 1989; Swets, Jacovina, & Gerrig, 2013; Tolins, Zeamer, & Fox Tree, 2018; Yoon & Brown-Schmidt, 2014). In this task, one participant (the Director) describes pictures (often abstract humanoid figures) to another participant (the Matcher), enabling the latter to rearrange these pictures in a predefined order. The task is repeated several times; the participants use the same set of pictures

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(in a different order) on each trial. Over trials, participants become more efficient, as the number of words and turns necessary to complete the task is reduced. This finding has been attributed to the participants negotiating conceptual pacts (i.e., specific labels to refer to the figures, such as *the guy in the boat*) in initial trials, thereby reducing the need for explicit negotiation in subsequent trials.

However, successful coordination that leads to a reduction of collaborative effort (fewer words, fewer turns) may not be entirely due to the effects of conceptual pacts. Mills (2014) distinguished between semantic and procedural coordination. Semantic coordination involves the development of conventional referring expressions via lexical entrainment and conceptual pacts. In turn, this may require participants to coordinate on the meaning of the constituent elements of those expressions, adapting the meaning of specific words to the specific context at hand. Procedural coordination concerns how to time and sequence individual contributions in order to progress in the task. In the matching task, for example, participants often need to come to an agreement about the order in which to place the cards. They may explicitly describe the spatial aspects of how the cards are placed (e.g., a grid with two rows of six cards each), and they may subsequently use previously grounded descriptions when coordinating on the next step in the task (*the first card in the second row*, with the meaning of *the second row* being clear from its having been defined in previous trials). Participants may also coordinate progress within the task, signaling they are ready to continue (*next?*) or on the contrary that they need more time (*wait*). They may engage in more implicit means of coordinating progress between parts of the task, using different kinds of acknowledgment tokens (Bangerter & Clark, 2003). For example, they might use acknowledgment tokens like *okay* or *all right* to mark opening and closing of a task or subtask, or *uh-huh* or *yeah* to mark understanding of one particular step in the task. Each of these forms of procedural coordination may evolve over time. So it seems that gains in collaborative efficiency are not due to purely semantic coordination, but also to the development of procedural routines (Mills, 2014). Indeed, just like semantic coordination, procedural coordination in the matching task may require dialogue partners to negotiate how to perform the task to start with. This information is then added to their common ground, implying that they can rely on it for the remainder of the task without having to negotiate it again. Just like with semantic coordination, procedural coordination would thus result in a decrease in the amount of collaborative effort (number of words and turns produced to perform the task). However, the contribution of procedural coordination to dialogue during the matching task has seldom been investigated. In many studies, procedural coordination may have either been ignored or lumped together with semantic coordination (but see Doherty-Sneddon, Anderson, O'Malley, Langton, Garrod, & Bruce, 1997). The neglect of procedural aspects in the study of the matching task is unfortunate, because it leads to an overestimation of the gains in efficiency due to the effects of semantic coordination, that is, to the establishment of conceptual pacts. Indeed, increases in the efficiency of collaborative referring may be due in part to cognitive and interpersonal processes beyond the establishment of conceptual pacts (Bangerter, Mayor & Knutsen, in preparation).

2. The Development of Procedural Coordination in the Matching Task

Mills (2014, p. 159) suggested that "experimental approaches that do study the emergence of conventions in dialogue typically restrict their analyses to the study of referring conventions, also eschewing analysis of how the interactive routines that yield these referring conventions are established and sustained". He proposed (p. 158) that coordination in dialogue involves both "semantic coordination of referring expressions" and "procedural coordination of the timing and sequencing of contributions". Procedural coordination develops via a similar conventionalization process as semantic coordination, but participants progressively converge on routines with complementary role structures (i.e., adjacency pairs, Schegloff, 2007). Building on Mills (2014), we distinguish two kinds of procedural coordination, *specific* and *generic*.

Specific procedural coordination concerns the efforts participants need to deploy to fulfill the requirements of a particular task. A case of specific coordination is Mills' (2014) analysis of a dyadic maze game. Participants progressed through three stages of increasing coordination. First, they overtly negotiated complementary roles (e.g., *you do X and I do Y*) to create basic couplings of their actions. Then, they developed a finer-grained sense of the activity and established the sequential junctures (Schegloff, 2007) where particular contributions were relevant. Finally, there emerged a contracted set of often idiosyncratic terms to refer to particular moves in the task, also with particular instrumental actions (e.g., opening a gate in the maze) acquiring a communicative meaning. In the similar Map task setting, Doherty-Sneddon and colleagues (1997) described various procedural routines or "games" that participants could use to complete the task. More generally, procedural coordination routines emerge in a context-specific way whenever recurrent joint actions are performed (Fusaroli, Rączaszek-Leonardi, & Tylén, 2014). A primary site for this concerns work in organizations (Malone & Crowston, 1990). Recurrent work tasks in organizations are typically prepackaged via coordination mechanisms like plans and rules, physical objects, roles that enable division of labor, or physical proximity (Okhuysen & Bechky, 2009). This leads to a highly specialized system geared towards optimal performance. For example, pit stop crews in Formula One racing use dedicated equipment (e.g., signaling boards, pneumatic wrenches) and roles (e.g., tire changers, jack men, the lollipop man) to consistently attain top performance (i.e., completing refueling and tire change within seconds) within a complex, institutionalized task environment.

Beyond specific coordination germane to a particular task, however, any kind of joint action poses similar basic coordination problems; these problems are addressed by dialogue partners through *generic procedural coordination.*

Because human beings have been coordinating joint action for a long time, language use has evolved to serve coordination (Clark, 1996; Levinson, 2006; Smith, 2010; Tomasello, 2008). As a result, natural languages provide users with procedures and conventional solutions for coordinating joint action. The turn-taking system (Holler, Kendrick, Casillas, & Levinson, 2015), for example, is a set of procedures for solving the problem of who is to speak when, i.e., avoiding too-long gaps in the floor, as well as overlap between speakers (Sacks, Schegloff, & Jefferson, 1974). Another example is the existence of universal procedures for repairing the ubiquitous problem of misunderstandings in conversation, as evidenced by the word *huh* which is used as an open-class repair initiator (Drew, 1997) in multiple languages (Dingemanse, Torreira, & Enfield, 2013). A further example relevant for the current analysis of the matching task is how discourse markers like *oh*, *and*, *but*, *so* or *well* or acknowledgment tokens like *uh-huh*, *mhm*, *yeah*, *right*, *okay* and *all right* form a conventional system of contrasts for signaling transitions within and between parts of an action structure (Bangerter & Clark, 2003; Schiffrin, 1987). Participants tend to produce *okay* and *all right* to signal transitions between large action units (i.e., to open and close actions), whereas they tend to use *mhm*, *uh-huh* or *yeah* to punctuate transitions from one step to the next within an action unit. Participants engaged in the matching task tend to use *okay* less and less often to mark the end of card description and placement sequences as they repeat the task. As their common ground accumulates and identifying cards becomes easier, the placement of each card becomes more and more like a brief step in an action sequence rather than an action in itself (Bangerter & Clark, 2003). Acknowledgment tokens used as signals of transitions from one task step to the next constitute efficient ways to solve a fundamental problem in all joint activities, namely coordinating progress.

To summarize, specific and generic procedural coordination likely constitute important demands on participants' conversation in joint action. Currently, however, little research has been undertaken in order to understand the unique contribution of procedural coordination to reducing collaborative effort in dialogue, separate from that of semantic coordination (Clark & Wilkes-Gibbs, 1986). What is more, to our knowledge, the distinction between generic and specific procedural coordination has not yet been explored in the matching task.

3. This Study: Procedural Coordination in the Matching Task

With this study, we make three contributions to the literature on collaborative referring using the matching task. The first contribution is to quantify the amount of communication dedicated to procedural coordination. Given the ubiquity of the matching task in research on collaborative referring, it is important to attribute communication to the correct coordination demands, especially given that previous analyses have tended to implicitly assume that communication is exclusively dedicated to semantic coordination (but see Mills, 2014). The second contribution is to establish and explore a conceptual distinction between (task-) specific and generic forms of procedural coordination, and to quantify the relative amounts of communication dedicated to each of them. The third contribution is to explore the relation between procedural and semantic coordination in the matching task, that is, whether procedural and semantic coordination are independent from each other, or linked to each other. For example, if semantic coordination becomes more difficult, will this affect procedural coordination as well?

Because participants in the classic version of the matching task quickly converge on conceptual pacts, the development of procedural coordination is inescapably confounded with increasing semantic coordination. Investigating this third issue thus requires a dataset where semantic coordination can be varied systematically. We used a matching task corpus (transcripts from Experiment 1, Bangerter et al., in preparation) where participants completed the task in either of two conditions: The classic (or control) condition, where cards did not change over trials, and new cards condition, where they placed a new set of cards on each trial. In the new cards condition, participants are not able to establish conceptual pacts about recurring objects of reference. In other words, unlike in the classic condition, it is difficult to achieve semantic common ground, despite them being able to achieve procedural common ground (as they perform the same task in each trial). Bangerter et al. (in preparation) found that, although lexical diversity decreased somewhat over trials in the new cards condition, collaborative effort did not. Thus, the new cards condition offers an opportunity to compare procedural coordination development in two situations of differing difficulty of semantic coordination, and thus whether semantic and procedural coordination are independent from each other.

We operationalized four aspects of procedural coordination. First, (*task-*) *specific* procedural coordination was communication relative to placing the cards (hereafter *card placement* or CP). The experimental instructions required placing eight cards in a grid with two rows and four columns. Card placement thus involves agreeing on the order in which to proceed, or once this has been achieved, mentioning a card's place. We operationalized *generic* procedural coordination as communication relative to progress within the task that would be similar in any kind of joint task. Generic procedural coordination has two sub-aspects. One is *explicit* generic coordination (EGC), i.e., queries and answers about whether both partners are ready to move on. The other is *implicit* generic coordination (IGC), involving the various acknowledgment tokens used to mark transitions from one step of the task to the next (Bangerter & Clark, 2003; by implicit we mean that the words used do not explicitly topicalize progress in the task). Each of these three forms of coordination can be produced in a discussion about a particular figure, and we thus coded the extent they were manifested in the participants' talk. However, a fourth aspect concerns the fact that participants can also discuss coordination requirements in a general manner that is independent of a specific figure, e.g., they may discuss how to do the task in general. We also coded this fourth aspect (hereafter referred to as *general procedural coordination*, or GPC).

Procedural coordination involves the development of complementary roles (Mills, 2014). In the matching task, Directors and Matchers make different contributions to semantic coordination according to their roles (Clark & Wilkes-Gibbs, 1986). If they do so in procedural coordination as well, this may entail their making particular contributions more or less frequently. For example, Directors may be in a better position to discuss card placement, whereas Matchers may naturally communicate about whether they are ready to move on to the next card. For all analyses, we therefore distinguished between contributions made by Directors and by Matchers.

4. Method

4.1. Participants

Participants (N = 44 native French speakers, 25 women) were recruited from the student body of a Swiss university. They completed the experiment in dyads in exchange for compensation of 10 CHF each. They were scheduled to arrive together, and were randomly allocated to either the director or matcher role. Dyads were randomly allocated to either the classic condition or the new cards condition. As we expected more variance in the new cards condition, 14 dyads were allocated to it, whereas 8 dyads were allocated to the classic condition.

4.2. Procedure and materials

Participants read and signed informed consent forms upon arriving in the lab. They then arranged a set of eight cards depicting humanoid tangram shapes as used in other matching task experiments. These were displayed to participants on a computer screen in two rows of four columns using a program we developed in Flash (Action Script). While the directors' view included cards already in placement slots, matchers saw their placement slots displayed above the cards. They moved cards to the slots by clicking and dragging them. Directors' cards could not be moved. When they were done with a trial, they each pressed a blue button on their screen to move on to the next trial. Participants first completed a practice trial where they placed eight cards depicting everyday objects (e.g., sneakers), so that they could familiarize themselves with the task in both conditions. Then, in the main experiment, for 5 trials, they placed eight cards with tangram figures (the same set for both of them but in a different order). The main experiment used a pool of 40 different tangram figures. In the classic condition, participants arranged the same set of cards on each trial (cards were drawn randomly from the pool and the order of the cards was randomized at each trial). In the new cards condition, eight cards were drawn without replacement from the pool on each trial. After having completed the task, participants were debriefed, paid, and dismissed.

4.3. Experimental design and dependent variables

There were three main independent variables (IVs) in this study. The first one was condition, which had two levels (between-subjects): classic and new cards. The second was trial number (five levels; within-subjects). Both linear and quadratic trends of trial number were tested (both were centered to simplify the interpretation of the results). We included quadratic trends to be able to detect nonlinear phenomena (e.g., a particular coordination variable decreases over trials but then increases again at the end of the experiment), which are quite common in matching task data (e.g., Clark & Wilkes-Gibbs, 1986). The third independent variable was participant role (within-subjects), which had two levels: Director and Matcher.

Four dependent variables (DVs) were examined, each measuring a specific aspect of procedural coordination. The first DV was whether or not the participant used card placement (CP) talk (e.g., *that one goes on the first row* or *it's the second card*) while discussing tangram figures during a trial. The second DV was whether or not the participant used implicit generic coordination (IGC) while discussing each tangram figure during a trial. This was defined as being largely analogous to the project markers investigated by Bangerter and Clark (2003), but included a wider range of words participants used to ground instructions and more generally mark progress in the task. Frequent examples (in French) include *ouais*, *okay*, *mhm*, *alors*, *bon*, *donc*, *d'accord exactement*, *cool*, or *parfait*. The third DV was whether or not the participant used explicit generic coordination (EGC), i.e., explicitly talked about progress while discussing a tangram figure. This category includes phrases like *shall we start?*, *got it*, *I see it*, or *are you finished?* It also includes single-word utterances explicitly related to coordination progress, e.g., *then* or *next*. Finally, it also includes elements of repair sequences relative to figure descriptions like *I don't understand* or *want me to repeat?* For these three DVs, we coded the number of words used in talk about each tangram figure. The fourth DV was general procedural coordination (GPC), defined as procedural coordination of any of the above types that was not relative to a specific figure. Examples include suggestions about how to proceed in general (*now second row* or *I think it's easier if you tell me*) or coordinating the end of the trial, after having placed the last card (*blue button?*, *are we done?*). Contrary to the three other DVs, we coded the number of words at the trial level rather than at the figure level.

To check interrater agreement, we double-coded data on CP, IGC and EGC from two dyads (one in each condition), and computed the correlations between the number of words coded by each coder for each turn (n = 422 turns). Because our primary measures (i.e., before transformation) are ratio-scale variables coded by two coders, we computed correlation coefficients as a measure of interrater agreement. Interrater agreement was generally high (r = .68 for CP, r = .97 for IGC, r = .87 for EGC, all ps < .001) Disagreements were resolved by discussion. A dialogue example illustrating how talk corresponds to the four aspects of procedural coordination is provided in **Table 1**.

We performed initial analyses to relate the prevalence of each type of procedural coordination to the overall collaborative effort in terms of word count. We then transformed these word counts into binary data, i.e., whether or not, for each figure, a specific type of procedural coordination (CP, IGC or EGC) was used as highlighted above.[1] Further, we computed whether or not, for each

Table 1: Dialogue Example Illustrating Card Placement Coordination, Implicit Generic Coordination, Explicit Generic Coordination and General Procedural Coordination.

Role	Talk	English translation	CP	IGC	EGC	GPC
M	*Ensuite j'en ai un qui est courbé ?*	*Next I have one that's bent over?*	–	–	*Next*	–
D	*Qui est courbé il est troisième, ligne en haut.*	*That's bent over he's third, top row*	*he's third, top row*	–	–	–
M	*Ouais*	*Yeah*	–	*Yeah*	–	–
D	*Voilà y'en a un qui a un grand dos un peu*	*That's it. There is one with a large back kind of*	–	*That's it*	–	–
M	*Ouais*	*Yeah*	–	*Yeah*	–	–
D	*Qui baisse la tête*	*Who's lowering his head*	–	–	–	–
M	*Ouais*	*Yeah*	–	*Yeah*	–	–
D	*Celui-ci c'est quatrième case en haut.*	*This one is fourth slot on top*	*This one is fourth slot on top*	–	–	–
M	*Donc ouais, ouais.*	*So yeah yeah*	–	*So yeah yeah*	–	–
D	*Pis le dernier bizarre que j'essayais de t'expliquer…*	*And the last weird one I tried to explain to you*	–	–	–	–
M	*D'accord*	*Okay*	–	*Okay*	–	–
D	*C'est le deuxième.*	*Is the second one*	*Is the second one*	–	–	–
M	*On valide ?*	*Shall we confirm?*	–	–	–	*Shall we confirm?*
D	*On valide.*	*Let's confirm*	–	–	–	*Let's confirm*

Note: Example from Dyad 6, new cards condition, Trial 1. English translations of French acknowledgment tokens and discourse markers vary; in such cases, we chose to prioritize functional/colloquial equivalence over literal meaning. CP: card placement. IGC: Implicit generic coordination. EGC: Explicit generic coordination. GPC: General procedural coordination.

figure, general procedural coordination (GPC) was used by combining the binary data on CP, IGC and EGC in a trial that was not related to the identification and placement of a specific figure (for example, CP talk not related to a specific figure might include utterances like *there are two cards left*).

4.4. Data analysis

The data were analyzed using logistic mixed models in SAS 9.4 (GLIMMIX procedure). Mixed models allow including random intercepts (accounting for the potential variability across dyads, across participants and across items) and random slopes (accounting for the fact that dyads, participants and items may differ in their sensitivity to any within-units IVs in the design) (Baayen, Davidson, & Bates, 2008; Barr, Levy, Scheepers, & Tily, 2013; Jaeger, 2008). We used logistic models because the four DVs were binary (Agresti, 2002; Jaeger, 2008).

Four sets of analyses were conducted – one per DV. Each set followed a rationale similar to that used by Bangerter et al. (in preparation). Specifically, in each set, we started by running an analysis which included participant role as the only IV. The purpose of this was to determine whether one of the roles was more likely to resort to the kind of coordination considered in the analysis. We then analyzed the data separately for Directors and Matchers (we decided not to run a single analysis including participant role and all other IVs in order to make the results easier to interpret). Significant interactions were interpreted based on the corresponding *b* coefficient.

In line with Barr et al.'s (2013) suggestion, all models included the maximal random effects structure justified by the design. Here, the maximal random effects structure would include by-dyad, by-participant and by-item (i.e., by-figure) random intercepts, as well as random slopes corresponding to all within-dyad, within-participant or within-item IVs (although note that by-participant random effects were not included in the models when the participants' data [Directors and Matchers] were analyzed separately). However, doing so often caused the models to fail to converge. Most convergence issues arising in mixed modelling are caused by random effects (random intercepts and/or slopes) that prevent the G-matrix of the model from converging. Removing these effects from the model usually solves all convergence issues (problematic random effects are identified automatically in SAS; Kiernan, Tao, & Gibbs, 2012). The results reported in this section thus correspond to the final models from which all problematic random effects were removed. The equation of the final model is provided for each analysis; a list of the symbols used in the equations is provided in **Table 2**.

5. Results

5.1. Prevalence of procedural coordination in matching task conversations

As an initial descriptive analysis, **Table 3** shows the mean number of words dedicated to each type of procedural coordination and the total amount of words produced to complete the task by condition. Together, the four types of procedural coordination make up 29.7% of the total amount of words in the classic condition and 28.9% of the total amount of words in the new cards condition. Thus, a substantial proportion of matching task conversation is dedicated to procedural coordination.[2]

Table 2: Symbols Used in the Equations.

Symbol	Description
β_0	Fixed intercept
β_1	Fixed slope (role)
β_2	Fixed slope (condition)
β_3	Fixed slope (trial – linear)
β_4	Fixed slope (trial – quadratic)
β_5	Fixed slope (condition × linear)
β_6	Fixed slope (condition × quadratic)
D_0	By-dyad random intercepts
P_0	By-participant random intercepts
I_0	By-item random intercepts
D_1	By-dyad random slopes (role)
D_2	By-dyad random slopes (condition)
D_3	By-dyad random slopes (trial – linear)
D_4	By-dyad random slopes (trial – quadratic)
P_1	By-participant random slopes (role)
P_2	By-participant random slopes (condition)
P_3	By-participant random slopes (trial – linear)
P_4	By-participant random slopes (trial – quadratic)
I_1	By-item random slopes (role)
I_2	By-item random slopes (condition)
I_3	By-item random slopes (trial – linear)
I_4	By-item random slopes (trial – quadratic)
d	Dyad
p	Participant
i	Item
π	Probability of an event occurring

Note: d, *p* and *i* are used as subscripts in the equations.

5.2. Card placement (CP) coordination

5.2.1. Effect of role on card placement (CP) coordination

The probability of card placement coordination occurring was .69 (SD = .47) in the talk of Directors and .16 (SD = .37) in the talk of Matchers. The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + P_{0p} + \beta_1 X_1 + e_{dpi}$$

As shown in **Table 4**, Directors were significantly more likely to resort to card placement coordination than Matchers. Following this initial analysis, Director and Matcher data were considered separately.

5.2.2. Effect of condition and trial number on card placement (CP) coordination in Directors only

The data corresponding to this analysis are shown in **Figure 1**.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + \left(\beta_2 + I_{2p}\right)X_2 + \left(\beta_3 + D_{3d} + I_{3p}\right)X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

As shown in **Table 5**, only a significant negative quadratic trend was found.

Table 3: Mean Number of Words per Dyad (SDs) for Explicit Generic Coordination, Implicit Generic Coordination, Card Placement Coordination, General Procedural Coordination, and Task Completion in Total.

	Classic condition		New cards condition	
	Mean	**SD**	**Mean**	**SD**
EGC	36.63	19.61	97.00	73.33
IGC	88.25	39.68	238.14	106.08
CP	83.00	39.70	250.21	152.24
GPC	43.50	42.55	72.57	40.62
Total	846.37	338.18	2273.28	857.89

Note: EGC: Explicit generic coordination. IGC: Implicit generic coordination. CP: card placement. GPC: General procedural coordination. Total: Total amount of words produced for task completion.

Table 4: Model Parameters, F statistic and Odds Ratio for Card Placement Coordination.

	***b* (*SE*)**	***p* value for *b* (fixed effects)**	***df* Num, Den (fixed effects)**	***F***	***p* value for *F* (fixed effects)**	***OR* (95% C.I.)**
Random effects						
By-dyad random intercepts	0.87 (0.64)					
By-participant random intercepts	1.56 (0.60)					
Fixed effects						
Intercept (fixed)	–2.10 (0.36)	<.001				
Role: Director	3.40 (0.42)	<.001	1, 21	66.71	<.001	30.01 (12.62; 71.36)

Note: Num: Numerator. Den: Denominator. OR: Odds ratio.

5.2.3. Effect of condition and trial number on card placement (CP) coordination in Matchers only

The data corresponding to this analysis are shown in **Figure 2**.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

As shown in **Table 6**, card placement coordination was significantly less likely to occur in the classic condition than in the new cards condition. There was also a significant negative linear trend and a significant positive quadratic trend. Finally, there was a significant linear trend by condition interaction (the linear trend was significant in the classic condition only).

5.3. Implicit generic coordination (IGC)

5.3.1. Effect of role on implicit generic coordination (IGC)

The probability of IGC occurring was 0.61 (SD = .49) for Directors, and .92 (SD = .28) for Matchers. The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + P_{0p} + I_{0i} + \beta_1 X_1 + e_{dpi}$$

As shown in **Table 7**, Directors were significantly less likely to resort to IGC than Matchers. Following this initial analysis, Director and Matcher data were considered separately.

5.3.2. Effect of condition and trial number on implicit generic coordination (IGC) in Directors only

The data corresponding to this analysis are shown in **Figure 3**.

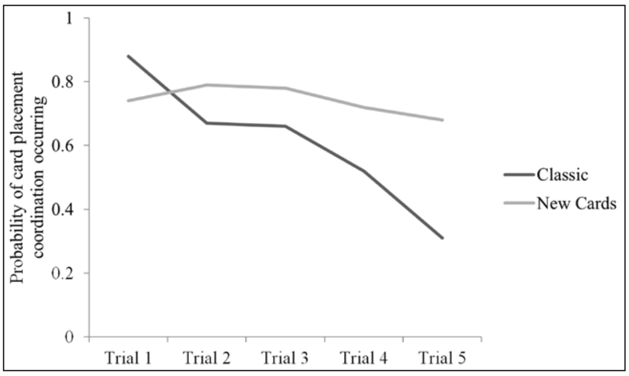

Figure 1: Director data – Probability of card placement coordination occurring as a function of condition and trial number.

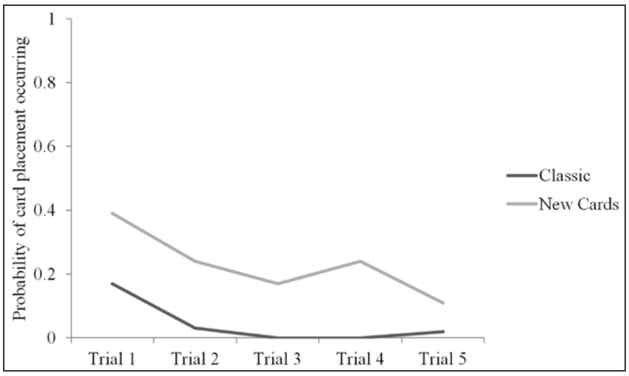

Figure 2: Matcher data – Probability of card placement coordination occurring as a function of condition and trial number.

Table 5: Model Parameters, F statistics and Odds Ratios for Card Placement Coordination – Director Data Only.

	b (*SE*)	*p* value for *b* (fixed effects)	*df* Num, Den (fixed effects)	*F*	*p* value for *F* (fixed effects)	*OR* (95% C.I.)
Random effects						
By-dyad random intercepts	4.07 (1.53)					
By-dyad random slopes corresponding to the linear trend	0.22 (0.11)					
By-item random slopes corresponding to condition	0.15 (0.14)					
By-item random slopes corresponding to the linear trend	0.02 (0.05)					
Fixed effects						
Intercept (fixed)	1.81 (0.58)	.005				
Condition: C	–1.14 (0.94)	.228	1, 78	1.48	.228	0.32 (0.05; 2.07)
Linear trend	0.70 (0.49)	.171	1, 18	0.62	.442	C: 0.93 (0.28; 3.12) NC: 2.01 (0.77; 5.24)
Quadratic trend	–0.13 (0.08)	.092	1, 725	4.12	.043	C: 0.88 (0.73; 1.07) NC: 0.88 (0.75; 1.02)
Linear trend × condition: C	–0.77 (0.79)	.326	1, 725	0.96	.326	
Quadratic trend × condition: C	<0.01 (0.13)	.968	1, 725	<0.01	.968	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

Table 6: Model Parameters, F statistics and Odds Ratios for Card Placement Coordination – Matcher Data Only.

	b **(*SE*)**	***p*** **value for *b* (fixed effects)**	***df*** **Num, Den (fixed effects)**	***F***	***p*** **value for *F* (fixed effects)**	***OR*** **(95% C.I.)**
Random effects						
By-dyad random intercepts	1.12 (0.46)					
Fixed effects						
Intercept (fixed)	–1.54 (0.31)	<.001				
Condition: C	–2.64 (0.74)	<.001	1, 854	12.89	<.001	0.07 (0.02; 0.30)
Linear trend	–0.74 (0.40)	.064	1, 854	9.38	.002	C: 0.02 (<0.01; 0.33) NC: 0.48 (0.22; 1.04)
Quadratic trend	0.06 (0.07)	.372	1, 854	5.05	.025	C: 1.77 (1.04; 3.01) NC: 1.06 (0.93; 1.21)
Linear trend × condition: C	–3.39 (1.59)	.034	1, 854	4.53	.034	
Quadratic trend × condition: C	0.51 (0.28)	.070	1, 854	3.30	.070	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

Table 7: Model Parameters, F statistic and Odds Ratio for Implicit Generic Coordination.

	b **(*SE*)**	***p*** **value for *b* (fixed effects)**	***df*** **Num, Den (fixed effects)**	***F***	***p*** **value for *F* (fixed effects)**	***OR*** **(95% C.I.)**
Random effects						
By-dyad random intercepts	0.42 (0.42)					
By-participant random intercepts	1.16 (0.49)					
By-item random intercepts	0.07 (0.06)					
Fixed effects						
Intercept (fixed)	2.88 (0.32)	<.001				
Role: Director	–2.30 (0.38)	<.001	1, 21	37.61	<.001	0.10 (0.05; 0.22)

Note: Num: Numerator. Den: Denominator. OR: Odds ratio.

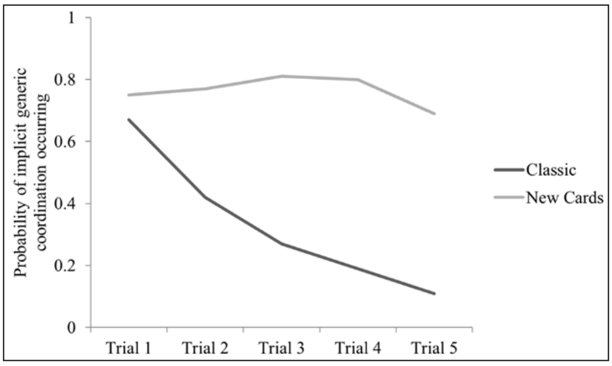

Figure 3: Director data – Probability of implicit generic coordination occurring as a function of condition and trial number.

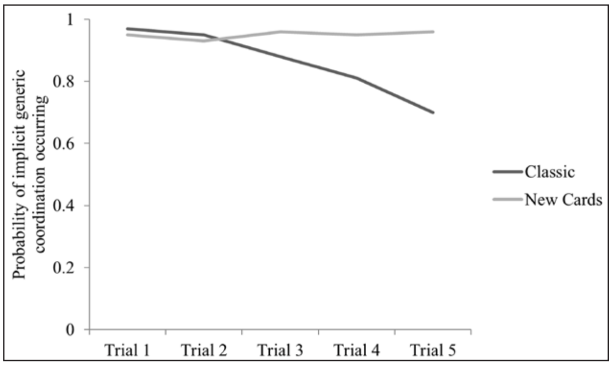

Figure 4: Matcher data – Probability of implicit generic coordination occurring as a function of condition and trial number.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + I_{0i} + (\beta_2 + I_{2i})X_2 + (\beta_3 + D_{3d} + I_{3i})X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

As shown in **Table 8**, implicit generic coordination was significantly less likely to occur in the classic condition than in the new cards condition. Further, there was a significant linear trend by condition interaction (a negative linear trend which was significant in the classic condition only) and a significant quadratic trend by condition interaction (there was a negative quadratic trend which was significant in the new cards condition only).

5.3.3. Effect of condition and trial number on implicit generic coordination (IGC) in Matchers only

The data corresponding to this analysis are shown in **Figure 4**.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + \beta_2 X_2 + (\beta_3 + D_{3d}) X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

As shown in **Table 9**, all effects failed to reach statistical significance.

5.4. Explicit generic coordination (EGC)

5.4.1. Effect of role on explicit generic coordination (EGC)

The probability of explicit generic coordination occurring was .37 (SD = .48) for directors, and .30 (SD = .46) for matchers. The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + P_{0p} + I_{0i} + (\beta_1 + I_{1i}) X_1 + e_{dpi}$$

Table 8: Model Parameters, F statistics and Odds Ratios for Implicit Generic Coordination – Director Data Only.

	***b* (*SE*)**	***p* value for *b* (fixed effects)**	***df* Num, Den (fixed effects)**	***F***	***p* value for *F* (fixed effects)**	***OR* (95% C.I.)**
Random effects						
By-dyad random intercepts	0.56 (0.25)					
By-dyad random slopes corresponding to the linear trend	0.01 (0.03)					
By-item random intercepts	0.06 (0.15)					
By-item random slopes corresponding to the condition	0.11 (0.17)					
By-item random slopes corresponding to the linear trend	0.04 (0.04)					
Fixed effects						
Intercept (fixed)	1.34 (0.24)	<.001				
Condition: C	–2.21 (0.39)	<.001	1, 58	32.35	<.001	0.11 (0.05; 0.24)
Linear trend	0.78 (0.39)	.064	1, 18	0.67	.424	C: 0.27 (0.10; 0.73) NC: 2.17 (1.00; 4.70)
Quadratic trend	–0.14 (0.06)	.031	1, 725	0.13	.720	C: 1.11 (0.94; 1.30) NC: 0.87 (0.77; 0.99)
Linear trend × condition: C	–2.07 (0.63)	.001	1, 725	10.68	.001	
Quadratic trend × condition: C	0.24 (0.11)	.025	1, 725	5.05	.025	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

Table 9: Model Parameters, F statistics and Odds Ratios for Implicit Generic Coordination – Matcher Data Only.

	***b* (*SE*)**	***p* value for *b* (fixed effects)**	***df* Num, Den (fixed effects)**	***F***	***p* value for *F* (fixed effects)**	***OR* (95% C.I.)**
Random effects						
By-dyad random intercepts	1.51 (0.78)					
By-dyad random slopes corresponding to the linear trend	0.14 (0.12)					
Fixed effects						
Intercept (fixed)	3.28 (0.41)	<.001				
Condition: C	–0.72 (0.66)	.274	1, 834	1.20	.274	0.49 (0.14; 1.77)
Linear trend	–0.36 (0.73)	.628	1, 20	1.09	.309	C: 0.44 (0.08; 2.41) NC: 0.70 (0.17; 2.92)
Quadratic trend	0.07 (0.12)	.534	1, 834	0.34	.559	C: 1.03 (0.80; 1.32) NC: 1.08 (0.85; 1.36)
Linear trend × condition: C	–0.47 (1.14)	.681	1, 834	0.17	.681	
Quadratic trend × condition: C	–0.05 (0.17)	.786	1, 834	0.07	.786	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

As shown in **Table 10**, no significant effect was found. Following this initial analysis, Director and Matcher data were analyzed separately.

5.4.2. Effect of condition and trial number on explicit generic coordination (EGC) in Directors only

The data corresponding to this analysis are shown in **Figure 5**.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + I_{0i} + \beta_2 X_2 + (\beta_3 + D_{3d}) X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

As shown in **Table 11**, EGC was significantly less likely to occur in the classic condition than in the new cards condition.

5.4.3. Effect of condition and trial number on explicit generic coordination (EGC) in Matchers only

The data corresponding to this analysis are shown in **Figure 6**.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + I_{0i} + (\beta_2 + I_{2i}) X_2 + (\beta_3 + D_{3d} + I_{3i}) X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

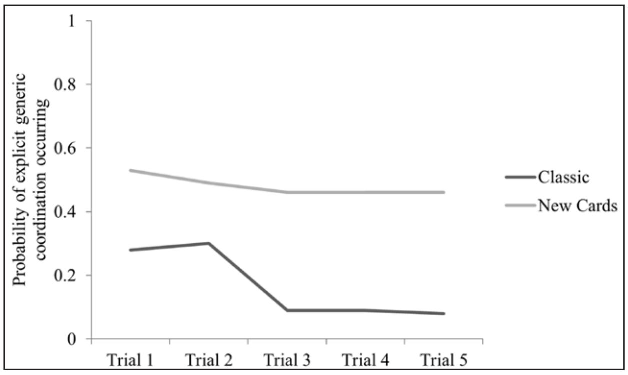

Figure 5: Director data – Probability of explicit generic coordination occurring as a function of condition and trial number.

Table 10: Model Parameters, F statistic and Odds Ratio for Explicit Generic Coordination.

	***b* (*SE*)**	***p* value for *b* (fixed effects)**	***df* Num, Den (fixed effects)**	***F***	***p* value for *F* (fixed effects)**	***OR* (95% C.I.)**
Random effects						
By-dyad random intercepts	0.59 (0.34)					
By-participant random intercepts	0.66 (0.25)					
By-item random intercepts	0.09 (0.06)					
By-item random slopes corresponding to role	0.01 (0.06)					
Fixed effects						
Intercept (fixed)	–1.01 (0.26)	.001				
Role: Director	0.34 (0.27)	.224	1, 21	1.57	.224	1.41 (0.80; 2.49)

Note: Num: Numerator. Den: Denominator. OR: Odds ratio.

Table 11: Model Parameters, F statistics and Odds Ratios for Explicit Generic Coordination – Director Data Only.

	***b* (*SE*)**	***p* value for *b* (fixed effects)**	***df* Num, Den (fixed effects)**	***F***	***p* value for *F* (fixed effects)**	***OR* (95% C.I.)**
Random effects						
By-dyad random intercepts	1.05 (0.38)					
By-dyad random slopes corresponding to the linear trend	0.03 (0.03)					
By-item random intercepts	0.13 (0.09)					
Fixed effects						
Intercept (fixed)	–0.11 (0.30)	.703				
Condition: C	–1.73 (0.50)	.001	1, 795	12.03	.001	0.18 (0.07; 0.47)
Linear trend	–0.26 (0.36)	.470	1, 18	1.44	.245	C: 0.58 (0.19; 1.78) NC: 0.77 (0.38; 1.55)
Quadratic trend	0.03 (0.06)	.595	1, 795	0.12	.727	C: 1.01 (0.83; 1.23) NC: 1.03 (0.92, 1.16)
Linear trend × condition: C	–0.28 (0.68)	.675	1, 795	0.18	.675	
Quadratic trend × condition: C	–0.02 (0.12)	.854	1, 795	0.03	.854	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

As shown in **Table 12**, EGC was significantly less likely to occur in the classic condition than in the new cards condition. A significant negative linear trend and a significant positive quadratic trend were also found. Finally, there was a significant linear trend by condition interaction (the linear trend was significant in the classic condition only) and a quadratic trend by condition interaction (the quadratic trend was significant in the classic condition only).

5.5. General procedural coordination (GPC)

5.5.1. Effect of role on general procedural coordination (GPC)

The probability of general procedural coordination occurring is .78 (SD = 0.42) in the talk of Directors and .73 (SD = 0.45) in the talk of Matchers.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + \beta_1 X_1 + e_{dpi}$$

As shown in **Table 13**, no significant effect of participant role was found. Following this initial analysis, Director and Matcher data were considered separately.

5.5.2. Effect of condition and trial number on general procedural coordination (GPC) in Directors only

The data corresponding to this analysis are shown in **Figure 7**.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + \beta_2 X_2 + (\beta_3 + D_{3d}) X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

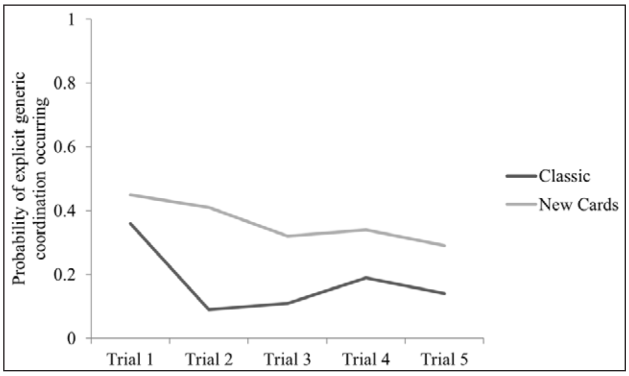

Figure 6: Matcher data – Probability of explicit generic coordination occurring as a function of condition and trial number.

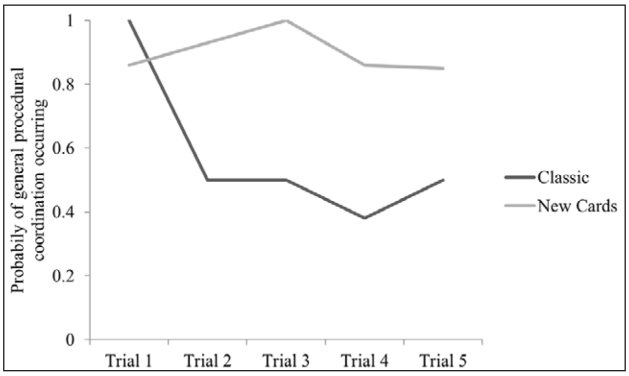

Figure 7: Director data – Probability of general procedural coordination occurring as a function of condition and trial number.

Table 12: Model Parameters, F statistics and Odds Ratios for Explicit Generic Coordination – Matcher Data Only.

	b **(*SE*)**	***p*** **value for *b* (fixed effects)**	***df*** **Num, Den (fixed effects)**	***F***	***p*** **value for *F* (fixed effects)**	***OR*** **(95% C.I.)**
Random effects						
By-dyad random intercepts	0.86 (0.32)					
By-dyad random slopes corresponding to the linear trend	0.02 (0.03)					
By-item random intercepts	0.04 (0.14)					
By-item random slopes corresponding to the condition	0.09 (0.16)					
By-item random slopes corresponding to the linear trend	0.04 (0.04)					
Fixed effects						
Intercept (fixed)	–0.68 (0.27)	.021				
Condition: C	–1.03 (0.46)	.029	1, 58	5.03	.029	0.36 (0.14; 0.90)
Linear trend	–0.33 (0.36)	.379	1, 18	8.96	.008	C: 0.19 (0.06; 0.56) NC: 0.72 (0.35; 1.47)
Quadratic trend	0.02 (0.06)	.717	1, 725	5.73	.017	C: 1.27 (1.06; 1.53) NC: 1.02 (0.91, 1.15)
Linear trend × condition: C	–1.34 (0.66)	.044	1, 725	4.07	.044	
Quadratic trend × condition: C	0.22 (0.11)	.046	1, 725	4.00	.046	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

As shown in **Table 14**, GPC was significantly less likely to occur in the classic condition than in the new cards condition. There was also a significant linear trend by condition interaction (there was a negative linear trend which was significant in the classic condition only) and a quadratic trend by condition interaction (there was a positive quadratic trend which was significant in the classic condition only).

5.5.3. Effect of condition and trial number on general procedural coordination (GPC) in Matchers only

The data corresponding to this analysis are shown in **Figure 8**.

The equation of the model used is

$$logit(\pi) = \beta_0 + D_{0d} + \beta_2 X_2 + (\beta_3 + D_{3d}) X_3 + \beta_4 X_3^2 + \beta_5 X_2 X_3 + \beta_6 X_2 X_3^2 + e_{dpi}$$

As shown in **Table 15**, a significant negative linear trend and a significant positive quadratic trend were found. There was also a significant linear trend by condition interaction (the slope was steeper in the classic condition than in the new cards conditions) and a quadratic trend by condition interaction (the trend was stronger in the classic condition than in the new cards condition).

6. Discussion

The purpose of this study was to quantify and qualify the role of procedural coordination in dialogue (e.g., Mills, 2014) during the matching task (Clark & Wilkes-Gibbs, 1986), which is heavily used in dialogue research. This study has produced four main findings (see **Table 16**).

First, although most researchers would probably agree that part of the participants' talk in the matching task involves procedural coordination, the exact amount of talk dedicated to procedural coordination (rather than

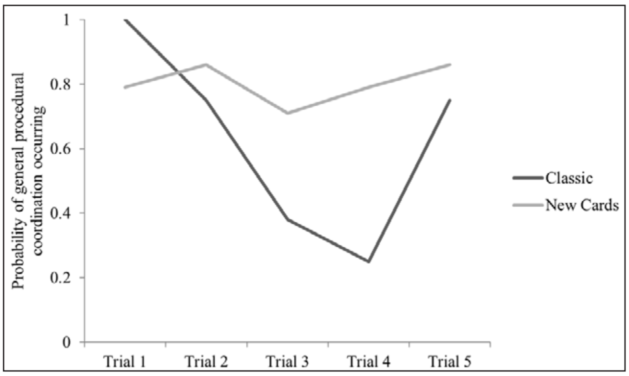

Figure 8: Matcher data – Probability of general procedural coordination occurring as a function of condition and trial number.

Table 13: Model Parameters, F statistic and Odds Ratio for General Procedural Coordination.

	b **(*SE*)**	***p*** **value for *b* (fixed effects)**	***df*** **Num, Den (fixed effects)**	***F***	***p*** **value for *F* (fixed effects)**	***OR*** **(95% C.I.)**
Random effects						
By-dyad random intercepts	1.66 (0.77)					
Fixed effects						
Intercept (fixed)	1.20 (0.37)	.004				
Role: Director	0.34 (0.35)	.325	1, 196	0.97	.325	1.41 (0.71; 2.81)

Note: Num: Numerator. Den: Denominator. OR: Odds ratio.

Table 14: Model Parameters, F statistics and Odds Ratios for General Procedural Coordination – Director Data Only.

	b **(*SE*)**	***p*** **value for *b* (fixed effects)**	***df*** **Num, Den (fixed effects)**	***F***	***p*** **value for *F* (fixed effects)**	***OR*** **(95% C.I.)**
Random effects						
By-dyad random intercepts	2.58 (1.50)					
By-dyad random slopes corresponding to the linear trend	0.05 (0.26)					
Fixed effects						
Intercept (fixed)	2.60 (0.66)	.001				
Condition: C	–1.98 (0.99)	.050	1, 63	4.00	.050	0.14 (0.02; 1.00)
Linear trend	1.96 (1.62)	.241	1, 20	0.97	.337	C: 0.01 (<0.01; 0.60) NC: 7.12 (0.28; 182.24)
Quadratic trend	–0.35 (0.27)	.197	1, 63	0.42	.517	C: 1.84 (1.09; 3.34) NC: 0.71 (0.42; 1.20)
Linear trend × condition: C	–6.45 (2.57)	.015	1, 63	6.30	.015	
Quadratic trend × condition: C	0.95 (0.40)	.020	1, 63	5.76	.020	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

Table 15: Model Parameters, F statistics and Odds Ratios for General Procedural Coordination – Matcher Data Only.

	b (*SE*)	*p* value for *b* (fixed effects)	*df* Num, Den (fixed effects)	*F*	*p* value for *F* (fixed effects)	*OR* (95% C.I.)
Random effects						
By-dyad random intercepts	1.67 (1.09)					
By-dyad random slopes corresponding to the linear trend	0.06 (0.23)					
Fixed effects						
Intercept (fixed)	1.59 (0.48)	.004				
Condition: C	–0.17 (0.95)	.860	1, 64	0.03	.860	0.85 (0.13; 5.63)
Linear trend	–0.61 (1.18)	.605	1, 20	8.70	.008	C: <0.01 (<0.01; 0.05) NC: 0.54 (0.05; 5.65)
Quadratic trend	0.11 (0.19)	.568	1, 64	8.59	.005	C: 3.82 (1.54; 9.48) NC: 1.12 (0.76; 1.64)
Linear trend × condition: C	–8.91 (3.44)	.012	1, 64	6.71	.012	
Quadratic trend × condition: C	1.23 (0.49)	.016	1, 64	6.17	.016	

Note: Num: Numerator. Den: Denominator. OR: Odds ratio. C: Classic condition. NC: New cards condition.

Table 16: Summary of the Results.

	Effect of role	Director data only	Matcher data only
CP	Director > Matcher	· Negative quadratic trend	· Classic < New cards · Negative linear trend in the classic condition · Positive quadratic trend in both conditions
IGC	Director < Matcher	· Classic < New cards · Negative linear trend in the classic condition · Negative quadratic trend in the new cards condition	· No significant effects found
EGC	No significant effect found	· Classic < New cards	· Classic < New cards · Negative linear trend in the classic condition · Positive quadratic trend in the classic condition
GPC	No significant effect found	· Classic < New cards · Negative linear trend in the classic condition · Positive quadratic trend in the classic condition	· Negative linear trend in both conditions · Positive quadratic trend in both conditions

Note: CP: card placement. IGC: Implicit generic coordination. EGC: Explicit generic coordination. GPC: General procedural coordination.

to semantic coordination) was previously unknown. The current study revealed that a substantial proportion of talk in matching task conversations (almost 30%) is dedicated to coordinating the activity itself and not to the establishment of referring conventions.

Second, a closer look at the results from the classic condition suggests that procedural coordination develops over trials. For Matchers, in this condition, where the establishment of conceptual pacts enables rapid completion of the task, explicit generic coordination, card placement coordination, and general procedural coordination decreased over trials. The only kind of procedural coordination that did not decrease for Matchers was implicit generic coordination, i.e., coordinating progress in the task via project markers (Bangerter & Clark, 2003). This remained at a high level (>0.90 probability of being used per figure) throughout the task, irrespective of experimental condition. It is noteworthy, however, that general procedural coordination and card placement coordination exhibited a quadratic trend in the classic condition. This may be due in part to explicit statements that the task was over at the end of the experiment (i.e., a kind of closing phase, as discussed in Bangerter & Clark, 2003).

For directors, findings in the classic condition were more complex. Directors' talk about explicit generic coordination in this condition showed no trends over trials, while their use of card placement and implicit generic coordination decreased over trials. On the other hand, their use of general procedural coordination was similar to Matchers' in the classic condition (i.e., decrease and an upswing in the last trial). Taken together, these findings suggest that in the classic version of the matching task, there are systematic trends in procedural coordination over trials. However, the trends depend on participants' roles.

Indeed, and third, there is a division of labor in the accomplishment of procedural coordination according to participants' roles, as suggested by Mills (2014). Because Directors' cards are in the correct order, they tend to talk more about card placement than Matchers. Matchers typically acknowledge Directors' descriptions, and so they produce more implicit generic coordination talk (and maintain high levels of such talk throughout). Directors typically enquire as to the possibility of continuing (*ready?*) or initiate discussion of the next card (*next*) once Matchers have acknowledged instructions, which should lead to high levels of explicit generic coordination. While their levels are not significantly higher than Matcher's levels, they do not decrease over trials (while Matchers' levels do). Thus, it seems that Directors and Matchers spontaneously take on responsibility for different types of procedural coordination, which is evidenced in the generally higher levels of talk relative to the specific type.

Fourth, procedural coordination is linked with semantic coordination. In the new cards condition, participants dealt with novel referents on each trial. This manipulation precluded the development of conceptual pacts (Brennan & Clark, 1996) and kept semantic coordination demands high over trials. In this condition, demands for several types of procedural coordination stayed high over trials, whereas they decreased over trials in the classic condition (except for general procedural coordination, which also decreased for Matchers in the new cards condition). Specifically, this difference between conditions was evidenced for card placement coordination (Matchers only), explicit generic coordination (Matchers only), and general procedural coordination (Directors only). These findings suggest that participants may trade off between demands of semantic and procedural coordination. When faced with recurrently novel referents (new cards condition), the risk that a card poses particular identification problems increases. Participants may then decide to temporarily suspend the placement of that card and focus on another card that may be easier to describe. This strategy decreases semantic coordination demands, but may require more effort to coordinate card placement. This is in part because the easier-to-describe card may be out of sequence, thereby requiring participants to talk about card placement, rather than simply proceeding to the "next" card. This may in turn require explicit coordination of suspension of a "next card" routine (e.g., *let's try one that's easier to describe*), further increasing procedural coordination costs.

Our findings have important implications for the experimental study of dialogue. First, in the matching task, the coordination problems participants must solve together are not only semantic, but also procedural. Reductions in collaborative effort in the matching task are not only due to the elaboration of conceptual pacts, but may reflect a range of coordination processes or even individual-level learning (see e.g., Bangerter, Mayor, & Knutsen, 2017). Because the matching task is the workhorse task for dialogue research, experiments using it should take into account the distinction between procedural and semantic coordination (Mills, 2014).

Second, the relation between procedural and semantic coordination needs further theoretical elaboration. As a first step, studies might focus on how the development of procedural coordination in the matching task is similar to or different from that of semantic coordination in other experimental dialogue tasks. The relative importance of semantic and procedural coordination may vary depending on the constraints of specific tasks, as suggested by Mills (2011), who used a task designed to make procedural coordination difficult and semantic coordination easy. Likewise, in our study, we manipulated the difficulty of establishing conceptual pacts, which allowed us to investigate whether procedural coordination is related to semantic coordination. However, some aspects of semantic and procedural coordination are difficult to conceptually separate in the matching task. Semantic coordination in the matching task in itself involves a *procedure* for negotiating conceptual pacts. This procedure is described in detail in Clark and Wilkes-Gibbs (1986) and consists of participants initiating a description of a tangram figure, refashioning it if necessary, and evaluating it. These steps also involve subprocedures. For example, refashioning can be accomplished via repair, expansion, or replacement. Thus, the improvement of semantic coordination in the matching task hinges in part on the increased efficiency of procedures for accomplishing collaborative referring, making it difficult to completely separate semantic from procedural coordination. We suggest that this will especially be the case for generic procedural coordination, which is based on universally shared interactional routines like turn-taking, adjacency pairs (Sacks, Schegloff, & Jefferson 1974), repair (Dingemanse et al., 2015), grounding (Clark & Schaefer, 1989) or transition marking (Bangerter & Clark, 2003). Another aspect where the two kinds of coordination may differ concerns the idiosyncratic paths taken in semantic coordination, which makes conceptual pacts increasingly opaque to overhearers (Schober & Clark, 1989). Because procedural coordination relies in part on task affordances or on routines that may be shared at least in part by all participants, its development may unfold faster and converge on less idiosyncratic solutions than semantic coordination. This may especially be the case for generic procedural coordination, which relies in part on the universal routines listed above. However, task-specific procedural coordination may converge more on a variety of idiosyncratic solutions. For example, in Garrod and Doherty's classic (1994) maze game experiments, pairs of participants kept using a wide range of idiosyncratic schemes throughout the task.

Third, investigating differences between semantic and procedural coordination will have important implications for existing models of dialogue (see Brennan, Galati, & Kuhlen, 2010, for an overview). Our findings are largely consistent with the *grounding* model of dialogue. However, that model often implicitly focuses on semantic coordination. This leads to the observation, for example, that within-dialogue variability in wording and perspectives is lower than between-dialogue variability (Brennan et al., 2010). As suggested by the above discussion of the less idiosyncratic nature of procedural coordination, that observation may have to be qualified. Moreover, we document a division of labor between directors and matchers involving procedural coordination, similar to emergence of interactional routines involving complementary contributions (Mills, 2011, and Fusaroli

& Tylén, 2016). Our findings thus converge with recent models of dialogue as interpersonal synergy (Fusaroli et al., 2014).

In conclusion, this study offers a better understanding of the role of procedural coordination in dialogue, and its interaction with semantic coordination. It sheds further light on the processes at play in the matching task, one of the most widely used tasks in dialogue research. Previous research has suggested that the decrease in collaborative effort usually observed in this kind of task reflects partners establishing and reusing conceptual pacts. The current findings nuance this claim by revealing that part of this decrease is in fact due to dialogue partners coordinating procedurally. We have also shown that all kinds of procedural coordination do not necessarily decrease as the interaction unfolds: this depends on whether coordination is general or specific, and on whether it is implicit or explicit. It also depends on the role in the dyad, and on whether participants can rely on semantic coordination as well.

Data Accessibility Statement

Materials, transcripts, coded data and analytical scripts are available at https://osf.io/ua59z/.

Notes

[1] Both word counts and binary data have advantages and disadvantages for our purposes. We decided to use binary data for our main analyses to facilitate two main comparisons. First, some forms of procedural coordination are more wordy than others (e.g., IGC involving single-word back-channels vs. longer expressions for EGC). Second, in the classic condition, coordination required fewer words than in the new cards condition. These comparisons make word counts (divided by total words) less straightforward to interpret than binary data.

[2] In an additional analysis, we tested whether the overall amount of words for procedural coordination was affected by the main independent variables. The main results were that Matchers' talk was more dedicated to procedural coordination than Directors', and that Matchers' talk was more dedicated to procedural coordination in the classic condition than in the new cards condition. The detailed analyses are available in the "additional analyses" folder on https://osf.io/ua59z/.

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

- Contributed to conception and design: AB, EM
- Contributed to acquisition of data: AB, EM
- Contributed to analysis and interpretation of data: AB, DK, EM
- Drafted and/or revised the article: AB, DK, EM
- Approved the submitted version for publication: AB, DK, EM

References

Agresti, A. (2002). *Categorical data analysis*. Hoboken, NJ: Wiley. DOI: https://doi.org/10.1002/0471249688

Baayen, R. H., Davidson, D. J., & **Bates, D. M.** (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*, 390–412. DOI: https://doi.org/10.1016/j.jml.2007.12.005

Bangerter, A., & **Clark, H. H.** (2003). Navigating joint projects with dialogue. *Cognitive Science*, *27*, 195–225. DOI: https://doi.org/10.1207/s15516709cog2702_3

Bangerter, A., Mayor, E., & **Knutsen, D.** (in preparation). Lexical entrainment without conceptual pacts? Revisiting the matching task.

Barr, D. J., Levy, R., Scheepers, C., & **Tily, H. J.** (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*, 255–278. DOI: https://doi.org/10.1016/j.jml.2012.11.001

Brennan, S. E., & **Clark, H. H.** (1996). Conceptual pacts and lexical choice in conversation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 1482. DOI: https://doi.org/10.1037/0278-7393.22.6.1482

Brennan, S. E., Galati, A., & **Kuhlen, A. K.** (2010). Two minds, one dialog: Coordinating speaking and understanding. In: Ross, B. H. (Ed.), *The psychology of learning and motivation*, *53*, 301–344. Academic Press. DOI: https://doi.org/10.1016/S0079-7421(10)53008-1

Brown-Schmidt, S. (2012). Beyond common and privileged: Gradient representations of common ground in real-time language use. *Language and Cognitive Processes*, *27*, 62–89. DOI: https://doi.org/10.1080/01690965.2010.543363

Clark, H. H. (1996). *Using language*. Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511620539

Clark, H. H., & **Brennan, S. E.** (1991). Grounding in communication. In: Resnick, L. B., Levine, J. M., & Teasley, S. D. (Eds.), *Perspectives on socially shared cognition,* 127–149. Washington: APA Books. DOI: https://doi.org/10.1037/10096-006

Clark, H. H., & **Marshall, C.** (1981). Definite knowledge and mutual knowledge. In: Joshi, A., Weber, B. H., & Sag, I. A. (Eds.), *Elements of discourse understanding*, 10–63. Cambridge: Cambridge University Press.

Clark, H. H., & **Schaefer, E. F.** (1989). Contributing to discourse. *Cognitive Science*, *13*, 259–294. DOI: https://doi.org/10.1207/s15516709cog1302_7

Clark, H. H., & **Wilkes-Gibbs, D.** (1986). Referring as a collaborative process. *Cognition*, *22*, 1–39. DOI: https://doi.org/10.1016/0010-0277(86)90010-7

Dingemanse, M., Roberts, S. G., Baranova, J., Blythe, J., Drew, P., Floyd, S., Gisladottir, R. S., Kendrick, K. H., Levinson, S. C., Manrique, E., Rossi, G., & **Enfield, N. J.** (2015). Universal principles in the repair of communication problems. *PLoS One*, *10*(9), e0136100. DOI: https://doi.org/10.1371/journal.pone.0136100

Dingemanse, M., Torreira, F., & **Enfield, N. J.** (2013). Is "Huh?" a universal word? Conversational infrastructure and the convergent evolution of linguistic items. *PloS One*, *8*, e78273. DOI: https://doi.org/10.1371/journal.pone.0078273

Doherty-Sneddon, G., Anderson, A., O'Malley, C., Langton, S., Garrod, S., & **Bruce, V.** (1997). Face-to-face and video-mediated communication: A comparison of dialogue structure and task performance. *Journal of Experimental Psychology: Applied*, *3*, 105–125. DOI: https://doi.org/10.1037/1076-898X.3.2.105

Drew, P. (1997). 'Open' class repair initiators in response to sequential sources of troubles in conversation. *Journal of Pragmatics*, *28*, *69–101*. DOI: https://doi.org/10.1016/S0378-2166(97)89759-7

Fusaroli, R., Rączaszek-Leonardi, J., & **Tylén, K.** (2014). Dialog as interpersonal synergy. *New Ideas in Psychology*, *32*, 147–157. DOI: https://doi.org/10.1016/j.newideapsych.2013.03.005

Fusaroli, R., & **Tylén, K.** (2016). Investigating conversational dynamics: Interactive alignment, interpersonal synergy, and collective task performance. *Cognitive Science*, *40*, 145–171. DOI: https://doi.org/10.1111/cogs.12251

Gambi, C., & **Pickering, M. J.** (2011). A cognitive architecture for the coordination of utterances. *Frontiers in Psychology*, *2*, 275. DOI: https://doi.org/10.3389/fpsyg.2011.00275

Garrod, S., & **Anderson, A.** (1987). Saying what you mean in dialogue: A study in conceptual and semantic co-ordination. *Cognition*, *27*, 181–218. DOI: https://doi.org/10.1016/0010-0277(87)90018-7

Garrod, S., & **Doherty, G.** (1994). Conversation, co-ordination and convention: An empirical investigation of how groups establish linguistic conventions. *Cognition*, *53*, 181–215. DOI: https://doi.org/10.1016/0010-0277(94)90048-5

Holler, J., Kendrick, K. H., Casillas, M., & **Levinson, S. C.** (Eds.) (2015). Turn-taking in human communicative interaction. *Frontiers in Psychology*, *6*, 1919. DOI: https://doi.org/10.3389/fpsyg.2015.01919

Horton, W. S., & **Gerrig, R. J.** (2005). The impact of memory demands on audience design during language production. *Cognition*, *96*, 127–142. DOI: https://doi.org/10.1016/j.cognition.2004.07.001

Hupet, M., Seron, X., & **Chantraine, Y.** (1991). The effects of the codability and discriminability of the referents on the collaborative referring procedure. *British Journal of Psychology*, *82*, 449–462. DOI: https://doi.org/10.1111/j.2044-8295.1991.tb02412.x

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, *59*, 434–446. DOI: https://doi.org/10.1016/j.jml.2007.11.007

Kiernan, K., Tao, J., & **Gibbs, P.** (2012). Tips and strategies for mixed modeling with SAS/STAT procedures. Presented at the 2012 SAS Global Forum, Orlando, FL.

Knutsen, D., Ros, C., & **Le Bigot, L.** (2018). Spoilt for choice: Initially considering several referential expressions affects subsequent referential decisions. *Language, Cognition, and Neuroscience*, *33*, 618–632. DOI: https://doi.org/10.1080/23273798.2017.1400080

Krauss, R. M., & **Weinheimer, S.** (1966). Concurrent feedback, confirmation, and the encoding of referents in verbal communication. *Journal of Personality and Social Psychology*, *4*, 343. DOI: https://doi.org/10.1037/h0023705

Levinson, S. C. (2006). On the human "interaction engine." In: Enfield, N., & Levinson, S. C. (Eds.), *Roots of human sociality: Culture, cognition and interaction*, 39–69. Oxford, England: Berg.

Malone, T. W., & **Crowston, K.** (1990). What is coordination theory and how can it help design cooperative work systems? In: *Proceedings of the 1990 ACM conference on Computer-Supported Cooperative Work*, 357–370. Los Angeles: ACM. DOI: https://doi.org/10.1145/99332.99367

Mills, G. J. (2011). The emergence of procedural conventions in dialogue. *Proceedings of the 15th Workshop on the Semantics and Pragmatics of Dialogue*, 210–211.

Mills, G. J. (2014). Dialogue in joint activity: Complementarity, convergence and conventionalization. *New Ideas in Psychology*, *32*, 158–173. DOI: https://doi.org/10.1016/j.newideapsych.2013.03.006

Okhuysen, G. A., & **Bechky, B. A.** (2009). Coordination in organizations: An integrative perspective. *Academy of Management Annals*, *3*, 463–502. DOI: https://doi.org/10.5465/19416520903047533

Pickering, M. J., & **Garrod, S.** (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences*, *27*, 167–226. DOI: https://doi.org/10.1017/S0140525X04000056

Sacks, H., Schegloff, E. A., & **Jefferson, G.** (1974). A simplest systematics for the organization of turn-taking for conversation. *Language*, *4*, 696–735. DOI: https://doi.org/10.1353/lan.1974.0010

Schegloff, E. A. (2007). *Sequence organization in interaction: Volume 1: A primer in conversation analysis.* Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511791208

Schiffrin, D. (1987). *Discourse markers.* Cambridge: Cambridge University Press. DOI: https://doi.org/10.1017/CBO9780511611841

Schober, M. F., & **Clark, H. H.** (1989). Understanding by addressees and overhearers. *Cognitive Psychology*, *21*, 211–232. DOI: https://doi.org/10.1016/0010-0285(89)90008-X

Smith, E. A. (2010). Communication and collective action: Language and the evolution of human cooperation.

Evolution and Human Behavior, *31*, 231–245. DOI: https://doi.org/10.1016/j.evolhumbehav.2010.03.001

Swets, B., Jacovina, M. E., & **Gerrig, R. J.** (2013). Effects of conversational pressures on speech planning. *Discourse Processes*, *50*, 23–51. DOI: https://doi.org/10.1080/0163853X.2012.727719

Tolins, J., Zeamer, C., & **Fox Tree, J. E.** (2018). Overhearing dialogues and monologues: How does entrainment lead to more comprehensible referring expressions? *Discourse Processes*, *55*, 545–565. DOI: https://doi.org/10.1080/0163853X.2017.1279516

Tomasello, M. (2008). *Why we cooperate*. Cambridge, MA: MIT Press.

Van Der Wege, M. M. (2009). Lexical entrainment and lexical differentiation in reference phrase choice. *Journal of Memory and Language*, *60*, 448–463. DOI: https://doi.org/10.1016/j.jml.2008.12.003

Yoon, S. O., & **Brown-Schmidt, S.** (2014). Adjusting conceptual pacts in three-party conversation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*, 919–937. DOI: https://doi.org/10.1037/a0036161

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