Peer Interaction and Scientific Reasoning Processes in Preschoolers
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Summary

1. Research Motivation and Context

As ‘little scientists’, children have spontaneous curious minds. They conduct small experiments, ask numerous questions and try to understand the world around them. Moreover, children are social learners. From the preschool age onwards, they are very good at playing and interacting with others – adults and peers –, creating games and exploring objects with incredible joy (see Gopnik, 2012). During their explorations, children are able to discover regularities even before they are exposed to formal knowledge about it.

The present dissertation explores how scientific reasoning and dyadic interaction of 5-year-olds emerge and change in a sequence of problem-solving tasks. The empirical studies are based on the children’s behaviors that occur in real-time, and are focused on analyzing the history of changes in the trajectories of their behaviors in the short- and long-term time scale. Inspired by the complex dynamic systems approach (van Geert, 2008), we were interested in understanding the real-time performances of reasoning and interaction. From this theoretical framework, the study the psychological phenomena are understood as abilities that are soft-assembled in a particular context (see Kloos & van Orden, 2009; Overton, 2014; van der Steen, Steenbeek & van Geert, 2012). Therefore, the interest is not only in describing the qualitative changes in behavior that occur over time, but on how changes take place (see Spencer, Perone & Buss, 2011). In each of the studies of this dissertation, we aim to understand how reasoning and interaction behavior emerge and change and how they are related to each other.

Consequently, the design consisted of six waves of data collection (repeated measures with the same children), spread over one school year. Over the six sessions, a set of practical scientific tasks with increasing difficulty was presented to the children (n = 14). The age of the participants was selected because it corresponds to a transitional period in the development of reasoning skills. Around the age of 5 years, children’s understanding becomes more complex because they change their focus from describing a single characteristic of the objects (i.e. ‘single representations’) to establishing relations between several attributes (i.e. ‘representational mapping’) (see Fischer, 1980, 2008).
The methodological approach of the studies presented in this dissertation is based on the *idiographic method* (Molenaar & Valsiner, 2005), which is centered on intra-individual variability. Across the studies, we applied a variety of techniques to capture the richness of these data. The empirical data are based on time series of coded behaviors of children working on problem-solving tasks (for instance, a marble had to reach a certain objective, a scale that had be balanced by using a certain number of weights, or a syringe had to make a platform go up). The time-series were explored with different techniques, such as Hierarchical Agglomerative Cluster analysis (HAC, Hastie, Tibshirani & Friedman, 2009), transition matrices (Ivanouw, 2007), State Space Grids (SSG, Hollenstein, 2013), Hamming distances (see Lichtwarck-Aschoff, Kunnen, & van Geert, 2009) and Cross Recurrence Quantification Analysis (CRQA, Marwan & Webber Jr., 2015). What these techniques have in common is that they reveal the characteristics and patterns of variability by tracing the temporal changes in the time-series of the observed behaviors.

2. Main Findings

In the first two studies (chapters 2 and 3), we analyzed the relation between interaction and scientific reasoning. In Chapter 2, we presented a case study of two dyads working in a single session of a balance-scale task. In contrast to the traditional approaches that provide an overall picture of the frequencies of the behavior, in this study, we carried out a micro-developmental analysis of the changes that take place from moment-to-moment. Here, the focus was on identifying the co-occurrence of five types of interactions (i.e. no work, passive, copy, parallel and collaborative work) with the use of the three types of scientific reasoning skills (i.e. descriptions, predictions and explanations) in children's verbalizations. The results show clear individual differences in scientific reasoning (e.g. the dyad were different in the way the children contributed to the solution of the task). In addition, use of scientific reasoning skills did not remain stable, but fluctuated over time. The cluster analysis showed that the dyads were different in the way the reasoning skills and interaction behaviors co-occurred over time. With regard to the interaction behaviors, parallel and passive work were the most frequent interactions displayed by the children, whereas collaborative work was barely present.

In Chapter 3, we used the individual categories of interaction behaviors to form a dyadic model of interaction that categorizes the dyadic interactions into two dimensions: Distributed Dyadic Interaction, DDI (dyadic interactions in which the work was divided, such as collaborative-collaborative and dominant-dominant) and Unequal Dyadic Interaction, UDI (dyadic interactions in which the distribution was
uneven, such as dominant-mimic or dominant-passive). These two dimensions specify the level of engagement of the dyad with the task and each other. The results based on a series of tasks on air pressure, show that the use of the most complex reasoning skills (i.e. explanations and predictions) were present during two main patterns of dyadic interaction (as in Chapter 2): parallel-parallel work (DDI) and parallel-passive work (UDI). These two patterns seemed to be rather stable across all sessions, even with the increasing difficulty of the tasks. As in the previous study (Chapter 2), we found that collaboration was barely present throughout the sessions. Whereas earlier studies suggest that collaboration is an ideal learning scenario, the current findings show that collaboration is not a central characteristic of spontaneous dyadic interaction as a way to solve problems at this age (Bahrami, Olsen, Latham, Roepstorff, Rees, & Frith, 2010; Koriat, 2012). Therefore, the findings indicate the presence of a spontaneous ‘independent’ style of problems solving and a limited interest in sharing views and building knowledge collaboratively (see also Mercer, 2004).

Chapter 4 examines the dyadic interaction from a different angle. Here, the two main dyadic dimensions of DDI and UDI – as described in Chapter 3 – were used to characterize the interpersonal coordination of the dyads in a series of problem solving tasks (in this case about air pressure and inclined plane task sets). By considering the dyad as a system evolving over time, we aimed to characterize the underlying dynamics of their interaction in terms of two attractor states (DDI and UDI) (see Hollenstein, 2013). The temporal analysis (Cross Recurrence Quantification Analysis, CRQA) showed the predominance of the coupling on DDI over UDI across the sessions, indicating that most of the time both children actively contribute to the solution of the task. However, the dynamics of the two attractors were similar in the sense that in both cases, the dyadic coupling became more flexible and complex over time. In addition, children's performance levels indicate a moderate to strongly correlation with the overall recurrence of DDI and UDI. This mean that children present the same type of interaction (DDI or UDI) at the same point in time or any other point in time, which can be seen as having the same global interaction 'style' across the session.

In Chapter 5, different aspects of the children's reasoning were brought together to examine the long-term development of reasoning in a sequence of problem-solving tasks (again on air pressure and inclined plane) in the context of spontaneous experimentation. Considering the increasing difficulty of the tasks, we examined the changes in the complexity of the optimal performance of the children's actions (implicit knowledge) and verbalizations (explicit knowledge), and also the transfer of scientific reasoning between tasks. For this analysis, we used a coding system based on Skill Theory (Fischer, 1980, 2008). In the first part of our examination, we found
that on average, the dyads displayed a better understanding of the tasks in their nonverbal attempts to solve them than when they were explaining how the tasks works. In actions, children were able to make partial and total relations with the tasks elements, while in verbalizations they were mainly focused on naming the attributes of the materials and establishing some basic relations between the task's elements. The difference was present across all six sessions. In addition, looking at the individual trajectories of reasoning, we found clear differences in the individual performance over time. This indicates that the findings of the group analyses cannot be generalized to the individuals and vice versa. The second part of our examination was about the trajectories of transfer in which we analyzed the changes in the elements used by the children to solve the sequence of tasks. On average, the children's performance seems to show a gain of knowledge in subsequent tasks. However, the intra-individual trajectories of transfer turned out to be more variable. There is no global increase or decrease of transfer (from one task to the next one) across time, but there are constant fluctuations.

3. Limitations and Implications

One limitation of the studies is related to the educational setting. In our studies, we have observed the behavior of the dyads working only in the presence of the researcher. We are aware that this context of interaction may not be fully representative of the natural conditions in a regular classroom, in which a teacher and a group of children are constantly interacting. In addition, the protocol used in these studies is not the same as the scaffolding process of the teacher with his/her students. Although the situations created for these studies may be less complex, we are convinced that the processes we have described in our studies can also be found in naturalistic conditions (e.g. a teacher working on a science lesson). However, we agree that when studying similar processes in a larger teaching group, more variations will probably be found, because changes in the interacting elements of the system can lead to different emerging behaviors (Alibali & Sidney, 2015).

In summary, the findings of this dissertation indicate scientific reasoning and interaction behaviors of preschoolers are characterized by moment-to-moment variability and the process of dyadic coordination. This supports the non-linear nature of developmental processes (Valsiner, 2006; van Dijk & van Geert, 2015). We hope that our findings are helpful for the design of learning contexts and assessments that involve different ways in which the children can achieve particular levels of knowledge. For instance, one implication of our findings is a call to teachers to be aware that knowledge is not only present in children's verbalizations - as it is
commonly assessed, but also in their actions (Goldin-Meadow, 2014), and that parallel (as collaborative) work is a valid and way of learning. Another important implication is that reasoning is highly context dependent and shows much temporal variability. Recognizing these aspects of peer interaction and reasoning can lead to more adaptive support in the classroom to foster the learning opportunities of the children, individually and in the interaction with others.