Microdynamics of Interaction: Capturing and Modeling Infants' Social Learning

***Abstract*—Social learning takes place within an interactional loop. The contributions of this Special Issue exemplify approaches capturing the microdynamics of interaction to provide us with insights into the adaptation and learning processes.**

***Index Terms*—Adaptation, interaction loop, microbehavioral research, microdynamics of interaction, social learning.**

I. The Scope of this Special Issue

RESEARCH in distributed cognition shows that social learning is not a process happening solely in the individual, but is distributed "over a system of people and objects within an environment" (see [1], p. 97; see also [2] and [3]). In this system, the information that is available for a novice learner is selected and shaped by their social partner [4]. This is true of the relationship between student and teacher, robot and user, or infant and parent. For example, when infants learn in a social environment, they do not simply pick up information passively. They response to, and learn from, the interaction as they jointly determine its content and quality through real-time contingent and reciprocal coaction [5]–[7]. Such learning-through-coaction continues well beyond infancy, however: Teachers in formal educational settings, for example, may attempt to instruct students using examples, gestures, and symbolic artifacts, and (ideally) modifying these actions based on students' behaviors (e.g., accuracy, facial expressions, etc.) [8], [9].

The term *social interaction loop* defines the action sequences during interactions between interlocutors. In asymmetric interactions, the loop takes place between an expert and novice. It is these asymmetric interaction loops that are the focus of the papers in this special issue. However, there are challenges to characterizing particular functions of social interaction loops across different contexts (such as learning or adaptation for a successful communication).

Some of these challenges are theoretical: for example, what common variables can be used to operationalize the loops? Some candidates might include consistency, synchrony, reciprocity, and similarity. Other candidates are outcome variables such as learning rate, replication or modification of novel actions (e.g., imitation), and transfer/generalization of behaviors. Another theoretical challenge is to find common explanatory frameworks: for example, Bayesian or Reinforcement Learning models of social adaptation and other supervised and unsupervised approaches, can be posited as possible theoretical models. Notable, many such approaches, as implemented in the machine learning literature have the limitation of focusing either on the learner's processing or teacher's strategies. However, approaches need to take the loop, i.e., both side into account when modeling learning during evolving interaction.

Other challenges are methodological. Most analyses of behavior or learning make clear assumptions about what are the dependent measures (outcomes) in a given situation, and what are the independent variables. However, in reciprocal social systems, we cannot so clearly assign causal priority. It is often difficult to single out the contribution of each participant. For example, how is the information available for a new learner selected and shaped by a parent or teacher? How do learners display their knowledge or ability, and how do tutors pick up on this information and adapt to it? One challenge of micro-behavioral research, then, is to capture large enough naturalistic behavioral datasets from dyads to extract the statistical structure of social interactions. The more complex and varied the behaviors are in a given context (thus the more naturalistic the study), the larger a dataset must be to extract patterns. Compiling such large data sets can be extremely laborious. For this reason, new approaches might use automated data collection instruments (e.g., motion capture), sophisticated coding tools, and other techniques to accelerate or enhance human coding.

A final challenge is to select the appropriate quantitative approaches to analyze interaction data so as to capture patterns from the dynamics of brief time scales to the qualitative shifts of longer (i.e., developmental time-scales). The difficulty is to find analytic tools that make the proper assumptions about dyadic behavioral interactions, and that also support falsifiable hypothesis-testing based on reliable, nonarbitrary definitions of high-level interaction constructs (e.g., "synchrony"; "responsiveness").

A major focus of this Special Issue is thus to accept the challenges and to precisely quantify and describe what the interaction loops provide; that is, the specific events and mechanisms that support social learning and adaptation on different time scales.

The contributions exemplify diverse approaches that capture microdynamics in interaction. The approaches are inherently challenging because different constructs and measures–for example, "physically based codes" (e.g., raising the eye brow) on the one hand and "socially based codes" (e.g., an expression of surprise) on the other hand (see [10], p. 19)–require different level of observation, and these must be conceptually and quantitatively related to each other. Traditional statistical methods cannot reveal the structure of social interactions that is hidden across time-scales and types and sequences of behaviors; new options involve models imported from machine learning.

II. Individual Contributions

The challenge of segmenting a continuous action stream into meaningful units is accepted in the first paper: "Mothers' Infant-

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Directed Gaze During Object Demonstration Highlights Action Boundaries and Goals." In this paper, **Rebecca Brand, Emily Hollenbeck, and Jonathan Frank Kominsky** apply physically based codes to answer the question of whether the eye gaze behavior of the mother provides cues that help their children segment and learn about the mother's meaningful actions.

A social loop exists also in nonverbal exchanges, as exemplified in the paper by **Catherine Tamis-LeMonda, Yana Kuchirko, and Lisa Tafuro** titled "From Action to Interaction: Infant Object Exploration and Mothers' Contingent Responsiveness." This contribution shows that infants' object exploration can elicit informative verbal input from their mothers. Thus, infants play an active role in their social experiences.

Joanna Rączaszek-Leonardi, Iris Nomikou, and Katharina Rohlfing further illustrate the active role of the infant through microanalytic observations in their paper, "Young Children's Dialogical Actions: The Beginnings of Purposeful Intersubjectivity." They argue that the beginnings of joint intentionality can be traced to the maternal practice of embedding the child's actions into jointly shaped episodes.

The role of such jointly established episodes in fostering communication skills is a process that can be addressed though theoretical models. This is demonstrated in the model simulation provided by **Thomas Cederborg and Pierre-Yves Oudeyer** in the paper titled "From Language to Motor Gavagai: Unified Imitation Learning of Multiple Linguistic and Sensorimotor Skills." This paper tackles the difficult problem of specifying the capacities of an agent that could underlie imitative learning of multiple kinds of actions.

In social interactions, input is ideally provided in a responsive way to the learner. However, there is little consensus about what short of responsiveness is predictive of language development. The study by **Michelle McGillion, Jane Herbert, Julian Pine, Tamar Keren-Portnoy, Marilyn Vihman, and Danielle Matthews** on "Supporting Early Vocabulary Development: What Sort of Responsiveness Matters?" introduces multiple dimension of the construct "responsiveness," and provides results not only about the temporal, but also semantic aspect of this phenomenon in younger children than previously studied.

Further specification of the sorts of multimodal, coordinated behaviors that promote language learning are explored in **Patricia Zukow-Goldring and Nancy Rader's** paper "SEED Model of Early Language Development: The Dynamic-Coupling of Infant-Caregiver Perceiving and Acting Forms a Continuous Loop During Interaction." The authors show that infants from two different cultures learn words more effectively when caregivers produce certain natural, gestural actions in coordination with naming. These findings are couched in a theoretical framework that is drawn from action theory, distributed cognition, and Gibsonian theory.

The final paper by **Kaya de Barbaro, Christine Johnson, Deborah Forster, and Gedeon Deák**, "Methodological Considerations for Investigating the Microdynamics of Social Interaction Development" gives a methodological overview of microlevel approaches and offers practical explanations as well as some best-practice suggestions in "bridging" different levels of observation.

In conclusion, the contributions to this volume will present readers with a wide-ranging, provocative set of phenomena, approaches, and theoretical concepts that explore a range of microdynamic interactions. The interactions explored here focus largely, though not exclusively, on social learning and adaptive coaction by infants in dyadic communication contexts. However, many of the ideas, constructs and phenomena, from microbehavioral ethnographic methods to imitative learning to interaction loops, have broader applications—to other situations, populations, and behaviors. We hope that these papers will therefore provide inspiration and ideas to other researchers who are addressing many diverse questions about social interaction from the perspectives of many disciplines and frameworks.

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