Role of Inter-Personal Synchrony in Extracting Social Signatures: Some Case Studies

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ABSTRACT

Originally studied by developmental psychologists, synchrony has now captured the interest of researchers in such fields as social signal processing (SSP). Developing metrics that can capture dynamics of social interaction is of particular interest, called here Social Signatures (behavioral characteristics). We describe several case studies for extracting robust and distinctive social signatures : early parent-infant interaction, new framework by exploring hormone changes as ground-truth labeling of quality of interaction and a robot learning approach based on neural networks is able to capture distinctive social signatures between clinical groups. Finally, we discuss future perspectives of learning and characterizing social signatures.

Categories and Subject Descriptors

J.4 [**Social And Behavioral Sciences**]: Psychology; I.5.4 [**Pattern Recognition**]: Applications-Signal Processing

General Terms

Modeling, Theory

Keywords

Social Signal Processing; Inter-personal Synchrony; Hormones; Robot Learning

1. INTRODUCTION

Synchrony is the dynamic and reciprocal adaptation of the temporal structure of behaviors between interactive partners. Numerous definitions have been proposed in the literature [1, 4]. Investigating this complex phenomenon has both practical and theoretical applications.

Synchrony has been studied in psychology and especially in developmental science [6, 5] including developmental disorders [18]. As in other areas, Social Signal Processing (SSP) plays a major role in the study of synchrony. Applications are ranging from psycho-therapy sessions analysis [12, 13] to Human-Computer/Robot Interaction [14, 15, 2]. The success of SSP in synchrony is certainly due to the paradigm change: from individuals to dyads or groups. For example in traditional studies of autism, explicitly modeling parent-infant synchrony makes it possible to highlight early signs of the pathology through bi-directional exchanges of social signals between parents and their infant.

The focus of this paper is to report new methodologies recently introduced to study synchrony. We will particularly discuss the notion of Social Signature that is the pattern of interaction between partners. The social signatures can be behavioral characteristics such as gestures, actions, sounds and/or words useful for communicating with the social environment. In a section 2, we describe how synchrony modeling has been relevant for the assessment of autism. Section 3 introduces a new investigation methodology that aims at using physiological signals, here hormones, as ground truth of quality of typical parent-infant interaction. In section 4, we show how the synchrony between a human and robot impacts imitation learning. Finally, we discuss challenges and perspectives of these approaches.

2. INTER-PERSONAL SYNCHRONY FOR THE ASSESSMENT OF AUTISM

Several authors showed in the field of infant development that the quality of interaction in terms of synchrony or reciprocity carries in itself information about the healthy development of the infant beyond the specific signs exhibited by the latter [5, 18, 11]. However, the main limitation comes from methodologies employed to date in psychology based on manual careful examination of movies.

In [16, 3], we proposed an integrative approach that explicitly considers the interaction synchrony of behaviors. The model is applied to the characterization of parent-infant interactions for differential diagnosis: autism spectrum disorder (ASD), intellectual disability (ID) and typical development (TD). We estimate transitions between behaviors of the infant and the parent by analyzing behaviors co-occurring in a 3s window. This process results in several bigram models that characterize the temporal structure of the interaction. To study these interactive patterns from an integrative perspective, we employ a more global model using non-negative matrix factorization (NMF), coupled with statistical representation, namely tf-idf (term frequency-inverse document frequency), to transform the scene annotations

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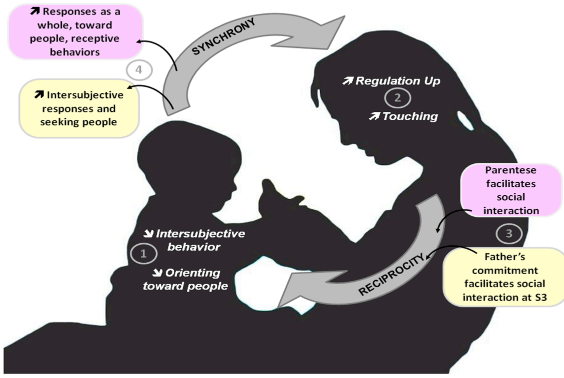

Figure 1: Infants who will later develop autism: pathologic trajectory of infant's behaviours and changes in parents' stimulation to adapt to their infant.

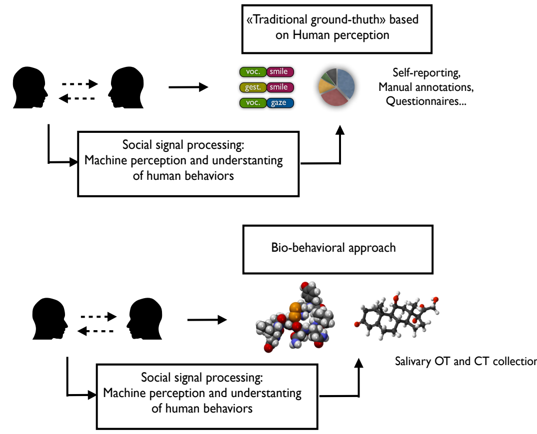

Figure 2: From traditional annotations to hormones changes prediction

(bi-gram) into a representation suitable for the learning algorithm and the clustering task (NMF).

The non-negativity constraints are relevant for the analysis of human behaviors as they allow only additive, not subtractive, combinations. Because of the mathematical properties of NMF, the analysis accommodates an integrative perspective by providing clusters of interactive behaviors. In addition, to understand the development similarity of TD infants compared with ASD and ID infants, we used Normalized Mutual Information (NMI); the NMI between two different clustering solutions measures their agreement. Interestingly, the NMI profiles fitted the clinical hypothesis closely, showing a pervasive development in ASD and a delayed development in ID.

This analysis process can be seen as an automatic summarization of social interaction resulting, here, in the extraction of a developmental signature. This process can be enriched by the extraction of several behaviors including emotional ones such as parentese [8]. Figure 1 is an example of semantic information that can be captured by the model. One has to note that this developmental social signature is directly useful to developmental psychologists.

3. LINKING BEHAVIORS TO HORMONES

These developmental perspectives have recently been strengthened by the discovery of brain correlates of synchronous between two partners [21] and the central role of the hormone oxytocin imitations link: this example builds trust between humans and stimulates the quality of early interactions [7]. In the experimental study of Weisman et al [23] inhalation of oxytocin by fathers improves the quality of interaction with their 5 month old baby and comes in response to an increase in the oxytocin baby. Based on these movies, our group explored automatic extraction of behaviors with the aim to link behavioral dynamics to hormonal dynamics. Obviously these dynamics are different and several computational challenges occur there. The most important one is the paradigm change where physiological signals are not used as features for classification, as done in emotion recognition, rather we map social signals (e.g., motion, turn-taking...) into hormones changes. Hormones that we considered to date are Oxytocin (OT) and Cortisol (CT) that are known to be respectively related to affiliation and stress. Figure 2 describes this new bio-behavioral framework.

In [22], we have shown that what determines the increase oxytocin level of infants during interaction is mainly driven by the speed of movement of the head's father. By applying state-of-the-art SSP techniques, we show a very strong correlation between these two parameters.

4. HUMAN-ROBOT INTERACTION FOR SOCIAL SIGNATURE CHARACTERIZATION

SSP is particularly interested by designing socially intelligent interfaces [19, 20]. Interestingly, social agents, and particularly social robots, give the opportunity of studying social behaviors using controlled stimuli [9, 10, 17]. The key idea there is to employ robots to understand human partners.

In [2], our specific aim was to assess the influence of participants on robot learning. We show that robust and distinctive Social Signatures are captured during experiments with children with ASD, TD children, and healthy adults. These metrics characterized the quality of the imitation based on visual features and reflected how the robot learned to recognize the postures of different participants (i.e., an adult, a TD child or a child with ASD). The naive system can be summarized as follows. Learning was performed without an explicit teaching signal that associated a specific posture with the robot's internal motor state. During the learning phase, the robot produced a random posture, and the participant imitated the robot: the robot associated what it did with what it saw via a sensory- motor architecture based on a neural network (N.N.). After this first phase, the roles were reversed, and the robot imitated the posture of the participant.

Figure 3 shows the evolution of the number of neurons needed to learn with different participants. This number is considered as a social signature that the architecture is continuously learning. The results showed the impact of a participant on both robot recognition and learning. The robot recognized and learned the postures of adults more easily than those of TD children or children with ASD.

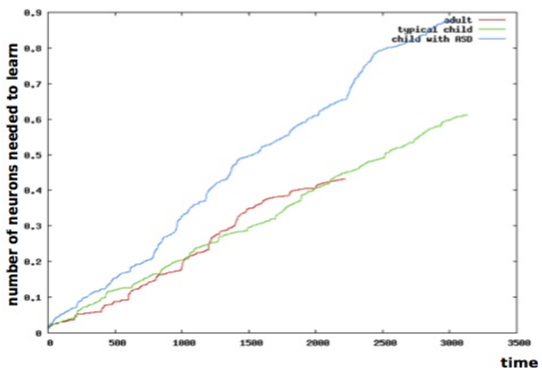

Figure 3: The number of neurons needed to learn with different participants (adults, TD children, and children with ASD) interacting with the robot: 11 adults (corresponding to 2000 images), 15 TD children (corresponding to 3100 images) and 15 children with ASD (corresponding to 3100 images) (from [2])

5. CONCLUSIONS AND PERSPECTIVES

The current paper attempted to show that the assessment of interactional synchrony bears both theoretical and applied questions. Due to large range of questions, multi-disciplinary approaches should be followed.

Through theses different examples: modeling of typical and pathological developmental trajectories, evaluation of quality interaction through hormones and influence of partners during robot learning, we aimed at showing that human communication dynamics can be captured and modeled by SSP techniques. The rationale is that synchrony reveals how we continuously modify our behaviors by taking into account our partners, and consequently reveals social information that we called social signature.

Works that we presented focus on different aspects of social interaction: perception of social signals, new paradigms (e.g. hormone based) and social intelligence for robots. These works contribute to a long-term goal aiming at characterizing social signatures. Indeed, there is still a lot to learn about social interaction itself and how computational methods can accompany theses efforts. Important steps have still to be made regarding many aspects ranging from definition of concepts to the collection and evaluation of them.

To be relevant methodologies and concepts should also be applied to real-life situations outside laboratories. Hospitals and homes are examples of these situations. Even if there are strong societal motivations for that, there are still lot of limitations. These limitations are not only technological. Indeed, there is a need developing projects, structures where people can share data. Challenges organized by SSP and affective computing research communities have allowed several teams to efficiently contribute to research, which is rarely the case in pathology. Another dimension is long-term interaction with related issues: data collection, personalization, big data...

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