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Citation

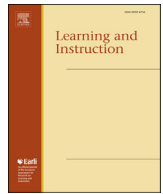
Pennings, H. J. M., Brekelmans, M., Sadler, P., Claessens, L. C. A., Want, A. C. van der, & Tartwijk, J. van. (2017). Interpersonal adaptation in teacher-student interaction. *Learning And Instruction*, 55, 41-57. doi:10.1016/j.learninstruc.2017.09.005

Version: Not Applicable (or Unknown)

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Note: To cite this publication please use the final published version (if applicable).



Interpersonal adaptation in teacher-student interaction[☆]



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ARTICLE INFO

Article history:

Received 17 September 2016

Received in revised form

1 September 2017

Accepted 8 September 2017

Available online 18 September 2017

Keywords:

teacher-student interaction

Adaptation

Interpersonal theory

Continuous coding

Time-series analysis

ABSTRACT

Teacher-student relationships play a crucial role in the quality of teaching and learning. Daily interpersonal interactions in classrooms are the building blocks of teacher-student relationships. With the aim to add to insights on teaching and learning, we specifically explored *interpersonal adaptation* in daily interactions. Adaptation, i.e., how people respond to each other's actions and reactions, is a defining characteristic of interactions.

We studied 35 classrooms in secondary education. Although the degree and nature of interpersonal adaptation was in general consistent with interpersonal theory, degree of adaptation varied considerably between classrooms. In classrooms with a more preferred teacher-student relationship, behaviour of teachers and the adaptation to the behaviour of their students was more in accordance with professional standards, compared to classrooms with a less preferred relationship.

Conceptualizations and results of the present study contribute to theory on teacher-student interaction, as well as the practice of teacher professional development (e.g., video coaching).

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1. Introduction

A crucial role of teacher-student relationships in the quality of teaching and learning has been demonstrated in many studies. Results showed teacher-student relationships to be associated with student cognitive learning outcomes and motivation (e.g., Cornelius-White, 2007; Den Brok, Brekelmans, & Wubbels, 2004; Pianta, 2006; Roorda, Koomen, Spilt, & Oort, 2011; Wubbels, Brekelmans, Den Brok, & Van Tartwijk, 2006), and with teacher well-being (e.g., Spilt, Koomen, & Thijs, 2011; Veldman, Van Tartwijk, Brekelmans, & Wubbels, 2013).

Daily interpersonal interactions in classrooms are the building blocks of teacher-student relationships (e.g., Granic & Patterson, 2006; Kiesler, 1996; Ramseyer & Tschacher, 2016; Vallacher, Nowak, & Zochowski, 2005). The present study focused on these interactions with the aim to add to the understanding of teaching

and learning. More specifically, we explored *interpersonal adaptation* (e.g., Burgoon, Stern, & Dillman, 1995; Cappella, 1996), i.e., how teachers and students respond to each other's interpersonal actions and reactions.

According to Burgoon et al. (1995), adaptation of behaviour in interactions is essential for effective communication. Cappella (1996) characterized adaptation as “the defining characteristic of interpersonal communication” (p. 354). He drew a strong distinction between two major components, arguing that both are necessary to understand interaction: (1) *mutual influence*, referring to correlated adjustments of overall levels during the course of interactions, and (2) *mutual adaptation*, referring to the dynamic process by which partners respond to changes in one another's behaviour during interactions. We focussed on the second component, as time-dependent interpersonal dynamics is understudied in education (e.g., Schmitz, 2006).

In the present study, we used a process oriented approach, providing a detailed description of daily classroom interaction. This micro-level investigation may add to outcome-oriented, macro-level investigations of teacher-student relationships (e.g., Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005; Schmitz, 2006). Furthermore, the present study concerns adaptation in the affective, social-emotional domain of educational processes, and thereby expands

[☆] The authors thank the reviewers for helpful comments on earlier versions of this paper and gratefully acknowledge the support provided by funding from the Netherlands Organization for Scientific Research, NWO/PROO 411-07-363.

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the current attention to adaptation in the cognitive domain (scaffolding, contingency; e.g., Van de Pol, Volman, & Beishuizen, 2010). Practical implications of the study appertain to teacher professionalization. Given that interactions are seen as the building blocks of relationships (Granic & Patterson, 2006), knowledge about fine-grained analysis of those interactions may be useful, in particular for the diagnosis of (problematic) interactions, but also for the designs of effective interventions that make use of (video-taped) classroom interaction data.

To explore interpersonal adaptation in daily classroom interaction, we largely followed the approach of Sadler, Ethier, Gunn, Duong, and Woody (2009), who combined insights from interpersonal theory (e.g., Carson, 1969; Horowitz & Strack, 2011; Kiesler, 1983, 1996) and literature on mutual adaptation in social interaction (e.g., Burgoon et al., 1995; Cappella, 1996; Warner, 1998). With a multiple case study of 35 classrooms, we explored (1) the degree of interpersonal adaptation and differences between classrooms, and (2) the assumed relevance of interpersonal adaptation, by studying the association of interpersonal adaptation with the quality of the teacher-student relationship in these classrooms.

1.1. Interpersonal theory

In the present study, we used two key principles of interpersonal theory to conceptualize interpersonal adaptation: (1) the principle of two interpersonal dimensions, and (2) the principle of interpersonal complementarity.

The first principle states that the most important aspects of human behaviour in interaction with other people can be captured by means of just two dimensions: *Agency*, which connotes ideas of dominance, power, status, and control, and *Communion*, which suggests love, affiliation, union, and friendliness (Gurtman, 2009). Agency and Communion are used as meta-concepts to label the two interpersonal dimensions (Bakan, 1966; Fournier, Moskowitz, & Zuroff, 2011; Wiggins, 1991). In specific contexts, alternative names, such as Control/Affiliation, Dominance/Friendliness, or Influence/Proximity are used (e.g., Sadler et al., 2009; Wubbels et al., 2012). Each word to describe the behaviour of a person (e.g., friendly, demanding) can be regarded a specific blend of Agency and Communion. The interpersonal meaning of the words is represented by their angular position on a circular continuum called the Interpersonal Circle (IPC; Fabrigar, Visser, & Browne, 1997; Gurtman, 2009; Horowitz & Strack, 2011; Kiesler, 1996).

Fig. 1 presents typical descriptions of classroom interpersonal behaviour of teachers (IPC-T) and students (IPC-S). For example, the descriptors *helpful* and *confrontational* in IPC-T, and likewise *supportive* and *confrontational* in IPC-S, share the same degree of Agency, but are opposite regarding the degree of Communion.

The Interpersonal Circle can also be used to describe (differences in) behaviour of persons at different time-scales: moment-to-moment behaviour (e.g., Mainhard, Pennings, Wubbels, & Brekelmans, 2012), average behaviour over the course of an interaction (e.g., Mainhard, Brekelmans, & Wubbels, 2011), and behaviour as it is generally consistent over a longer period of time, such as a school year. A person's habitual interpersonal behaviour is often referred to as *interpersonal style* (e.g., Sadler & Woody, 2003; see also Fig. 4). With the Interpersonal Circle differences in frequency and intensity of behaviour can be mapped in terms of dimensions (i.e., Agency and Communion, see Fig. 4) or typical descriptions (like imposing or helpful, e.g., Wubbels et al., 2006).

According to the second key principle of interpersonal complementarity (Kiesler, 1983), a person's interpersonal behaviour is not random, but contingent upon the interpersonal behaviour of the other person(s) with whom he or she is interacting. Behaviour of people in interaction includes a specific interpersonal

bid that tends to initiate, invite, or invoke specific behaviour from others. The interpersonal bid tends to elicit *oppositeness* regarding Agency, and *sameness* regarding Communion (Kiesler, 1983, 1996; see also; Sadler et al., 2009). For example, imposing behaviour of a teacher tends to invite withdrawn student behaviour and helpful teacher behaviour tends to invite collaborative student behaviour (see Fig. 1). Earlier research has shown the importance of complementarity for stable and healthy relationships (e.g., Kiesler, 1996; Sadler, Ethier, & Woody, 2011).

According to Kiesler (1996) the formulated direction of complementarity “primarily applies to naturally occurring, relatively unstructured interpersonal situations, the extent to which it applies in various structured situations or in other environmental contexts remains to be determined” (p. 49). For example, in classrooms, the specific role and status of teachers and students (e.g., Carson, 1969; Cothran & Ennis, 1997; Pomeroy, 1999) provide a specific structure to their interaction. Teachers, with far more education and experience of life than their students, have a different set of behavioural resources, and, as professional educators, also a different set of responsibilities. They are expected and trained to act in the best interest of their students. Therefore, they will be motivated to sometimes inhibit the tendency to react in complementary ways to student behaviour (Thijs, Koomen, Roorda, & Ten Hagen, 2011). For example, when faced with hostile student behaviour (e.g., confrontational, dissatisfied, see Fig. 1), teachers may refrain from responding with hostility, and instead may respond with neutral, or even friendly behaviour (e.g., helpful, understanding, see Fig. 1). For example, to set the stage for favourable classroom processes for all students, a teacher may in specific situations ‘override’ agentic behaviour of (individual) students. When faced with this student behaviour, a certain degree of teacher Agency, especially together with teacher Communion, may support classroom structure, thereby affording all individual students to foster their learning process. While studying interpersonal adaptation in the present study, we explored these refinements of the general tendencies of the principle of interpersonal complementarity.

1.2. Insights from literature on mutual adaptation in social interaction

In the literature on mutual adaptation in social interaction (e.g., Cappella, 1996), interpersonal adaptation is conceptualized similarly to interpersonal theory. Authors conceptualize interpersonal adaptation as associations between (a) behavioural patterns of partners in interaction (i.e., moment-to-moment behaviour), and (b) as overall levels over time (i.e., interpersonal styles). What the literature on mutual adaptation especially adds to insights from interpersonal theory is the attention to rhythmicity in interpersonal behaviour. This rhythmicity refers to temporal cyclical patterns “in which behaviour progresses repeatedly from a point of origin, through a pattern, and back to the same or very similar point of origin” (Werner & Haggard in Van Lear, 1996, p. 46). For example, a teacher may be leading, when introducing a class of students to new concepts, and students may follow and try to comprehend. When students start to understand the new concept, the teacher may become less leading, implicitly encouraging students to play with and assert their newfound understandings. When the teacher subsequently supplies further information or steers students to specific strategies, the more and less leading cycle in teacher behaviour may repeat. Likewise, student behaviour may form a repeating cycle, in which their behaviour first is relatively submissive, then increases to be more assertive, and then lowers again, only to increase again. In this example, teacher and students' recurrent cycles are highly synchronized. As a metaphor, one could visualize high synchrony in dancing, when there is flowing, agile,

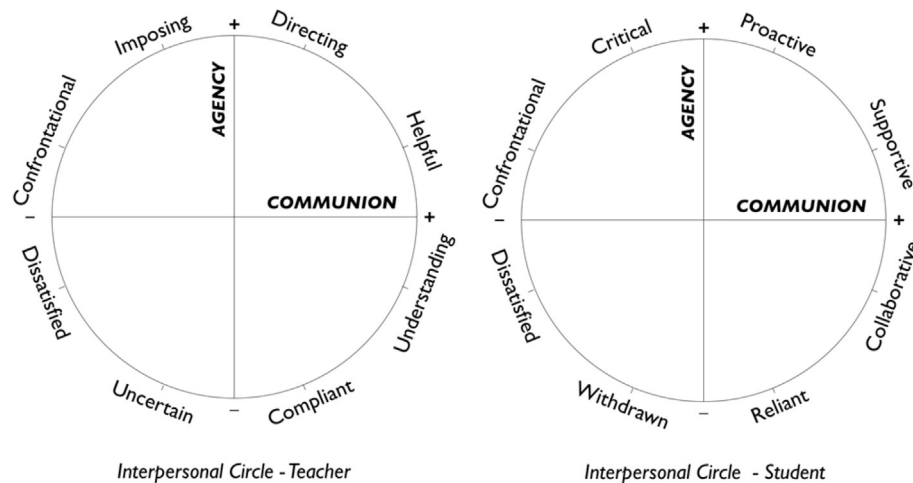


Fig. 1. The Interpersonal Circle for Teachers (left, IPC-T) and Students (right, IPC-S). Words at the circumference of the circle are typical descriptions of interpersonal teacher and student behaviour each representing a specific blend of Agency and Communion (cf. Claessens et al., 2017; Wubbels et al., 2012).

and continuous rhythm with enmeshed movements of both partners, each with his or her own balance (e.g., Burgoon et al., 1995; Sadler et al., 2009). Burgoon et al. (1995) termed these entrained patterns *interactional synchrony*, and defined it as “similarity in rhythmic qualities and enmeshing or coordination of the behavioural patterns of both parties” (p.128).

To study how temporal patterns in behaviour of people in interaction may be interrelated, Warner (1998) proposed four different types of associations to indicate interpersonal adaptation: (1) association between *trends* in the time series, (2) association between *cyclical patterns*, (3) association between *residual fluctuations*, and (4) association of the raw time series, i.e., an “estimate of overall coordination—combining the contributions of any trends, cycles, and residuals” (Warner, 1998, p. 135; italics added). Examining the association of trends and cyclical patterns focuses on the match of regular patterns in moment-to-moment variation in teacher and student behaviour in classrooms. Examining the association of residual fluctuations (after removing trends and cyclical patterns) focuses on a more momentary match of behavioural patterns (e.g., adaptation to unexpected eruptions of hostility). The distinction between several types of indicators has been adopted in several papers investigating dyadic social interaction, particularly from the perspective of interpersonal theory (e.g., Sadler et al., 2011; Thomas, Hopwood, Woody, Ethier, & Sadler, 2014).

1.3. Studies on interpersonal adaptation in the context of education

In the context of education, there are only a few studies available (Mainhard et al., 2012; Pennings, Van Tartwijk et al., 2014; Roorda, Koomen, Spilt, Thijs, & Oort, 2013; Thijs et al., 2011) examining moment-to-moment teacher-student interaction using a two-sided approach (i.e., examining both teacher and student behaviour). A two-sided approach is inherently needed to study interpersonal adaptation. These studies generally confirmed teacher-student interaction to be consistent with the principle of interpersonal complementarity.

In small scale studies (two classrooms) in secondary education, Mainhard et al. (2012), and Pennings, Van Tartwijk et al. (2014) illustrated the principle of interpersonal complementarity in momentary teacher-student interactions, and showed that interactions in the classroom of the teacher with an interpersonal style characterized by high levels of Agency and Communion, had a higher degree of complementarity than interactions in the

classroom of the teacher with an interpersonal style characterized by lower levels of Agency and Communion. Results of a study by Thijs et al. (2011) on individual kindergartners ($N = 69$) in interaction with teachers during a dyadic task outside the classroom, were also consistent with the principle of interpersonal complementarity. Thijs et al. found a positive correlation between the level of Affiliation (i.e., Communion) displayed by teachers and students, and a negative correlation between their levels of Control (i.e., Agency). Roorda et al. (2013) studied interactions between teachers ($N = 48$) and selected kindergartners with a variety of externalizing and internalizing behaviours ($N = 179$) in a small group task setting within the naturalistic classroom setting. They found that reactions of teachers and students followed the complementarity principle on the Control dimension, but not on the Affiliation dimension.

1.4. Present study

With the present study, we aimed to contribute to research on teacher-student interaction by adding knowledge on the interpersonal adaptation of teacher and student behaviour, with the aim to better understand teaching and learning. More specifically, we aimed to add knowledge by (1) studying natural classroom settings in secondary education, (2) using a relatively large sample of classrooms, in view of the time-consuming data-management, and (3) exploring the interrelation of moment-to-moment time-series data of teachers and students using different indicators of interpersonal adaptation. We performed a multiple case study of 35 classrooms. Due to the small body of available knowledge in the educational context, and the small size and convenience character of the sample, we refrained from testing specific hypotheses about population parameters. Instead, we used an exploratory, descriptive approach (e.g., sample frequencies, central tendencies). The following research question guided the study: *What is the degree and nature of interpersonal adaptation in moment-to-moment teacher-student interaction in secondary classrooms?*

Consistent with the complementarity principle as specified by interpersonal theory, we basically anticipated sameness regarding Communion and oppositeness regarding Agency, for all four indicators of interpersonal adaptation, i.e., overall coordination, and match of trends, cyclical patterns, and residual fluctuations. From the perspective of the specific role and status of teachers and students in secondary classrooms, we anticipated specific refinements from the general tendencies.

To contribute to validation of the assumed theoretical and

practical relevance of interpersonal adaptation for teaching and learning, we explored the association of the degree and nature of interpersonal adaptation with the teacher interpersonal style. We selected the teacher interpersonal style for validation, because (1) empirical evidence from earlier studies showed teacher interpersonal style to be associated with student cognitive and affective outcomes (e.g., Den Brok et al., 2004), and teacher well-being (e.g., Brekelmans, 1989; Veldman et al., 2013), (2) teacher interpersonal style is an important indicator of teacher-student relationships (Wubbels et al., 2006), and daily interpersonal interactions are considered the building blocks of relationships (e.g., Granic & Patterson, 2006; Kiesler, 1996; Ramseyer & Tschacher, 2016; Vallacher et al., 2005), (3) adaptation is considered a defining characteristics of interaction (e.g., Cappella, 1996). We anticipated differences between classrooms in teacher interpersonal styles to go together with differences in interpersonal adaptation in daily teacher-student interaction.

2. Method

2.1. Participants

Participants in the study were teachers and students from secondary schools in the Netherlands. From a larger sample of teachers who agreed to participate in a longitudinal study on classroom climate ($N = 189$), a smaller group of teachers and their classes ($N = 36$) was selected for a more in-depth analysis. For this group of teachers, data were available in at least three school years, namely video-taped lessons to observe teacher and student behaviour, questionnaire data on the interpersonal style of the teacher in the video-taped classrooms, and recorded interviews with the teachers. We based the present study on the video- and the questionnaire data of the first wave of the longitudinal study. We had to remove one of the classrooms because the video did hardly display interactions between teachers and students due to students taking a written test. This left us with a (convenience) sample of 35 classrooms (35 teachers, 746 students, 27 schools).

Teachers in our sample (age 22–59 years, $M = 42.4$, $SD = 10.7$; 14 female) had different levels of teaching experience (1–35 years, $M = 11.3$, $SD = 11.4$) and taught different subjects (i.e., languages: $N = 6$; science: $N = 18$; history, geography, economy: $N = 8$; and art related subjects: $N = 3$). Classes were from different levels of secondary education (preparatory secondary vocational ($N = 8$), senior general secondary ($N = 5$), university preparatory ($N = 14$), combined school types ($N = 3$)), and from different grades (7: $N = 4$; 8: $N = 9$; 9: $N = 4$; 10: $N = 9$; 11: $N = 3$; 12: $N = 1$; i.e., age groups 12–18 years). For five classrooms class information was missing.

Parental consent was in accordance with policies of the schools of the participating teachers. Most schools had written consent of parents allowing their children to participate in research and video-observation. In schools without such a policy, teachers were provided with consent letters for parents to return when they objected to their child being filmed. After data collection was finished, teachers received the video recordings and a written report on their interpersonal style.

2.2. Capturing moment-to-moment teacher-student interaction

2.2.1. Continuous coding of agency and communion

To study interpersonal adaptation in classrooms, we largely followed the approach used by Sadler and colleagues (e.g., Lizdek, Woody, Sadler, & Rehman, 2016; Sadler et al., 2009; Thomas et al., 2014). The approach captures interpersonal dynamics as a continuous, contextualized flow of behaviour as it unfolds over time, based on continuous coding of videotaped behaviours, using a

computer joystick apparatus, and monitoring software.¹

In the present study, we recorded for each teacher a lesson with: (a) one camera positioned in the back of the classroom, resulting in a video to code teacher behaviour, and (b) one camera in front of the classroom, resulting in a video to code student behaviour. For each teacher and student video, Agency and Communion was coded by two out of four trained observers,^{2,3}.

The corresponding software is programmed to record, by default, behaviour coordinates every half-second, and coordinates range from -1000 = very low Agency/Communion to $+1000$ = very high Agency/Communion (i.e., to ensure maximum sensitivity of the computer joystick device). Inter-rater reliability (intra class correlations, $ICC(k = 2)$, Markey, Lowmaster, & Eichler, 2010) indicated strong agreement between the observers (LeBreton & Senter, 2008), teacher Agency: $M = 0.84$ ($SD = 0.09$), teacher Communion: $M = 0.74$ ($SD = 0.11$), student Agency: $M = 0.88$ ($SD = 0.09$), and student Communion: $M = 0.81$ ($SD = 0.14$). Accordingly, ratings of Agency and Communion of the two observers were aggregated at each time point for both teachers and students, thus dampening idiosyncratic observations. This resulted in two behavioural trajectories for each teacher, and two trajectories for the students. Because the trajectories are exactly coordinated in time, they can be combined to study their moment-to-moment association.

Class-level dynamics. In the present study, we coded Agency and Communion in teacher and student behaviour to represent the class-level dynamics (cf. individual-level dynamics). When the behaviour of the teacher was coded, observers took a shared student perspective. When the behaviour of the class of students was coded, observers took a teacher perspective and coded pooled Agency and Communion in students' behaviour as a class composite. We coded interactions in all types of educational settings (teacher-whole class, teacher-small group, teacher-individual student interaction), but in all settings, this was done at the class-level.

First 10 min of a lesson. To handle time-consuming coding of the videos, we restricted coding to the first 10 min of a lesson of each participating teacher with his or her class. We chose this part of the lesson, because it is important for an effective teaching-learning environment and is especially demanding regarding class-level dynamics (Van Tartwijk, Brekelmans, Wubbels, Fisher, & Fraser, 1998; Van der Want et al., 2015). Also, according to Sadler et al. (2009), a period of 10 min is of sufficient duration to identify adaptive patterns in moment-to-moment interactions.

¹ The joystick-monitoring software program is available via www.wlu.ca/science/psadler.

² On the website of Teaching and Teacher Education corresponding to Pennings, Van Tartwijk et al. (2014) a detailed description of the coding procedure and a video of an observation with the computer joystick can be found.

³ To illustrate the coding procedure some examples: A teacher who stands up straight in front of the class, and speaks in a normal to loud voice would be coded as more agentic than a teacher in the same situation who speaks in a quiet inaudible voice. Depending on the intonation and content of the teacher's message, etc. the teacher would be coded as either more communal or less communal. If a teacher asks the students a question, teacher Agency would go down but would not become submissive when it is the teacher who allows students to answer the question. A teacher's Agency becomes submissive when the teacher turns his/her back completely towards the students to write for a longer period on the blackboard, as the teacher cannot oversee what is happening with the class. Important for coding the degree of teacher Agency is the amount of control a teacher has on student actions (e.g., student talking). When students start talking or shouting very loudly through the classroom, their level of communion would go down, and if the teacher reacts to that with shouting or punishing students, the teacher's level of Communion would go down as well. If the students get bored, sit in a slouched position, their level of Communion as well as their level of Agency would decrease.

2.2.2. Analysis of time-series data

To explore the degree and nature of interpersonal adaptation in our sample of 35 classrooms, we first submitted each classroom to time-series analyses, and then summarized these results over the entire sample.

The observation of the first 10 min of the lesson, captured by 0.5-s time points by the joystick software, resulted in 1200 data points. Following Warner (1998), we removed (1) the first 20 data points (10 s) of observation allowing the observers to orient themselves to the interaction moving the joystick from the origin to the appropriate position, and (2) the codes after 588 s (9.8 min) to ensure an equal number of data points for all classrooms. This left us with time series of $N = 1176$ data points, for both the teacher and the students, in each of the 35 classrooms.

For the remainder of this section, we will explain the time-series analysis method and illustrate its application with data of a specific teacher-class combination (Classroom16: senior general secondary education; subject: physics; teacher: male, 27 years of age, 2 years of teaching experience, students: age group 14–15 years; teacher interpersonal style: see Fig. 4).

2.2.2.1. Interpersonal level and variation. The proposed indicators of interpersonal adaptation (overall coordination and match between trends, cycles, and residual fluctuations) presume variation in both teacher and student interpersonal behaviour during the interaction. Fig. 2 presents visual information on the level and variation of agentic and communal behaviour in Classroom16.

The graphs in Fig. 2, show time (in half-seconds) along the x-axis and the dimension of behaviour along the y-axis. The top graph shows that, for the most part, the levels of teacher and student Communion tend to increase and decrease together, and for the first 410s or so, teacher Communion is greater than student Communion, which markedly increases between 310 and 470s. The bottom graph shows that typically when the teacher is higher in

Agency, the students are lower in Agency, and when teacher Agency increases, student Agency tends to decrease. Variation in terms of the standard deviation supplements that this variation of teacher Communion was just over half of that of the students ($SD_{teacher} = 141$ and $SD_{students} = 262$), while variation in Agency was larger compared to Communion for both teachers and students, and for the teacher again lower than for students ($SD_{teacher} = 326$ and $SD_{students} = 458$). In Classroom16 the mean level of Communion was positive for both the teacher ($M = 627$) and the students ($M = 485$). The mean level of Agency was positive for the teacher ($M = 466$) and negative for the students ($M = -258$). These results make sense in that, to accommodate a supportive classroom structure for student learning, a teacher starts a lesson, normatively, in a directing and helpful manner, and students follow in a reliant and collaborative way. It probably is also in line with professional standards for a teacher, compared to students, to restrict variation in behaviour and not to be too hostile nor too submissive.

Fig. 3 presents density plots to visualize the variation of the combination of agentic and communal behaviour for the teacher and students, both collapsed over time (Thomas et al., 2014). The intersection of mean levels of Agency and Communion is represented by a white plus sign, and variation around this intersection as shading with the less dense parts coloured with lighter shades. The density plots graphically show positive communal behaviours during the first 10 min of the lesson for both the teacher and the students in Classroom16. It is evident that the variation does not equally spread in all directions: the behaviour of the teacher and the students involves changes in dominance while maintaining friendliness.

2.2.2.2. Interpersonal adaptation. Overall coordination. Visual inspection of Fig. 2 reveals that fluctuations in teacher and student Communion scores track each other quite closely. For Agency, there

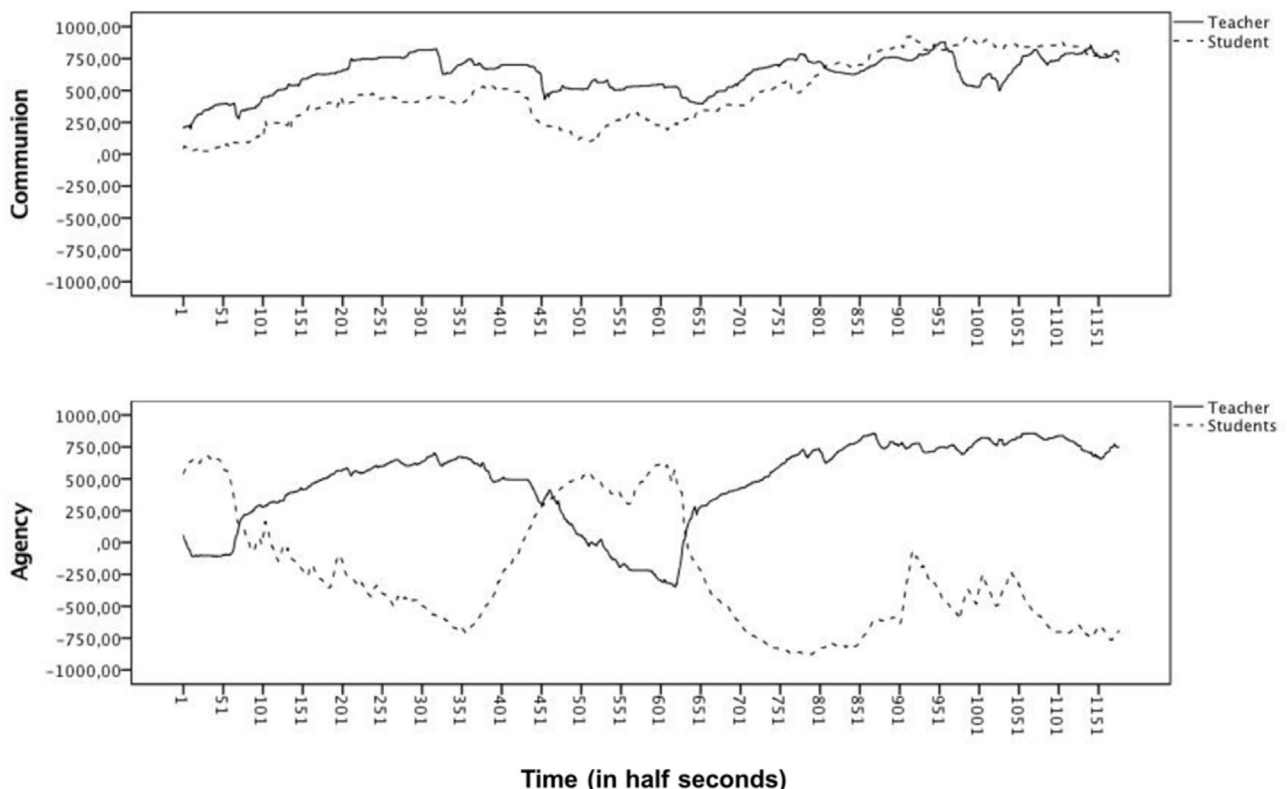


Fig. 2. Bivariate time series of teacher and students (Classroom16) for Communion (above) and Agency (below).

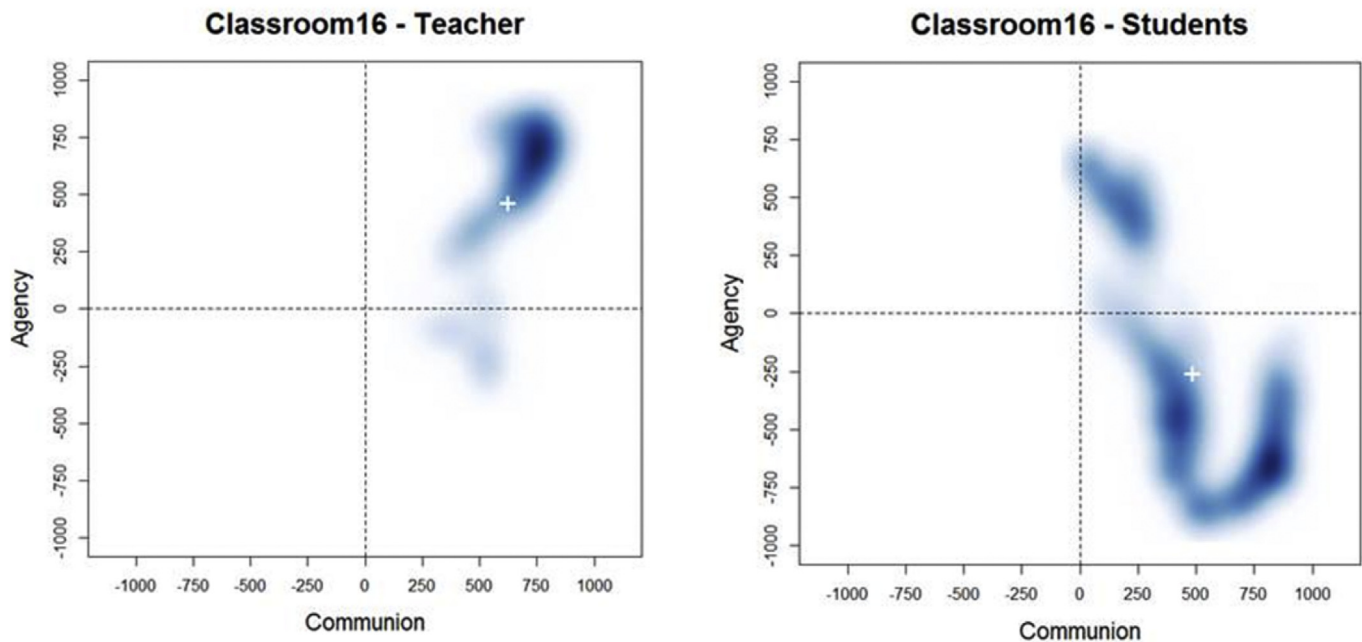


Fig. 3. Density plots (Agency and Communion combined) for the teacher (left) and students (right) of Classroom16.

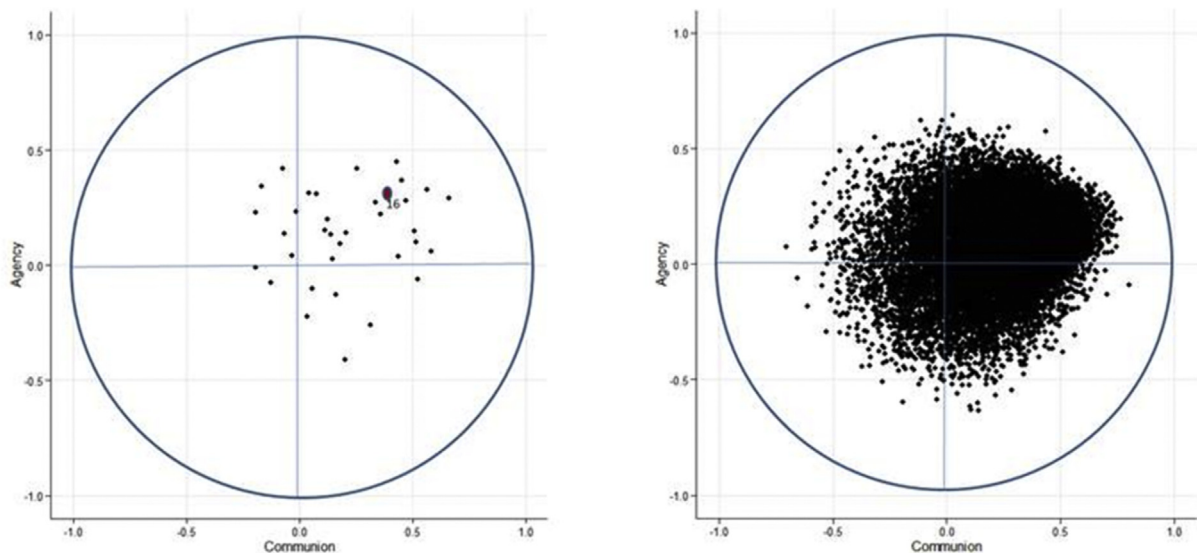


Fig. 4. Teacher interpersonal style presented in IPC-T, study-sample (Left, $N = 35$, dot-16 refers to the interpersonal style of the teacher in Classroom16, see 2.2.2), and large Dutch Sample (Right, $N > 18,000$).

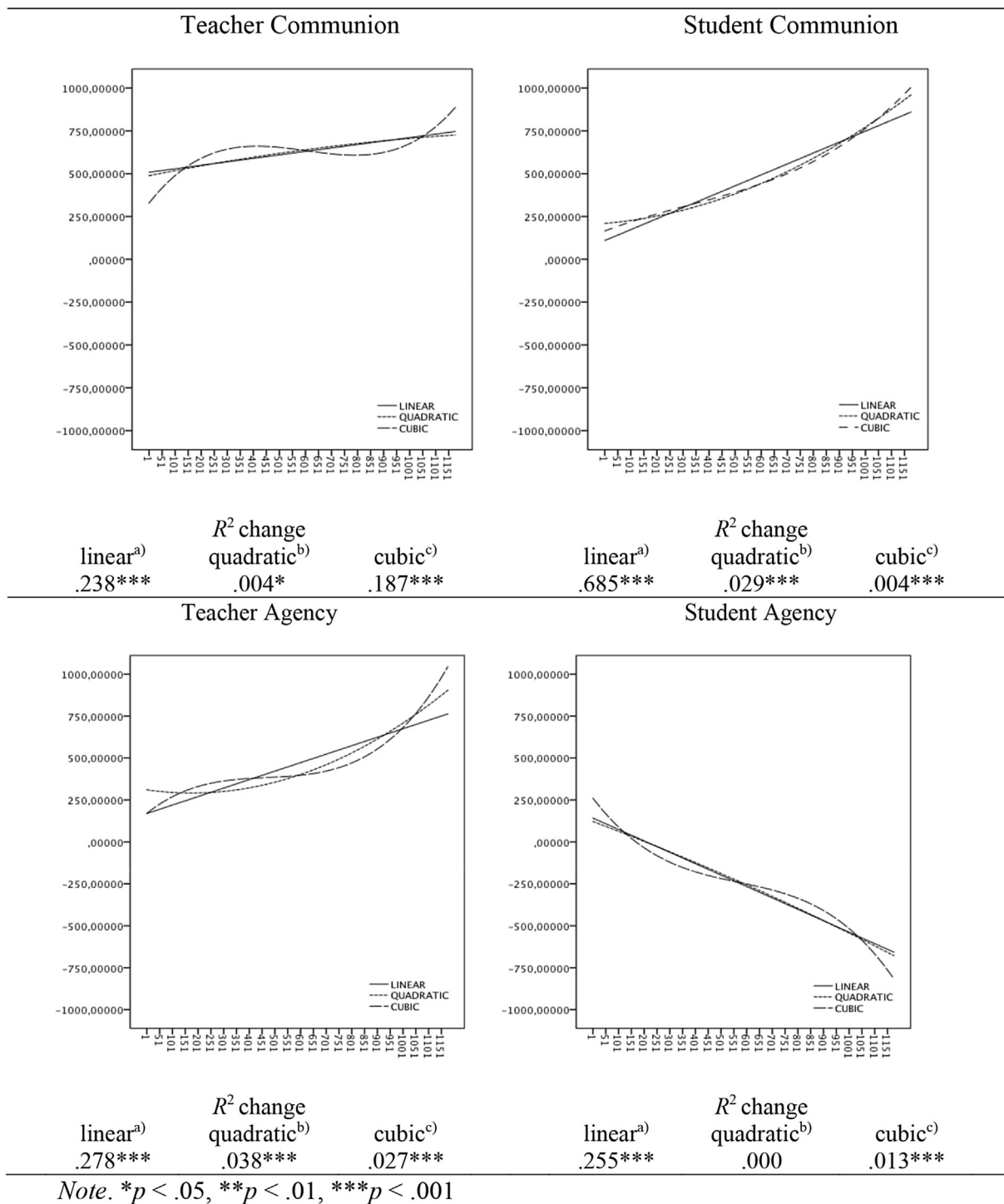
is a consistently strong inverse association in the moment-to-moment levels: peaks in one time series go together with troughs in the other. The overall coordination, i.e., the cross-correlation between raw data of the time-series of the teacher and the students of Classroom16, was -0.86 for Agency and 0.71 for Communion, both, indeed, representing strong associations that are consistent with the complementarity principle.

Trends. To explore the entrainment of trends in the time series of teachers and students, we first tested for the existence of trends in both time series separately. We tested for linear, and curvilinear trends (quadratic and cubic) using ordinary least squares regression analyses with Agency and Communion as the criterion variables and time as the predictor variable. Table 1 shows the graphs of the scores predicted by the linear model, the quadratic model

(curvilinear with one bend), and the cubic model (curvilinear with two bends), and also the variance explained (R^2 change) after adding (1) a linear term, (2) a quadratic term, and (3) a cubic term. For the graphs of the observed scores of Classroom16, we refer to Fig. 2.

For the student and teacher time series of Classroom16, curvilinear terms improved the linear model, favouring the cubic model as the best fitting trend model. Based on visual inspection of the graphs, the entrainment of trends in teacher and student behaviour are in line with the complementarity principle, with both teacher and student Communion showing an upward trend over the first 10 min, and teacher Agency an upward trend and student Agency a downward trend. These results suggest that the first 10 min of the lesson in Classroom16 functioned as a period of regulating the

Table 1
Trends in teacher and student time series in Classroom16.



Agency and Communion level of students towards more positive student Communion and a lower level of student Agency. From the perspective of class-level dynamics, this represents a more supportive atmosphere to start up the learning process of all students (see also section 1.1).

Cyclical patterns. To explore interactional synchrony (i.e., the degree of association between cyclical patterns in behaviour of

teachers and students), we first examined the existence of cycles that may occur superimposed on trends. As trends (i.e., changes in level over time) may bias the assessment of cyclical patterns, they have to be removed (Warner, 1998). To “detrend” time series, Warner (1998) recommends using regression analysis instead of differencing, as this last method can lead to problems. We removed the cubic trend (linear + quadratic + cubic term) from the time

series of Classroom16.

On the detrended data, we performed spectral and cross-spectral analyses (SPSS-SPECTRA, version 24). With spectral analysis, we could assess the extent to which both teacher and student behaviour on the Agency as well as the Communion dimension contain, over time, cyclical patterns (i.e. sinusoidal curves), superimposed on the cubic trend. With cross-spectral analysis, we then could assess how synchronized (i.e., coordinated in time) these cyclical patterns were. For a detailed explanation of spectral analysis, we recommend Warner (1998).

Examination of assumptions for spectral analysis (Warner, 1998) showed that the time series data of Classroom16 did not have extreme outliers (no standardized scores in excess of 3.29, Tabachnick & Fidell, 2013) and were approximately normally distributed (based on inspection of (detrended) normal Q-Q plots; skewness and kurtosis between -1.17 and 0.63 , i.e., between -1.5 and $+1.5$, Tabachnick & Fidell, 2013). Spectral and cross-spectral analyses were smoothed using a Tukey-Hamming window with a span of 5 (Warner, 1998).

As regular cycles in both teacher and student behaviour are a prerequisite for interactional synchrony, we first tested the significance of recurrent cycles in the detrended time series of teachers and students separately (Fisher test, $p < 0.05$, Warner, 1998). For Classroom16 this significance was confirmed. Thus, behaviour of both teacher and students shows cyclical patterns.

If the cyclical nature of communal and agentic behaviour during classroom interactions is not perfectly regular, conceptually it would not make sense to restrict the consecutive analyses to recurrent cycles with only one particular cycle length. Instead, in accordance with other work (Lester, Hoffman, & Brazelton, 1985; Sadler et al., 2009; Warner, 1998) we based the analyses on a set of cyclical components. To decide on the number of cyclical components we selected the components with more than trivial contributions to the variation in the detrended Agency and Communion scores (i.e., explaining more than 1% of the variance, Sadler et al., 2009). Because the pacing and strategies used by teachers in classrooms may differ markedly, we preferred not to assume the same set of cyclical components for all classrooms (in contrast to Sadler et al., 2009), but used a classroom specific cut off to decide on the number of components. For the sake of simplicity, we chose only one cut off for all four time series of each classroom. Whenever the number of cyclical components differed for the teacher and student time series of Agency, we selected the smaller of the two, and used the same procedure for Communion. Whenever the number of cyclical components then differed for Agency and Communion, we used their rounded average.

For Classroom16, the index of rhythmicity (i.e., the proportion of variance explained by the selected set of 7 out of 588 possible cyclical components in the detrended scores of the teacher time series) was for the teacher time series 0.82 for Communion and 0.96 for Agency, and for the student time series 0.94 for both Communion and Agency. These large rhythmicity values (>0.80 , see Sadler et al., 2009) indicated the presence of reasonably regular cycles in both teacher and student behaviour in Classroom16.

To explore interactional synchrony between teacher and student behaviour, we computed the *average weighted coherence* and *average weighted phase* using cross-spectral analysis. Coherence indicates the degree of entrainment of cycles across teacher and student time series of Agency and Communion. Phase represents the displacement of cycles in teacher and student time series, indicating who is leading in Agency and Communion.

Coherence (ranging from 0 to 1) is a non-directional measure of interpersonal adaptation and may be interpreted as the estimated portion of variance shared by the two time series for a specific cycle length. To determine the coherence for the set of cycle lengths, we

averaged the coherence values after weighting them by the proportion of variance in the teacher and student univariate spectra at each cycle length. Classroom16 had an average weighted coherence of 0.88 for Communion and 0.85 for Agency, showing a considerable degree of synchrony of cyclical patterns between the teacher and student time series (compare to R^2 ; large effect = above 0.26, Cohen, 1988, p. 414).

To determine phase for the set of cycle lengths, we averaged the phase values after weighting them by the proportion of variance in the teacher and student univariate spectra at each cycle length. Phase represents the degree of displacement from the teacher's peak in a time series to the students' peak, which could readily be explained as a time lag familiar within the act-to-act approach (i.e., approach with segmentation of interaction into separate acts). We expressed phase as the fraction of a full cycle by which the peaks in teacher and student behaviour are separated. A positive phase indicates that the teacher tends to lead and students follow, whereas a negative phase indicates students tend to lead and the teacher follows. For Classroom16, average weighted phase was positive for Agency and Communion.

Residual fluctuations. To explore associations between "random" behaviours of teachers and students, we removed cubic trends and cycles (residuals of second order autoregressive model, see Sadler et al., 2009; Warner, 1998) and computed the lagged cross-correlation functions interrelating the pairs of residuals for teacher and student Agency, and teacher and student Communion, considering substantial lags in either direction ($N = 250$). In Classroom16, there were no clear high points (the cross-correlations for Communion and Agency at these various time lags ranged between -0.08 and 0.08). In sum, for Classroom16, the associations between these random fluctuations in behaviour appeared to be relatively unimportant, and do not signal adaptation to unexpected eruptions of behaviour.

2.3. Capturing teacher interpersonal style

To explore the relevance of differences between classrooms regarding the degree and nature of interpersonal adaptation, we related the indicators of adaptation in the first 10 min of one lesson to long term teacher interpersonal style. Teacher interpersonal style was measured by the class-aggregated student observations of their teacher's interpersonal behaviour across at least six months of classroom experience, using the Dutch 24-item Questionnaire on Teacher Interaction (QTI; Wubbels et al., 2006; Brekelmans, Den Brok, & Wubbels, 2011). Examples of items are "This teacher has humour", and "This teacher is dissatisfied". Every item consists of a five-point scale (1 = *never* and 5 = *always*). We derived Agency and Communion scores by weighting the items based on their position on the Interpersonal Circle (Locke, 2011). Based on a large database, the circumplex structure (Browne's circular stochastic process model tested with CIRCE; Grassi, Luccio, & Di Blas, 2010) showed satisfactory model fit indices for individual student perceptions (χ^2 (28, $N = 18,424$; of each classroom one student was chosen at random) = 64,917.46; $p < 0.01$, RMSEA = 0.043; CFI = 0.99, TLI = 0.97; Pennings, Brekelmans et al., 2014).

In the present study, the aggregated class measurements were sufficiently reliable: internal consistency of the dimension scores (Cronbach's α) for Agency was 0.89, for Communion 0.95, with $r = 0.13$ as the correlation between Agency and Communion; consensus between students of a class (ICC(k = class size), Lüdtke, Robitzsch, Trautwein, & Kunter, 2009) varied in the 35 classrooms for Agency from 0.95 to 0.98 ($M = 0.97$, $SD = 0.01$), for Communion from 0.93 to 0.97 ($M = 0.96$, $SD = 0.01$). We assumed one measurement a year to be representative for the teacher-interpersonal style in a specific school year, as earlier research showed that

interpersonal style as perceived by students is quite stable during a school year (Brekelmans, 1989; Mainhard, Brekelmans, Den Brok, & Wubbels, 2011).

Fig. 4 presents the combination of Agency and Communion scores of the interpersonal styles of the teachers in IPC-T (see Fig. 1) in our sample and in a large Dutch sample ($N > 18,000$ classrooms). In line with the large Dutch sample, teacher interpersonal styles in our sample are not equally distributed over all four quadrants (from upper right to upper left: our sample: 60%, 17%, 6%, 17%, large Dutch sample: 63%, 22%, 6%, 9%).

We explored the association of interpersonal adaptation indices of moment-to-moment behaviour with teacher interpersonal style by means of correlations with the Agency and Communion dimension in teacher styles. As linearity of the association was not strongly anticipated, and to be able to relate interpersonal adaptation to teacher interpersonal styles in terms of a combination of Agency and Communion, we also explored the association with interpersonal adaptation by comparing groups of classrooms characterized by the combination of Agency and Communion in teacher interpersonal style. Due to the small sample size, we used a division in two groups: classrooms with a teacher who had a more preferred interpersonal style (MP-classrooms), and classrooms with a teacher who had a less preferred interpersonal style (LP-classrooms). To decide on “more or less preferred”, we used (a) information on teacher interpersonal styles as they are favoured by teachers and students, and (b) information from research on the association of teacher interpersonal styles with cognitive and affective student outcomes. Specifically, (a) an analysis of perceptions of teachers of their ideal interpersonal style ($N = 7958$) showed that 99% favoured a style in the directing-helpful area of the IPC-T, (see Fig. 5, and see also Wubbels et al., 2006). Styles positioned in this part of the IPC-T have relatively high scores on both Agency and Communion. This ideal perception of teachers is also in line with how students, on average, perceive the interpersonal style of their best teacher, which is positioned in the same area of IPC-T. Furthermore, (b) research on the association between student outcomes and teacher interpersonal style (e.g., Den Brok et al., 2004) showed that higher teacher Agency and Communion go together with higher student cognitive and affective outcomes. We

therefore qualified interpersonal styles located in the upper right area of Fig. 5 as more preferred interpersonal styles, and the ones in the remaining four areas as less preferred.

3. Results

3.1. Degree and nature of interpersonal adaptation in daily classroom interaction

3.1.1. Interpersonal level and variation

Table 2 summarizes information on the level (i.e., mean) and variation (i.e., standard deviation) of teacher and student Agency and Communion in each classroom during the first 10 min of a lesson, averaged across the 35 classrooms.

As can be seen in the first row of Table 2, the level of Communion during the first 10 min of the lesson, on average across the 35 classrooms, was positive for both the teacher (403) and the students (238). The level of Agency was positive for the teachers (293) and negative for the students (−122). In 88% of the classrooms, the level of Communion was positive for both the teacher and the students, in 65% of the classrooms, the level of Agency was positive for the teacher and negative for the students. These results make sense in that, to accommodate a supportive classroom structure for student learning, a teacher starts a lesson, normatively, in a directing and helpful manner, and students follow in a reliant and collaborative way. In four classrooms (11%), the level of teacher Agency was negative, and in one of these classrooms, so was the level of teacher Communion.

As can be seen in the second row of Table 2, student variation, on average across the 35 classrooms, was higher than teacher variation, for both Communion (243 vs. 169) and for Agency (376 vs. 287). For Communion, in 83% of the classrooms student variation was higher than teacher variation, for Agency, higher in 77% of the classrooms. These results make sense in that teachers likely restrict their behaviour in the classroom to be in line with professional standards and their roles as leaders, instructors, adults, and role models (e.g., so, that their behaviour is not too hostile nor too submissive).

3.1.2. Interpersonal adaptation

Overall coordination. Overall coordination (i.e., cross-correlation between the 1176 measurements of the teacher and the students of a classroom) was, averaged across all 35 classrooms, 0.41 for Communion ($SD = 0.38$), and −0.44 for Agency ($SD = 0.40$), which is consistent with the principle of interpersonal complementarity (i.e., negative for Agency and positive for Communion). For Agency, overall coordination (range −0.95 to 0.59) was negative in 80% of the 35 classrooms and for Communion (range −0.63 to 0.92) positive in 86% of the classrooms. Taking cross-correlations for both Agency and Communion into account, we found that in 71% of the classrooms, the overall index of adaptation followed the



Fig. 5. IPC-T (see Fig. 1) with areas of less preferred (i.e., understanding-compliant, dissatisfied-uncertain, imposing-confrontational, and struggling) and more preferred (directing-helpful) teacher interpersonal styles. Radius circular area in the middle is 0.2*radius area IPC-T.

Table 2

Summary statistics for level and variation in teacher and student time series (35 classrooms).

	Communion				Agency			
	Teacher		Students		Teacher		Students	
	M	SD	M	SD	M	SD	M	SD
Level (mean over 10 min)	403	207	238	248	293	219	−122	247
Variation (st.dev. over 10 min)	169	54	243	71	287	79	376	113

Note: M represents the mean of the levels and the variations across the 35 classrooms. SD represents the standard deviation in the mean and the variations across the 35 classrooms. Communion and Agency range from −1000 to +1000. For convenient reasons, we left out decimals.

interpersonal complementarity principle on both dimensions.

From the perspective of the professional role of the teacher, we explored the overall coordination specifically when teachers were facing hostile ($N = 29$ classrooms) and dominant behaviour of students ($N = 35$ classrooms). On average, the cross-correlation for Communion was -0.10 ($SD = 0.47$) in the face of hostile student behaviour, compared to 0.36 ($SD = 0.37$) when student behaviour was friendly. So, with hostile student behaviour, teacher behaviour was less complementary. In the face of dominant student behaviour, the cross-correlation for Agency, on average, was -0.23 ($SD = 0.43$), compared to -0.33 ($SD = 0.38$) in the face of subordinate behaviour of students. So, with dominant student behaviour, teacher behaviour also was less complementary. In 69% of the classrooms, cross-correlations were less complementary in the face of hostile student behaviour, and in 60% of the classrooms in the face of dominant student behaviour. These results are in line with the idea that teachers could occasionally refrain from hostile behaviour in the face of hostile student behaviour and to override the interpersonal bid of submissiveness in the face of dominant student behaviour.

Cross-dimension associations. Given that the role and status of teachers and students is different, we explored if teacher-student interactions were atypical in terms of cross-dimension correlations. Interpersonal theory expects these correlations in general to be small and unimportant (Sadler & Woody, 2003). Because both teachers and students will consider each other's role and responsibility for the process of adaptation as different (e.g., "we do not start with the lesson until the teacher forces us to do so", "students have to listen"), students' friendliness may be dependent not only on their teacher's friendliness, but also on the teacher's dominance; and students lowering their level of dominance may be dependent not only on their teacher's dominance, but also on the teacher friendliness. Therefore, to examine how the combination of teacher Agency and Communion affects student Agency and Communion, we explored cross-dimensional *part correlations*.

The cross-dimensional part correlations between moment-to-moment student Communion and teacher Agency (i.e., controlling for the effect of teacher Communion) showed, on average, a positive added effect of teacher Agency on student Communion ($M-r_{\text{part}} = 0.10$, $SD = 0.36$). Part correlations between student Agency and teacher Communion (i.e., controlling for the effect of teacher Agency), showed on average a negative added effect of teacher Communion on student Agency ($M-r_{\text{part}} = -0.16$, $SD = 0.28$). In 60% of the classrooms the part correlation was positive for student Communion and teacher Agency, and in 77% of the classrooms the part correlation was negative for student Agency and teacher Communion.

These results can be explained with the assumption that higher agentic behaviour of teachers may be valued or even needed by students in the first part of a lesson to bring along a higher level of student Communion than could be expected based merely on the Communion level of the teacher. In the same vein, higher Communion may bring along a lower level of Agency of the students than could be expected based merely on the Agency level of the teacher. Students may accommodate more smoothly with the Agency of the teacher when the teacher displays a higher level of Communion. This result is in line with research of Thijs et al. (2011) showing that in a dyadic task of teachers and individual kindergartners outside the classroom, children reciprocated teachers' controlling behaviours more with passive behaviours when the relationship with the teacher was experienced as warm and without conflict than in a less warm relationship (see also Roorda et al., 2013).

Trends. We tested for linear, quadratic (i.e., curvilinear with one bend) and cubic (i.e., curvilinear with two bends) trends in teacher

and student behaviour during the first 10 min of a lesson. Table 3 provides information on the proportion of variance explained (R^2 change) after adding (1) a linear term, (2) a quadratic term, and (3) a cubic term, averaged across the 35 classrooms.

On average, quadratic and cubic terms improved the linear model. In 65% of the tested models in individual classrooms, the linear term made the strongest contribution, in 23% the quadratic term, and in 12% the cubic term.

We selected the cubic model for all classrooms to describe the entrainment of trends in teacher and student behaviour. Fig. 6 presents the graphs for cubic models based on the mean scores of the parameters of the cubic models of the 35 classrooms.

On average, during the first 10 min of the observed lesson, the entrainment of trends in teacher and student behaviour are in line with the complementarity principle. According to the average cubic model, the lesson started with a positive Communion level for the teacher ($M = 254$) and a rather neutral level for the students ($M = 19$). Then, in the first 10 min of the lesson, both teachers and students increased to a more equal level of Communion (teacher $M = 501$, students $M = 448$). Regarding Agency, students started with a higher level ($M = 304$) than the teacher ($M = 74$). In the first 6 min, teachers increase in Agency (to $M = 379$) and students decrease (to $M = -327$). After 10 min, teachers end up with a lower level of Agency ($M = 215$) and students with a higher (but still subordinate) level ($M = -229$). Based on visual inspection, we judged this average match of increasing and decreasing trends present regarding Agency in 79% of the classrooms, regarding Communion in 69%. These results suggest that for most classrooms the first 10 min of a lesson function as a period of regulating the Agency and Communion level of students towards more positive student Communion and a lower level of student Agency. From the perspective of class-level dynamics, this represents a more supportive atmosphere to start up the learning process of all students (see also section 1.1).

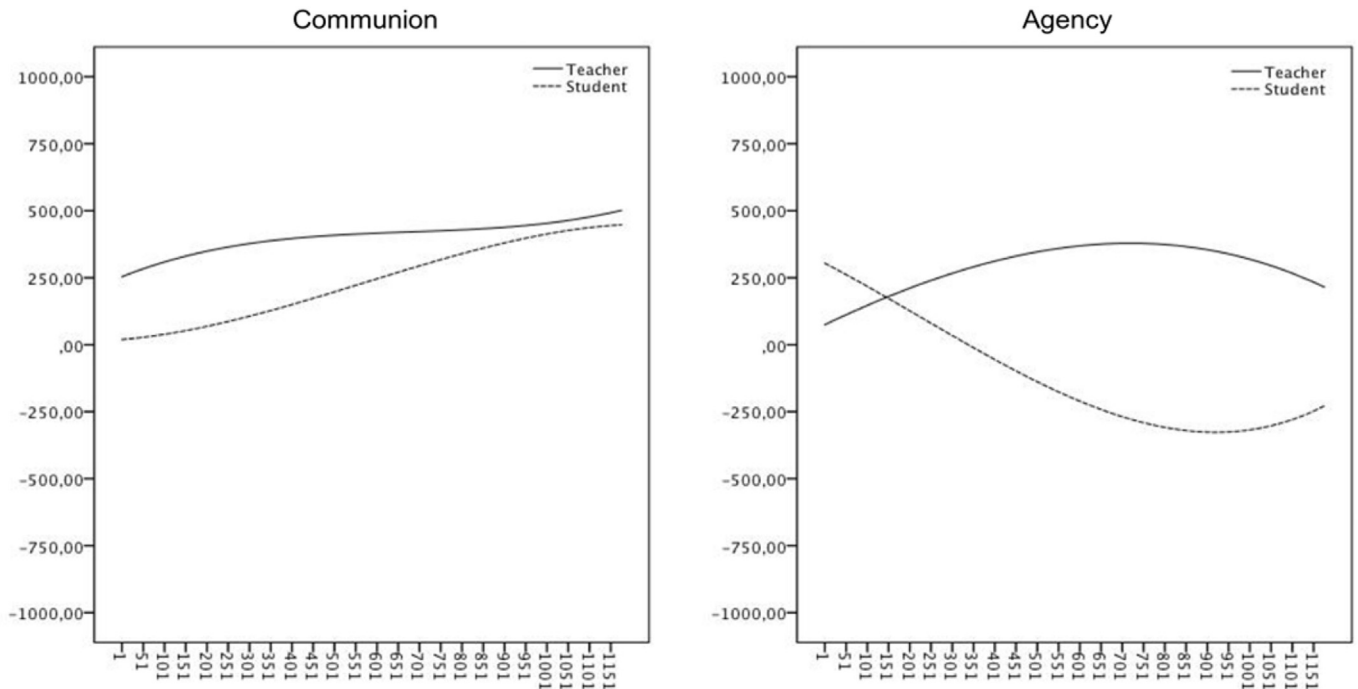
Correlations between the levels of Communion and Agency at the start of the lesson (i.e., the intercepts) for teacher and student time series showed a positive ($r = 0.33$) value for Communion and a negative value ($r = -0.44$) for Agency. That is, if the teacher behaved more communally at the very beginning of the lesson compared to other teachers, his or her students also behaved more communally. If the behaviour of the teachers was more agentic compared to teachers from other classrooms, the behaviour of students was less agentic. Because students and teachers knew each other from earlier lessons, some interpersonal adjustment at the very beginning of a lesson was unsurprising. Sadler et al. (2009), found that, even for unacquainted partners, quite a lot of adjustment had already occurred at the start of the coding period (which in their study was 10 min into the interaction). Also, the correlations between the linear, quadratic, and cubic changes in teacher and student behaviour were in accordance with the interpersonal complementarity principle (Communion: lin $r = 0.09$, quad $r = 0.24$, cub $r = 0.33$; Agency: lin $r = -0.44$, quad $r = -0.55$; cub $r = -0.60$), indicating further alignment of teacher and student behaviour after the start of the lesson.

Cyclical patterns. Using (cross-)spectral analysis, we explored the degree of interpersonal adaptation of teacher and student behaviour in terms of the synchrony of the cyclical behaviours that may occur superimposed on the cubic trend. Before performing spectral analysis, we removed the cubic trend (linear + quadratic + cubic term) from the time series of all classrooms.

In Table 4 we present information on the cyclical nature of the teacher and student time series in terms of the index of rhythmicity, and information on the synchrony of the cyclical patterns in terms of average weighted coherence. For all teacher and student time

Table 3Trends in Teacher and Student behaviour: R^2 change (M, SD) After Adding a Linear, Quadratic, and Cubic term (35 classrooms).

	Communion						Agency					
	Teacher			Students			Teacher			Students		
	lin ^{a)}	quad ^{b)}	cub ^{c)}	lin ^{a)}	quad ^{b)}	cub ^{c)}	lin ^{a)}	quad ^{b)}	cub ^{c)}	lin ^{a)}	quad ^{b)}	cub ^{c)}
Mean	0.307	0.112	0.069	0.505	0.095	0.054	0.275	0.159	0.094	0.336	0.129	0.076
St. dev	0.277	0.144	0.088	0.289	0.121	0.066	0.263	0.181	0.124	0.269	0.158	0.108

Note. ^{a)} linear term ^{b)} quadratic term ^{c)} cubic term.**Fig. 6.** Trends in teacher and student behaviour (averaged across 35 classrooms).**Table 4**

Summary statistics for spectral analyses of teacher and student time series (35 classrooms).

	Communion		Agency	
	M	SD	M	SD
Teacher rhythmicity	0.82	0.09	0.87	0.08
Student rhythmicity	0.89	0.06	0.93	0.03
Average weighted coherence	0.41	0.19	0.49	0.25

series, we found significant cyclical components (Fisher's test, Warner, 1998). The large amounts of variance accounted for (captured by the index of rhythmicity) showed that both teacher and student behaviour strongly tended to fall in reasonably regular cycles.

Average weighted coherence values of 0.41 and 0.49 are considered large effects (compare to R^2 ; large effect = above 0.26, Cohen, 1988, p. 414), and show that, on average, the peaks and troughs of the cyclical patterns in teacher and student behaviour tend to be well related to each other over time. An average weighted coherence above 0.26 was found in 77% of the classrooms for Communion, and in 83% for Agency.

Results regarding phase showed that in 20% of the classrooms ($N = 7$), the teacher leads on both Communion and Agency, and in 26% of the classrooms ($N = 9$), the teacher follows students on both Agency and Communion. In 20% of the classrooms ($N = 7$), the

teacher is leading on Agency and following the students on Communion, and in 34% of the classrooms ($N = 12$) the teacher is following students on Agency and is leading on Communion. Thus, classrooms showed a varied pattern of who is leading the interactions in the first 10 min of a lesson.

Residual fluctuations. To examine associations between “random” behaviours of teachers and students, we removed trends and cycles (residuals of second order autoregressive model, see also Sadler et al., 2009; Warner, 1998). When we computed the cross-correlation functions, interrelating the pairs of residuals for teacher and student Agency, and teacher and student Communion, we only found small correlations (Communion: $M = 0.01$; range -0.08 to 0.10 ; 86% n.s.); Agency: $M = -0.02$; range -0.12 to 0.08 ; 77% n.s.) with no clear high points. Therefore, across the 35 classrooms, the associations between “random” behaviours appear not to make an important contribution to interpersonal adaptation.

3.2. Interpersonal adaptation and teacher interpersonal style

The degree and nature of interpersonal adaptation varied considerably between classrooms. Indeed, in some classrooms, the patterns of interpersonal adaptation were very different from those expected based on the teacher's professional role during the beginning of a lesson. To explore the associations of adaptation in daily classroom interaction with teacher interpersonal style, we related the four types of indicators of interpersonal adaptation of

moment-to-moment teacher and student behaviour (observed in 10 min of interaction in one lesson) to the degree of Agency and Communion in teacher interpersonal style (perceived by their students over a longer period). We also compared the different indicators for interpersonal adaptation for classrooms with a more preferred teacher interpersonal style (MP-classrooms, see section 2.3) and classrooms with teachers with a less preferred teacher interpersonal style (LP-classrooms, see section 2.3).

On average, the class aggregated perceptions of students of their teacher's interpersonal style (scale -1 to $+1$) ranged in the present study for Agency from -0.41 to 0.45 ($M = 0.14$, $SD = 0.21$) and for Communion from -0.20 to 0.66 ($M = 0.21$, $SD = 0.25$). In 18 classrooms (51%), the teacher had a more preferred interpersonal style, and in 17 classrooms (49%) a less preferred style.

Interpersonal level and variation. In Table 5, we relate the level and variation in teacher behaviour in the first 10 min of a lesson to teacher interpersonal style. Correlations in Table 5 indicate a rather strong alignment between Agency/Communion of teacher interpersonal style, representing a more long term time level (i.e., school year) and Agency/Communion of teacher behaviour, representing a moment-to-moment time level (i.e., every half-second in the first 10 min of a lesson). Regarding the interpersonal level, effect sizes were large (large effect: $r > 0.50$, Cohen, 1988, p. 80). Regarding variation, effects were less strong, but in line with earlier studies, where less variation in teacher behaviour was found in interactions of teachers with higher Agency and Communion in their interpersonal style (Mainhard et al., 2012; Pennings, Van Tartwijk et al., 2014). Differences between interpersonal level and variation in teacher behaviour in the MP- and LP-classrooms represented similar trends as were shown by the correlations. Thus, observing moment-to-moment interactions during only 10 min of only one lesson, already reveals differences between classrooms with teachers with different interpersonal styles. For MP-classrooms, teacher behaviour is more in line with what can be expected based on the professional teacher role and characteristics of an effective classroom environment to start up a lesson (i.e. directing-helpful).

Overall coordination. In Table 6, we relate overall coordination of moment-to-moment teacher and student behaviour in the first 10 min of a lesson (cross-correlations) to teacher interpersonal styles.

Regarding Communion, the overall coordination of moment-to-moment interpersonal adaptation (cross-correlation) of MP-classrooms was, on average, more consistent with the interpersonal complementarity principle of sameness. Regarding the Agency dimension differences between MP- and LP-classrooms regarding the association between teacher interpersonal style and moment-to-moment overall coordination were very small.

Refraining from hostility in case of hostile behaviour of students occurred more frequently in MP-classrooms (79%) compared to LP-classrooms (60%). Overall coordination in terms of cross-dimensional part correlations showed only small differences between MP- and LP-classrooms for the added effect of Teacher

Agency on student Communion (0.12 vs. 0.08).

Trends. Fig. 7 presents graphs based on the mean scores of the parameters of the cubic models for MP- and LP-classrooms.

The cubic trend model shows that teacher and student Communion increase, on average, during the first 10 min, in MP- and LP-classrooms. In MP-Classrooms, teacher Communion is higher at the very beginning of the lesson compared to LP-classrooms ($M = 311$ vs. $M = 193$), student Communion, is, on average, more alike ($M = 6$ vs. $M = 33$). However, in MP-classrooms, student Communion increases faster to a higher level after 10 min ($M = 588$ vs. $M = 299$) than in LP-classrooms.

Regarding Agency, teachers in MP-classrooms start, on average, with a lower level ($M = -38$ vs. $M = 194$), and students start with a higher level of Agency ($M = 378$ vs. $M = 225$). During the first 10 min of the lesson, teachers in MP-classrooms, on average, increase their Agency during about four minutes and hold on to that level. In the same period students decrease their Agency. In LP-classrooms teacher Agency increases less strongly, and after about six minutes decreases again. Students decrease Agency when teachers increase and increase Agency, when teachers decrease. LP-classrooms end up with lower teacher Agency ($M = 21$ vs. $M = 398$) and higher student Agency compared to MP-classrooms ($M = -54$ vs. $M = -0.394$). MP-classrooms are more in line with the prevailing standard in education (i.e. directing-helpful teachers with the students following in a reliant-collaborative way). Probably interpersonal adaptation at the very start of the lesson in a classroom is less indicative for the quality of the teacher student relationship, than after 10 min. When taking a speculative causal stance, results could reveal that, in MP-classrooms, moment-to-moment teacher behaviour was more appropriate for raising the Communion level and reducing the Agency level of students during the first 10 min of the lesson.

Cyclical patterns. Table 7 shows the comparison of rhythmicity of teacher and student behaviour in MP- and LP-classrooms. Neither the rhythmicity nor the average weighted coherence values differed appreciably.

Results regarding phase showed that in MP-classrooms the teacher was more often leading in Agency (50% versus 29%), but less often in Communion (50% versus 59%).

In summary, in classrooms with a more preferred teacher interpersonal style (MP-classrooms), during the first 10 min of a lesson, the moment-to-moment interpersonal behaviour of teachers and the adaptation to the behaviour of their students was for most indicators more in accordance to professional standards compared to classrooms with a less preferred teacher interpersonal style, i.e., higher levels of momentary teacher Agency and Communion, faster increase of student Communion and decrease of student Agency, more teachers with refraining from hostility and subordinate behaviour, more teachers leading in Agency. Results regarding variation and overall coordination with Agency, and results for the entrainment of cyclical patterns were less clearly related to teacher interpersonal style.

Table 5
Level of Moment-to-Moment Teacher Behaviour and Teacher Interpersonal Style (35 classrooms).

Teacher behaviour	Teacher interpersonal style							
	Communion				Agency			
	Less preferred		More preferred		Less preferred		More preferred	
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>d</i>	<i>r</i>	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>d</i>	<i>r</i>
Level (mean)	297 (204)	502 (157)	1.13	0.54	228 (257)	354 (160)	0.59	0.47
Variation (st.dev)	184 (55)	154 (50)	-0.57	-0.20	290 (95)	284 (63)	-0.07	-0.07

Note. Teacher Interpersonal styles: More preferred ($N = 18$), Less preferred ($N = 17$). For convenient reasons, we left out decimals (M and SD).

Table 6
Moment-to-Moment Interpersonal Adaptation (Overall Coordination) and Teacher Interpersonal Style (35 classrooms).

	Teacher interpersonal style							
	Communion				Agency			
	Less preferred	More preferred	<i>d</i>	<i>r</i>	Less preferred	More preferred	<i>d</i>	<i>r</i>
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)			<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)		
Overall coordination	0.33 (0.40)	0.49 (0.34)	0.43	0.21	-0.44 (0.42)	-0.45 (0.39)	-0.02	-0.04

Note. Teacher Interpersonal styles: More preferred (*N* = 18), Less preferred (*N* = 17).

4. Discussion

In the present study, we explored interpersonal adaptation in daily interaction in 35 classrooms. We delved into micro-processes to get a better understanding of daily classroom interaction. We explored the degree of interpersonal adaptation in terms of the general tendencies of interpersonal complementarity (sameness for Communion, oppositeness for Agency) and some refinements of these tendencies based on the specific professional role and status of the teacher. To explore the assumed theoretical and practical relevance of the attention to these micro-processes, we used as a point of reference the association with teacher interpersonal style, which was shown in earlier research to be important for student cognitive and affective outcomes, and teacher well-being.

Although the degree and nature of interpersonal adaptation was in general consistent with interpersonal theory, degree of adaptation varied considerably between classrooms. For most indicators, behaviour of teachers and the adaptation to the behaviour of their students was more in accordance with professional standards in classrooms with a more preferred teacher interpersonal style compared to classrooms with a less preferred teacher interpersonal style. More research is needed to explain the absence of differences in some of the indicators of interpersonal adaptation.

As our exploration of the processes in daily classroom interaction and associations with teacher interpersonal style contributed to the understanding of differences in classrooms, this study supported the conjecture that attention to micro-processes in classrooms has added value to outcome-oriented, macro-level investigations of teacher interpersonal styles and interpersonal relationships in education. In the remainder of this section, we highlight some contributions of the present study to research on teacher-student interaction, present limitations, and lines of future research.

4.1. Variation

One of the major advantages of continuous coding is that it promotes explicit consideration of the dynamic variation that occurs in momentary interactions between people. Our study illustrates that not only the level of interpersonal behaviour, but also the variation *within* students and teachers, and *across* classrooms contributes to the understanding of classroom micro-processes. For example, in Classroom16, the mean levels of Agency and Communion do not tell the whole story. In accordance with the white sign in the density plot in Fig. 3, we may have concluded that the teacher always behaved in a directing-helpful manner with students following in a reliant and collaborative way; however, these mean levels do not adequately capture that there are periods of time when the students were considerably more agentic and less communal. The pattern of variation in Classroom16 also demonstrates that student dominant behaviour reduces without hostile behaviour of the teacher. Other classrooms show a different pattern of variation, for example, with teachers who do not refrain from hostility.

Another example of the informative value of variation are the trends in teacher and student behaviour. For example, in the present study, we found a substantial reduction of student Agency and a rise in student Communion during the first 10 min of a lesson, especially in classrooms with a more preferred teacher interpersonal style.

4.2. Teacher professional role

We expected teachers to be able to refrain from hostility and subordinate behaviour in classrooms. We indeed found a substantial number of teachers to be able to refrain from responding with hostility when confronted with student hostility (69%), as well as refrain from reacting subordnately to dominant student bids (63%). Regarding the leading role of the teachers in the coordination of the entrainment of the cyclical patterns in teacher and student behaviour (“Who is following whom?”), we found different types of leading in classrooms, but teachers with a leading pattern on Agency were more prominent in classrooms with a more preferred teacher interpersonal style. Perhaps these different types of leading connect with the educational debate on whether it is better for the teacher to act as “sage on the stage” or as a “guide on the side” (e.g., King, 1993). In classrooms, teachers can be viewed the central figure, the ones who have the knowledge (“sage on the stage”) which they transmit to students. In the constructivist view of learning, students are placed at the centre of the process and actively participate in thinking and discussing ideas to help them understand the new material with the teacher as a “guide on the side”, facilitating learning in less directive ways.

To further understand the specific mechanisms underlying the interpersonal lead-lag relationship and refrainment of hostility, additional research is needed. From the perspective of the teacher as a professional, these studies can be guided by questions like: To what degree do teachers themselves view leading/following or friendliness/hostility as defining components of an effective classroom atmosphere?; To what degree do teachers apply leading/following, or friendly/hostile behaviour as a specific strategy given the educational setting of the lesson at the beginning of a lesson?; To what degree are teachers able to apply their desired strategy, taking into account that their interpersonal expertise develops during their professional career (Brekemans, Wubbels, & Van Tartwijk, 2005)?

4.3. Adaptation as a process of anticipation

The question of “Who is following whom?” connotes a stimulus-response perspective, i.e., individual acts that are driving each other. This conception of adaptation does not fully acknowledge the findings of the present and other studies. Rather than simply responding to the immediately preceding behaviour, partners respond also to each other's anticipated behaviour (Pincus, 1994). “The process may be akin to music improvisation, in which musicians must anticipate where their partners are going before they get there. Music is full of cyclical structures that facilitate such

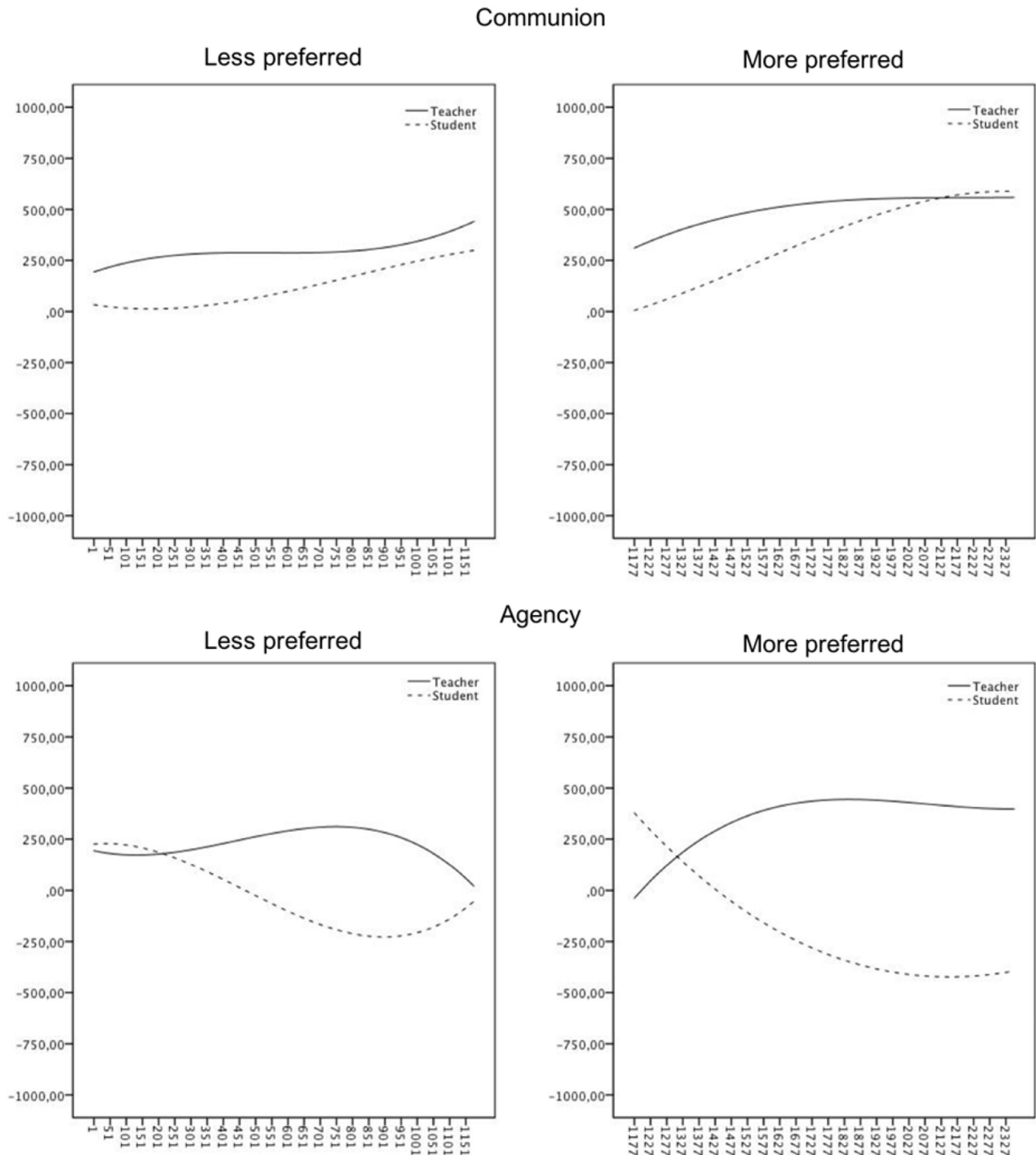


Fig. 7. Trends in teacher and student behaviour (averaged across 35 classrooms).

anticipations. Arguably, social interaction is similar” (Sadler, Woody, McDonald, Lizdek, & Little, 2015, p. 539). Also the results in the present study suggest, and for similar results see e.g., Sadler et al. (2009), that an underlying process of anticipating interaction partner’s behaviours may be occurring, as is apparent from (a) the size of the cross-correlations (with no time lag), (b) the existence of

cyclical patterns (recurrent behaviour, which inherently includes the possibility of predicting future behaviour), and (c) the size of the correlations between teacher and student behaviour at the very beginning of the lesson. The concept of anticipation as one of the components contributing to interpersonal adaptation adds to the understanding of the complexity of teacher-student interaction and

Table 7Interpersonal Adaptation (Spectral indicators) for Classrooms with Teachers with More ($N = 18$) and Less Preferred ($N = 17$) Interpersonal Styles.

	Teacher interpersonal style							
	Communion				Agency			
	Less preferred	More preferred			Less preferred	More preferred		
Interpersonal adaptation	$M (SD)$	$M (SD)$	d	r	$M (SD)$	$M (SD)$	d	r
Teacher rhythmicity	0.80 (0.11)	0.83 (0.06)	0.34	0.15	0.85 (0.08)	0.90 (0.06)	0.70	-0.11
Students' rhythmicity	0.88 (0.06)	0.90 (0.05)	0.36	0.14	0.93 (0.03)	0.93 (0.02)	0.03	-0.01
Average weighted coherence	0.38 (0.17)	0.45 (0.20)	0.38	0.04	0.52 (0.27)	0.47 (0.23)	0.20	-0.04

Note. Teacher Interpersonal styles: More preferred ($N = 18$), Less preferred ($N = 17$).

teacher interpersonal expertise, but at the same time makes interpretation of results regarding phase more complex.

4.4. Interrelating time scales

In the present study, we made a connection between moment-to-moment behaviour of teachers and students, and long-term teacher interpersonal styles. The interrelations between micro- and macro-level time scales are the primary focus of Dynamic Systems Theory when studying development (e.g., [Granic & Patterson, 2006](#); [Steenbeek & Van Geert, 2013](#)). Moment-to-moment interactions are the building blocks of interpersonal styles. Stabilized interpersonal styles not only function as outcomes of previous micro-processes but also constrain subsequent moment-to-moment interactional processes. For example, moment-to-moment teacher friendliness contributes to a directing-helping interpersonal style. A directing-helping interpersonal style may prevent disruptive student behaviour during the lesson, which then makes teacher moment-to-moment friendliness easier. With the aim of validating the relevance of knowledge on daily classroom interactions for teacher student relationships, the present study examined the reciprocal association of teacher-student interaction and teacher interpersonal style only one sided, with teacher interpersonal style as a criterion variable. The present study only examined the association between *multiple* measurements of behaviours in interaction and *one* measurement of teacher interpersonal style. To reveal the mutual influence of interactions and relationships, and/or how interpersonal style develops from micro-level interactions and constrains these interactions, longitudinal research with multiple measurements of both interactions and teacher interpersonal style is needed. As an example of speculation of possible results based on the type of associations of teacher interpersonal style with moment-to-moment interactions we found in the present study, we expect a higher degree of interpersonal adaptation to contribute to the development of a more preferred interpersonal style.

4.5. Limitations

Because participation in this study was limited to those classrooms where teachers agreed to make video recordings in their lessons and with data available on teacher interpersonal styles, one may wonder about the generalizability of the results from this sample. Comparing the interpersonal styles of the sample of 35 classrooms with a large Dutch sample ($N > 18,000$ classrooms) revealed that distribution of the teacher interpersonal styles over the four quadrants of the IPC-T was not too different (see [Fig. 4](#)). Furthermore, in the large sample 56% of the teachers had a more preferred teacher interpersonal style compared to 51% in our sample. Mean scores of Agency and Communion were in the large sample, on average, respectively 0.09 ($SD = 0.18$) and 0.22 ($SD = 0.22$), compared to 0.14 ($SD = 0.21$) and 0.21 ($SD = 0.25$) in the sample of the present study. However, even though the teacher

interpersonal styles in our present study seemed not very different from the larger database, the sample size was small, therefore, generalization should be treated with caution. The descriptive results of the comparison between teachers with more and less preferred interpersonal styles of the present study provide hypotheses that can be tested in future studies.

Restrictions also apply to generalization of the results on interpersonal adaptation to all educational situations as we only studied the first 10 min of a lesson. In this part of the lesson whole class interaction is in most classrooms an important component. In this educational setting, students as a group may generate more (undesired) dominance than an individual student in a one-to-one interaction with a teacher. Combined with the perspective of class-level dynamics as used in the present study, this may have generated results different from a study on educational settings with mainly teacher-individual student interactions and even more different when combined with a perspective of individual-level dynamics. Comparing interpersonal adaptation in lesson starts of different lessons, comparing lesson starts with other specific situations (positive/negative from the perspective of teacher-student relationships), and assessing the representativeness of interpersonal adaptation in the first ten minutes for the whole lesson, would evidence the specificity of the lesson part and the lesson chosen in the present study. However, the correlation with the general teacher interpersonal style in the present study, may not only indicate that the beginning of a lesson is an important part of the lesson to predict a specific teacher interpersonal style, but may also point at the representativeness of this lesson part for the whole lesson and other lessons.

Although time-series analyses of Agency and Communion separately are informative, analyses would have profited from analysing quantitative measures that present the blended character of interpersonal behaviours, in line with the interpersonal circumplex model. Unfortunately, circular statistics is currently still in its infancy. In the present study, we did include the blended character of Agency and Communion when we associated momentary interpersonal adaptation with teacher interpersonal style, by making a qualitative distinction in (only) two groups of interpersonal styles.

In the present study, we held to a descriptive approach with the aim of a first exploration of interpersonal adaptation in the educational context with just a small sample size. A multilevel approach ([Singer & Willett, 2003](#)), Bayesian estimation in conjunction with informative prior distributions (e.g., [Van de Schoot, Broere, Perryck, Zondervan-Zwijnenburg, & Van Loey, 2015](#)) would have been alternative options that we however leave for the future.

4.6. Lines of future research

As we only explored the rather new domain of micro-processes in classrooms, there is a lot of work left. Besides future studies to be directly inferred from unexplained results and the limitations of the

present study, we suggest some other research lines that may contribute to further understanding of the dynamic interplay of teacher and student behaviour.

(1) Because professional teachers may be expected to realize an adequate adaptation pattern in every classroom, it is interesting to study the same teachers with different classes and the same classes of students with different teachers (in cross-classified educational settings) to get a more complete insight in teacher's ability to react in an adaptive way to students' behaviour. For example, which teachers are more interpersonally adept to react in an adaptive way in a wide variety of classrooms? Likewise, is an adequate adaptation pattern more difficult to realize in certain classrooms, and what sorts of teacher behaviour and micro-processes seem to contribute?

(2) Teacher-student interaction comprises different settings (i.e., teacher-whole class, teacher-small group, and teacher-individual student interaction), and in each setting the interpersonal dynamics can be investigated using different perspectives (i.e., individual, a (small-)group, or class-level perspective). In the present study, we focussed on the class-level perspective to interactions. In future studies, other combinations of settings and perspectives (e.g., studying teacher-whole class interactions by observing individual students' behaviours), may add important insights in the differentiated effects of settings and perspectives on teacher-student interactions. Also, besides differences *between* settings, also, stability of dynamic parameters *within* settings deserves attention.

(3) Although we delved into micro-processes in the classroom by describing patterns in variation during the beginning of a lesson, studies can add by taking a closer and qualitative look at special or deviant moments (e.g., hostile and/or dominant student behaviour), for example by transcribing, coding, and analysing the specific verbal and non-verbal interaction sequences. These moments can be identified in the stream of behaviour with use of the joystick approach (for a description, see Pincus et al., 2014, p. 70), and later, together with previous, and subsequent behaviour, tested for specific hypotheses (e.g., regarding ruptures and repairing of the classroom equilibrium). Further, windowed cross-correlations and peak picking (Boker, Xu, Rotondo, & King, 2002) can be used to examine whether there are important changes over the course of the interaction in the size of the cross-correlation and time lags (Sadler et al., 2009).

(4) The present study examined natural occurring classroom settings. Experimental manipulation, providing teachers with specific tasks in interaction with students (e.g., systematically refraining from hostility, or systematically reacting with submissive behaviour when students show agentic behaviour), may add, for example, to insights in the causality of mutual adaptation in micro-level processes in classrooms.

4.7. Practical implications

We are aware that formulating practical implications based on the results of the correlational design of the present study presupposes causality, and that this is not evidenced. We still think some points of action can be identified for designing teacher education and in-service professional developmental trajectories. As interaction of teachers with students in classrooms is intentionally strategic but also automatic, becoming aware of potential (in) effective interaction patterns and possible directions to change may be a first step in improvement. Results of the present study can inform teacher professionalization regarding the diagnosis of (problematic) interpersonal styles and contribute to the design of effective interventions that make use of (video-taped) daily classroom interaction. Looking at classrooms from the perspective of

interpersonal adaptation promotes an explicit focus on the classroom system, rather than just on the teacher, and may make the (student-)teacher mindful of variation in behaviour and its cyclical nature. Aspects of the continuous coding procedure and indicators of interpersonal adaptation could be useful for (student-)teachers and their educators and supervisors. Together with annotations of specific moments (e.g., critical incidents), quantitative indicators can be used to diagnose the classroom micro-processes in and across students and educators in a comparable and more complete way. See also Pincus et al. (2014) who applied the joystick approach during clinical supervision to teach therapists-in-training. The combination of behavioural analyses with teacher's interpersonal knowledge (e.g., Claessens et al., 2016) and appraisals of interpersonal classroom processes (e.g., Van der Want et al., 2015) may also contribute to a more effective intervention (Claessens et al., 2014).

To conclude: (1) We consider the present study an illustration of the applicability of continuous coding for describing interpersonal dynamics in the educational context. We consider continuous coding not only suitable for investigating teacher and student behaviour, but also for investigating teacher and student emotions and knowledge. (2) We consider the present study an illustration of the added value of attention to micro-processes, both at the level of individual and multiple classrooms. Conceptualizations and results can contribute to theory on teacher-student interaction as well as the practice of teacher professional development.

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