# Communicative Efficiency and Miscommunication: The Costs and Benefits of Variable Language Production

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**Abstract**

Although negotiating joint action through dialogue can be difficult, dyads may be able to improve collaborative performance by managing communicative efficiency in language production, balancing effort (words per turn) with output (turn-level success). Comparing dyads with high, medium, and low levels of accuracy in communication, growth curve modeling revealed a negative relationship between success and excessive variability in levels of efficiency. Dyads performed better by maintaining moderately fluid efficiency (seen in high-success dyads) or minimizing efficiency variability (seen in medium-success dyads), rather than scrambling for efficiency only as needed (seen in low-success dyads). Balancing efficiency variability in language production may create flexible but relatively stable interaction structures, laying the groundwork for successful communication.

**Keywords:** miscommunication; growth curve; production effort; interaction; joint action

## Introduction

What makes some conversations flow successfully while others simply flounder? Numerous factors undoubtedly contribute to these outcomes, but the current paper focuses on *one* possible contributor: *communicative efficiency* of speech production. While we recognize that the term "efficiency" may have specific implications in some circles, we operationalize and situate it within the context of speech production as communicative success relative to the number of words used per turn in a corpus of turn-based dyadic interactions (i.e., Bloco® corpus; Paxton, Roche, Ibarra, & Tanenhaus, 2014; Roche, Paxton, Ibarra, & Tanenhaus, 2013). While interaction is a complex interplay between speakers and listeners, we focus here only on language production. Speakers' efficiency–broadly defined for our purposes as the balancing of the costs and benefits of language planning and production–may be one factor contributing to communicative success. As we describe below, we argue that more successful dyads may maintain a relatively steady level of communicative efficiency in language production throughout an interaction—while less successful dyads may exhibit more variability in their communicative efficiency.

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## Balancing the Cost of Communication

One factor that guides conversational choices is the amount of effort required by both conversation partners (Grice, 1976). Gricean principles hold that a speaker should put *precisely* enough effort into her utterances so that her listeners can navigate the communicative context with ease, with the intention that neither she nor her partner bears all the conversational burden (whether in production or comprehension; Grice, 1976). However, some interlocutors may be better than others at gauging this minimally sufficient production effort (e.g., through taking advantage of common ground; Clark & Brennan, 1991), and this ability may be an important difference between successful and unsuccessful communicators.

Research suggests that speakers have the ability to manage communication costs across various levels of an interaction. For example, at a local level (e.g., the "word" level), speakers may achieve efficiency by uniformly distributing information across an utterance (Jaeger, 2011; Levy & Jaeger, 2008). At a global level (e.g., the "interaction" level), using too few words can save time, but it also increases the likelihood of a misunderstanding, which must be resolved—requiring the exertion of additional effort. Ideally, interlocutors should maintain consistency in information transmission at the global level to be more *communicatively efficient*.

One way speakers may do this is by engaging automatic processes during on-the-fly production planning which can be fairly "cheap," requiring fewer cognitive resources (Houde & Jordan, 1998; Pickering & Garrod, 2004; Tremblay, Shiller, & Ostry, 2003; Vogel, Fletcher, & Maruff, 2014). However, production planning required during crucial points in the conversation is a delicate balancing act, which may require more cognitively "expensive" processes (especially at the beginning of a conversation or during miscommunication resolution).

If a speaker's strategies are too "cheap," the interaction is likely to flail or flounder during miscommunication or other difficulties. On the other hand, if a speaker's strategies are too "expensive," the interaction may suffer under heavy cognitive demands. Below, we present two types of cognitive "cost-saving" strategies along with more effortful ways that interlocutors may resort to when these techniques fail. Although exploring speakers' strategies in depth is outside of the scope of the current paper, we build our hypotheses about overall language production using these specific strategies as guides.

**Omission and Repair** One way in which a speaker may save effort when producing language is to omit words. This may reduce some of the constraints of planning a more complex coherent message (Bock, 1986; Branigan, Pickering, & Cleland, 2000; Ferreira, & Bock, 2006; Bard, Anderson, Chen, Nicholson, Harvard & Dazel-Job, 2007). These seemingly innocuous omissions, however, may increase the chance of miscommunication. When planning utterances, a speaker must weigh the cost of potential miscommunication with the benefit of reduced effort. If the effort-saving choice results in miscommunication, the speaker may be required to clarify, which would increase production effort.

Omission, when used in moderation, may provide some of the benefits of reduced effort while minimizing the costs of miscommunication. However, a speaker who too often omits key words may, over time, increase her overall effort by repeatedly clarifying herself. This may be evident through high variability in language production, with the interlocutor seesawing between short and long utterances.

**Egocentric and Other-centric Perspectives** Research suggests that interlocutors differ in perspective-taking style (*egocentric* or *other-centric*; Duran, Dale, & Kreuz, 2011). Engaging in one style over the other may be directly related to the anticipated cost of miscommunication relative to the production effort needed to avoid it. For example, if a speaker lacks information, she may adopt an egocentric perspective to quickly and easily obtain necessary information from her conversation partner. Effort is saved if her perspective is similar to her partner's, reducing the need to mentally represent her partner's perspective.

Speakers may not always make conscious decisions about perspective taking. Ego- and other-centrism may not be a defining characteristic of the *speaker* but may instead be a defining characteristic of the *context*. Duran et al. (2011) maintain that individuals can switch perspective-taking strategies if provided the appropriate cues, even if that perspective is more costly. Context appears to provide vital cues to guide perspective-taking choices. Without this information, it may be unclear which perspective would be most beneficial to a given situation—thus encouraging the interlocutor to sample various strategies to resolve communication breakdown and reducing communicative efficiency.

**Budgeting Production Costs** Engaging effort-saving strategies not only makes conversation easier but also promotes adaptation and flexibility. Should the context require it, interlocutors can switch from cheaper mechanisms to more expensive ones to adapt to the language context (Horton & Keysar, 1996). At the local or short-term level, after realizing that there has been some miscommunication interlocutors may increase their production effort until the problem is resolved (e.g., repairing an omission). However, adjustment may also occur at the global or long-term level (e.g., altering perspective), turning attention to shared history to increase understanding across the interaction (e.g., Brennan & Clark, 1996; Clark & Brennan 1991). Speakers must approach new conversations with relative flexibility to adapt to constant changes in conversational demands.

These cost-saving strategies may require initial investment in production effort, since establishing common ground and conceptual pacts (e.g., Brennan & Clark, 1996; Clark & Brennan, 1991) may require increased language production (e.g., during initial negotiations). However, over time, this investment should lead to "cheaper" production costs later, allowing speakers to use shared shorthand to convey even complex concepts. Finding a *good* method of responding early may promote communicative success, but the ability to adapt when something goes wrong may be just as beneficial. Active monitoring allows for the interlocutor to clear up miscommunication as needed while saving effort when possible (Keysar, 2007). However, conversation is not always so simple: If a speaker has difficulty communicating effectively (e.g., due to inexperience or lack of knowledge), she may take longer and sample many more strategies than others—or the conversation may simply fail.

## The Present Study

We explore the context-dependence of communicative success from the perspective of speech production. Speakers must balance producing "cheap" (i.e., fewer words per turn) speech acts with more "costly" (i.e., higher words per turn) ones based on the needs of the listener and the current task goals. Effective communication, then, may perhaps be characterized by an ability to realize when these cheaper language production choices are useful and when they need to be abandoned for more resource-intensive ones. This ability may be evidenced in relatively stable levels of speech throughout an interaction (cf. Jaeger, 2010): Fewer troughs (i.e., very cheap speech acts) and peaks (i.e., very costly speech acts) may be a sign that interlocutors are exploiting context-appropriate strategies.

We predict that—during a cooperative task with powerful external constraints—higher performance should be associated with a better ability to predict the necessary cost of speech acts. This should be evident by a more even level (i.e., lower variability) of language production throughout the interaction. Lower-performing dyads, on the other hand, are predicted to have higher variability during language production throughout the interaction. These dyads may vary widely in the amount of speech they provide or solicit from their partners as they struggle to find appropriate strategies to complete their task. However, exploring these specific strategies is outside the scope of the present paper.

In what follows, we investigate whether task success is affected by the efficiency of production effort over the course of a dyadic interaction. We use growth curve analysis to evaluate word production throughout the interaction for high-, medium-, and low-performing dyads. This allows us to look beyond measures of the overall interaction to explore turn-by-turn dynamics of performance and language production.

# Method

The current project analyzed part of a larger corpus aimed at capturing the linguistic and behavioral dynamics of dyadic task performance without shared visual fields (Bloco® corpus; Paxton et al., 2014; Roche et al., 2013). In the present subset of the Bloco® corpus, participants worked together to build individual versions of an identical three-dimensional puzzle—either a grasshopper or lizard—using a sequence of pictorial instruction cards, each depicting a single step in the building process.

To create a sort of "turn-taking" director task, each participant was each given half of the total instruction cards required to completely build the figure. The instruction cards were divided so that the director and listener roles alternated with each step (i.e., instruction card): One participant would serve as director for all even-numbered steps, and their partner would serve as director for all odd-numbered steps. Participants were unable to see their partner, their partner's workspace, or their partner's instruction cards during the interaction and were only able to coordinate building through spoken language exchanges.

Each dyad received feedback about their construction only after completing all of the steps on the instruction cards. This allowed dyads to discover any instances of miscommunication, much as miscommunication occurs in the real world. That is, rather than having an external entity (e.g., experimenter) identify errors at each stage, miscommunication emerged naturally as a function of the building (e.g., inability to complete next step). All but one dyad correctly built the figure by the end of the interaction, with only a minor error in the final figure.

## Participants

Twenty dyads of undergraduate students ($N = 40$; females = 26; mean age = 19 years) from the University of Rochester participated in interactive communication task in return for $10. All participants were native speakers of American English, with normal to corrected vision and no diagnosed speech or hearing impairments.

## Measures

The dyadic interactions were transcribed and annotated for various measures (see Table 1 for summary table).

**Word Count (WC)** was assessed with LIWC (Linguistic Inquiry and Word Count; Pennebaker, Booth, & Francis, 2007). No other LIWC category was considered in the present study. A total of 80,267 words were produced across the corpus, with an average of 9.45 words produced per turn ($SD = 11.46$).

**Turns** were coded as soon as a participant began to speak. During interruptions or overlapping speech, we maintained the turn structure by first transcribing the speaker who held the floor at the time of the interruption, and the interrupter was transcribed second. There were a total 8,491 turns ($M =$ 413 turns; $SD = 74.09$) across all dyads.

Table 1: Summary statistics for mean number of turns, accuracy, mean word count (WC) per turn, and communicative efficiency (CE) by performance group.

| Success Level | Mean Turns | Overall Accuracy | Mean WC per Turn | CE |
|---|---|---|---|---|
| Low ($n = 8$) | 383.5 | 52.3% | 9.65 | 0.32 |
| Medium ($n = 8$) | 498.1 | 69.9% | 9.46 | 0.21 |
| High ($n = 4$) | 359.5 | 87.5% | 8.89 | 0.42 |

**Visual Congruence (VC)** was a measure of task success. We chose VC because it acted as a direct consequence of the current linguistic context. Contrasting with other possible measures of miscommunication (e.g., repairs), VC provided a continuous measure of breakdown, regardless of whether or not miscommunication was recognized by the dyad at any given moment.

VC was operationalized as whether the state of the interlocutors' workspaces matched (Paxton et al., 2014). An undergraduate research assistant (RA) coded the dyads' workspaces as either matching (VC+) or mismatching (VC-) on a turn-by-turn basis. As a toy example, a speaker ($T_a$) may have needed to describe an object's spatial orientation to her partner ($T_b$). If $T_b$ physically moved the object to the correct orientation (as intended by $T_a$ based on by $T_a$'s workspace and instruction card), the current turn was marked as VC+. However, if $T_b$ failed to put the object in the correct orientation, the turn was marked as VC-. For clarity, Figure 1 provides an example of what a VC- turn may look like. In this turn, $T_a$ instructed $T_b$ to orient the holes in an upward fashion, but the ambiguous use of "up" resulted in a VC- turn.

VC was evaluated at each turn to better capture the nuances of task performance and communication. We checked reliability of the coding by having two additional blind coders (with no prior knowledge of the experiment) evaluate 5% (425 turns) of the original visual congruence determinations. The blind coders were asked to code agreement/disagreement with the original codes. These agree/disagree determinations were then subjected to an inter-rater reliability analysis, and we found high agreement with the primary coders (kappa = .96). Across the entire corpus, 5,491 trials were coded as VC+, indicating that miscommunication (VC-) occurred in 3,000 turns (35.5%) across the corpus.


Figure 1: Visually incongruent (VC-) orientation for $T_a$'s instruction to $T_b$: "Put the holes facing up."

**Accuracy and Accuracy Groups** was calculated as a running proportion (at the turn level) of VC+ of the participants' workspaces throughout the task. Using these data, dyads were separated into three groups, resulting in the following categories: High Accuracy (at or above +1 *SD* accuracy), Low Accuracy (at or below -1 *SD* accuracy), and Medium Accuracy (from -1 to +1 *SD* accuracy). Evaluation of VC+ by the predictor (dyad) and moderator (turn) indicated that adding the interaction term resulted in significantly better fit ($F = 4.93$, $p < .05$). A test of simple slopes indicated that these groups did significantly differ from zero, $t(17) = 559.94_{Low}$; $3809.59_{High}$ ($p < .01$).

**Communicative Efficiency (CE)** captured how well each dyad balanced communication goals with effort over the course of the interaction. To calculate this measure of efficiency, we calculated a running average of words per turn at each turn for each dyad. We then weighted this running average using the dyad's raw running accuracy score until that same turn. Therefore, a higher CE was an indication of a more efficient dyad, producing relatively even numbers of words per turn throughout the interaction. These stable levels of production are taken as a sign that interlocutors are being effective at *locally* planning production (e.g., providing only as much information as needed) and *globally* tracking instructions and monitoring for miscommunication (e.g., catching mistakes quickly).

## Results

As a preliminary analysis, we created a mixed-effects model to determine whether the accuracy groups significantly differed in relative efficiency across the course of the interaction. The model predicted CE with accuracy group (i.e., High, Medium, Low), a fully specified random effects structure using Accuracy group identity as a random slope and Dyad and Turn as random intercepts. Overall, as expected, the High Accuracy group was significantly more efficient than the Low ($\beta = .05$, $SE = 0.01$, $p < .001$) and Medium Accuracy groups ($\beta = .03$, $SE = 0.01$, $p < .01$).

However, these *overall* differences across groups do not capture differences in the groups' unfolding *dynamics*. Understanding the moment-to-moment changes in language production is required to answer questions about how communicative efficiency affects performance in time. To explore how time courses of the different dyads differ, the following analysis looks specifically at efficiency across the interaction. We used standardized (or normalized) turn as our measure of time. Using standardized turn instead of raw turn counts allowed us to compare the dyads despite the variability in total turns.

**Growth Curve Analysis** was used to evaluate the patterns in communicative efficiency over the course of the interaction. Growth curve analyses afford a finer-grained evaluation of the progression over time than linear models because they allow the data to vary in shape and form over time. Specifically, growth curve models can evaluate data when it is not necessarily linear. An initial visual analysis of CE showed a clear nonlinear component to the variable (see Figure 2). Thus, evaluating the curvature of one's data is often more informative than simply stating what the mean differences are between groups.

We calculated orthogonal polynomials for standardized turn up to the 5th order, in order to best represent the conversation data[1]. Mirman, Dixon, and Magnuson (2008) explain that using orthogonal polynomials to represent the time-course data decouples the dependencies in the time variable, thus making them independent within the model. The orthogonals provide information about the intercept (grand mean), linear slope (1st orthogonal), symmetry of the curvature (2nd orthogonal), and the steepness of the inflection point (i.e., point of change in the curvature; 3rd+ orthogonal; Mirman et al., 2008).

We then created a mixed-effects model that considered the effects of group performance on communicative efficiency (CE). Dyad was set as a random effect with fully specified random slope, and the random effect for dyad-by-accuracy-group was included with slopes for only the 1st and 2nd order polynomials (as suggested by Mirman et al., 2008).[2] The results indicated significant main effects for the 2nd-5th orthogonals and significant interactions for the 4th and 5th orthogonals for the Low and High Accuracy groups.

[1] Chosen based on the number of points of inflection in the Low Accuracy group.

[2] The random effects beyond the cubic orthogonal were excluded because they are computationally expensive and relatively less informative (cf. Mirman et al., 2008)

The main effect on the 2nd orthogonal indicates that as efficiency increases, so does the curvature symmetry ($\beta$ = .08, $SE$ = 0.04, $p$ < .05). This suggests that, overall, dyads peak in CE partway through the interaction and then decline in CE until the end. This may have been an effect of the task: As the dyad progresses towards completion and the object becomes more concrete, speakers may invest more effort, realizing that they need to re-establish shared perspectives and common ground to move forward.

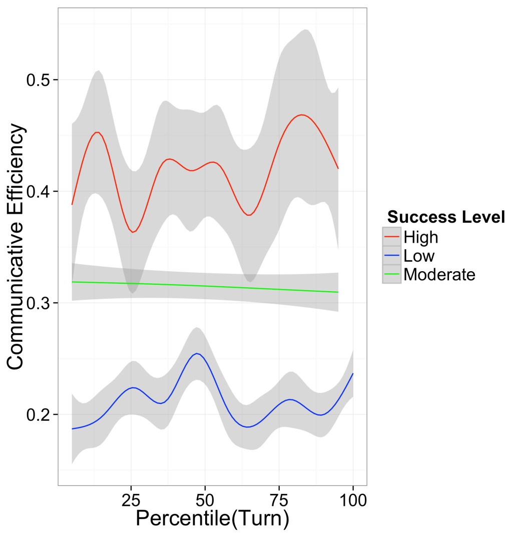


Figure 2: Communicative efficiency over standardized time for each group (High = red; Medium = green; Low = blue).

The other significant main effects indicate a decrease in inflection points for the 3rd and 5th orthogonals (3rd orthogonal: $\beta$ = -.05, $SE$ = 0.2, $p$ < .01; 5th orthogonal: $\beta$ = -.01, $SE$ = 0.002, $p$ < .01) but an increase in inflection points for the 4th orthogonal ($\beta$ = .02, $SE$ = 0.004, $p$ < .001). Taken together, these increased inflection points may functionally measure variability (i.e., increased peaks and troughs) in efficiency throughout the interaction.

Comparing other groups to the Medium Accuracy dyads, CE data were best fit by the fifth orthogonal for the Low Accuracy dyads ($\beta$ = .01, $SE$ = 0.003, $p$ < .01). We also see a trend towards significance of the 5th orthogonal in the High Accuracy dyads ($\beta$ = .01, $SE$ = 0.005, $p$ = .06) The results point to steeper and more variable curvature in effort exerted to produce an instruction throughout the interaction for both High and Low Accuracy dyads (relative to Medium).

## Discussion

When individuals communicate with one another, numerous factors contribute to the success of the interaction—perspective taking, ability to repair, adaptation, and flexibility (to name a few). The present study examined just one possible factor: *communicative efficiency in production*. Specifically, we investigated whether dyads produce relatively stable amounts of words-per-turn over an interaction. More stable performance may be an indication that the dyad is effectively balancing "cheap" and "costly" communication strategies (Houde & Jordan, 1998; Pickering & Garrod, 2004; Tremblay, Shiller, & Ostry, 2003; Vogel, Fletcher, & Maruff, 2014), while increased variability may be a sign that the dyad may have had difficulty choosing an appropriate strategy.

We found partial support for our hypotheses. As predicted, we did find that lower-performing dyads exhibited significantly higher variability in language production than the medium-performing dyads. Interestingly—and contrary to our expectations—high-performing dyads were also variable in their language production, although it did not quite reach the statistical significance seen in the low-performing dyads. The *medium*-performing dyads, on the other hand, showed the steady levels of efficiency that we expected from the high-performing dyads.

These results suggest that variability in language production in itself may be neither helpful nor harmful. Viewing this variability as a proxy for employing cheap or costly communication strategies, the present findings may suggest that high-performing dyads may simply be *better* at switching between cheap and costly strategies as needed. The low-performing dyads may be unable to settle on the strategy appropriate to current demands, instead sampling a wide variety of behaviors. The medium-performing dyads may have put *just enough* effort into the interaction to balance cheap and costly strategies, minimizing variability while performing adequately. The high-performing dyads' relatively fluid levels of variability throughout their interactions may have given them the flexibility to adopt new strategies as needed. Further research is needed to examine this possibility.

Beyond the aggregate differences across dyads' interactions, it is important to note that the dyads also *structured* their interactions differently. Overall, the high-performing dyads were more efficient overall than either the average or low-performing dyads. The high-performing dyads produced significantly fewer turns than the other groups, but growth curve analysis preserved the ebbs and flows of production effort employed by each group, highlighting the dynamics that characterize each group's performance.

### Future Directions

In the current study, we focused primarily on the *amount* of language produced in the interaction as an indication of production planning and effort but did not consider many of the other factors that could have influenced performance. Future analyses will examine how specific lexical choices (e.g., spatial terminology, disfluencies, repair) affect the dynamics of the interaction during both production and comprehension. This may help shed light on the specific strategies employed by speakers *and* listeners in maintaining communicative efficiency.

For example, previous analysis of lexical selection in the Bloco® corpus showed that groups differed in the numbers of spatial references used. Low-performers used spatial terminology more than high-performers, with low-performers producing roughly 2,500 more spatial terms overall. Therefore, dyads' lexical choices directly result in higher miscommunication and lower communicative efficiency (Roche et al., 2013). How dyads handle these breakdowns should mirror their ability to take perspective and to initiate repair. Understanding the role of multiple factors in miscommunication gets us one step closer to understanding why we miscommunicate and how we recover from it. Once we capture the behaviors leading to miscommunication, we may be better able to develop more controlled experiments to assess and address it.

## Conclusions

Successful speakers balance cheaper language acts with more costly ones, investing just enough to achieve their goals. Although some pairs never found this equilibrium, even less-than-successful partners muddled through to complete their task after substantial time and effort. However, by being a little more flexible in adapting to the needs of the moment, speakers may be better able to work together, improving joint performance while conserving effort.

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