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Microdevelopment in Parent-Child Conversations: From Global Changes to Flexibility

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In previous studies we demonstrated that the speech of a language-acquiring child and that of her parent can be characterized as a transactional process of dynamic adaptation. We reported a striking attunement between child and parent in the global development of mean length of utterance and utterance length between the ages of 1.5 and 2.5 years.

Here we present a reanalysis of these data, focusing on the utilization of different categories of utterance length. In particular we analyzed the temporal structure of the dialogue on the linguistic level using the technique of cross-recurrence quantification. This type of analysis enabled us to study the interaction between interlocutors at the microlevel, revealing the dynamics of child-parent conversation and how this changes over time.

Results showed decreasing values for measures quantifying the vertical line structures as well as an increasing average length of the diagonal lines in the recurrence plot. This was interpreted as indicating an increasing flexibility in the patterns of parent-child dialogue over the period of 1 year.

Emphasizing the information content of the temporal structure of behavior has been one of the major scientific contributions of Guy Van Orden's work, particularly—but certainly not exclusively—in the language domain (e.g., Holden, Van Orden, & Turvey, 2009; Van Orden, Holden, & Turvey, 2003). During the last decade or so, researchers following on this path have been exploring the

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fundamental insight that real-time variability is reflective of the self-organizing processes underlying human behavior. This is true not only for the behavior of a single individual but also in dyadic interaction, such as child-parent conversation in early childhood (Dale & Spivey, 2006). Variation (e.g., due to context and exploration) and adaptation (e.g., to changing proficiency levels) of speech characteristics are notable features of language use, which play an important role in language development, as is discussed later. However, it is still largely a mystery how the gradual and abrupt changes in a child's developing language use interchange with the microscale (i.e., moment-to-moment) dynamics of child-adult conversation.

ADAPTATION BETWEEN CHILD LANGUAGE AND CHILD DIRECTED SPEECH

Since Snow's (1972) seminal publication on the characteristics of the language spoken to children, it has repeatedly been demonstrated that this type of speech is not stable over time but that it becomes more complex as the child gets older (e.g., Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2007; Kaye, 1980; Phillips, 1973; Rondal, 1980; Snow, 1972). Child-adult language interaction can be seen as a transactional process, which results from the dynamic and continuous adaptation between both speech partners. Here, the child adapts to the Child Directed Speech (CDS), which functions as the "input" of the target language for the child. The caretaker, on the other hand, continuously adapts his or her language to the level of the child and uses language that is a slightly more complex than the language of the child. CDS has been conceptualized as a specific case of scaffolding, where the caretaker uses his or her language to "bridge" the distance between the target language and the actual language level of the child (Del Rio, Galván, & Gràcia, 2001; Tomasello & Brooks, 1999; Vilaseca & Del Rio, 2004). In Van Dijk et al. (2013), we reported a striking global attunement between child language and CDS in the (smoothed) development of the mean length of utterance in words (MLU-w). A high degree of variability (in the form of fluctuations from session to session) was also clearly present. One interpretation is that the variability is caused by context changes that both partners respond to in a similar manner. However, the data did not provide much evidence for the existence of this type of local adaptation because the session-to-session variability of the child and the adult were uncorrelated. The results mainly demonstrated the existence of global communicative adaptation: global changes across time as the language of the child increases in complexity. These findings are consistent with those from the single case study of Roy, Frank, and Roy (2009), who reported most evidence for "coarse tuning": global adaptation to the general linguistic competence of the child.

UTTERANCE LENGTH AS A MEASURE OF GRAMMATICAL DEVELOPMENT

In 1973, mean length of utterance (MLU) was put forward by Roger Brown as the best estimation of grammatical complexity of child language. MLU was computed by dividing the total number of morphemes by the number of utterances (in a sample greater than 100 utterances; Brown, 1973). The development of MLU was conceived as a reflection of the global increase of grammaticality. Despite much criticism of the quantitative nature of the measure in relation to the qualitative aspect of grammatical complexity, the measure is still very popular. Nowadays, it is more often expressed in words instead of morphemes (predominantly for practical reasons).

MLU is by definition an *average* of a sample and does not bear information about the distribution of the length of individual utterances. For this reason, other studies report on relative occurrence of utterances with a specified length, for instance, the number of one-word utterances, two-word utterances, three-word utterances, and so on. Bassano and Van Geert (2007) propose a categorization of utterance length in three classes: (a) one-word utterances (W1), (b) two- and three-word utterances (W2/3), and (c) utterances of four words or more (W4+). They argue that these classes reflect qualitative linguistic “styles,” which are the result of three different “generators” of language development. First, the one-word utterances are considered characteristic of an early “expressive” style of single words (“holophrases”). Second, two- and three-word utterances are indicative of a simple “combinatory” style where the different words fulfill different linguistic functions. Finally, utterances of four words or more are thought to reflect a more “grammatical” style. According to Bassano and Van Geert, four words seem to be a minimal length for making syntactically correct utterances containing linguistic symbols and syntactic structures. Analyses of a single case study by Bassano and Van Geert showed that W1, W2/3, and W4+ utterances showed very distinct patterns of development. Evidence was found for two transitions: one from the holophrastic to the combinatorial stage and one from the combinatorial to the syntactic stage (for a further discussion on these categories and results, we refer to Bassano & Van Geert, 2007).

Closer analysis of the data used in Van Dijk et al. (2013; as presented in Van Dijk & Van Geert, 2011) on the relative occurrence of one-, two/three-, and more-word utterances reveal that the three children all start out using predominantly one-word utterances. In the course of the measurement period, their utterance length becomes more varied. In the CDS, the change is much more subtle. From the very first measurement onward, the predominant category is that of more-word utterances. The number of 4+-word utterances increases slightly in the course of the measurement period.

In this article we add to these findings a reanalysis of the data of Van Dijk and Van Geert (2011) and Van Dijk et al. (2013) with the tools of nonlinear time-series analysis, specifically recurrence quantification analysis (RQA; see, e.g., Marwan, Romano, Thiel, & Kurths, 2007; Webber & Zbilut, 2005). This enables us to capture the relation between the real-time dynamics of the parent-child interaction at the microlevel and developmental changes at the longer timescale.

METHODS

Participants

The database used in this study consists of samples of longitudinal speech from 1 Dutch-speaking girl named Jessica (between ages 1;7 and 2;6 years) in spontaneous conversations with her mother. In the beginning of the study, Jessica was in the one-word stage whereas at the end of the observation period her language showed various characteristics of the differentiation stage. At this stage, children generally acquire the major lexical categories (such as nouns, verbs, adjectives/adverbs) and increasingly use morphological and syntactical rules.

Data Collection and Processing

The child was videorecorded at home in unstructured interactive sessions (60 min in length each) with her mother (in the presence of an observer). All child and child-directed adult speech was transcribed orthographically (CHAT format; MacWhinney, 2000). The independent interobserver reliability was calculated in a very strict way as the overlap percentage of exact utterance length of all individual utterances. The estimation is based on roughly 10% of all transcribed material and resulted in a value of 88%.

The corpus was part of a larger database collected for earlier research projects (see Van Dijk & Van Geert, 2005, 2007). The data are also used in other linguistic and descriptive analyses (as reported in Bassano et al., 2011; Van Dijk & Van Geert, 2011) and model testing (Van Dijk et al., 2013). The measurements were taken in six waves of six observations with Jessica and one parent. The waves were evenly distributed over the measured period and took 2 weeks each. In the current analyses, *only* the sessions with her mother were used (the number of observations per wave were 3, 2, 4, 3, 4, and 6, respectively), leading to a total of 22 data points. The analyses are based on the first 220 utterances of both child and mother so as to have equally long time series within each session. Within each sample, the number of one-, two/three-, and more-word utterances (excluding fillers) were calculated. One-word utterances were recoded as “0”

(W1; “holophrasic”), two/three-word utterances as “1” (W2/3; “combinatory”), and four- and more-word utterances as “2” (W4+; “grammatical”), so as to create categorical time series for each of the interlocutors and for each session.

Data Analysis

A special-purpose MATLAB script was used for performing cross-recurrence quantification analysis (CRQA; Shockley, Butwill, Zbilut, & Webber, 2002) on the time series of linguistic categories (see Dale & Spivey, 2006, and Reuzel et al., in press, for examples of CRQA on language data). The functions “dl” and “tt” from Marwan’s (2009) CRP Toolbox were used to calculate the distribution of diagonal lines and vertical lines from the recurrence matrix, respectively. MATLAB output was further processed using Excel. Statistical analyses over sessions were performed with a Monte Carlo method. First, the slope of the empirically found values was calculated, which could be positive or negative. Second, all empirical values were repeatedly shuffled across time (resampling all values with replacement; 10,000 simulations). Third, the empirically found slopes were compared with the simulated ones. When the empirically found slopes were replicated by the simulated values in only 5% of simulations or less, the result was considered significant.

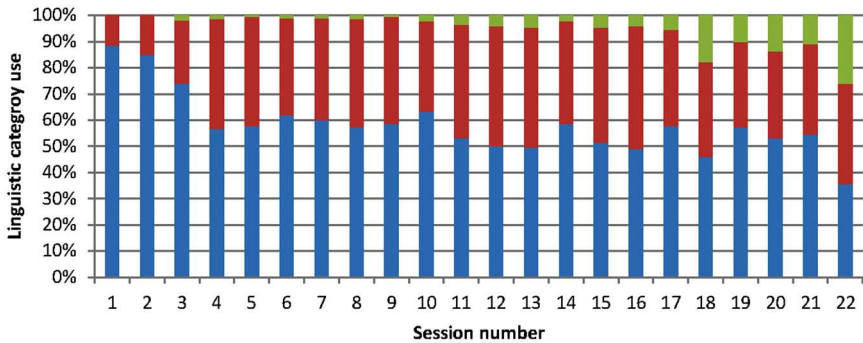
RESULTS AND DISCUSSION

Figure 1 presents bar graphs of the use of the three linguistic categories (W1, W2/3, and W4+), for both the child and the mother separately, over the time course of the 22 sessions. A gradual increase is visible in utilization of the W4+ category for both parent and child as percentage of the total number of utterances (see also Van Dijk & Van Geert, 2011). This becomes particularly clear during the second part of the observed period.

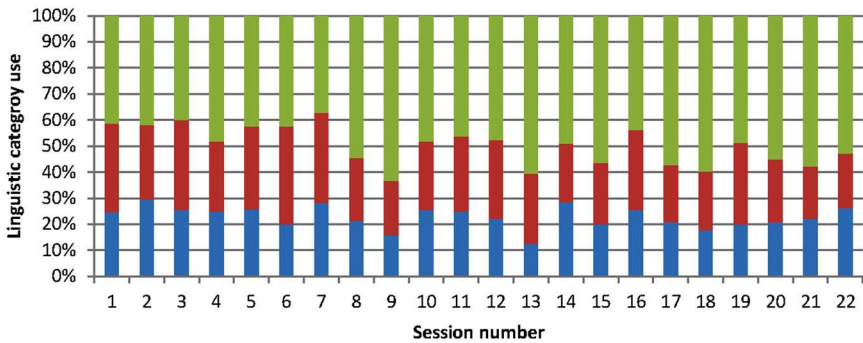
Recurrence Quantification Analysis

The results of the cross-recurrence quantification analysis on the categorical time series of utterance-length categories show significant linear decreases of Laminarity (LAM), Trapping Time (TT), and the maximum length of vertical lines (MaxVL) in the recurrence plot over the subsequent sessions (for all slopes, $p < .001$; Figure 2).

LAM values drop from 0.90 in the first sessions to 0.58 in the final session. A similar pattern is visible for TT, dropping from 8.3 to 2.6. With respect to MaxVL there is a sharp decrease from high values in the first three sessions



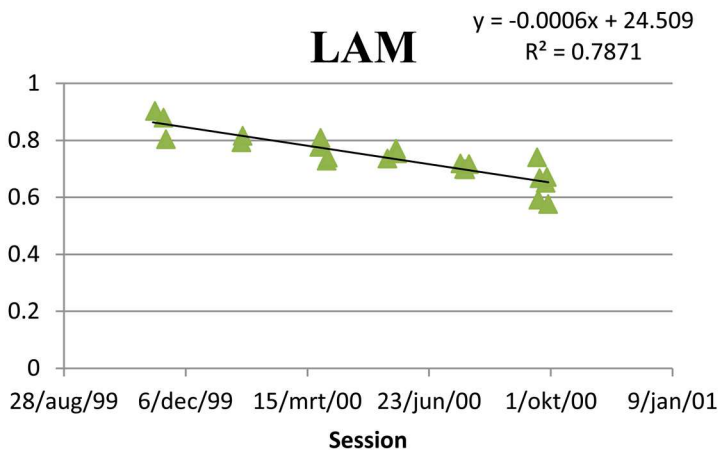
(a)



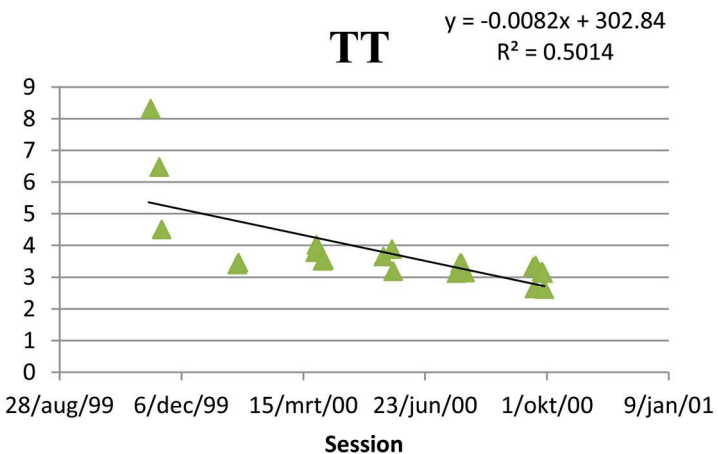
(b)

FIGURE 1 Bar graphs of child (a) and parent (b) use of the three linguistic categories over the subsequent sessions. Legend: blue = W1-Holophrasic; red = W2/3-Combinatory; green = W4+-Grammatical. (color figure available online)

(30, 26, 22) to values between 8 and 15 for the remaining 19 sessions. All three of these measures quantify the presence of laminar states in a system's behavior (see, e.g., Marwan et al., 2007), and their combined result reveals a clear decrease in the amount and length of these states. In the context of the present study, laminar states refer to specific dyadic patterns in which mother and child capture each other's grammatical form, possibly over multiple timescales. More concretely, a high degree of laminarity occurs when at some point one of the speech partners chooses a single linguistic category (either W1, W2/3, or W4+) for some uninterrupted period of time and when such episodes are mirrored by the other repeatedly throughout the conversation. TT in particular

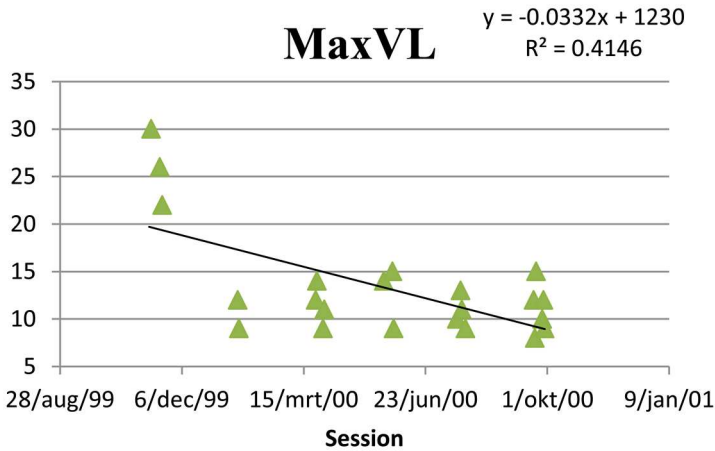


(a)



(b)

FIGURE 2 Laminarity (LAM; a), Trapping Time (TT; b) and maximum vertical line length (MaxVL; c) for the parent-child conversation over sessions, as retrieved by the categorical cross-recurrence quantification analysis on the linguistic categories. (color figure available online) *(continued)*



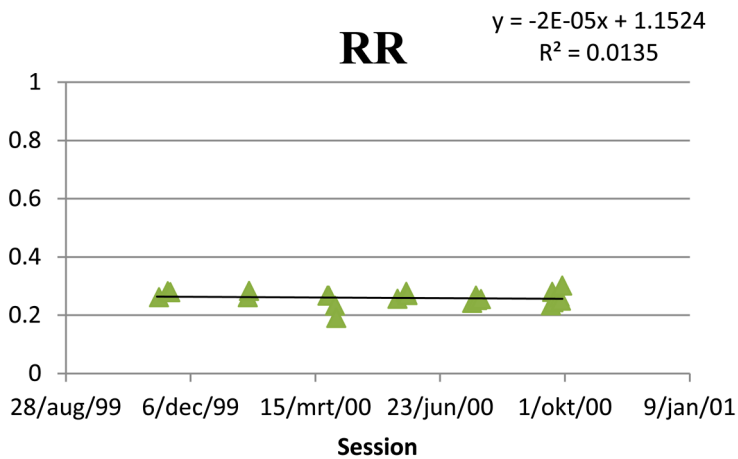
(c)

FIGURE 2 (Continued).

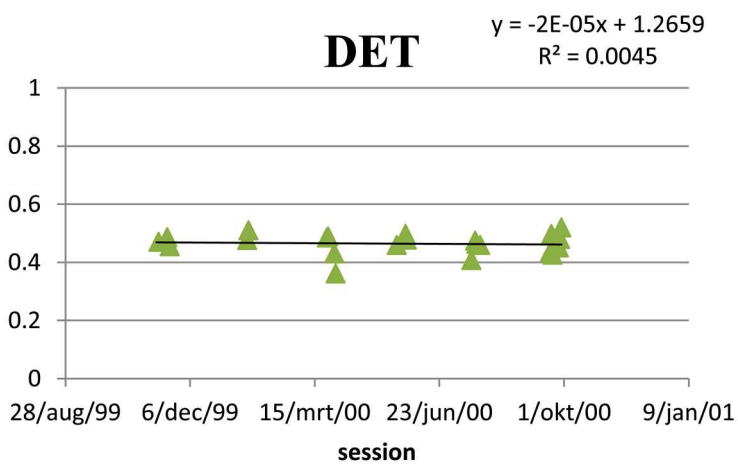
has been associated with “interactional rigidity” in a previous study on mother-infant gaze (De Graag, Cox, Hasselman, Jansen, & De Weerth, 2012). Following this interpretation, the decline in laminar-states measures as seen here reflects a decrease of rigidity of the parent-infant conversation, or, likewise, an increase in the flexibility of (coupled) use of the three categories of utterance length.

Of the RQA measures quantifying the diagonal lines in the recurrence plot, only the average diagonal line length (MeanL) changes significantly over the sessions ($p = .041$). In Figure 3, the diagonal-line measures Determinism (DET) and MeanL as well as the Recurrence Rate (RR) are shown.

RR hovers around a relatively stable value of 0.26 with a range of 0.19 to 0.30. For completely uncorrelated, unstructured processes (i.e., of parent and child utterances) the recurrence rate would attain the (a priori) value of $1/3$ because there are nine different combinations in the utterance categorization, of which three are recurrent. The slight deviation from this a priori value reflects that certain categories are more prominent within the dyad and that individual utterances might be coupled. DET also remains stable over the subsequent sessions with a mean intersession value of 0.46 (range: 0.36–0.52). This means that the conversations are equally regular and patterned over sessions. About 46% of the recurrent points constitute a diagonal line; the rest of them are isolated recurrences. Although the linear decrease in MeanL is significant, the range is limited, between 2.2 and 2.5, and the average diagonal line length is close to the minimum of 2 for all sessions, which makes this effect rather weak.

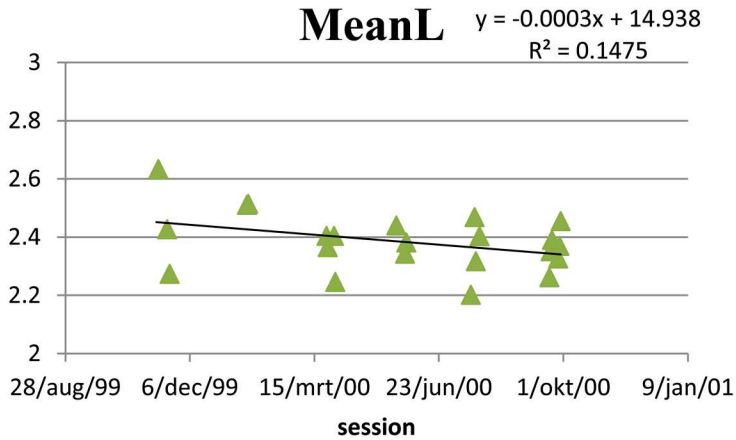


(a)



(b)

FIGURE 3 Recurrence Rate (RR; a), Determinism (DET; b) and the average diagonal line length (MeanL; c) for the parent-child conversation over sessions, as retrieved by the categorical cross-recurrence quantification analysis on the linguistic categories. (color figure available online) *(continued)*



(c)

FIGURE 3 (Continued).

From a developmental perspective, the broadening of the distributions of linguistic-category use in the conversations at later sessions (see Figure 1), that is, the increase in utterances length over time, could play itself out in any number ways at the level of moment-to-moment interaction. For instance, although a higher degree of variation arises for each member of the dyad, the use of the holophrastic, combinatory, and grammatical categories might still be tightly coupled between interlocutors. This would effectively entail an (instantaneous as well as deferred) imitation in speech for both parent and child where relatively long patterns of the same linguistic category occur repeatedly. This kind of behavior was mainly observed in the initial sessions. On the other hand, the rise in expressive range might lead to more flexible and adaptive use of distinct grammatical forms, which was increasingly observed toward the final sessions of parent-infant conversations.

Summarizing, the results of the microdevelopmental analysis presented here suggest that language development reveals itself (among other ways) in terms of the utilization of grammatical forms that become more loosely coupled between interaction partners. **In other words, along the developmental timescale in this period of observation, the structure of conversation seems to move toward a more "adult" level in which grammatical form and communicative content generally appear less tightly connected.** As the conveyance of thoughts, ideas, and desires become more detailed and sophisticated, the lengths of subsequent utterances become less predictive of each other and of patterns of utterance lengths further

on in the conversation. Instead, grammatical form in proficient conversation is much more linked to context and its functional role in discourse (viz., question, answer, remark, statement).

Finally, this study showcases how a microgenetic approach combined with nonlinear time-series methods (e.g., CRQA) is able to provide valuable insights about coupling and flexibility in parent-child dialogue and its role in language development. Within the field of developmental psychology in general this approach has not been applied as much as it should be, with some exceptions (Aßmann, Romano, Thiel, & Niemitz, 2007; Dale & Spivey, 2006; De Graag et al., 2012; Lichtwarck-Aschoff, Hasselman, Cox, Pepler, & Granic, 2012; Wijnants, Hasselman, Cox, Bosman, & Van Orden, 2012). The ongoing improvements of techniques and the appearance of powerful new measures based on recurrence analysis, especially for categorical time series, will make this approach increasingly important and appealing for the study of developmental processes. As a prominent exponent of the complexity approach in the cognitive and behavioral sciences we owe gratitude to Guy Van Orden for familiarizing us with these techniques.

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