

The Social Meaning of Physical Action

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Abstract. Intelligent systems should be able to initiate and understand social interactions, which are always brought about by physical actions. Thus, all physical actions need to be interpreted for their social effects. This paper gives an analytical framework that identifies the main challenges in modelling social interactions. Such interpretation is subjective and might lead to misunderstandings between participants in the interaction. In real life, people use rituals, such as greetings, as a method for common grounding. Greeting as an essential prerequisite of joint activity is taken as case study to illustrate our approach.

1 Introduction

Intelligent systems will never play an important role in our lives, unless they acquire social intelligence. As social creatures, people are highly dependent on others in almost all aspects of life, not just for their physical well-being but especially for their psychological welfare. Well coordinated joint action is essential for success, which is only possible if there is enough common knowledge amongst the actors to anticipate each other's behaviour, thus increasing the effectiveness of the joint activity. Existing literature in agent technology on social interaction already covers many aspects of joint actions, coordination, cooperation and task dependencies but mainly treats these in terms of objectively observable effects. However, social interaction has essential effects on social reality, which can even outweigh the importance of the physical effects, but which are not directly nor objectively observable.

Our framework is based on the observation that joint activities are not just about physical actions, but also about the social interpretation of these actions, and the expectation that the other actors will continuously monitor and interpret these actions for their social meaning. Social interpretation is a private activity that is not objectively observable by others. However, social interpretation influences future actions that in turn might give others an indirect and subjective idea of the first social interpretation. For example, the forward motion of person A, might (wrongly) be interpreted by person B as a threat (social interpretation). As a result person B steps away. Which in turn person A might (wrongly) interpret as a “please come inside” gesture of person B. The smile with which person A enters B's house might convince B that A is no threat after all.

Considering the possible social meaning of any physical actions, might be confused with social interaction, as defined by [13], Chapter 9 as follows. *Social interactions are the acts, actions, or practices of two or more people mutually oriented towards each other's selves, that is, any behavior that tries to affect or take account of each other's subjective experiences or intentions.* In our framework we also consider the fact that people might attach social meaning to an action of another that did not intend to affect the other person's subjective experiences or intentions. For example, a door slammed shut because the wind pulled it out of the hand of a person A might be attributed as an angry action of A by another person B that had a somewhat conversation with A just a few minutes before. Person A might have had no such intention. Therefore, although the literature on social interaction is the most important source of inspiration for our work, social interaction is a subset of the actions studied in this paper, i.e., the set of all actions that can be attributed social meaning.

In this paper we introduce an analytical framework of the social meaning of physical action including the relevant concepts with which we can model social interactions, analyse where possible misunderstandings might take place, and what might be done to minimize these misunderstandings. Based on this framework we can design systems that perform more realistic interactions with possible social meaning. From this initial work we can infer that agent should keep an elaborate model of social reality in order to perform realistic social interactions. In order to illustrate the functioning of our framework we discuss the greeting ritual, as it contains all major elements of social interaction, i.e., physical coordination of joint activities, and their possible social interpretations and misunderstandings.

The rest of this paper is organized as follows. First some related work is presented in Section 2. In Section 3 our analytical framework for social interactions is presented. We illustrate the framework on a small case study of the greeting ritual in Section 4. In section 5 some conclusions are drawn.

2 Related Work

Social interactions have been extensively studied in social psychology and form an important subset of the set studied in this paper, i.e., the set of all physical actions that might have social meaning. The aspects that we distinguish in our framework are inspired by this area of research as exemplified by [2], [13], [15]. Moreover, we chose aspects that are not only important for describing social interactions but are also useful (necessary) for designing socially interacting systems. Within the AI community social interactions have a close relation to the research on joint actions, plans and goals. Joint action (and its related plans and goals) are per definition focussed on agents that are involved in activities with a joint goal and for reasons of performance, the actions of each participant are meant to have an effect on the other participants [8].

Especially we can build on the theoretical work from [7] and [11] that indicate the joint mental attitudes that are necessary to perform joint actions. In general

this work provides a formal basis for the intuition of “common ground” necessary for joint action. These theories indicate that in order to successfully complete a joint plan you need to have a common belief about this plan and its subplans (or the goal and subgoals). We use this part later on to check how much of this common belief is actually established by the context (e.g. culture, history, place, etc.) and what part needs to be established through the interaction itself. However, in more practical-oriented research, the emphasis is on how to distribute a given plan over a set of actors and how to coordinate the plan such that this joint activity is realized efficiently and effectively (see e.g. [8]). For this purpose GPGP [5] and its implementation platform TAEMS [10] define hierarchical plans with some specific relations that allow for easy distribution of parts of the plan to different actors. Teams will try to find optimal distributions of a plan over actors with their own capabilities. It also provides a monitoring capability to keep track of the plan during execution. However, in our situation we do not start with a known joint plan, but rather with an interaction of which not all steps might be fixed or known on forehand. Even if a ritual is performed (such as greeting) it is not sure that all parties of the ritual share the same idea about how the ritual should be performed and thus might have different expectations about the actions of the other parties. Besides this important difference social interactions also explicitly include the social interpretation of the actions of the parties. A party performs actions with the expectation that these actions will be socially interpreted by the others. However, it is difficult to check whether this interpretation is actually made (correctly). Thus we need mechanisms to cope with these differences.

A similar issue arises in communication. The effect of communication acts is also not (directly) observable. This has led to many debates about the semantics of (agent) communication [1]. All aspects identified in communication also play a role in the type of social interactions studied in this paper. Especially we will also use the work on common ground for communication (see e.g. [3]). However, we do not focus on the possible interpretations of the content of the message, instead we focus on the physical aspects and their social interpretation of the interactions. Finally, social interactions also are linked to research on Theory of Mind [12]. Theory of Mind tries to build up a model of the mental attitudes of a person based on the perceived actions. Although this model helps to establish common expectations and understanding of social relations, this is not the focus of our current research. In first instance we focus on the direct social intentions with which actions are performed rather than longer term social goals that a person might have. E.g. we do not need to find out an ulterior (social) goal of a greeting, but only want to infer whether a person wants to establish a peer-to-peer relation or establish himself as a superior.

Another important link between physical activity and social interpretation is context, i.e. timing or location, see e.g., [9],[4],[16]. This is also an issue in the research on Intelligent Virtual Agents (see e.g. [17]), but most of that work only focuses on one physical aspect at the time and does not consider the complete physical context in relation to the social interaction. In social interaction, these

links are however essential. Taking again the greeting example, consider two persons, A and B, that meet for the first time. Person A (the initiator) extends a hand to the other person, looks B in the eyes and utters a greeting phrase. The timing of these activities is essential. From what distance does this greeting start? While walking up to the other we can already start extending our hand, while looking the other in the eye. However, when B starts to respond by also raising his hand, which A observes while maintaining eyecontact, at some point A needs to focus her eyes on the handshaking, and so should B. If not, A and B might poke each other, miss the hand completely, and so on. So proximity (distance), timing, continuous monitoring of the hands during a specific part of the greeting, and eye contact is important in this western culture greeting.

We conclude that a social interaction implies a common ground of the participants, knowledge about the possible actions in relation to context, knowledge about the possible social interpretations of those actions in relation to context. Social interaction is impossible without a form of monitoring of the activities and effects by all participants. Such monitoring has to include both the observation of the physical aspects of the activities as well as the social interpretation of physical activities and their effects.

3 Analytical Framework

Before listing the elements of our analytical framework we should say a few words about the concept of *social reality*. Although this concept has been used by several philosophers and sociologists (cf. [6],[14]), unlike physical reality, there is no general accepted definition or even common understanding about what it exactly constitutes. Intuitively it is the set of rules and believes that people have in common and that guide our social interactions. However, where for physical reality there are theories from physics, chemistry and biology to model reality from different perspectives and using connected models, the theories from social science about social reality are incomplete and disconnected. Thus creating models for physical reality for applications is easier than creating models for social reality. For the physical reality model we just have to decide how realistic the model has to be and choose the model delivering that amount of realism. I.e. for some video games realistically moving characters are important and they are modelled using bones and muscle structures, while in other games they can be cartoon-like. For social reality this choice is less obvious and depends mainly on the type of application. Realism depends more on which type of aspects are modelled than how many aspects are modelled.

We will show in the rest of the paper that modelling social reality in a similar way as physical reality and connecting the two in a principled way is essential for creating realistic social intelligent systems.

Using the literature discussed in the previous section, we identify the following concepts as being relevant for an analytical framework of social interactions:

- **Personal goal**
- **Physical context**
 - *Time & Space; Observability*
- **Physical action**
 - *Time-scale & Space (proximity) of the action; Monitoring ; Refinement of action to tune with the actions of the other participants; Dynamics*
- **Social context**
 - *Type of ritual; Relationships & Stakeholders; Expectations from stakeholders; Common understanding / common ground (e.g. History, Point of departure, Social purpose); Social consequences of success and failure*
- **Social action**
 - *Expectations; Trust; Predictability*

Our analysis of social interactions starts with identifying the **goal** of the social interaction. The goal depends on the context and determines the action. Both context and action have a physical, as well as a social aspect.

Social interaction is always realised through **physical actions**. I.e. there is a *counts-as* relation or interpretation relation that indicates the social effects of physical actions. However, physical actions can also have a functional purpose and effect. Thus the social effects of an action are determined by the way an action is performed. E.g. closing a door has a functional effect of the door being closed. If the door is closed very carefully, the social effect is that the person is seen as deferring towards the persons in the room. If the door is slammed closed, he might be seen as being angry or indifferent to the persons in the room.

Because the social action is connected to physical actions the **physical context** is important. Especially, because the social meaning of an action is usually conveyed by variations on how the action is performed rather than that this meaning can be derived from the physical purpose of the action. Thus shared space and time is needed in which all participants can observe the actions performed. Moreover, the observability of actions by the participants is important. The physical effect of closing a door is still observable after the action has been performed. However, the social effect needs to be established by direct observation of the performing of the act itself, because social effects are virtual and not (directly) observable afterwards. E.g. when a person slams a door, someone seeing the door closed 5 minutes later cannot derive anymore that the person closing the door was angry.

Further analysis of the physical context of the physical action itself concerns the time scale and proximity of the action as determinants social signals. By time scale we mean both the time it takes to complete an action with respect to the interaction with partners and the level of detail that is available in the (implemented) physical action. An action like “going out in town” has a long duration and can lead to a strong social relation (including a large common ground) between the participants. A greeting action is short and can only be used for basic social effects. Even with short actions it is important to know how much level of detail is available that can be used to convey social signals. E.g. when shaking hands, we can note how strong the handshake is, whether eye contact

is made, whether the other hand remains static or moves to elbow or shoulder of the partner, whether the upper body remains static or not. Shaking hands itself can denote a certain formal relation between the participants (opposed to giving a hug), but each of these details might convey whether there is a friendly or less friendly relation, who is considered the boss, etc. However, if we do not model these details but only have a standard greeting action available in our model none of these signals could be given or perceived.

Similarly the proximity plays a big role. When two people greet in a crowded room they might not be close enough to shake hands or kiss and thus wave hands if their history of social interaction allows for this option. However, in this situation having no physical contact does not indicate social distance, as it is enforced by the context.

Given the above elements it is clear that monitoring the physical actions and the rate with which the monitoring can be done also determines how well social signals can be perceived. This is directly linked with the following point; reactive behaviour is based on perceived social signals. Because the social interaction is by definition a joint interaction the partners should react as quick and accurate as possible on each others' parts of the interaction. This implies an active monitoring of the actions of the partners in order to check whether they conform to the expectations and if needed to perform a corrective action to give an immediate signal of possible misinterpretations. This monitoring and reaction to actions is in principle similar to what happens in any joint plan. However, in a joint plan you are not interested in every action of the other partners. You are usually only interested in the results of those actions in as far as your own actions or the joint goal depend on them. Usually this means that it suffices to monitor some key events or results. As stated before, in social interactions the social signals are carried in the actions themselves, thus a much closer level of monitoring is needed. Note that the level of monitoring depends on the level of expectation of the actions and the trust that they will be performed. E.g. when I greet someone in a well-known (common ground) situation with a handshake, I will not monitor the handshake very close (and might also miss some subtle signals). Because the close monitoring of every action of the partners in an interaction is (computationally) very expensive, we try to minimize the level of monitoring. This can be done by using more standard interactions and creating a known context. The more of these elements are known, the more accurate expectations we can form and the less points we have to monitor for deviations of these expectations.

Besides the physical context, the **social context** also determines which social signals can be conveyed and interpreted in an interaction. Firstly, we have to determine whether a ritual is used. Rituals are interaction patterns that can be assumed to be common knowledge within a group with the same culture. Often, rituals contain mainly actions that have little functional purpose and therefore are easily recognized and interpreted for their social effects. E.g. the handshake in a greeting in itself has no physical purpose except for synchronizing attention. Due to its limited functional purpose one can turn attention to the

social interpretation of the handshake in the current context. Handshake rituals are commonly used to indicate group membership.

Of course, besides the ritual used the participants or stakeholders in the interaction and their social relations play a role in the social interpretation of the interaction. Do the partners know each other already? Do they have a peer-to-peer relation or is one dependent on the other? Do they have a formal relationship connected to a specific context (such as work, committee, sport, etc.) or are they general friends or family? Given such a starting point certain social signals of the interaction either confirm the relation, try to establish a relation or try to change (or end) it. Also, given certain roles of the stakeholders certain expectations of behaviour will arise within the interaction.

The next element that plays a role in the analysis of the social interaction is the common social ground of the partners. Do the partners have a shared history which determines whether the social signal they give confirms their relation or are they strangers and does the social signal establish such a relation? The historic relation is a part of the social common ground which is used to interpret the interaction. The second part follows from this history but adds the knowledge of the social departure point of the current social interaction. Do all partners believe that they are starting a certain ritual in order to establish a social relation or do they have different interpretations of their point of departure? E.g. one might expect a formal greeting at the start of a meeting, while the other only expects a head nod. The last part of this element is the social purpose of the interaction. This purpose might be perceived differently by all partners, but it does determine for each the way they interpret each social action and its purpose. E.g. a meeting can be seen by one participant as synchronizing and exchanging knowledge in order to coordinate further actions. However, another participant might see the meeting as a means to establish a power order between the participants that is used to make decisions later on.

A final aspect of the social context is the importance of success or failure of the social interaction. E.g. the consequence of a failed job interview is much larger than the consequence of a failed greeting of a person on the street who you wanted to ask for directions. When the consequences of failure are large the partners will perform a much closer monitoring function and also use many more aspects of the context in order to make optimal interpretations of the social signals and check whether they conform to the expectations of the other partners in order to create as much social common ground as possible. For less important interactions a crude interpretation of the social signal suffices.

The final component of the analysis consists of the **social action** itself. We consider three aspects that are important for the interpretation: *expectation, trust and predictability*. If a social action is expected by all partners the interpretation of the action is easy and common to all partners. It follows a standard that apparently is part of the common ground (and which made all partners expect this action). When the partners trust each other they implicitly expect each other to conform to the expectations. Thus when the social interaction is trusted it will be less heavily monitored and standard interpretations will be

used by default. Computationally this is very efficient. The predictability is also related to this aspect. If an action is completely predictable within a sequence of actions then there is no need to closely monitor it or do an extensive run time interpretation. The default interpretation can be used that is appropriate for the context and thus the social effects follow directly from the action. E.g. when a Dutch man greets another man in a business setting he will shake hands. This is completely predictable. However if the man greets a woman the action is less predictable. He might either kiss or shake hands. Thus this context requires closer monitoring and synchronization of actions.

4 Using the Analytical Framework

In this section, we provide a first, informal, description of an operational model for the social interaction framework. We don't take all aspects discussed in the previous sections into account but describe the most salient ones and provide some insights on how to extend and detail the framework. In figure 1, we describe how to refine the usual functional planning used by agents to account for social effects of actions. We assume that each possible functional goal corresponds to a specific method in the agent's plan. Each abstract method can be realized in possibly many different ways, each having a different social effect. Depending on the desired social effect, the agent will replace an abstract method in its functional plan by the concrete method most suitable for that social effect. We therefore assume that planning for social goals does not interfere with but refines planning for functional goals. This simplification suffices for many situations. Given this approach to planning, the main consequence of social reasoning is to determine which concrete method should be chosen given a social goal. In the following, we sketch a reasoning algorithm that can be implemented over an agent's reasoning engine. We assume that agent's belief base contains a social ontology describing the association between social and physical actions. A tuple (pa, sa, v) in this ontology, indicates the potential effect v for social action sa related to physical action pa . We can now introduce the relation *preferred social action*, \succeq , between action tuples. If the aim is to realize social action sa , then

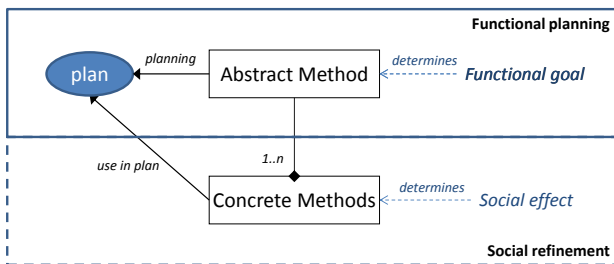


Fig. 1. Example of social refinement

of two actions $pa1$ is preferred over action $pa2$ when the potential value of $pa1$ is higher than that of $pa2$, and the amount of needed common ground to realise $pa1$ is less than that for $pa2$. Formally:

$$(pa_1, sa, v_1) \succeq (pa_2, sa, v_2) \text{ iff} \\ cg_a(c_i, pa_1) \subseteq cg_a(c_i, pa_2) \text{ and } v_1 \geq v_2$$

where $cg_a(c_i, pa)$ stands for the required common ground knowledge that is still lacking for agent a , in context c_i . Using this comparison, and assuming that

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while  $p \in plan(a)$  do
  PossAlt =
    Select  $(pa, sa, v)$ 
    From  $Soc\_ontology(a)$ 
    Where  $sa \in sg(a) \wedge pa \in concrete\_methods(p)$ ;
    End
   $(px, sx, vx) = max(PossAlt, \succeq)$ ;
   $replace(p, px, plan(a))$ ;
end

```

Algorithm 1. Social refinement of agent plans

for each abstract physical method the agent may know several concrete methods with different possible social effects, Algorithm 1 describes the reasoning process of agent a to choose the most appropriate functional plan, given a social goal $sg(a)$. Informally, the reasoning is as follows. Given a component p of the agent's functional plan $plan(a)$, it first selects all possible tuples (pa, sa, v) from $Soc_ontology(a)$ for which the social action, sa , contributes to the agent's social goal $sg(a)$, and for which the physical action pa is a concretization of p . From this list, the agent chooses the physical action px , with the highest *preferred social action*, \succeq , to replace p in $plan(a)$. The result is a social refinement of the original functional plan for the social goal of the agent.

Subsequently the perceiver is selects a social action that best corresponds to the physical action. However, it uses its own ontology, which might be different from that of the other agent. The social actions that are selected depend on the expected actions and also on how these social actions fit with the believed social goal of the other agent. Finally, the common ground of the agent is updated with the new perceived social fact. In the previous section we discussed the importance of the monitoring of the other agent during the social interaction. Three things are worth to mention here. The perceived physical action can be short and only a portion of a complete action when the monitoring is frequent. Secondly, the perception action itself ($perceive(pa)$) might also be observed by the other agent which has its own peception cycle. He might compare the perceived perception action ($perceive(perceive(pa))$) with the expected perception of the action pa and interpret that again as having a specific social effect. Finally, an agent's past experiences with the other agents influence both the perception and the interpretation of the actions of these other agents.

```

while true do
  perceive(pa);
  PercSoc =
    Select (pa, sa, v)
      From Soc_ontology(a)
      Where expected(sa) ∧ sa ∈ believed(sg(b));
  End
  (px, sx, vx) = max(PercSoc, ≥);
  cga(ci+1) = cga(ci) ∪ vx;
end

```

Algorithm 2. Perceived effect by agent *a* of social action of *b*

Application Example . In order to show the applicability of the ideas proposed in this paper, we consider the (deceivingly) simple example of greeting another agent in the setting of an international conference. In this scenario, we assume agents to have different national backgrounds and be aware that others are possibly different. When greeting someone, people behave according to certain rituals. E.g. where it is usual in Latino countries for people of opposite sex to kiss each other (also in a first encounter), this would be unheard of in Asiatic cultures. Thus the default action taken when greeting is clearly determined by the cultural context. In this situation, we assume that the social refinement of plans with respect to greeting in professional contexts is depicted in Figure 2. We introduce two agents, *Alice* and *Bob*, each with a different social ontology, as in Figure 3. Given these ontologies, in an encounter between *Alice* and *Bob*, where both are assumed to have the same social goal, namely that of establishing a professional relation, within the overall functional plan of meeting participants in the conference, *Alice*'s reasoning would lead her to take the action 'Handshake' (cf. Algorithm 1) whereas *Bob* expects a 'Bow' (cf. Algorithm 2). When *Alice* starts with the handshake, *Bob* will monitor closely because he is uncertain in this environment whether his expectations are correct. Once he perceives the start of the handshake action he will again check his social ontology to find out whether there is a corresponding social action that still promotes the assumed social goal. In this case he finds that a handshake is also a formal greeting. At this point

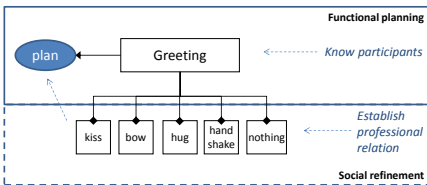


Fig. 2. Social refinement model

Soc-ontology(Alice)			Soc-ontology(Bob)		
pa	sa	v	pa	sa	v
Kiss	Formal-greeting	2	Handshake	Formal-greeting	2
Handshake	Formal-greeting	4	Bow	Formal-greeting	3
Bow	Formal-greeting	3	Do-nothing	Formal-greeting	1
Hug	Formal-greeting	1			
Long handshake	friendly greeting	2			

Fig. 3. Social ontologies in greeting example

Bob recognizes that he and *Alice* are executing the ritual of a formal greeting and if *Bob* performs the next step in this ritual, which is extending his hand to shake *Alice*'s hand, he confirms to *Alice* his acknowledgement of taking part in the formal greeting ritual. The moment *Alice* perceives *Bob* extending his hand, which is the expected physical action within the ritual, she also acknowledges that she and *Bob* are jointly performing the formal greeting ritual.

As the ritual for both *Alice* and *Bob* will have a number of expected actions they will both monitor and expect these actions to take place in the sequel. However, also in these steps the exact expected actions can differ between *Alice* and *Bob*. E.g. *Bob* might expect the handshake to last 5 seconds, while *Alice* only expects it to last 2 seconds. The longer handshake of *Bob* can lead *Alice* to reevaluate and check her ontology and interpret now that *Bob* might try to give a friendly greeting. Another situation occurs when *Alice* would decide for a 'Kiss' as the refinement of Greeting, for instance because she sees it happening in the conference. In this case, *Bob* would not be able to interpret *Alice*'s action as a form of Formal greeting, and would need to reassess the situation as another type of social interaction.

5 Conclusions

In this paper we argued that it is essential to model social reality in order to create real intelligent interacting systems. It does not suffice to just add some protocols that implement social rituals as these might differ across cultures and persons in many subtle ways.

In Section 3 we have sketched aspects that are important in order to analyse and model social interactions. Because the social actions are performed through physical actions, both the physical as well as the social context have to be taken into account. Although our framework for the social meaning of physical actions can build upon the theories for joint plans and goals (in as far as the physical actions that execute the social interactions are joint plans) there are some additional considerations that influence the social interpretation of actions. First of all, the effects of social actions are purely mental. They change social reality, which exists based on (implicit) tacit agreements, but cannot be objectively checked. The effects are also achieved by interpretation of the receiver of the social signal. This interpretation again is subjective and internal and thus not observable by the performer of the social action. The interpretation of an action as a social signal depends on many factors from both the physical as well as the social context and upon the particular physical action that is used. Although we could not indicate all the formal connections in this paper we tried to give a flavour of what is involved to model this appropriately. In order to reduce the amount of aspects to be monitored rituals can be used. The main idea of a ritual is that the actions are easily recognizable as conveying a social signal and they can be assumed to be part of the common ground already, even if the specifics of the ritual might be unknown to some of the participants. Thus many aspects that influence the interpretation of the social actions in a ritual are standardized and can be assumed fixed.

Through the example in Section 4 we have shown that our framework can be used to design realistic social interactions, which is imperative for many applications. However, it also shows that adding social interactions to existing systems requires an extensive model of social reality and keeping track of social actions. In our future work we will expand upon this aspect. We are working towards a virtual reality application that helps people become aware of and know how to handle cultural differences in social interaction. For now the main recommendation for those developing agents for social interaction is to make a clear separation in the actor between the physical actions and the social intent of that action, and within the other (observing) agent to make a clear separation between the objectively observable action and the subjective interpretation of an intended social effect and of the social effect on the observer.

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