

論文の内容の要旨

A Model of Continuous Social Play Co-creation through Exploratory Response Elicitation

(応答の探索的引き出しを通じた連続的やりとり遊び共創モデル)

氏名 栗山 貴嗣

Social plays are an early interaction before speech where an infant and a caregiver engage in simple interaction such as ball game, give and take, and gonna get you, also emergent interactions in each dyad such as a play where an infant chases a newspaper and a father flips it, and so on. This research proposes infant's cognitive model which works out continuous social play co-creation with a caregiver. The infant is always judging whether current interaction works or not through response prediction to balance two policies: continuing a stable interaction or trying a new interaction.

The thesis is organized in eight chapters as follows:

[Chapter 1. Introduction]

Social plays are significant as a foundation of social intelligence because they are manifestation of cognitive ability to understand that own action affects others and to find means of communication. Social plays don't finish at one play, but new ones are continuously co-created. However, existing interaction model research focuses on social plays' convergent feature toward stable interaction, or their divergent feature toward interaction modification at all of the time. It is not solved how these convergent and divergent features go together.

[Chapter 2. Social Plays]

An infant's behavioral stages in social play development are: (d1: observes passively), (d2: initiates and participates partially), (d3: follows the convention), (d4: generates

modification). As a strong feature of social plays, we focus on interaction rules where a caregiver responds in a specific way to an infant's specific action. We interpret the four stages from a perspective of interaction rules, and we propose a phase cycle of interaction rule co-creation: (c1: making response prediction) the infant explores and makes prediction of responses by generating some actions, (c2: confirming response prediction) the infant confirms the response prediction by taking the corresponding action, (c3: quitting the play for next one) the infant marks the interaction rule as stable and quits the confirmation. As a result, continuing the cycle, the dyad is expected to travel among co-created social plays.

[Chapter 3. Interaction Rule Learning through Response Elicitation]

We propose (m0: elicitation of predicted responses) as the fundamental mechanism for interaction rule learning. Monitoring and making prediction of the caregiver's responses, the infant is motivated to generate actions to confirm the predicted responses from the caregiver. The interaction is reciprocated as a result. We conducted interaction experiments between an infant robot based on the proposed model and participants using a ball to investigate whether the infant can learn interaction rule or not. The result shows that the interaction is inclined to be one-directional. A reason is considered that a participant just waits for the infant or behaves one-directionally like requesting some actions from the infant without responding to the infant because s/he cannot understand the infant's actions. The infant's behavior is so consistent that a participant cannot be patient with the infant. Another reason is considered that participants' behavior is simply easy to change. They change the way of response even if they understand current interaction rule works. These are differences from robot-robot interaction.

[Chapter 4. Continuous Co-creation through Response Habituation]

Toward continuous social play co-creation, the infant model was too stable to meet caregivers. We now propose (m0: elicitation of predicted responses) and (m1: response habituation) as the fundamental mechanisms of the infant for the co-creation cycle. Monitoring and making prediction of the caregiver's responses, the infant is motivated to generate actions to confirm the predicted responses from the caregiver. The interaction is reciprocated as a result. After it is habituated to the responses, it inhibits the confirmation and generates other actions. This makes a chance for other rules. Put it simple, the mechanisms are represented as exploratory response elicitation. We conducted interaction

experiments between an infant robot based on the proposed model and participants using a ball to investigate whether response habituation is needed or not to continuously co-create social plays. According to an analytic result of causality from the infant to a participant, the participants with a faster-habituated infant respond in 1.2-1.5 second delay to the infant's actions while the participants with a slower-habituated infant have difficulty in responding to the infant. Various patterns of interaction emerged between a participant and a faster-habituated infant, such as passing the ball back and forth, rolling and catching, feint passing, and role-reversal feint passing. The result shows the two mechanisms are fundamental for social play co-creation. We also propose a method that measures diversity in social plays to evaluate continuous social play co-creation. We define causality in a part of interactional sequence as "local causality" to capture short-term social play. We define causality in whole interactional sequence as "global causality" to determine the referential level of causality. Local causality is high and global causality is low if multiple interaction rules are included because the causality analysis assumes consistent interaction rules through one interactional sequence. So the ratio (local causality / global causality) measures diversity of interaction rules in one sequence. The result shows that diversity of interaction rules from the infant to participants has a peak in a middle response-habituation parameter, indicating proper response-habituation contributes to interaction rule diversity and continuous social play co-creation.

[Chapter 5. Searching for Communicative Actions within Imitation]

The minimal mechanism for generating some actions in (c1: making response prediction) is generating random actions. To accelerate (c1), we propose a mechanism (m2: imitating the caregiver's action) for imitative strategy: selecting actions from the caregiver's actions. This strategy expects that the caregiver's actions are not meaningless but social-play-relevant, and so imitating the actions leads to smooth search for a new social play. In experiment with the infant with the combination of (m0: elicitation of predicted responses) and (m2: imitating the caregiver's action), the infant successfully understands interaction rules and goes into social plays, adaptively combining the strategy of (m0) and (m1).

[Chapter 6. An Integrated Model for Continuous Co-creation]

We finally propose an integrated social play model with (m0) to (m2). This winds the social play co-creation cycle continuously. The result shows diversity of interaction rules from the infant to participants in the integrated model is higher than one in the response-habituation model, indicating that the infant's imitation contributes to finding communicative actions and interaction rule diversity. Diversity of interaction rules from participants to the infant in the integrated model is also higher than one in the response-habituation model, indicating that the finding communicative actions through imitation also increases the infant's chance to respond to the participants. Put it together, imitation contributes to continuous social play co-creation.

[Chapter 7. Discussion]

We simplified and abstracted interaction rules in the proposed cognitive model and the experimental settings to focus on fundamental principles of general social plays. In discussion, we point what we simplified and abstracted-----face-to-face setting, object recognition and localization, involved objects, interaction rule space, action timing and interaction rule chunk-----, discuss what we can/cannot capture, and suggest a vision toward complex and realistic social plays. We also discuss additional supporting elements for social plays: the infant's vocalization and infant-like appearance. We finally discuss the possibility to explain autistic children behavior and to apply to therapy from a viewpoint from developmental changes of exploratory response elicitation, and the roles of response habituation.

[Chapter 8. Conclusion]

As a conclusion, we proposed an infant cognitive model for continuous social play co-creation. The model is composed of the fundamental mechanisms (m0: elicitation of predicted responses) and (m1: response habituation) and the accelerating mechanisms (m2: imitating the caregiver's action). The model winds the social play co-creation cycle (c1: making response prediction), (c2: confirming response prediction), and (c3: quitting the play for next one) continuously. This leads to foundations of understanding of social intelligence that produces diversity, understanding and therapy of autistic children with limited diversity of interaction, and application to social robots that keep us interested.