



## Real-time teacher–student interactions: A Dynamic Systems approach



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### HIGHLIGHTS

- We studied the discriminant validity of characteristics of real-time interactions.
- These were interpersonal content, structure, and complementarity.
- By observing two teachers' interactions with students, with a computer joystick.
- We found that interpersonal content discriminated between the two teachers.
- We found that interpersonal complementarity discriminated between the two teachers.

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### ABSTRACT

Teacher–student relationships develop from real-time teacher–student interactions. These real-time interactions can be characterized by interpersonal content, structure, and complementarity. We studied how teacher–student interactions measured in terms of these characteristics differed for two teachers with distinct teacher–student relationships. A computer joystick device enabled us to measure teacher and student interpersonal behavior as a two-dimensional construct, a blend of Agency and Communion. Our results indicated that interpersonal content and complementarity discriminated between teachers, and that interpersonal structure did not. Measuring these characteristics seems promising to understand differences in teacher–student relationships.

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Good relationships between teachers and students are important for student motivation, their academic achievement (Brekelmans, 1989; Cornelius-White, 2007; Den Brok, 2001; Goh, 1994; Hamre & Pianta, 2001; Henderson, 1995; Henderson & Fisher, 2008; Roorda, Koomen, Spilt, & Oort, 2011; Thijs & Koomen, 2008), and for teachers' well-being (Evertson & Weinstein, 2006; Spilt, Koomen, & Thijs, 2011; Wubbels, Brekelmans, Den Brok, & Van Tartwijk, 2006). Poor teacher–student relationships are related to classroom management issues and are an important reason for

leaving the profession (De Jong, Van Tartwijk, Verloop, Veldman, & Wubbels, 2012; Walker, 2009). Many studies have been carried out all over the world to study teacher–student relationships in various countries (e.g., The Netherlands, the United States, Canada, Australia, China, and Indonesia) and various educational contexts (e.g., secondary, vocational, and university education). All of these studies reported the significant and crucial role of teacher–student relationships in education (e.g., Fisher & Rickards, 1998; Fricke, Van Ackeren, Kauertz, & Fisher, 2012; Georgiou & Kyriakides, 2012; Henderson & Fisher, 2008; Klem & Connell, 2004; Lepointe, Legault, & Batiste, 2005; Levpuscek, Zupancic, & Socan, 2012; Maulana, Opdenakker, Den Brok, & Bosker, 2011; Mireles-Rios & Romo, 2010; Pianta, Mashburn, Downer, Hamre, & Justice, 2008; Wei, Den Brok, & Zhou, 2009; Wentzel, 1998, 2012). Teacher–student relationships develop from daily classroom interactions between teacher and students. The knowledge base on the relation

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between these daily interactions and the teacher–student relationship is limited. With the present study we want to add to this knowledge base.

In this study we define interactions as real-time behavioral exchanges of two or more participants (e.g., teacher–student or student–student) (Markey, Lowmaster, & Eichler, 2010), and relationships as relatively stable patterns in these behavioral exchanges (Mainhard et al., 2012). When studying how daily classroom interactions and teacher–student relationships influence each other, it is fruitful to use an approach based on Dynamic Systems (DS) theory (Granic & Hollenstein, 2003; Hollenstein, 2007, 2013). According to this theory any development of a system (e.g., a person, a dyad or a group) is hierarchically nested in time (Hollenstein, 2007; Thelen & Smith, 1998). Development is therefore studied by examining the relation between experiences and processes on different time levels, i.e., micro-level (e.g., real-time teacher–student interactions) and macro-level (e.g., teacher–student relationships). Experiences and processes on a *real-time* level denote what happens within or between humans from second to second. Experiences and processes on a *developmental time* level denote the relatively stable state of certain human characteristics. Studying the development of teacher–student relationships using a DS approach includes three basic tenets (a) real-time interactions between teachers and students in classrooms are the building blocks of teacher–student relationships (Granic & Hollenstein, 2003); (b) these relationships become manifest through the development of recurrent, relatively stable patterns in real-time interactions (Thelen & Smith, 1998); and (c) these relationships constrain real-time processes and experiences (Hollenstein & Lewis, 2006).

In various social contexts studies on relationships have been carried out using a DS approach. Examples are studies on parent–child relationships (Granic & Hollenstein, 2003), on homogeneous interaction partners (e.g. females; Markey et al., 2010), and on mixed-sex relationships (Sadler & Woody, 2003). Harjunen (2012) emphasized the importance of power in classroom interactions as dynamic systems. Yet, to our knowledge only very few studies have been carried out using this DS approach to empirically study interpersonal relationships in educational settings (Mainhard, Pennings, Wubbels, & Brekelmans, 2012; O'Connor, 2010; Roorda, 2012).

In studies that use the DS approach real-time interactions are characterized by their content and structure. In the present study we will study these characteristics in the context of teacher–student relationships: interpersonal content and interpersonal structure. According to Mainhard (2009) identifying the interpersonal content and interpersonal structure in teacher–student interactions may be critical for understanding teacher–student relationships. We will also add a third distinctive characteristic of real-time interactions that is used in studies building on Interpersonal theory (Horowitz & Strack, 2011; Kiesler, 1996): interpersonal complementarity (De Jong et al., 2012; Kiesler, 1983; Sadler, Ethier, Gunn, Duong, & Woody, 2009; Tracey, 2004). According to Gurtman (2001) interpersonal complementarity is probably the most predictive characteristic of interactions for studying differences in relationships.

As a first step in studying on the relation between real-time teacher–student interactions and teacher–student relationships we will explore if teachers with different relationships with their students also differ in interpersonal content, structure and complementarity of the real-time interactions with their students. This discriminant validity of these real-time characteristics is a prerequisite for studying the relation between real-time (micro-level) and developmental time (macro-level) processes and experiences. Insight in the relation between real-time and

developmental time processes and experiences contributes to the understanding of the development of teacher–student relationships, and to interventions to improve teaching practice.

## 1. Interpersonal content

In the present study we conceptualize the interpersonal content of the interactions in terms of *attractors*. Attractors are commonly used in studies based on DS Theory (Granic & Hollenstein, 2003; Mainhard et al., 2012). An attractor is a behavioral *state* (e.g., a mode of behavior) a system prefers (Thelen & Smith, 2006), an attractor represents stable and recurrent patterns of real-time behaviors or interactions (Granic & Hollenstein, 2003; Mainhard et al., 2012). When a particular state or typical positions in real-time interactions occur both frequently and for a longer time, this is a sign of the presence of an attractor (Granic & Hollenstein, 2003). These attractors in real-time interactions contribute to the development and characterization of relationships on a developmental time-scale. For example, when a teacher often compliments students, thus encourages students to participate in classroom processes this might imply that this teacher has a positive relationship with his or her students.

## 2. Interpersonal structure

Dishion, Nelson, Winter, and Bullock (2004) and Hollenstein & Lewis (2006) refer to variability and stability of the systems' behavior (e.g., participants in the real-time interactions) as the structure of the interactions. In studies on mother–child interactions it has been found that variability is necessary for development of healthy parent–child relationships (Granic & Hollenstein, 2003). However, in a study that compared two teachers with a desirable and less desirable teacher–student relationship, Mainhard et al. (2012) found that less variability was related to the desirable relationship and high variability was related to the less desirable relationship. They concluded that stability in interactions seems important to accomplish positive teacher–student relationships.

## 3. Interpersonal complementarity

Before defining interpersonal complementarity, we first describe the underlying theoretical framework of interpersonal

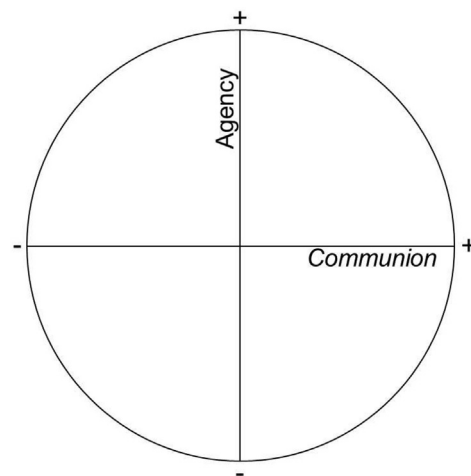


Fig. 1. Interpersonal circle. Note. A video representation is provided to explain the interpersonal circle.

theory (Horowitz & Strack, 2011; Kiesler, 1996). In interpersonal theory two basic dimensions form the basis for studying interpersonal behavior of a person. These dimensions have been given various names in the literature depending on the context in which they are used (Wubbels et al., 2006; Bruckmüller & Abele, 2013; Wiggins, 1991). According to interpersonal theorists, these various names should be interpreted in reference to the meta-concepts Agency and Communion (Gurtman, 2009; Horowitz & Strack, 2011). In this study, we use these meta-concepts to describe both teacher and student interpersonal behavior. A high position on the Agency dimension means someone is dominant, takes matters in his or her own hand, has power, and control; a high position on the Communion dimension means that someone shows love, friendliness, and affiliation (Gurtman, 2009). According to interpersonal theory, the interpersonal meaning of each behavior represents a specific blend of Agency and Communion, that can be graphically represented using the interpersonal circle (IPC, see Fig. 1) (Fabrigar, Visser, & Browne, 1997; Gurtman, 2009; Kiesler, 1983; Leary, 1957; Sadler et al., 2009).

Interpersonal complementarity is a central aspect of interpersonal theory. This concept defines the interplay of behavior between two participants in interaction. It describes how the interpersonal behaviors of both participants fit together, mutually adjust to each other, and how this dynamically changes during interactions (Sadler et al., 2009; Sadler, Ethier, & Woody, 2011). Complementary in terms of Agency is defined as *reciprocity*, and tends towards *oppositeness*. For example, if a teacher takes control (high Agency) students usually tend to listen and go along with the teacher (low Agency). Teacher behavior then elicits opposite student behavior, thus, reciprocity. Complementary in terms of Communion is defined through *correspondence*, and tends towards *sameness* (Sadler et al., 2009).

For example, if the Teacher acts friendly towards the students (high Communion), it is likely that the students act friendly towards the teacher (high Communion). Teacher behavior then elicits the same student behavior, thus, correspondence (Fig. 2).

Interpersonal complementarity has hardly been studied in educational settings. Roorda (2012) studied interpersonal complementarity in interactions between teachers and kindergartners and the relation of interpersonal complementarity with externalizing and internalizing behaviors of kindergartners. De Jong et al. (2012) studied interpersonal complementarity in teachers' expectations of student responses, using vignettes describing teacher behavior and asking for anticipated student reactions. Mainhard et al. (2012) studied interpersonal complementarity in real-time secondary educational classroom situations, as a percentage of reciprocity and correspondence in interactions.

#### 4. The present study

In the past several studies on teacher–student interactions have been carried out. These studies (1) used surveys completed by the teacher or the students to measure their perceptions of the behavior of the other participant in the interaction (e.g., Mainhard, Brekelmans, & Wubbels, 2011; Buyse, Verschueren, Doumen, Van Damme, & Maes, 2008); or (2) observed when and how the teachers behaved towards the students, not what the students' behavior or reaction was (e.g., Davis & Nicaise, 2011; Pianta et al., 2008; Rubie-Davies, 2007; Yan, Evans, & Harvey, 2011); or (3) tallying the occurrence of teacher or student behavior towards teachers, students or peers (e.g., Booren, Downer, & Vitiello, 2012; Harper & McCluskey, 2003). None of these observational studies reported observing both teacher and student behavior and combining these observations to describe interactions. In the present study we will use observations of both teacher and students'

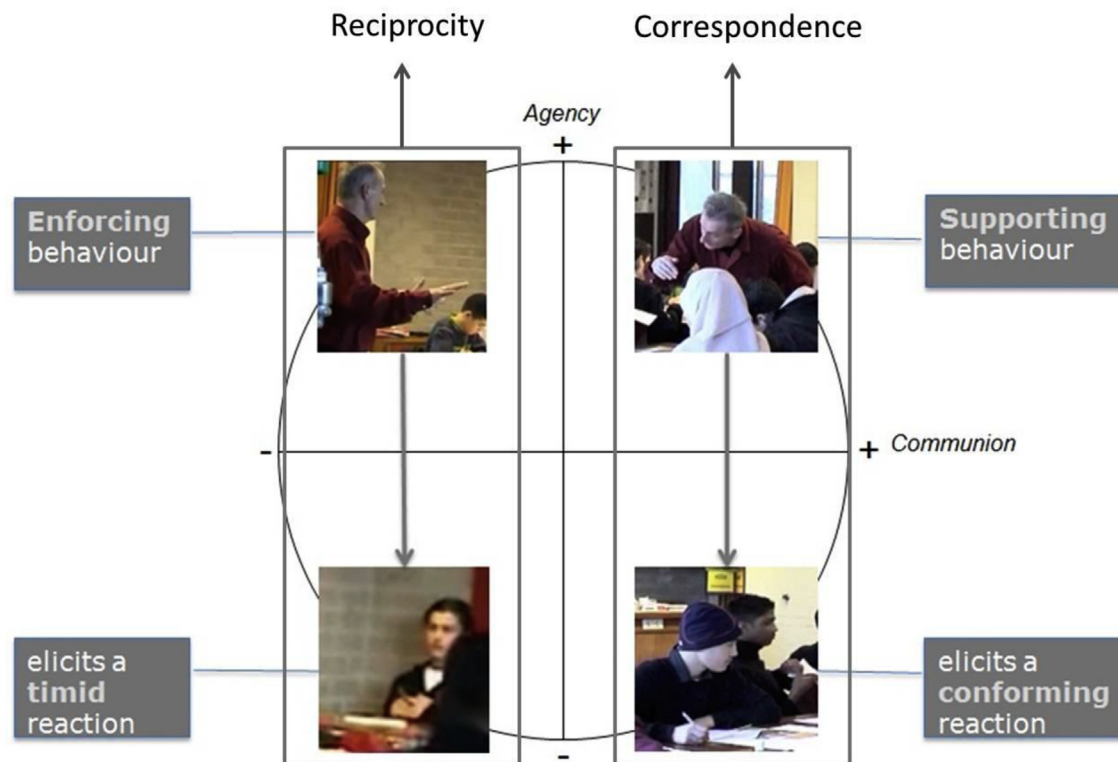


Fig. 2. Interpersonal complementarity. Note. A video representation is provided to explain complementarity.

behavior to study three characteristics of interactions. Real-time interactions are the building blocks of relationships and relationships can be improved by intervening on these characteristics. Therefore, more knowledge about these characteristics of real-time interactions is needed.

Until now interpersonal content, interpersonal structure, and interpersonal complementarity as characteristics of interactions have only been studied separately in educational settings (e.g., De Jong et al., 2012; Mainhard et al., 2012; Roorda, 2012; Thijs & Koomen, 2008). In the present study we want to add to these studies by exploring the discriminant validity of these three characteristics in real-time teacher–student interactions together in one study. To do this, we compared the characteristics of real-time teacher–students interactions of two teachers with different relationships with their students: a teacher whose relationship with students is characterized by high Agency and low Communion according to students and a teacher whose relationship with students is characterized by low Agency and high Communion according to students.

## 5. Method

### 5.1. Design

For our exploration of discriminant validity of interpersonal content, interpersonal structure, and interpersonal complementarity in real-time interactions for the study of relations between real-time interactions and teacher–student relationships, we used two single subject case studies (Gast, 2010). Single subject case studies are ideal to highlight detailed descriptions of individual differences in behavior over time (Gast, 2010). We included two cases perceived as distinct in the nature of their relationship with their students to explore the discriminant validity of the three characteristics of real-time interactions.

### 5.2. Participants

Two teachers were selected from a larger database on the basis of their students' scores on the Questionnaire on Teacher Interaction (QTI; Wubbels et al., 2006). These student scores allowed us to describe the teachers in terms of their Agency and Communion behavior as perceived by their students on a developmental time level (Wubbels et al., 2006). The first teacher is a 48-year-old mid-career female French teacher and her class of 9th grade students from a pre-vocational education level. This teacher's behavior was perceived by her students as high on Agency and low on Communion. For the remainder of this article we refer to this teacher as Teacher A. The second teacher is a 36-year-old mid-career male arts teacher and his class of 10th grade students from a pre-vocational level. This teacher's behavior was perceived by his students as low on Agency and high on Communion. For the remainder of this article we refer to this teacher as Teacher B.

### 5.3. Measures

#### 5.3.1. Interpersonal teacher and student behavior

Interpersonal content, interpersonal structure, and interpersonal complementarity are characteristics of the real-time interactions between individuals. In the present study interactions between teacher and students were operationalized by the combination of individually observed teacher and student behavior. Student behavior was observed as a class composite, the class was observed as a whole and an average degree of Agency and Communion shown by the whole class was recorded.

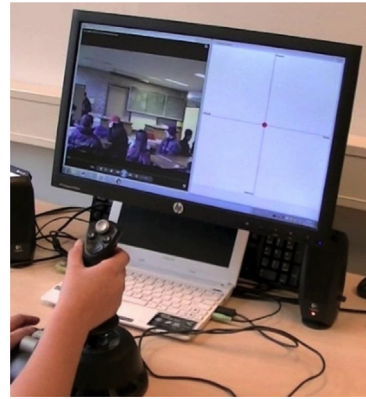


Fig. 3. Interpersonal joystick data gathering. Note. A video representation of the Computer Joystick Method is shown.

5.3.1.1. *Sadler's joystick tracking device.* Interpersonal behavior of students and teachers was coded continuously within the IPC following an online-scoring procedure and using Sadler's joystick tracking device (see Fig. 3) (Sadler et al., 2009).

First teacher behavior and then student behavior was coded in separate observation sessions. According to Markey et al. (2010) the joystick tracking device is designed to observe verbal and non-verbal behaviors that have clear interpersonal meaning. The observer can move the joystick to represent the teacher's or the student's ongoing interpersonal behavior, while watching a video recording of a lesson. The joystick device enabled us to observe behavior as a specific blend of Agency and Communion, instead of coding behavior separately for both dimensions. By moving the joystick in a certain direction the behavior of the teacher or the students can be observed (a) continuously in time (online observation) and (b) represented as a degree of both Agency and Communion (Markey et al., 2010).

This joystick tracking device comes with a computer program (Joymon.exe; Lizdek, Sadler, Woody, Ethier, & Malet, 2012) that numerically records the exact location (based on X- and Y-coordinates) of the joystick within a two-dimensional space, meant to represent the IPC (Markey et al., 2010; Sadler et al., 2009). During the observation, a dot in the IPC (i.e., presented in a separate screen) marks the exact location of the joystick. These behavior coordinates ranged from  $-1000$  (i.e., very low Agency/Communion) to  $+1000$  (very high Agency/Communion). This range is a default setting of the joymon program and ensures maximum sensitivity of the computer joystick device. Also, by default the program is set to record the joystick location twice per second. In the current study we also used this default setting to record teacher and student behavior twice per second.

Thus, in the present study, about 1500 behavior coordinates were provided for Agency and Communion, per teacher and class. For a more elaborate description of this computer joystick procedure see Lizdek et al. (2012).

To learn how to observe teacher–student interactions with the computer joystick one of the researchers (first observer) participated in a computer joystick training.<sup>1</sup> To establish inter-rater reliability a second observer was trained by the first observer to use the computer joystick method for the present study. By practicing and discussing how to code interpersonal teacher and

<sup>1</sup> The joystick training was provided by Pamela Sadler and Ivana Lizdek at Wilfrid Laurier and Waterloo University in Canada. This training included general observations of interpersonal behavior with the joystick and was not related to the educational context.

student behavior reliably, together, they established some rules for coding the teachers and students in educational settings. For example, if the teacher, after whole class instruction, starts writing something on the blackboard, with his back to the classroom, the joystick movement goes down on Agency, because the teacher cannot see what is happening in the classroom. As a rule for coding students behavior was that if students engage in what the teacher asks them to do this is by definition coded as low on Agency.

After ten hours of training and discussing the observations, the quality of the observations was tested. In order to do so we calculated the Pearson correlation coefficient as a measure for inter-rater reliability for the coded Agency and Communion in all fragments of Teacher A:  $r = .68$  for Agency and  $r = .73$  for Communion.

#### 5.4. Procedure

To observe teacher and student behavior, one lesson was videotaped with two cameras. One camera was positioned in front of the classroom, the other in the back of the classroom. Consent for videotaping 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. If schools did not have such a policy teachers were provided with consent letters that parents could return if they objected to their child being filmed. Of the teachers selected for this study none of the parents objected to their child being videotaped for this study.

Another researcher selected three fragments of the recorded lesson were selected for coding: the lesson start, a situation where the teacher was dissatisfied about student behavior (e.g., the student did not listen to the teacher and the teacher sent the student out of the classroom) and a situation where the teacher seems to feel satisfied (e.g., laughing or joking). To illustrate these situations we provided four one-minute fragments of these situations on the accompanying website.<sup>2</sup>

Supplementary videos related to this article can be found online at <http://dx.doi.org/10.1016/j.tate.2013.07.016>.

#### 5.5. Analyses

After coding the real-time behavior as a blend of Agency and Communion the joymon program provides the location coordinates for both dimensions separately. Thus, by using the joystick device to observe teacher and student behavior following an online-observation procedure individual time-series of behavior were generated for the teacher and the students. By aggregating the combined time-series in various ways it was possible to analyze the interpersonal content, interpersonal structure and interpersonal complementarity as characteristics of real-time interactions.

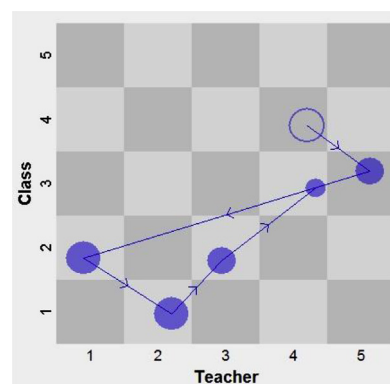
##### 5.5.1. Interpersonal content and interpersonal structure

To study interpersonal content in terms of attractors and interpersonal structure in terms of variability in the teacher–student interactions we used State Space Grid (SSG) analysis (Hollenstein, 2013; Lewis, Lamey, & Douglas, 1999). In order to do this, teacher and student behavior coordinates were recoded into 5 categories per dimension: (1) *very low* =  $-1000$  to  $-600$ , (2)

*low* =  $-599$  to  $-200$ , (3) *neutral* =  $-200$  to  $200$ , (4) *high* =  $200$  to  $599$ , and (5) *very high* =  $600$  to  $1000$ . On the Agency dimension the “very low” category indicates very passive, submissive or following behavior, and the “very high” category indicates very strict, dominant or leading behavior. On the Communion dimension the “very low” category indicates very hostile, irritated and angry behavior, and the “very high” category indicates very friendly, understanding and praising behavior. These combinations of teacher and student behaviors were plotted against each other in a SSG to create a visual representation of their interactional behavior (Fig. 4). The X-axis represents teacher behavior and the Y-axis represents student behavior. The cells in the grid represent states, combinations of teacher and student behavior in interaction. For example the cell 33 means both teacher and students show neutral behavior. The duration of the interaction state is represented by the size of the dot in the corresponding cell. The larger the dot the more time the teacher–student interaction resided in this specific state. The example in Fig. 4 represents teacher and student Communion. The interaction trajectory starts in cell 44, this means high student and teacher Communion, the teacher and students are friendly towards one another. The interaction then moves to cell 35, that means neutral student Communion and very high teacher Communion. Then the situation escalates and the trajectory then moves to cell 21, which means low student Communion and very low teacher Communion. Thus, both teacher and the students show unfriendly behavior in interaction with each other. The next step is cell 12, which represents very low student Communion and low teacher Communion. After some time the situation becomes more positive and gradually both the teacher and the students become friendlier. Thus the interaction moves to cell 23, which means low student Communion and neutral teacher Communion and to cell 34, which represents neutral student Communion and high teacher Communion.

**5.5.1.1. Content.** When the teacher–student interaction shows specific combinations of teacher and student behavior often and if the duration of such combinations is long, this is an indication that this is an attractor for this teacher–student interaction.

**5.5.1.2. Structure.** To indicate the variability or structure of the interaction *dispersion* and *entropy* were used. Dispersion is a whole-grid measure indicating the number of visited cells, controlling for proportional duration in each visited cell (Hollenstein, 2013).



**Fig. 4.** Example State Space Grid. *Note.* This is a hypothetical example of teacher and student Communion, and is solely designed to illustrate what a State Space Grid looks like. The X-axis represents teacher behavior and the Y-axis represents student behavior. The opaque dot represents the start of the interaction trajectory. In this example we also included the trajectory lines and arrows to show the direction of the trajectory. A video representation of how the interaction trajectory moves through the SSG is provided.

<sup>2</sup> The video-clips provided on the accompanying website show simulations of the original scenes. Simulations were used and not the original scenes, to ensure the teachers' and students' privacy. The simulations are as close to the original scenes as possible, with the exception that the teacher and students on the original recordings spoke Dutch and the teacher and students on the simulations speak English. The original video recordings were coded to explore the characteristics of real-time interactions.

Dispersion is expressed in a value between 0 (no variability) and 1 (maximum variability). Entropy is whole-grid measure that represents the number of transitions between cells. Low entropy indicates a highly organized pattern in interactions, this means that the interaction consists of a combination of a small number of transitions between cells in the grid. High entropy means that the interaction consists of a combination of a large number of transitions between the cells in the grid, indicating that the pattern of interaction is relatively unpredictable (Dishion et al., 2004; Hollenstein, 2013). Entropy is computed by the logged conditional probabilities of behavior transitions (Dishion et al., 2004).

### 5.5.2. Interpersonal complementarity

To quantify the degree of interpersonal complementarity in real-time variation in teacher–student interactions we used detrended cross-correlations that quantitatively capture what can be seen in the visual representation of the time-series (Sadler et al., 2011) by removing the linear trend from the raw time-series data with regression analysis and correlating these detrended time-series with each other. Detrending is necessary because a regular cross-correlation procedure fails to distinguish shared trends between interaction partners over time. For example, if the degree of Communion increases over time, this trend produces a larger positive correlation (and thus higher complementarity) compared to a situation where there is no such trend.

## 6. Results

### 6.1. Interpersonal content and interpersonal structure

In order to obtain information about the interpersonal content and structure the interaction trajectories of the three fragments were combined and visualized together in State Space Grids separately for the two dimensions. The teacher–student interactions trajectory of Teacher A is presented in blue and in yellow for Teacher B (Figs. 5 and 6).

#### 6.1.1. Content

In Fig. 5 the two grids representing the interpersonal content of the interactions are presented. The X-axis shows real-time teacher behavior and the Y-axis shows real-time student behavior. The cells in the grid represent different types of real-time teacher–student

interactions. The interpersonal content of the teacher–student interactions is visualized with the dots, the larger the dot the longer the interaction with the corresponding teacher and student behavior lasted.

In the grid for the Communion dimension (Fig. 5) it can be seen that the teacher–student interactions of Teacher A mainly took place within the areas representing high Communion with some occasional deviations from these areas to areas where the interaction consists of a combination of very low Communion behavior for both the teacher and students. The teacher–student interactions of Teacher B mainly took place in the areas combining Neutral to Very high Communion in teacher behavior and Low to High Communion in student behavior. Thus, on average the interactions of Teacher B seemed to show slightly more Communion than the interactions of Teacher A.

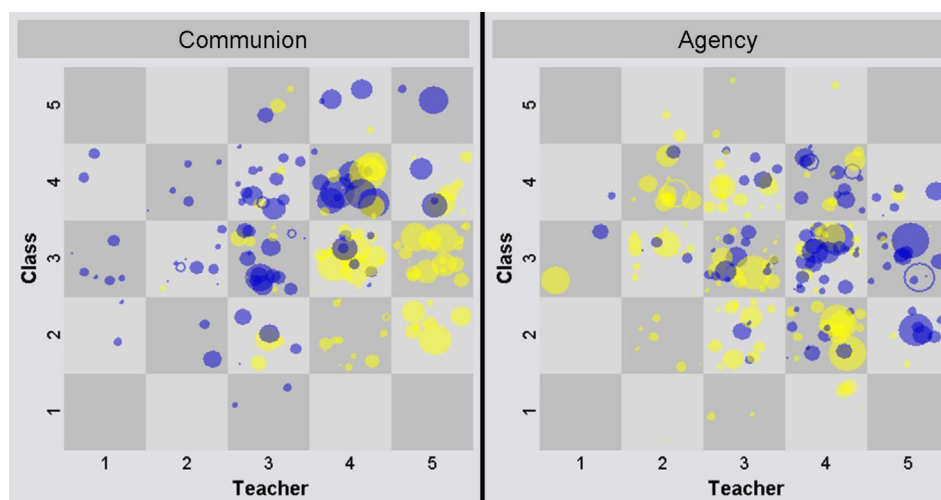
By looking at the grid for the Agency dimension it can be seen that the teacher–student interactions of Teacher A mainly took place within the areas combining Neutral to Very high Agency in teacher behavior with Low to High Agency in student behavior. The teacher–student interactions of Teacher B mainly took place in the areas combining Low to High teacher and student Agency behavior. Also, a rather long interaction took place in the area with very low teacher and neutral student Agency behavior. Thus, the interactions of Teacher A seemed to show more Agency than the interactions of Teacher B.

These results show that there were differences in interpersonal content of real-time teacher–student interactions between the teachers in these three situations. Thus, by measuring interpersonal content it was possible to discriminate between two teachers who were perceived by their students as having a relationship with students with distinct degrees of Agency and Communion.

#### 6.1.2. Structure

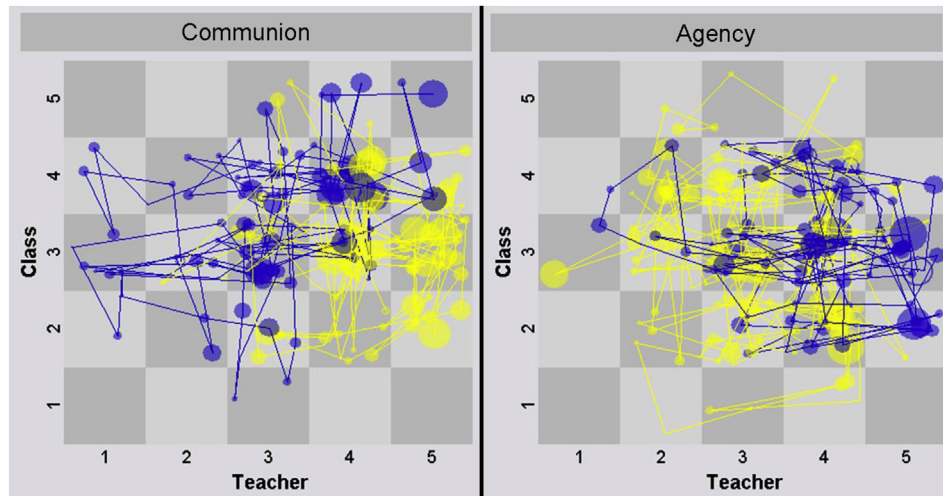
In Fig. 6 the two grids representing the variability of the interactions are presented. Again, the X-axis shows real-time teacher behavior and the Y-axis shows real-time student behavior. The cells in the grid represent different types of real-time teacher–student interactions. The lines in the grids are the transitions between interaction states and represent the variability of the teacher–student interaction trajectory.

Two grid measures were calculated to express the variability of the teacher–student interactions: Dispersion and Entropy. These



Note. Blue = Teacher A; Yellow = Teacher B.

Fig. 5. State Space Grids representing the interpersonal content of teacher–student interactions.



**Fig. 6.** State Space Grid representing the interpersonal structure of teacher–student interactions. Note. Blue = Teacher A; Yellow = Teacher B. A video representation of how interpersonal structure moves in the SSG is provided.

measures were calculated overall, for Agency, Communion, and for the three fragments separately.

**6.1.2.1. Dispersion.** As explained in the [Method](#) section dispersion was expressed in a value between 0 (no variability) and 1 (maximum variability) ([Hollenstein, 2007](#)). Total dispersion was .82 for Teacher A and .81 for Teacher B, this means that the teacher–student interactions of both teachers in general showed a rather large amount of variability. Dispersion for Teacher A's Agency was .84 and .80 for Communion. Dispersion for Teacher B's Agency was .83 and .79 for Communion, indicating that also the dispersion per dimension was rather high for both teachers.

In [Table 1](#) it can be seen that the dispersion for Teacher A was lower for Communion in the positive situation. Thus, the teacher–student interactions of Teacher A showed less variation in the positive situation than in the lesson start and the negative situation. For Teacher B it can be seen that the teacher–student interactions were less variable for Communion in the negative and the positive fragment than in the lesson start. Overall variability for both teachers was high and the lesson start was the most variable and the positive situation the least variable. For Communion variability in the negative situation was higher for Teacher A than for Teacher B. This indicates that measuring interpersonal structure in terms of dispersion only discriminates between these two teachers with respect to Communion, mainly in the negative situation.

**6.1.2.2. Entropy.** Entropy is a grid measure that indicates how predictable interactions are based on the transitions between the visited cells ([Dishion et al., 2004](#)). Total entropy for Teacher A is 2.00 and for Teacher B entropy is 1.99. For Teacher A entropy per dimension resulted in 1.95 for Agency and 2.06 for Communion and for Teacher B entropy per dimension was 2.13 for Agency and

1.84 for Communion. Thus, for Teacher A Agency behavior was more stable than Communion and for Teacher B Communion behavior was more stable than Agency. When comparing these entropy values to the values found by [Dishion et al.](#) (i.e., values ranging from 2.2 to 3.7), these values indicate that differences in the interpersonal structure of the interactions of the teachers in this study were relatively small. Differences between teachers can also be regarded as small, because differences within teachers (between situations of one teacher) are larger than differences between teachers.

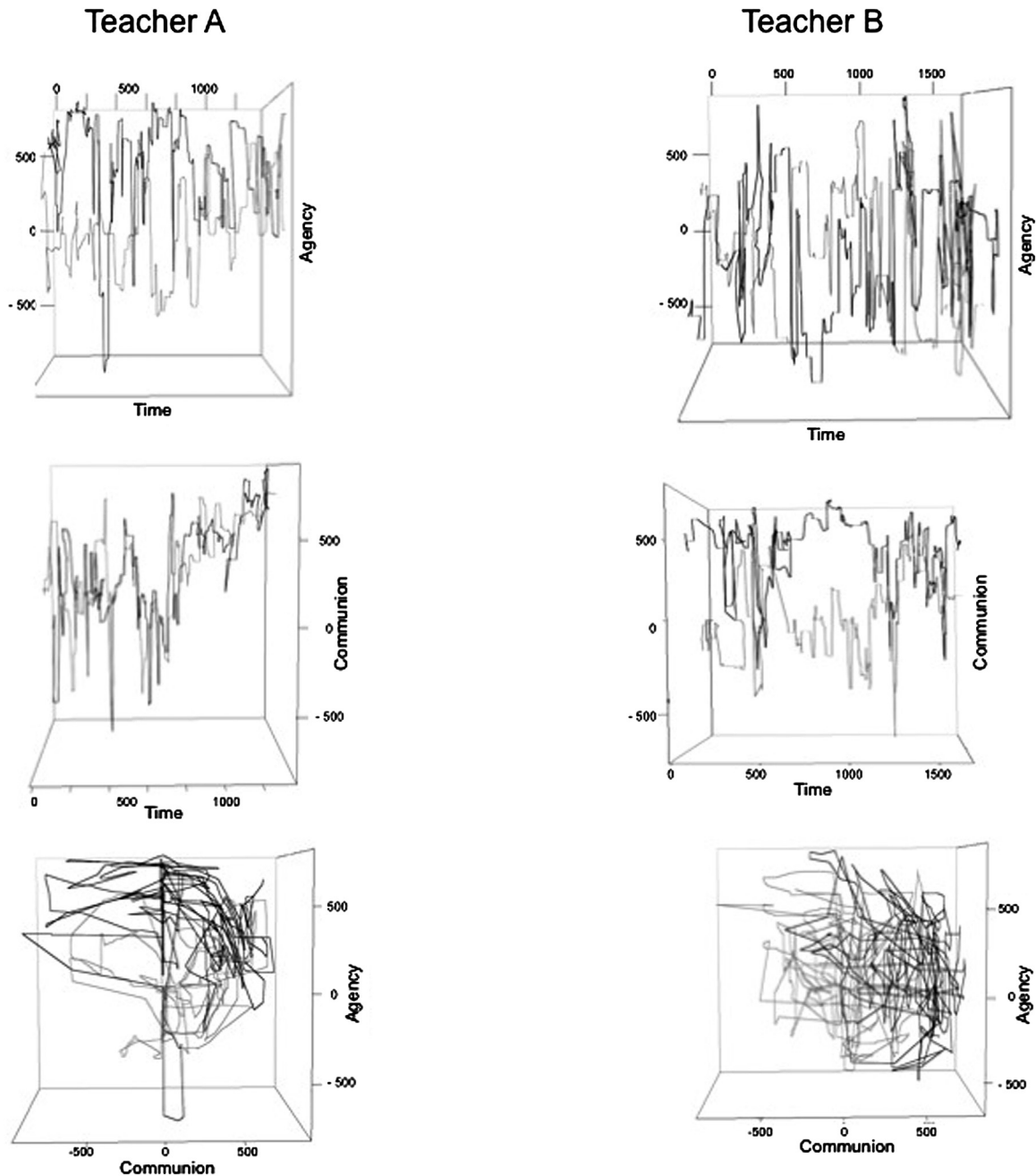
The entropy values per situation are also presented in [Table 1](#). It can be seen from these values that the positive situation showed the most predictable patterns of interactions for Teacher A: Communion was = 1.56 and Agency 1.59. Yet, for Teacher B the negative situation showed more predictable patterns: Communion was 1.33 for Teacher B. However, entropy of Agency of Teacher B in the negative situation was rather high, 2.12, thus, in the negative situation Agency in the interactions of Teacher B was less predictable, at least compared to the lesson start and Communion in the negative situation.

From the results of the dispersion measure we can conclude that variability is rather high in the teacher–student interactions of both teachers. Yet, from the results of the Entropy measure we can conclude that in comparison to the results of [Dishion et al. \(2004\)](#) variability is small. This indicates that, although the teacher–student interaction trajectories move to a large amount of cells, these are still rather predictable compared to interactions found in family or peer-relations studies (e.g., peer- or mother–child interactions). Interpersonal structure discriminates between the two teachers for Communion in the negative situation in terms of dispersion. The measure of entropy discriminates in the positive situation and to some extent in the negative situation.

**Table 1**  
Grid measures for the variability of teacher–student interactions per situation.

	Teacher A						Teacher B					
	Communion			Agency			Communion			Agency		
	S	N	P	S	N	P	S	N	P	S	N	P
Dispersion	.84	.83	.72	.84	.86	.80	.88	.74	.75	.81	.87	.80
Entropy	2.19	2.42	1.56	2.05	2.09	1.59	2.06	1.33	2.11	1.82	2.12	2.47

Note. S = lesson start, N = negative situation, P = positive situation.



**Fig. 7a.** Time-series of real-time teacher and student behavior (Teacher A). *Note.* Black = teacher behavior; Grey = student behavior. A video representation is provided to show how the time-series move in 3D.

**Fig. 7b.** Time-series of real-time teacher and student behavior (Teacher B). *Note.* Black = teacher behavior; Grey = student behavior. A video representation is provided to show how the time-series move in 3D.

## 6.2. Interpersonal complementarity

In Fig. 7 the time-series data are visualized.<sup>3</sup> We combined the interactions in the three situations to one time-series (start, negative fragment, positive fragment). The time-series for Teacher A are presented left and for Teacher B the time-series are presented on the right. The dark grey line shows teacher behavior and the

light grey line shows student behavior. In these visualizations of the interactions between the teacher and the students fit together in time.

The upper part of Fig. 7 shows the time-series of Agency as it occurs in time. It can be seen that the time-series that Teacher A has a higher level of Agency than her students and Teacher B's level of Agency is similar to his students' level of Agency. The level of Agency of Teacher A shows reciprocity with her students (i.e., where her level of Agency goes up, students' level of Agency goes down). For Teacher B the level of reciprocity with his students; level of Agency is less clear. In the middle part of Fig. 7 the time-series for Communion are presented. It can be seen that Teacher B shows a higher level of Communion in his behavior than Teacher A. The

<sup>3</sup> See the accompanying website for a 3D animation of the time-series. Also, visit Pamela Sadler's website for a more elaborate 3D demonstration of moment-to-moment complementarity in interactions ([http://www.wlu.ca/page.php?grp\\_id=277&f\\_id=1&p=23438](http://www.wlu.ca/page.php?grp_id=277&f_id=1&p=23438)).



time-series for Teacher A's level of Communion show some correspondence with her students' level of Communion especially in the middle part (i.e., negative fragment), the teacher and student time-series are also almost at the same level of Communion. For Teacher B especially in the middle part (i.e., negative fragment) the level of Communion is different. Yet, when Teacher B's level of Communion increases, his students' level of Communion also seems to increase. In the lowest part of Fig. 7 the combination of both Agency and Communion is presented, this is essentially a visualization of how the joystick was moved through the IPC.

Following the theory on interpersonal complementarity, we expected negative detrended correlations (reciprocity) for Agency and positive correlations for Communion (correspondence). Ten out of twelve correlations showed the expected sign (see Table 2).

The data for the positive situation in the class of Teacher A showed a negative correlation for Communion instead of the expected positive correlation. The data for the negative situation in the class of Teacher B showed a positive correlation for Agency instead of the expected negative correlation. None of the correlations showed perfect complementarity ( $-1.00$  for Agency and  $1.00$  for Communion). Regarding differences in interpersonal complementarity we conclude that Teacher A (with a relationship with more Agency than Teacher B) showed less reciprocity in his real-time interactions with students during lesson start and in the negative situation, but higher reciprocity in the positive situation. But reciprocity of Teacher B was higher in the lesson start than for Teacher A. Teacher B (with a relationship with higher Communion than Teacher A) showed more correspondence in his real-time interactions than Teacher A in all three situations.

## 7. Discussion

The present study explored the discriminant validity of interpersonal content, interpersonal structure and interpersonal complementarity in real-time teacher–student interactions for teachers with different relationships with students. In order to do this, we compared these characteristics in real-time interactions of two teachers with a distinct teacher–student relationship in their classrooms.

### 7.1. Interpersonal content

The results of this study showed some differences in interpersonal content of real-time teacher–student interactions between the teachers. On average the interactions of Teacher A showed more Agency than the interactions of Teacher B whereas the interactions of Teacher B showed more Communion than the interactions of Teacher A. Thus, measuring interpersonal content in only a couple of minutes allowed us to discriminate between two teachers in a way that is consistent with student perceptions of the (general) relationship with these teachers. This is promising for research aiming to connect the level of relationships with the level of real-

time interactions. For practice this is useful in helping teachers to understand their general relationship with students based on characteristics of their daily interactions with their students.

### 7.2. Interpersonal structure

Results on interpersonal structure of real-time teacher–student interactions showed that in general the differences between teachers are relatively small: differences between situations are larger than differences between teachers. This may imply that variability differentiates more between situations than between teachers. This would mean that it is important to take the situation into account when comparing variability in teacher–student interactions of different teachers.

### 7.3. Interpersonal complementarity

Regarding differences in interpersonal complementarity we found that the teacher–student interactions were complementary in most situations. Teacher B, with the higher Communion relationship, showed consistent correspondence in the real-time interactions with students in all three situations. For Teacher A results showed no correspondence in the positive situation. Teacher A, with the higher Agency relationship, showed consistent reciprocity in the real-time interactions with students in all three situations. For Teacher B results showed no reciprocity in the negative situation. These results indicate a connection between the level of Agency or Communion in teacher–student relationships and complementarity in the corresponding dimension in real-time interactions.

### 7.4. Limitations and suggestions for future research

We are aware that our study has some limitations that should be taken into account in future studies. First, this was only an exploratory study that compared two teachers with distinct teacher–student relationships. Yet, within the population of teachers there is a lot of variation in teacher–student relationships (Wubbels et al., 2006). These relationships vary in terms of Agency and Communion. To fully understand the discriminant validity of interpersonal content, structure and complementarity, we should compare these characteristics in interactions of teachers with other types of teacher–student relationships than in the present study.

Second, we analyzed teacher and student behavior separately for Agency and Communion. However, according to interpersonal theory, the relation of both dimensions can best be represented within a circular plane: the IPC (Gurtman, 2011). Gurtman (2011) described a vector-based method that takes into account the circular nature of the interpersonal construct. Circular statistics (Berens, 2009) is a promising technique to analyze data with a circular nature. In the future, using circular statistics will enable us to take behavior as a blend of Agency and Communion into account.

**Table 2**

Detrended cross-correlations as an indicator for the degree of complementarity.

		Students					
		Lesson start		Negative situation		Positive situation	
		Agency	Communion	Agency	Communion	Agency	Communion
Teacher A	Agency	<b>−.36**</b>		<b>−.15**</b>		<b>−.52**</b>	
	Communion		<b>.05</b>		<b>.21**</b>		<b>−.36**</b>
Teacher B	Agency	<b>−.70**</b>		<b>.40**</b>		<b>−.26**</b>	
	Communion		<b>.29**</b>		<b>.49**</b>		<b>.46**</b>

Note. \*  $p < .05$ , \*\*  $p < .001$ . The correlations showing the expected sign for complementarity are bold faced.

### 7.5. Practical implications

The ultimate goal of our study is to increase understanding of how teacher–student relationships (macro-level) develop from real-time interactional processes (micro-level). We hope that such an understanding will help teacher educators create awareness among their student–teachers of, for example, the effect of teacher behavior on the interactions with students and how these interactions will affect the teacher–student relationship and the classroom climate.

Teachers experience difficulties in changing routines or patterns in their behavior (Eraut, 2004). Van Eekelen, Vermunt, & Boshuizen (2006), however, contend that teachers are highly motivated to learn or change when they see the effect of their behavior on students. Video coaching and video guided training have been used in teacher professional development programs effectively to create a better understanding of the role of teacher behavior in teacher–student interactions (Brouwer, 2011; Fukkink, Trienekens, & Kramer, 2011; Tripp & Rich, 2012). Actively analyzing the role of teacher behavior in interactions and for instance zooming in on situations where knowledge of the complementarity principle could help teachers (re)gaining control of a situation, will encourage them to stay focused, view their practice from another perspective, and implement change (Tripp & Rich, 2012).

### 8. Conclusion

The current study was an exploratory study on the discriminant validity of three characteristics of real-time teacher–student interactions. The results of this study suggest that interpersonal content, interpersonal structure, and interpersonal complementarity indeed discriminate between teachers with distinct teacher–student relationships. This study was a first step in studying teacher–student interactions as a micro-level process. The next step is to increase the number of teachers to study the discriminant validity of these three characteristics. Research on teacher–student relationships mainly focused on teacher behavior and less on the effect of this behavior on students. Studying interpersonal content, structure and complementarity in real-time interactions helps to increase knowledge about the effect of teacher behavior on student behavior. This provides clues to intervene and change behavior in the classroom to improve relationships and the classroom climate.

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