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Within-teacher differences in one-to-one teacher–student interactions in instrumental music lessons

Elisa Kupers^{a,*}, Marijn van Dijk^b, Paul van Geert^b

^a Department of Pedagogy and Educational Sciences, University of Groningen, The Netherlands

^b Department of Developmental Psychology, University of Groningen, The Netherlands

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ABSTRACT

The aim of this study was to look at within-teacher differences in scaffolding behaviors and patterns over longer periods of time. We analyzed scaffolding on different levels of increasing complexity, ranging from frequencies of scaffolding behaviors to measures of the variability of the teacher–student scaffolding interactions. We tested whether the scaffolding behaviors and patterns were systematically different when the same teacher interacted with four different students, and whether these patterns changed over the course of 18 months. Overall, the findings confirm that differences in scaffolding patterns in the interaction with different children exist, especially between the high-performing student and the other below-average performing students. Specifically, the teacher–student interaction with the high-performing student showed higher levels of contingent scaffolding and more intra-individual variability in the interactional patterns. In general, little evidence was found for systematic increases or decreases of scaffolding quality and intra-individual variability measures over time.

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1. Introduction

The aim of this paper is to investigate the differences in one-to-one scaffolding interactions of four students and one music teacher, in order to discover how differences in overall characteristics between students play a role in learning in the here-and-now. We conceptualized the student–teacher interactions on different levels, namely in terms of frequencies of teacher and student behaviors, in terms of one-lag sequences and in terms of the structure of the whole time series within each lesson.

1.1. Defining scaffolding

“The most important single factor in learning is what the learner already knows. Ascertain this and teach him accordingly” (Ausubel, 1968, p. iv).

This assumption summarizes a fundamental principle of teaching, which is that the teacher adapts his or her instruction to the level of the student. This principle is central to constructivist teaching in general and scaffolding in particular. In learning, based on the theory of Vygotsky (1978), scaffolding refers to temporary support by an adult to help the child complete a task that is just beyond the current level of the child (Granott, Fischer, & Parziale, 2002; Wood, Bruner, & Ross,

1976). After successful scaffolding, the support can be toned down so that the child can function independently at a higher level.

Attention for the concept of scaffolding in educational research has been increasing over the past decades, but its use tends to be overgeneralized (Puntambekar & Hubscher, 2005). The problem is that the term is increasingly being used as a synonym for ‘support’ (such as hints and feedback by the teacher), while the original definition of scaffolding is more specific and describes how teachers *adapt* their support or level to what the student is showing at one particular moment in time. This also implies that not all teacher–student interactions can be called ‘scaffolding’. For the remainder of this article, we will use the term scaffolding when referring to interactions where the teacher adapts his or her level to the student, and the more neutral term ‘interactions’ in cases where the transactions might be either adaptive or non-adaptive.

The focus of the current study is on contingency, which is a central mechanism in scaffolding. Contingency implies that the teacher adapts his or her teaching level to the performance level of the student, and that, as a result, the student’s level increases (Van de Pol, Volman, & Beishuizen, 2009; 2010; Van Geert & Steenbeek, 2005). This teaching level can be conceptualized as the assignments that the teacher gives, the type of support that the teacher provides through asking questions, etcetera. Importantly, the levels of these ‘scaffolds’ are assigned in the same way that a level of skills or knowledge is assigned to the student’s response to these tasks. The levels of the student and the teacher are dynamically coupled (Van Geert & Steenbeek, 2005) and there is an optimal distance between the two. If this distance is too large, the student will not be able to pick up the instruction, but if the distance is too small,

* Corresponding author at: Grote Rozenstraat 38, 9712 TJ Groningen, The Netherlands
E-mail addresses: w.e.kupers@rug.nl (E. Kupers), m.w.g.van.dijk@rug.nl (M. van Dijk), p.l.c.van.geert@rug.nl (P. van Geert).

the student will not be able to learn anything new. This optimal distance is not a fixed property, but can be different for different students (Steenbeek & van Geert, 2006). The process of scaffolding also implies a coupling of timescales: Long-term learning and teaching outcomes emerge out of moment-to-moment interactions, and these same long term outcomes or 'distal factors' restrict the range of future real-time interactions (Van Geert & Steenbeek, 2005).

1.2. Individual differences in educational interactions

Many studies show that contingent scaffolding is related to positive learning outcomes, such as improved metacognitive skills (Azevedo, Cromley, Winters, Moos, & Greene, 2005; Mercer, Dawes, Wegerif, & Sams, 2004) and improved cognitive representations (Murphy & Messer, 2000). This effect can disappear if the teacher's scaffolding of a smaller group of students is detrimental to the on-task behavior of the other students who are left more to their own devices (Van de Pol, 2012).

Although scaffolding appears to be an effective teaching method in general, there are large differences in the extent to which teachers actually apply contingent scaffolding in everyday educational practice. Research has shown that these differences can be attributed to the varying levels of teachers' expertise (Borko & Livingston, 1989; Meyer, 2004) or individual teacher's attitudes (Suk Lee, Baik, & Charlesworth, 2006). The role of individual differences between students in teacher-student interactions has received much less attention. Pat El, Tillema, and Koppen (2012) found that individual differences in the students' sense of autonomy, competence and relatedness mediated the relationship between the instructional behaviors of the teacher and the motivation of the student. In a multiple-case study on dynamic assessment (a concept closely related to scaffolding), Ensing, Van Geert, Van der Aalsvoet, and Voet (2014) found that interaction patterns in kindergarten were different when the teacher interacted with two different children. More specifically, the children differed in the way they (tried to) elicit help from their teacher.

In sum, scaffolding centers around mutual adaptations between teacher and student that occur in the here and now of learning and teaching. Because of the coupling of the timescale with long-term development, we expect that differences in distal factors, such as student characteristics, are related to different patterns in teacher-student interactions.

1.3. Analyzing educational interactions from a dynamic point of view

Learning processes on the micro-level timescale are often characterized by complexity and nonlinear growth (Jörg, Davis, & Nickmans, 2007; Steenbeek & van Geert, 2013). Therefore, there is a need for research designs focusing on individual processes, i.e. the real-time processes that occur between a particular teacher and student(s), with dense observations over time (Kupers, Van Dijk, McPherson, & Van Geert, 2014). These dense measurements allow us to analyze not only the *content* of the teacher-student interaction, but also at its temporal *structure*, for instance in terms of intra-individual variability over time (see also Mainhard, Pennings, Wubbels, & Brekelmans, 2012).

According to complexity-based theories of development and learning, intra-individual variability is a fundamental characteristic of development. Variability allows a system (for instance, the teacher-student dyad) to explore different ways of adapting to one another. This exploration is necessary in finding a new, optimal state (van Dijk & van Geert, *in press*; Thelen & Smith, 1994). Long before the introduction of complexity-based theories, Skinner (1950; 1981) pointed at intra-individual variability as a core principle of learning. According to Skinner, behavior spontaneously varies over time. The variations that are reinforced through the environment are more likely to re-occur in the future (operant conditioning).

The empirical literature on variability and learning shows that an increase of variability (or disorder) is often an indicator of a developmental transition. For instance, children showed more variability in the number of errors they made just before discovering a new strategy to address a matrix-completion task (Siegler & Svetina, 2002). Research that addresses variability in real-life classroom settings (contrary to laboratory settings) is relatively scarce (Mainhard et al., 2012).

1.4. The current study

Because research on patterns in teacher-student interactions is scarce, our study will provide a first exploration of how to measure the relevant characteristics of microgenetic interaction patterns (including contingency and intra-individual variability) over time. This study tests whether several structural microgenetic measures allow us to differentiate between four students of a single teacher with highly different overall characteristics (e.g. students with varying levels of overall progress). Through this closer look at the differences in patterns at the micro-level, future studies will be able to better understand how interactional patterns within the lesson can contribute to different outcomes on the long term (Kupers, Van Dijk, McPherson, & Van Geert, 2014).

The aim of this study is to reveal the most important characteristics of the interaction patterns over time, such as the extent to which the interaction patterns are variable, and whether these patterns differ between students. One way of studying these structural aspects over time is by specifying the interaction in a state space, which is a collection of all the possible states of a system (Lewis, Lamey, & Douglas, 1999). The data of each teacher-student dyad can be plotted in a State Space Grid (SSG) (Lewis et al., 1999). The degree of movement across the SSG is an indicator of the variability of the interaction within one lesson.

Our study is conducted in the context of individual violin lessons, which is a highly relevant context for studying scaffolding, as learning to play a musical instrument requires many complex skills that have to be 'scaffolded'. Furthermore, individual music lessons provide continuous one-to-one communication, and therefore much opportunity to observe uninterrupted patterns of dyadic interaction.

1.5. Research questions

Main question: Are there systematic differences between the interactions of one teacher with different students?

The relevance of studying differences between students in interactional patterns is twofold. First, the pre-existing differences between students are expected to play a role in how the teacher might shape effective scaffolding. Second, different levels of overall progress emerge out of the repeated micro-level interactions.

We look at the within-teacher differences at levels of increasing complexity. At the most simple level (L1), we want to know whether the teacher and student behaviors are different for the different dyads. At the second level (L2), we will look at differences between interaction sequences, e.g. whether the teachers' *responses* to student performances differ and whether there is a difference in the extent to which these responses are contingent. And at the third (most abstract) level (L3), we will investigate differences in the *structure* of the interaction with different students with measures of intra-individual variability.

Sub questions:

1. Are there differences between students in the level of the teacher assignments during the lessons, and in the level of student performance on these assignments (L1)?
2. Are there differences between students in the amount of contingent sequences during the lessons (L2)?
3. Are there differences between students in the structure of the interaction patterns (L3)?

4. Do interaction patterns show trends over longer periods of time (18 months), and are these patterns different between the four students (L2 + L3)?

We expect differences between the interactions of different teacher–student dyads to be connected to overall student characteristics. Because the study deals with the early stages of learning in music lessons, we expect contingency in the interactions to increase over time as teacher and student get to know each other better.

2. Method

2.1. Participants

The data of this study was the result of a larger longitudinal study (Kupers, 2014). One violin teacher and four of her beginning students participated in the current study. The teacher was experienced and taught violin lessons in a private practice, according to the Suzuki method. This is an internationally used method to teach string instruments to young children (Suzuki, 1969). At the start of the study, the students (Milou, Adam, Joyce and Daphne) were between 5;1 and 5;11 years old and had been following music lessons for between 1 and 8 months (see Table 1). At the end of the measurement period, the teacher rated the progress of each student on a 5-point scale, ranging from 'below average' (1) to 'above average' (5). On the basis of this score, we selected the teacher with the most variation in student progress scores. Informed consent was requested from both parents and the teacher, in line with the University of Groningen's Psychology Ethics Committee guidelines.

2.2. Measurements

The two key variables in this study were the level of the student performance and the level of the teacher assignment at each point in the lesson. The level of the teacher assignment was measured in relation to the previous assignment, and the level of the student performance was measured in relation to the previous teacher assignment. These measures were used to compare student and teacher behaviors (L1). If these variables are plotted over time, it is possible to construct the higher-level process measures: scaffolding sequences (L2) and the structure of the interaction (L3).

2.2.1. Behavioral measures (L1)

1. *Teacher assignment level* was measured every time the teacher gave the student a new assignment in the lesson (verbally or non-verbally). Each assignment was rated in terms of complexity relative to the previous assignment and assigned to one of four ordinal categories: *Forward* (more complex than the previous assignment, e.g. combining more task elements), *Backward* (less complex than the previous task, e.g. eliminating task elements), *Repeat* (a repetition of the previous task) or *New task* (the current task being unrelated to the previous task, e.g. play another piece). This coding scheme is based on Siebenaler (1997).
2. *Student performance level* was measured after each assignment given by the teacher. The student's attempt to execute this specific assignment was either rated as *Correct*, *Partially correct* or *Incorrect*.

Table 1
Student characteristics.

Name ^a	Adam	Daphne	Joyce	Milou
Age (years; months)	5;10	5;1	7;4	5;11
Months of lessons	1	3	3	8
Progress	2	1	2	5

^a Students' names were changed for the sake of privacy.

Fig. 1. Example of a State Space Grid of one lesson. The states with a black line represent contingent scaffolding.

This coding scheme is a simplified version of the coding scheme used in Kupers, Van Dijk and Van Geert¹ (2014, p. 9).

Inter-observer reliability was determined for 10 videos (from the larger dataset). First, the first two authors determined agreement on the unit of analysis, for which the agreement was 89% (agreement levels between 81 and 98% per video). Second, Teacher assignment level and Student performance level were coded, resulting in Cohen's Kappa of .91 for Teacher assignment level (agreement between 67 and 100%) and Cohen's Kappa of .78 for Student performance level (agreement between 63 and 95%).

2.2.2. Process measures (L2 and L3)

1. *Contingency (L2)*. For each coded lesson, the actions and reactions of teacher and student level are plotted in a State Space Grid (Lewis et al., 1999; see Fig. 1). On the basis of the literature on scaffolding, we determined which sequences of actions (e.g. cells in the SSG) could be labeled as contingent scaffolding (see the yellow-lined cells in the SSG). Contingent scaffolding implies that there should be an optimal distance between the level of the student and that of the teacher, with the teacher being (slightly) ahead. For instance, the teacher can make the assignment less complex following an incorrect student performance.
2. *Dispersion (L3)*. Dispersion is a measure that reflects the extent to which interactions are variable over time (Hollenstein, 2012). It can take a value between 0 (all sequences are in one cell of the grid, for instance in the Partially correct–Repeat cell) and 1 (all sequences are equally spread out over the grid).
3. *Visit entropy (L3)*. Entropy is another measure of within-lesson variability. It quantifies the orderliness or predictability of communication patterns, with low entropy indicating a very ordered pattern (Partially correct–Repeat–Partially correct–Repeat, etc.) and higher

¹ The coding scheme for student performance used for the case studies in Kupers, van Dijk, and van Geert (2014) measures the progress on two specific goals. Because numerous goals were addressed in the data of this study, the decision was made to alter the coding scheme and reduce it to three levels (instead of a continuous scale) to make it broadly applicable to all possible goals that are addressed in each lesson.

Fig. 2. Overall percentage of performance level categories for the four students.

values of entropy indicating a more random, disordered pattern (Correct–Repeat–Partially correct–Backward etc.) (Dishion, Nelson, Winter, & Bullock, 2004; Hollenstein, 2012). Both Entropy and Dispersion measure whether the teacher–student interaction has strong attractor states (i.e. patterns in the student–teacher interaction that keep recurring) or the interactions are flexible, i.e. show constant change. Also, both measures represent characteristics of the interaction in a lesson as a whole, which has consequences for the quality of learning but cannot be brought back to specific teaching strategies (unlike the other measures). Unlike the Dispersion, Entropy does not have a set range of possible values; the range depends on the number of cells and the distribution of the data.

2.3. Procedure

For each student, 7 lessons were recorded at three-month intervals. Adam quit his violin lessons after 4 measurements. The recordings were made by the first author; teachers and students were asked to carry out their lesson as they normally would. The first 10 min of every lesson video (which lasted between 15 and 30 min) was coded using Observer (version 10.5, Noldus).

2.4. Analyses

First, we explored differences between the four students with regard to the frequencies of specific teacher and student behaviors (Teacher assignment level and Student performance level; research question 1). The differences were tested with a Chi-Square test using SPSS.

Second, we tested whether the students differed in the level of contingent scaffolding (research question 2), the mean amount of Dispersion (research question 3) and the mean amount of Visit entropy (research question 3) with a non-parametric Monte Carlo (MC) test. The first step of the MC test consists of calculating the average levels of contingency for each student, as well as the differences between these average levels. As a second step, the column with all data points (one data point per lesson) is randomly shuffled, after which another four averages (one per student) are calculated (maintaining the original number of data points for each student) and the differences between these averages are calculated. The random shuffling of the data corresponds with our null hypothesis (there are no systematic differences between students). This second step is repeated 1.000 times. And as a final step, we used a Monte Carlo simulation to test whether the differences between students in the actual data were larger than the differences in the randomly shuffled data. This procedure was repeated for the other two variables (Dispersion and Visit entropy).

Third, the differences between students in the frequencies of teacher responses after Correct, Partially correct and Incorrect performances were tested using Chi Square tests (separate tests for teacher frequencies after Correct, Partially correct and Incorrect performances) (post hoc analyses for research question 2).

Finally, we plotted all variables over time and tested the trends non-parametrically using a Monte Carlo test (research question 4), comparing the slope of the empirical data with the slope of randomly shuffled data.

3. Results

The first three sub questions all relate to testing whether there are systematic differences between the four students, regardless of time. If the differences do not turn out to be statistically significant, this does not mean that the teacher has a rigid style of scaffolding. Instead it means that the different interactions with the same student are as variable as the differences between students (i.e. the inter-individual variability is relatively small compared to the intra-individual variability).

3.1. Research question 1: Are there differences between students in the level of the assignments of the teacher during the lessons, and in the level of the student's performance on these assignments?

Overall, the vast majority (x%) of the performances was labeled as Correct or Partially correct (see Fig. 2). This relatively high level of performance throughout the 18 months of recording, can indicate that the teacher is scaffolding relatively low in the zone of proximal development (she picks assignments that the students at least partially master). Furthermore, the analysis revealed significant differences between the four students ($X^2 = 26.05$, $df = 6$, $p < .01$) (see Fig. 2). Milou had far higher levels of correct performances during the lessons, while Adam had a far higher percentage of partially correct performances, compared to the other children.

Fig. 3 shows that the vast majority of the teacher assignments (%) involve repetition of the previous assignment. Compared to the other students, Milou had a somewhat higher percentage of New tasks and Backwards, and a lower percentage of Repeat. However, overall there are no significant differences between the students ($X^2 = 13.70$, $df = 9$, $p = .16$).

3.2. Research question 2: Are there differences between students in the amount of contingent sequences during the lessons?

Overall, 48.4% of the interaction sequences could be labeled as 'contingent scaffolding'. If we compare the lessons of the four students, we see that Milou's lessons contain higher levels of contingent scaffolding (53.7%) than Adam, Daphne and Joyce's lessons (44.5, 41.0 and

Fig. 3. Overall percentage of teacher assignment level categories for the four students.

Table 2a

Level of teacher assignment after a Correct performance for the four students. Bold font indicates the contingent sequences.

	New Task	Forward	Repeat	Backward	Total
Adam	3 (15.8%)	4 (21.1%)	11 (57.9%)	1 (5.3%)	19 (100%)
Daphne	12 (15.8%)	18 (23.7%)	41 (53.9%)	5 (6.6%)	76 (100%)
Joyce	12 (25.0%)	10 (20.8%)	22 (45.8%)	4 (8.3%)	48 (100%)
Milou	22 (28.2%)	23 (29.5%)	21 (26.9%)	12 (15.4%)	78 (100%)

43.6% contingent scaffolding respectively). The difference between Milou's level of contingency and the average level of the other three students is significant ($p = .03$). Of the individual comparisons between all students (Adam vs. Daphne, Adam vs. Milou, etcetera), only the difference between Daphne and Milou is significant ($p = .05$).

In order to further explore in what way (contingent and non-contingent) the teacher's interaction sequences differ for the different students, we compared the teacher's responses to the individual students' performance levels. Tables 2a, 2b and 2c show the level of the first assignment after the students' Correct, Partially correct and Incorrect performances, respectively.

After Partially correct and Incorrect performances, the level of the next teacher assignment did not differ between the four students ($X^2 = 4.34$, $df = 9$, $p = .89$ for the responses after Partially correct; $X^2 = 4.32$, $df = 6$, $p = .63$ for the responses after Incorrect, although the latter has to be interpreted with caution due to the low overall frequencies). The responses after Correct performances were different for the four students at a near-significant level ($X^2 = 15.94$, $df = 9$, $p = .07$). Again, we mainly see differences between Milou and the other three students. The teacher tends to respond to a correct performance by Milou with either Backward or Forward, rather than a Repetition of the task.

3.3. Research question 3: Are there differences between students in the structure of the interaction patterns?

The SSGs yielded high levels of Dispersion (between .73 and .94 on a scale of 0 to 1, with an average level of .85), which means that in general, the interactions are characterized by flexibility and do not have strong attractors, i.e. states towards which the interaction is drawn (such as long chains of Correct–New tasks). The Dispersion in Milou's lessons is significantly higher than in those of the other three students ($p = .01$) (see Table 3), while the Dispersion in Adam's lessons is significantly lower than in those of the other three students (Milou–Adam $p = .001$; Joyce–Adam $p = .04$; Daphne–Adam $p = .04$). The other inter-individual comparisons are not significant (Milou–Joyce $p = .16$; Milou–Daphne $p = .11$; Joyce–Daphne $p = .47$). Like the findings on Dispersion, the scaffolding patterns in Milou's lessons show a significantly higher level of entropy than the level in the other three students' lessons ($p = .004$). From the inter-individual comparisons, we see significant differences between Milou and Joyce's entropy levels ($p = .05$) as well as a difference between Milou and Adam ($p = .001$).

3.4. Research question 4: Do scaffolding patterns show trends over longer periods of time (18 months) for the four students?

Figs. 4, 5 and 6 show the scaffolding pattern variables over the seven measurements for the four students (respectively Contingency,

Table 2b

Level of teacher assignment after a Partially correct performance for the four students. Bold font indicates the contingent sequences.

	New Task	Forward	Repeat	Backward	Total
Adam	6 (15.4%)	4 (10.3%)	23 (59.0%)	6 (15.4%)	39 (100%)
Daphne	8 (13.6%)	11 (18.6%)	28 (47.5%)	12 (20.3%)	59 (100%)
Joyce	7 (12.3%)	7 (12.3%)	33 (57.9%)	10 (17.5%)	57 (100%)
Milou	4 (10.5%)	4 (10.5%)	20 (52.6%)	10 (26.3%)	38 (100%)

Table 2c

Level of teacher assignment after an Incorrect performance for the four students. Bold font indicates the contingent sequences.

	New Task	Forward	Repeat	Backward	Total
Adam	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3 (100%)
Daphne	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3 (100%)
Joyce	0 (0%)	0 (0%)	5 (100%)	0 (0%)	5 (100%)
Milou	0 (0%)	1 (11.1%)	6 (66.7%)	2 (22.2%)	9 (100%)

Dispersion and Event entropy). The Contingency shows variable levels over time, with no clear increase or decrease for any of the four students (p -values of the slopes range between .53 for Adam and .14 for Joyce; see Fig. 4).

In contrast, the Dispersion stays remarkably stable over time for all four students (Fig. 5), with relatively high values throughout the time series. Milou shows a slight, significant increase in Dispersion ($p = .03$) while the other students do not show a significant increase (Adam; $p = .07$; Joyce: $p = .30$; Daphne: $p = .35$). We see very slight increases over time in Visit entropy (Fig. 6), none of which are statistically significant (p -values of .50 (Adam), .26 (Daphne), .28 (Joyce) and .14 (Milou)).

4. Discussion

4.1. Conclusion

The aim of this study was to look at within-teacher differences in teacher and student interaction patterns over longer periods of time. We analyzed scaffolding on different levels of increasing complexity, ranging from frequencies of behaviors (L1) to interaction sequences (L2) to variability of the teacher–student interactions. We tested whether the behaviors and interaction sequences/patterns differed systematically when the same teacher interacted with different students. Overall, the findings confirm that such differences exist, especially between the high-performing student and the other students who were performing at a below average level.

4.1.1. Question 1. Differences between students in teacher assignment levels and student performance levels

The results show differences between the students' performance levels during the lessons. The fact that Adam had a relatively low percentage of correct performances compared to the other students, corresponds with the literature on how students who eventually quit music lessons show lower success rates, possibly leading to diminished motivation (Costa-Giomi, Flowers, & Sasaki, 2005). However, it should be noted that among all four students, there were very few instances of incorrect performances. It seems that the teacher stays relatively low in the zone of proximal development. This teacher opts for assignments that she knows the students can at least partially master, rather than running the risk of having them experience failure. Repetitions of previous assignments often occurred. Because of the complex set of skills which playing a musical instrument requires, frequent repetitions are necessary to instill the previously learned skill. We will come back to the relation between scaffolding and consolidation later on in this section.

Table 3

Mean levels of within-lesson Dispersion and Visit entropy for all four students.

Student	Dispersion	Visit entropy
Adam	.79	1.51
Daphne	.85	1.70
Joyce	.85	1.66
Milou	.89	1.84

Fig. 4. Levels of Contingency over time for the four students.

Fig. 5. Levels of Dispersion over time for the four students.

4.1.2. Question 2. Differences between students in the interaction sequences

There is evidence for a positive relation between contingency and student performance (e.g. Mercer et al., 2004). Our findings are in line with this association. The student who showed above average progress had a higher level of contingency, which provides support for the assumption that contingent scaffolding promotes learning. However, the direction of the effect is still unknown; it might be easier to provide contingent teaching to a well-performing student because the teacher might have a bigger repertoire of tasks to choose from. Looking closely at the content of the sequences reveals that the teacher's responses after correct student performance were more varied for the above average student, whereas no differences occurred after a partially correct or incorrect performance.

4.1.3. Question 3. Differences between students in structure of interactional patterns

Again, we mainly observed differences between the well-performing student (more variability/flexibility) and the others. This is reminiscent of findings on the function of variability in other domains of child development; variability offers room for exploration and flexibility in the (dyadic) system and therefore acts as a driving force of developmental growth and learning, which in turn contributes to long-term outcomes (van Dijk & van Geert, in press). The role of intra-individual variability has been investigated in diverse settings, such as parent–child interactions at home (Lunkenheimer, Olson, Hollenstein, Sameroff, & Winter, 2011), therapy (Lichtwarck-Aschoff, Hasselman, Cox, Pepler, & Granic, 2012), feeding interactions (Van Dijk, Hunnius, & van Geert, 2009) and the classroom (Mainhard et al., 2012). These findings point in different directions: in affective parent–child interactions, greater variability was positively associated with long term outcomes (Lunkenheimer et al., 2011) whereas in classroom interactions, variability was negatively associated with learning outcomes (Mainhard et al., 2012). Other studies that focused on specific transitions in different contexts found a spike in variability around the transition (Bassano & van Geert, 2007; Chow, Davids, Hristovski, Araújo, & Passos, 2011; Lichtwarck-Aschoff et al., 2012; Van Dijk et al., 2009). The exact role of variability seems to depend on both the topic of the study and the timing of the measurements (see also Van Dijk & van Geert, in press).

How does this relate to scaffolding and to our findings? Scaffolding implies constant change towards a higher level, since the teacher and student levels are coupled. Translated to the state space of their interaction, this implies a moving attractor state and thus a high amount of variability. However, the aspect of consolidation of skills (discussed earlier in the Discussion section) is not incorporated in the scaffolding concept. In order to truly consolidate a basic skill, an assignment should be repeated extensively. In terms of the state space, this would mean that

there is a temporary attractor where the teacher assignment stays at the same level and the student repeats correct performances, leading to less-variable interactions. In our case, only the lower-performing students had these lower levels of variability. It might well be that these students need longer periods of consolidation of the basic skills.

4.1.4. Question 4. Differences between students in trends over time

In this study, the levels of contingency and dispersion did not show an increase or decrease over time. This is in contrast with results from Steenbeek, Jansen & van Geert (2012), where a decrease in quality of interactions over time was found, for a student in special education. This suggests that problematic learning trajectories may be associated with a decrease in contingency, but that the opposite is not necessarily true.

4.2. Directions for future research

The literature on the role of variability in educational settings describes mixed results, which led us to hypothesize that the role of variability in learning depends on the context and timing. One issue that makes research on variability in educational settings harder to interpret is the fact that in past developmental studies, researchers have looked at developmental processes that have a clear time window in which transitions are likely to occur. Also, in educational settings there are learning processes with rapid qualitative changes (such as learning to read). Future research could zoom in on these educational transitions to increase our understanding of the role of variability, including the role of consolidation.

Our study provided some support for the hypothesis that inter-individual differences in distal characteristics play a role in how

Fig. 6. Levels of Event Entropy over time for the four students.

interactions unfold in real time. Future research could additionally incorporate differences in teacher characteristics, such as the teacher's concerns (see (Steenbeek & van Geert, 2013)).

Overall, this study made a contribution to a rarely-studied topic: within-teacher differences in scaffolding. It shows a) how we can capture important aspects of the temporal structure of the teacher–student interaction over time and b) how the student's overall progress can be an important factor contributing to the differences between interactions by the same teacher with different students. This study adds an interesting perspective to research on contingent and non-contingent sequences (Steenbeek, Jansen, & Geert, 2012; Van de Pol et al., 2009) by looking at longer interaction patterns, which allow us to look at intra-individual variability. Our study showed that these measures of variability can provide valuable information on the workings of scaffolding.

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