Designing Hybrid Intelligence Techniques for Facilitating Collaboration Informed by Social Science

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ABSTRACT

Designing (socially) intelligent systems for facilitating collaborations in human-human and human-AI teams will require them to have a basic understanding of principles underlying social decision-making. Partner selection - the ability to identify and select suitable partners for collaborative relationships - is one relevant component of social intelligence and an important ingredient for successful relationship management. In everyday life, decision to engage in joint undertakings are often based on impressions made during social interactions with potential partners. These impressions, and consequently, partner selection are informed by (non)-verbal behavioral cues. Despite its importance, research investigating how these impressions and partner selection decisions unfold in naturalistic settings seem to be lacking. Thus, in this paper, we present a project focused on understanding, predicting and modeling partner selection and understanding its relationship with human impressions in semi- naturalistic settings, such as social interactions, with the aim of informing future designing approaches of (hybrid) intelligence system that can understand, predict and aid in initiating and facilitating (current and future) collaborations.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative and social computing**.

KEYWORDS

Social Signal Processing; Partner Selection; Impression formation; User-modelling; Collaboration

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1 INTRODUCTION

Current efforts in computer science are focused on designing intelligent system that can closely collaborate with and assist humans in social environments [3], such as providing recommendations on e-learning platforms [43] or assisting in therapy [12]. Developing intelligent systems to facilitate collaboration will require them to understand human behavior and make predictions of human (partner) preferences in diverse situations, such as social interactions. The best source of information about human preferences is their behavior and the choices they make [37]. However, this link between human preference and their behavior is not always as straightforward. Thus, first we need to understanding how humans form impressions and choose available partners for collaboration and if and how multi-modal social cues inform these impressions and later on their actions (i.e. decisions and behaviors) to design systems that can identify and extract information from behavioral cues, and show intelligent behavior in social interactions as they unfold [37].

A field motivated by this assumption is *Social Signal Processing* (*SSP*). SSP advocates that the ability to understand social cues of the person we are interacting with is at the core of social intelligence, where the next generation of intelligent systems need to incorporate this ability to successfully interact with humans [41]. SSP is motivated by effort of creating intelligent systems able to understand and interpret the meaning of social cues in the emergence of higher cognitive (social) concepts, such as impressions. Aside from understanding which social cues give rise to these (social) concepts, such as person and conversation impressions (i.e. rapport), we also need to understand how they contribute to the formation of future actions and behaviors (e.g., partner selection). This, in turn, requires that we first deepen our understanding of a) how humans select their partners and b) how their impressions and beliefs relate to these choices and their future behaviors.

One fundamental aspect for understanding how people initiate collaborations and avoid costly interactions with non-cooperative others is partner selection. *Partner Selection* can be defined as one's ability to identify and preferentially interact with individuals who are able and willing to work together toward a mutual benefit [7]. To be effective, partner selection needs to involve "selective intelligence" (i.e. accurate discrimination between partners) [11]. Nevertheless, partner preferences and this discrimination process are not as straightforward, where individual and situational difference are an important factor to take into account. For example, a good and preferred partner for one person, might not be for the other [2]. Similarly, what might be a good partner for one situation

(e.g. giving car purchase advice), might not be good for the other (e.g. managing a team). Despite this variance, previous literature shows that, independent of context, individuals have a preference in choosing partners that are willing to work towards a mutual benefit [14]. However, this constant precedence of one's intention and willingness to benefit versus their actual ability to benefit can lead to biased decisions, resulting in a sub-optimal selection of future collaborative partners.

To date, we know very little about the relationship between social cues, impressions management and their consequence for future actions as they unfold in real-time interactions. Thus, to shed light on how humans select their partners, the role of impressions in partner selection, and whether we can use social cues to predict impressions and partner selection, this paper presents a 4-year project aiming to explore this link, in part, through an analysis of a multi-modal dataset containing audio-visual recordings of dyadic social interactions (i.e., free-form conversation and collaborative interactions), person and situational impressions collected via self-reports.

2 BACKGROUND AND RELATED WORK

In the attempt to explain the puzzle of cooperation, social science researchers have promoted partner selection as one of the three plausible mechanisms for promoting future cooperative and collaborative behavior [6]. If this selection is informed by accurate impressions, it can help avoid costly interactions with non-cooperators, thereby contributing to the facilitation of future cooperative and collaborative behavior [17, 38, 39]. Thus, individuals need to make well calibrated impressions of the other person and the situation to make a "good" selection and isolate non-cooperative individuals [11].

Social psychology theories found people tend to form impressions of other people along two dimensions: warmth and competence. Warmth indicates ones intent (i.e. willingness to benefit or hurt), while competence indicates the ability to act on this intent [20]. Other theories propose competence can also be thought of as performance or intelligence [1]. However, one open question is how do people form these impressions? More specifically, which signals do individuals use to form impressions of other people and make decisions with whom to collaborate? One theory offering a link between impression formations and behavioral cues in social interactions is the *(social) signaling theory* [13, 36, 40]. (Social) Signaling theory proposes that individuals (i.e. senders) engage in behaviors that are indicative of some underlying trait or quality they posses, such as trustworthiness, competence, etc, that the other person (i.e. receiver) can use to form impressions. That is, if senders are, intentionally or unintentionally, conveying information about their traits, intents or goals, the receiver should be able to use these behaviors to infer their hidden qualities (e.g. "Are they trustworthy?") [40]. This process can be viewed as a signal detection problem where optimally solving for this problem would result in a better partner selection [32]. Despite the perceived importance of social cues in impression formation and social decision making, there is a lack of literature investigating their mutual contribution in multi-modal, dynamic settings, such as social interactions. Thus, another aim of this research is to examine a) whether social cues can be used to predict person and conversation impressions and b) the role of these perceptions in guiding one's partner choices and their future (cooperative and collaborative) behavior.

Lastly, in terms of partner selection, literature has shown that people more strongly value warmth in a prospective partner, compared to competence [28]. This creates a market-like environment for selecting valuable partners [7, 31], where partners higher on warmth (e.g. trustworthiness) are seen as more valuable. However, for some situations, competence should be seen as a more valuable trait [15]. Thus, this precedence of warmth, steering one's selection, can lead to sub-optimal and biased partner choices for different joint undertakings. Despite this, it is still unknown whether people adjust their selection criteria in response to the task type and whether they shift their attention to different social cues as a function of task type.

3 RESEARCH AIMS AND RESEARCH QUESTIONS

In efforts to combine presented literature from different fields and fill the gaps by answering new research questions, research aims of this project are three-fold, branching into three different scientific fields (Social Science (SS), Cognitive Science (CogS) and Computer Science (CS)). Concretely, the following research aims are:

- a) understanding and b) predicting partner selection decisions for settings in which individuals need to work towards a mutual benefit (i.e. cooperation and collaboration). More specifically: (1) Can we predict and model an individual's partner choice only based on objective characteristics (i.e. social cues) and their social perceptions (i.e. person and situation perceptions)?, (2) Do individuals adjust their partner choices as a function of task demands (i.e. warmth-oriented task vs. competence-oriented task)? and (3) Investigating the sufficient and necessary predictors of partner choices (CogS,SS)
- a) identify and b) capture which social cues contribute to the emergence of higher-order social constructs such as conversational perceptions (e.g. rapport) (SS, CS(SSP)) and c) whether these social cues are predictive of partner selection outcomes, willingness for future interactions, as well as cooperative and collaborative performance.
- design a social behavior-based multi-modal feedback system and/or recommendation system to help individuals make better informed partner choices for collaborations in human-human and human-AI interactions(CS) and help them better understand how they are perceived during social interactions

4 RESEARCH PLAN

This venture is a 4-year PhD project. The first two years were oriented towards: a) exploring the current state of the literature, b) getting familiar with the state-of-the-art in multi-modal machine learning, as well as, current approaches in designing intelligent and recommendation systems guiding individual's decision-making, c) designing the procedure for collecting a multi-modal dataset, d) creating the system and the infrastructure to support the envisioned design (e.g., self-developed system for data collection and monitoring participants) and e) data collection. The (current) third

year will put emphasis on data engineering (i.e. data cleaning and feature extraction), data modeling and analysis. Efforts for designing an intelligent system will continue in the fourth year, where the emphasis will be on creating a complete story of how we can use insights provided by our past research as a guide for creating intelligent systems intended to work together with humans and help them make more informed partner choices.

5 METHODOLOGY

For the purpose of this project, a multi-modal dataset for understanding, predicting and modeling partner selection, person and situation perceptions and collaborative behavior in dyadic (online) interactions was collected. It captures participants' self-reports and perceptions of other individuals during an online face-to-face conversations and collaborations among strangers and their performance on cooperative and collaborative tasks. The final dataset offers access to multi-modal data containing audio-video recording of dyadic 3-minutes conversations and collaborations, self-reported ratings of another person, situation and team perceptions, conversation perceptions, as well as self-reported ratings on traits and qualities of interest.

5.1 Data collection

5.1.1 Participants. All participants were recruited via an online platform Prolific (http://www.prolific.co). Only participants who participated in both parts of the study will be included in future analysis. In total, 304 participants, from the United Kingdom, took part in both parts of the study.

5.1.2 Procedure. The study was designed as a two-part online study in Qualtrics (http://www.qualtrics.com): (1) Intake session and (2) Main (interaction) study. In the intake session, all participants were given a 40-minute survey which they needed to fill in a week before the main part of the study, while in the main study participants needed to interact with other participants via a video-conferencing tool in real time and provide ratings after every interaction.

In the intake season, individuals filled in a survey measuring relevant traits, such as personality, trust, etc. Participants were further asked to provide three email addresses of individuals from their social network, who received an invitation to provide third-party ratings of the same traits.

In the main study, each participant was put in a 6-, 5- or 4-person round-robin, depending on their availability. In the introduction, all participants were reminded about the main goal of the study and the task for which they will be selecting partners. One half of participants was presented with a *Joint Trust task* and another half was presented with a *Joint Competence task* (see Sec. 5.1.4). All participants needed to take a picture, which was used as a reminder when providing reports. Following the introduction, participants were asked to select partners among the five individuals in their group and rate participant on warmth and competence only based on photographs. Later, they engaged in a dyadic conversations with all of the participants in their group. After each conversation, all participants completed a short 5-minute survey measuring person, situation, team and conversation impressions. Later, all participants were again asked to report their partner selections for the decision task. Following the selection, they engaged in a one-on-one decision task. There was no (online) face-to-face interaction in this task, only photographs were used to indicate with whom they are doing the task.

At the end of the study they were introduced to the final task - collaborative Feud task. Again, participants were prompted to select partners for the Feud task. Regardless of their selection, all participants did a one-on-one 3-minute Feud task with everyone in their group via the same video-conferencing tool used in the conversation stage. After each collaborative task, participants needed to fill in the same short survey as after the conversation (see Sec. 5.1.3. The duration of the second part was between two and three hours, depending on the participants' pace. After all participants finished with the collaborative task, they were asked to upload video-audio recordings and were participants were debriefed about the aims of the research project. The study was approved by the Research Ethics Review Committee of Free University of Amsterdam.

5.1.3 Collected Measures. Previous literature indicated that anxiety [35], psychopathy[22], trust[19], honesty - humility [23] and many more are predictive and can influence one's (cooperative) behavior and decisions in social interactions. Thus, to measure and control for them, in the intake session, participants filled in a 40-minute survey created as a combination of questionnaires measuring personality (*HEXACO-60*; [4]), social anxiety (SIAS-6;[34]), psychopathic personality traits (*Psychopathic Personality Traits Scale* (PPTS); [9]), factors of trust (ability, benevolence, integrity and propensity [29]). All constructs were measured on a 5-point Likert scale, where higher values indicated higher presence of the trait or quality in question. Furthermore, willingness to help was measured with *Social Value Orientation* (SVO; [30]). *Partner preferences* were measured with an altered ideal partner designing task (see [28]). Lastly, to (objectively) capture one's competence, participants took part in a 10-minute non-verbal intelligence task - *University of California Matrix Reasoning task* (UCMRT; [33]).

In the main study, person perceptions were measures as evaluations of other participants on warmth (i.e., morality and sociability) and competence [27],[24]. All three constructs were measured on a three-item scales, respectively. *Situation perception* was measured using a 10-item version of Situational Interdependence Scale (SIS; [21]). *Team perception* was measured using a modified six-item orienting on *task* and *social cohesion* [10] and a two-item scale measuring *entitativity* [25]. *Willingness for future interaction* was measured with a one-item measure as used in [42]. Participants needed to make a decision if they would meet with this person in real life (0 – no; 1 – yes), as used in [42]. *Partner Selection* was measured with one item (e.g. "Would you want to do a decision task with this person?") (0 – *"no"*; 1 – *"yes"*). Participants who stated they wanted to choose this person needed to indicate the strength of the decision (i.e., *"How strongly do you want to be paired with this person?"*) (0 – *"Not at all"*; 100 – *"Very much"*).

Except self-reports, in the main study, three tasks were used to capture task performance in tasks affording for cooperation, trust, competence and collaboration. Two tasks affording for cooperation, trust and competence were used: *Joint Trust Task* and *Joint*

Competence Task. Collaboration was measured as a performance on a Feud task where individuals needed to work together to come with a solution (see Sec. 5.1.4). Additionally, participants' behavior during conversation and collaboration was recorded on video.

5.1.4 Cooperative and Collaborative task. *Joint Trust Task* is a one-on-one cooperative decision mixed-motives task. Joint Trust Task was created by adjusting the original Trust game [8]. The main goal was to distribute the money between themselves and their current partner. However, MU's they decide to give to their partner were worth more for their partner than for them (i.e., multiplied by 1.20). Participant were free to choose how much they want to give to their partner (0-10 MU) from their initial endowment of 10 MU. Each MU was worth 0.50 pounds. The maximum amount each participant could earn was 22 MU (i.e., 11 euros). Each participant repeated the task five times with five different participants.

Joint Competence Task is a one-on-one decision task. Each participants started with an initial endowment that corresponded to half of correct answers in the UCMRT. Thus, participants who had better performance in the intelligence task, had more endowment. The possible amount of the initial endowment ranged from 0 to 10 euros. In each pairing, participants were told that their endowment and the endowment of their partner will be put in a shared pool, and they need to (independently) solve one more abstract problem from the new version of the UCMRT to distribute the money. If both participants solved the problem correctly the amount in the shared pool would be distributed evenly to both participants. If one of the participants solved the problem incorrectly, the amount in the shared pool was decreased by half before the even distribution. Finally, if both participants solved the problem incorrectly, they lost all the money from the shared pool.

The Feud Task the Feud task was designed as a one-on-one task where individuals' main aim was to come up with a three most popular answers in 3-minutes on one question (e.g."Who needs to wear white clothes at work?). Compared to the joint decision task, this task involved active communication via the video-conferencing tool. This task was adopted as a means for measuring and facilitating collaborative behavior between participants (see [26]).

Audio-video recordings Audio-visual recordings of 3-minute conversations and collaboration tasks were collected. The video-recordings present a frontal perceptive of each participants during the conversation and the collaboration tasks. Due to the online setting, we were unable to control for the setting, such as lighting, quality of the video- and audio-recordings, and background noise. However, based on the initial inspection, the data is suitable for further behavior analysis and automatic feature extraction.

Two types of audio-video recordings were collected - local and global - to disentangle the effects of latency and disruptions in audio-video quality of recordings susceptible to internet connection quality. Local recordings are recordings that were recorded locally on the browser (i.e. self-recording). On the other hand, global recordings are recordings that were sent to and recorded by other participants during the conversation (i.e. other-recording). Thus, each participant had one local recording of themselves and one global recording of the other participants. These recordings will be used for further (automatic) feature extraction and analysis.

6 RESULTS AND FUTURE WORK

In this section we provide a short overview of previous studies, preliminary results and future analyses which will help us address aforementioned research aims (see Sec. 3).

6.1 Results

Closely related with the current project, our previous work oriented on understanding and creating measures of (situational and relationship) interdependence (i.e. individuals' perception of how potential outcomes of a situation are determined by their own and other's behavior) in social interactions. In a recent paper [16], we show that a) we can detect and predict situation perceptions (e.g. perceptions of interdependence) from behavioral cues in negotiations and b) the importance of coupling self-other behaviors when analyzing social interactions. Creation and validation of the (relationship) interdependence measure is still underway. Interdependence is thought to have an important impact on how individuals perceive and behave towards others, making these insights highly relevant for the current project.

Preliminary analysis of the (current) project, suggests that participants' partner perceptions of warmth and competence based on static stimuli (e.g. photographs) and after conversations are predictive of their partner choices, expectations and cooperative behavior. These results show valuable insights concerning partner perceptions, partner selection and cooperative behavior and enable us to continue working towards extending our models by combining both subjective (e.g. self-reports) and objective (e.g., social cues) characteristics.

6.2 (Future) data pre-processing and analyses

Future analyses will orient on conducting statistical analysis investigating the relationship between partner selection, person perceptions, expectations and cooperative behavior, as well as feature engineering for feature extraction and, machine-learning techniques for predicting partner selection.

6.2.1 Feature engineering. To extract relevant features, we will use feature engineering. For audio, we plan to extract various acoustic cues using off-the-shelf OpenSMILE toolkit [18], such as speech rate, pitch, etc. Furthermore, for video we plan to use OpenFACE toolkit [5] for facial feature extraction, such as facial action units, head pose, etc. Higher-level social behaviors in conversations, such as mimicry and synchrony, will also be measured, to explore possible contribution when coupling self- and other-behaviors. Lastly, we plan on annotating and transcribing conversations to extract the content of the speech.

6.2.2 Machine-Learning Algorithms. Together with subjective self-reports, extracted features will be used to train machine-learning models to perform binary classifications and predictions of higher-order social concepts, such as partner selection and perceptions of conversational atmosphere. We plan to estimate and compare between models performance when specific modalities and social cues are left out. This will help us better understand which modalities and social cues are more relevant for predicting partner selection and person perceptions, as well as conversational perceptions.

7 CONCLUSION AND CONTRIBUTIONS

Social interactions involve multitude of multi-modal behavioral cues which humans can use as signals to inform their future behavior and decisions. Social Signal Processing is a promising field for studying and decoding communication and social interaction, and it can help us advance our understanding of impression formation and partner selection in naturalistic settings.

Specific contributions of this project are threefold. First contribution of this project is the creation of a large-scale dynamic, multi-modal and interactive dataset to research topics such as impression formation, partner selection, cooperation and collaborative behavior, and the role of social cues in formation and prediction of these processes. Second contribution are research insights from experimental research contributing to our understanding of a) partner selection and b) the role of multi-modal social cues in impression formation and partner selection. Furthermore, (future) insights from this project can help us inform efforts in different fields such as human-computer interaction (HCI) and human-robot interactions (HRI) to create more socially aware intelligent systems. For instance, research on partner selection can inform efforts on designing matching and recommendation algorithms for collaborative situations, such as e-learning [43]. Understanding which social cues have the power to transmit information about specific psychological and cognitive states and traits, can help model (intelligent) systems, that can better adapt in social interactions and be more intuitive for humans when interacting with them.

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