

Modelling Patient-Centric Healthcare Using Socially Intelligent Systems: The AVICENA Experience

Ignasi Gómez-Sebastià^{1,3(✉)}, Frank Dignum², Javier Vázquez-Salceda¹,
and Ulises Cortés¹

¹ Department of Computer Science, Universitat Politècnica de Catalunya
(BarcelonaTech), Barcelona, Spain

`{igomez,jvazquez,ia}@cs.upc.edu`

² Department of Information and Computing Science,
Universiteit Utrecht, Utrecht, The Netherlands

`F.P.M.Dignum@uu.nl`

³ Department of Computer Sciences and Statistics,
Intelligent Pharma, Barcelona, Spain

`igomez@intelligentpharma.com`

Abstract. One of the effects of population ageing is the increase in the proportion of long-term chronic diseases, which require new therapeutical models that mostly take place at the patients' home rather than inside a health care institution. This requires that patients autonomously follow their prescribed treatment, which can be especially difficult for patients suffering some kind of cognitive impairment. Information technologies show potential for supporting medication adherence but the main challenge is the distributed and highly regulated nature of this scenario, where there are several tasks involving the coordinated action of a range of actors. In this paper we propose to use socially intelligent systems to tackle this challenge. These systems exhibit, understand, and reason about social behaviour, in order to support people in their daily lives. Such systems present an opportunity when applied to information technologies for supporting treatment adherence. We explore how concepts of socially intelligent systems, including social practices and social identities, can be applied to AVICENA, an ongoing project to create a platform for assisting patients in several daily tasks related to their healthcare. We first introduce AVICENA, briefly describe our previous attempts to model the system from an organizational perspective and an institutional one and discuss some of the limitations found in those models. Then the core concepts of socially intelligent systems are introduced and we show how they can be applied to create a socially aware framework for supporting medication adherence.

Keywords: Multi agent systems · Social intelligence · Assisted Living

1 Introduction

One of the main challenges that national healthcare programs will face in the near future is population ageing (i.e., the increase of the proportion of old people within the total population). In the European Union the size of the population aged between 65 and 80+ years at this moment is 80 million, but studies indicate that this number may double by 2050 [30]. In the United States of America the group of older people (aged 60+ years) is estimated to grow from the current 11% to a 22% by 2050 [26]. Moreover this is not just a problem in developed countries, as population ageing is also present in developing countries and might have an even bigger impact in those countries.

One of the impacts of population ageing is the epidemiological shift in disease burden, from acute (short-term, episodic) to chronic (long-term) diseases. From the patients' perspective, chronic diseases imply lengthy treatments often involving the combination of various medications to be taken at different times. It is undeniable that many patients experience difficulties in following treatment recommendations, and poor adherence to these long-term therapies compromises their effectiveness and may even become a cause of death. Adherence to long-term therapy for chronic illnesses in developed nations averages 50%. In developing countries, the rates are even lower [32]. Adherence rates are typically higher in patients with acute conditions, as compared to those with chronic conditions, with adherence dropping most dramatically after the first six months of therapy and in prophylaxis [24]. Patients' non-adherence to a therapeutic regimen may result in negative outcomes for them and may be compounded in populations with multiple morbidities that require multiple drug therapy. The elderly exemplifies such population. Adherence may also be affected by access to medications, which may be restricted by the use of formularies or insurance programmes. However, non-adherence may represent a greater risk in older people resulting in poor disease control that may be compounded with multiple morbidity and poly-pharmacy. There are many reasons why patients do not follow their therapy as prescribed. One of the reasons is that they cannot tolerate the (long-term) side effects such as loss of hair or constant feeling of tiredness. It may also be that the high cost of some medicines prohibits acquisition of their medication. Where a condition is asymptomatic (such as hypertension), the patient may be lulled into thinking that their treatment has worked and that they no longer require to take their medication or follow their diet; distracted by the hectic pace of everyday life, perhaps they simply forget to take their pills.

From the national healthcare programs' perspective, the epidemiological increase of chronic diseases implies the need of a major shift of the programs, from the current one centered on rapid response to episodic, acute illnesses where most of therapies and treatments are managed and delivered inside the official institutional care setting, into one where most of the medical therapies for managing chronic diseases (*e.g.*, hypertension, diabetes, depression, Parkinson's disease, *etc.*) are performed away from the institutional care setting, typically at home. This distributed approach to daily care requires patients, especially elderly, to be capable and committed to autonomously taking various

medications at different time intervals over extended periods of time. This can easily lead to forgetfulness or confusion when following the prescribed treatment, especially when the patient is suffering multiple pathologies that require a treatment with a cocktail of drugs. This gets worse when elderly suffer a cognitive impairment. Medication compliance is a critical component in the success of any medical treatment and can become a cause of death. Both concordance and adherence management are of high priority, having a significant effect on the cost effectiveness of therapy. This is especially important where there are disorders with high healthcare costs, such as oncological diseases, psychiatric disorders, HIV, geriatric disorders or dementia. Initiatives attempting to address medicine non-adherence promote patient involvement in treatment decisions but remain ineffective with older patients or with patients with cognitive disorders. Interventions using applied high-technology show potential for supporting medication adherence in patients with diseases that require poly-pharmacological treatment, as they could help to reach optimal cooperation between patients and the healthcare professionals.

In previous work, we presented the COAALAS project (Companion for Ambient Assisted Living on ALIVE SHARE-*it* platforms) [16], a framework for multi-agent systems that combines organisational and normative theories with Ambient Assisted Living (AAL) technologies. The project aims to create a society of organizational aware devices (typically sensors and actuators) that are able to adapt to a wide range of AAL situations. COAALAS models the device network around the user as a society, including the set of behavioural patterns the devices are expected to follow. COAALAS effectively supports smart assistive tools that integrate human actors with the surrounding devices, contributing to the state-of-the-art in semi-autonomous and intelligent devices for the elderly people by allowing the devices to be both social- and norm-aware.

The mid-term objective of COAALAS was to integrate a wide range of sensors and actuators in a domotic setting, in order to transparently assist the user in their daily activities, while keeping all the participants of the healthcare workflow involved. The first design and implementation of such a sensor/actuator is the social electronic reminder for pills [15], which tackles the supply of the required stock of medicines to a user with difficulties to leave their house, while supervising that he follows the medical treatment prescribed by his doctor, not missing any dose due to forgetfulness or taking it at the wrong time due to confusion.

In this context, Assistive Technologies (AT) have been able to provide successful solutions on the support of daily healthcare for elderly people, mainly focused on the interaction between the patient and the electronic devices. However, the distributed approach that such kind of healthcare has to follow in the current socio-economical setting requires more complex AT designs that go further than the interaction with a tool and are able to focus on the relationship between the patient and his social environment, mainly: caregivers, relatives and health professionals. In this paper we describe how AVICENA, a patient-centric AT system to support patients in their daily healthcare, may be enhanced into

a socially aware system that promotes treatment adherence by keeping track of the patient’s motivations. Next section describes AVICENA. Then in Sect. 3 we introduce the core concepts of socially intelligent systems that we will use for our solution. Section 4 shows how these concepts are used to convert AVICENA into a socially-aware system to support medication adherence. In Sect. 5 we discuss some related work and we end with some final conclusions and future work.

2 AVICENA

AVICENA is an ongoing project that proposes the development of an innovative m-Health [19] platform and well-tailored personalized services to substantially improve chronic patients’ medication and treatment adherence. *AVICENA* offers the opportunity to solve the patient’s non-adherence to treatments by encouraging self-management of the treatment and promoting the continuity of therapeutic regimen, reducing costs to the patient, the caregivers and the health system. *AVICENA* focuses on developing innovative control mechanisms for collaborative, adaptive, dynamic and user centred medical concordance assessment and management systems at preferred environments and highly cooperative, intuitive patient/machine/pharmacist/doctor interfaces over a network. The *AVICENA* platform (depicted in Fig. 1) includes:

- **a Smart pill dispenser** that provides the medication at the prescribed times. It controls missed doses via integrated sensors, controls the drug stock and contains a reasoning engine offering Smart services,
- ***AVICENA* mobile app**, empowering users with the ability to self manage their treatment, obtaining tailored information and feedback depending on their medical treatment adherence,
- **a new care model** involving all the stakeholders in the chronic treatment process and in the assessment and management of the treatment adherence,
- ***AVICENA* social network** connects all the stakeholders in the care process (i.e., patients, clinicians, caregivers and pharmacists).

The main goal of *AVICENA* [15] is to improve individuals’ adherence to medical treatments. A major application of the system will be the assistance of elderly individuals with chronic systemic diseases for which complex drug therapies are prescribed. In fact, several factors may affect adherence to medical treatments of this individuals, among which memory failures and psychological frailty play a relevant role. Indeed, cognitive disorders and psychopathological alterations such as mood fluctuations, anxiety and reduced efficiency of control mechanisms, are relatively frequent in this clinical population. *AVICENA* should directly influence the caregiver-patient efficiency to follow medical prescriptions by improving both the communication with the other agents of drug therapy assistance (e.g., physician, pharmacist) and the capacity of the caregiver-patient system to recognize and cope with factors likely related to reduced compliance.

In previous work [15] we presented an early version of *AVICENA*’s model based on the ALIVE [3] framework. In that first stage of the work we focused

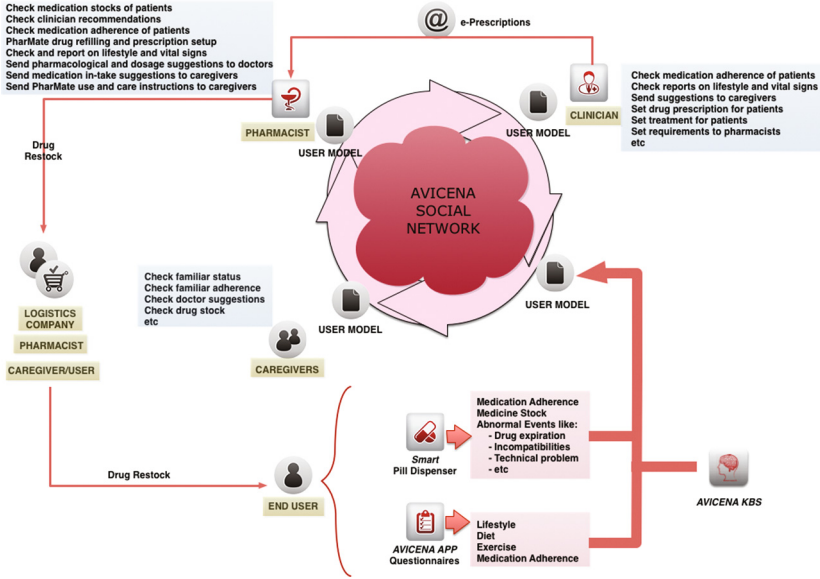


Fig. 1. AVICENA architecture

on the organizational model, and the ALIVE framework eased the design of the social network built around the patient (i.e., patient, doctor, health insurance company, pharmaceutical, delivery person, domotic house, intelligent medical dispenser and medical monitor) through a rich organisational, role-based model based on OperA [11]. The roles in all the scenarios were clearly defined, including their responsibilities and dependencies. But the normative model was still a simple one, and it was properly extended in [14]. Figure 2 shows some sample norms. The expected behavioural patterns to be abided by the actors in the scenario (including both human actors and computational agents) were properly connected to both constitutive and regulative norms, and an institutional monitor was set up to be able to infer the institutional state of an AVICENA setup. As a result we had a rich model which described the system from both a functional, organizationally-oriented perspective, an institutional perspective. Expected behaviour for all actors was clearly stated, and for those cases of non-compliance, violation-handling norms were added. But the patient being obliged to follow her treatment does not lead to its compliance, and there is no effective sanction mechanism that can be placed in this scenario that can handle forgetful patients or unmotivated ones. Furthermore, in the case of informal caregivers there is no contract establishing their precise roles and responsibilities, and very often they play a key role in the daily treatment process, exceeding their responsibilities as relatives by partially or completely taking a caregiver role. Modelling these informal interactions is the main motivation of the rest of this paper.

Property	Value
Activation Condition	\bigwedge isPatient(p) \wedge isTime(t) \wedge isQuestionnaire(q) \wedge Presented(q, p, t)
Deadline	atom Answered(q, p)
Expiration Condition	\bigwedge isTime(tt) \wedge hasTimeDifference(t, tt, OneDay)
Maintenance Condition	atom true
Norm ID	ID n1
Property	Value
Activation Condition	\bigwedge isDoctor(d) \wedge isTime(t) \wedge isPatientReport(r) \wedge sentReport(r, d, t)
Deadline	atom reviewReport(r, d)
Expiration Condition	\bigwedge isTime(tt) \wedge hasTimeDifference(t, tt, ThreeDays)
Maintenance Condition	atom true
Norm ID	ID n2
Property	Value
Activation Condition	\bigwedge isMedicationDose(m) \wedge isPatient(p) \wedge isTime(t) \wedge hasDose(m, p, t)
Deadline	atom takeDose(m, p)
Expiration Condition	\bigwedge isTime(tt) \wedge hasTimeDifference(t, tt, halfHour)
Maintenance Condition	atom true
Norm ID	ID n3
Property	Value
Activation Condition	atom violated(n1)
Deadline	atom lowerReputation(p)
Expiration Condition	atom false
Maintenance Condition	atom true
Norm ID	ID s1
Property	Value
Activation Condition	atom violated(n2)
Deadline	\bigwedge isCompetentAuthorityOf(p, d, dd) \wedge notified(dd)
Expiration Condition	atom false
Maintenance Condition	atom true
Norm ID	ID s2
Property	Value
Activation Condition	atom violated(n3)
Deadline	\bigwedge isSPD(spd) \wedge isPatient(p) \wedge isMedicationDose(m) \wedge (isCaregiver(c, p) \vee isRelative(c, p)) \wedge removeDose(spd, d) \wedge log(m) \wedge postNotify(c, p, m)
Expiration Condition	atom false
Maintenance Condition	atom true
Norm ID	ID s3

Fig. 2. Example of norms in *AVICENA* (source: [14]).

3 Socially Intelligent Systems

The goal of the actors in the *AVICENA* [15] scenario is for the patient to follow the treatment as accurately as possible while maintaining as much autonomy as possible. The second part of the goal is more interesting, because it leads to important social requirements. If the patient should be as autonomous as possible then the course of action should be driven mainly by internal motivations and not by contracts, obligations and prohibitions. Motivations differ from norms in the sense they are not enforced by external factors, but internalized by the agent, typically via social influences. Therefore, the agent (e.g., patient) will pursue his goals (e.g., follow the treatment) not because he has the obligation to follow, but because he is motivated to do it. Ideally, we would like the patient to have an internal motivation and capabilities to follow the necessary treatment with the support of caregivers whenever needed. In order to get to

this situation we need models that go beyond the functional goals of following the treatment and that also take into account social aspects of the actors. In particular we need the *motives* (achievement, affiliation, power and avoidance), *values* (leading to preferences for types of situations), *social relations* (power, trust, status, responsibility, etc.), *social identity* (image that one wants to give, leading to coherent behavior around values and practices, norms and roles) and *social practices* (indicating standard packages of social and functional behavior combinations and interpretations of interactions that lead to both functional as well as social goals). These social aspects are introduced in [10]. In this document we will motivate the use of all these aspects in the AVICENA inspired scenario, discuss some of their background and their use in the scenario.

3.1 Motives

As we already indicated above the goal of AVICENA is not just that the patient gets her treatment, which could be achieved by having a person or system take care of reminding the patient or even forcing the patient to follow the treatment. However, the autonomy of the patient requires the careful consideration of social aspects that surround the treatment. In [9] we argued that agents can only become truly social when we take into consideration all basic types of motives as defined by McLelland [23]. Besides the *achievement motive*, which can be thought to drive the traditional functional goals achievement (i.e. trying to achieve a state of the world) he distinguished the affiliation, power and avoidance motives.

The *affiliation motive* underlies the need of people for (positive) social contact. This motive can be used (or abused) when a patient is not very mobile and is dependent on other people to come by for most social contacts. In that case a professional caregiver or family member that comes by to ensure that the patient follows the treatment (takes a pill or performs an exercise) also can fulfil the affiliation need of the patient as long as the person shows enough personal interest in the patient.

The *power motive* is NOT about gaining social power over other people. It is actually meant to designate the drive people have to master capabilities and thus processes. E.g. sportsmen practising skills and enjoying doing so comes from this motive. This motive can lead to the will to autonomously perform some actions related to a treatment. E.g. performing exercises that need physical or mental skills.

The *avoidance motive* drives people to avoid unwanted situations. This plays a role in treatments when medicines might have negative side-effects or it is unknown how they will affect a patient. This uncertainty might lead a patient to avoid taking the medicines.

3.2 Social Identity

The second important aspect that needs to be taken into account is the social identity of a person. In short, the social identity of a person determines what other people expect from someone in certain contexts. The social identity consists

of three elements: the *perceived physical appearance*, the *identification with a stereotype* and *membership of social groups*.

The first element relates to what a person believes are his capabilities and thus what he believes other people expect him to do. I.e. if you are old you don't have to stand up for other people in public transport; if you consider yourself athletic you will take initiative when physical tasks have to be done for a group; if you consider yourself to be handicapped or ill (e.g. with heart failure) you might avoid going up stairs or taking a walk.

The second element of a social identity indicates an ideal image (or prototype) that one strives to mirror. Thus one compares himself with the expected behaviour of the ideal identity and also uses the expected behaviour to guide one's own behaviour. Thus if one believes that an ideal husband takes care of all broken appliances in the family home then the man will try to fix all of them or try to learn how to do this. He will consider himself bad if he fails in such tasks (even if they are not realistic). So, if a patient sees himself as a basically healthy person and healthy persons do not need assistance with any daily activity, the patient might refuse the support (even though he "knows" that he needs the support for the activity). This second element can be modelled with two parts; the first is the set of values that a person attaches to the ideal and that he therefore tries to uphold and the second is a set of social practices that he considers to be appropriate given this ideal. The social practices come again with their own set of norms and default behaviours and roles. In the next section we discuss the social practices in more detail.

The third element of the social identity of a person is his group membership. If a person is part of a social group he will adopt the social practices of this group and uphold its values. In how far he does this depends on his role in this group. The captain of a basketball team is more likely to follow the social practices of the team than a substitute. Membership and status of a group can in themselves also be goals of a person. Thus being a good family member can entice a patient to accept advice of another family member.

3.3 Social Practices

The final aspect of social agents that we will include in our models is that of social practices. In our every-day life most of our behaviour is governed by social practices. They are a kind of standardized way in which we conduct all kinds of interactions. They combine standard physical behaviours with standard social interpretations of this behaviour. E.g. greeting a person in The Netherlands at work with a handshake shows respect and an understanding that the meeting is formal. Someone that you see every day or who you consider to be a peer/friend you will greet by just saying "Hi". Thus there is both a *standard physical action* as well as *standard social meaning* attached to a social practice. The fact that these are combined makes them convenient in a complex world as it avoids to have to reason about both physical and social aspects separately. The reason that they work is exactly because they are standard. Thus their usefulness derives from their use rather than some intrinsic value of the actions themselves.

The existing theory on social practices is rather sparse (but see [27,31] for some background) and not geared towards the use of them in operational contexts. However we use this social science theory as starting point. They have proposed a representation of social practices based on three broad categories [18]: materials, meanings and competences.

- Material: covers all physical aspects of the performance of a practice, including the human body (relates to physical aspects of a situation).
- Meaning: refers to the issues which are considered to be relevant with respect to that material, i.e. understandings, beliefs and emotions (relates to social aspects of a situation).
- Competence: refers to skills and knowledge which are required to perform the practice (relates to the notion of deliberation about a situation).

Based on these ideas, we developed a model to represent social practices that can be used in social deliberation by intelligent systems. Obviously, as is the case with e.g. the representation and use of norms, other representations of social practices are possible, given the many dimensions of the use of social practices. Our proposal, depicted in Fig. 3, is especially suitable for use in agent reasoning. The components of this representation model are as follows:

Abstract Social Practice - Visiting a relative		Abstract Social Practice - Visit of caregiver	
Physical Context		Physical Context	
Resources	Drinks, chairs, tables	Resources	medicines, AVICENA tools,
Places	Geometric position of all objects	Places	Geometric position of all objects
Actors	a1, a2	Actors	a1, a2
Social Context		Social Context	
Social interpretation	family loved, father respected	Social interpretation	Patient in bad health, caregiver trusted,
Roles	Father(a1), Daughter(a2)	Roles	Patient (a1), Non-professionalCaregiver(a2)
Norms	Father should be autonomous Father should respect Daughter and Daughter respect Father One should tell family about problems	Norms	Patient should comply to treatment Caregiver must support patient and respect autonomy of patient Doctor is obliged to try to keep patient alive
Activities	give advice, give news, chit chat, drink,...	Activities	Take medicine, give advice, comfort patient,...
Plan patterns	Inform about news before drink If problem then give advice before leaving Drink before leaving	Plan patterns	Comfort patient before give medicine Give medicine before leaving
Meaning	Show love and respect	Meaning	Show care
Competences	<ul style="list-style-type: none"> • Domain knowledge and skills: know preferences family • Coordination skills : know when to drink Choice/deliberation skills: • When problems give advice • ... 	Competences	<ul style="list-style-type: none"> • Domain knowledge and skills: know medicines • Coordination skills : know when to consult Choice/deliberation skills: • When patient health is bad consult doctor • When patient refuses medicine start enquiring why • When doctor advices caregiver needs to be able to explain advice • ...

Fig. 3. Abstract social practices

- *Physical Context* describes elements from the physical environment that can be sensed:
 - *Resources* are objects that play a role in the practice such as medicines, wheel chair, water, table and bed in the scenario.
 - *Places* indicates where all objects and actors are located relatively to each other, in space or time.
 - *Actors* are all people and autonomous systems involved, that have capability to reason and (inter)act.
- *Social Context* contains:
 - *Social Interpretation* determines the social context in which the practice is used.
 - *Roles* describe the competencies and expectations about a certain type of actors.
 - *Norms* describe the rules of (expected) behaviour within the practice.
- *Activities* indicate the normal activities that are expected within the practice. Not all activities need to be performed. They are meant as potential courses of action.
- *Plan Patterns* describe usual patterns of actions defined by the landmarks that are expected to occur.
- *Meaning* refers to the social meaning of the activities that are (or can be) performed in the practice. Thus they indicate social effects of actions
- *Competences* indicate the type of capabilities the agent should have to perform the activities within this practice.

Looking at the characteristics of social practices as given in Fig. 3 one can notice some resemblance to the aspects that also play a role in agent organization models (see e.g. [11]). This list can be seen as an analogue of the connection between imposed and emerging norms. Both organizations and social practices give a kind of structure to the interactions between agents. However, organizations provide an imposed (top-down) structure, while the social practices form a structure that arises from the bottom up. Thus where organizational interaction patterns indicate minimal patterns that agents should comply with, the patterns in a social practice indicate minimal patterns that can and are usually used by the agents.

3.4 Social Intelligent Systems

As we argued above socially intelligent agents should use motives, social identity and social practices. Although we will not develop a complete agent architecture for socially intelligent agents in this paper, we sketched some preliminary ideas in [12] where we combine the different aspects. What is important to mention here is that social practices provide a number of triggers that can be checked in the environment such as the time of day, the location, people and available objects. Those physical elements determine whether a social practice is relevant. If so, it can be started and used as a template context in which the agent finds the possible actions, roles, norms and expectations to follow. If any of the parts

is not filled in or gives rise to choices the agent will get into its deliberation cycle in order to fill in the choices.

The social identity of an agent plays a major role in two ways. The different parts of the social identity of an agent all correspond to a set of social practices that are normally shared within a group or are seen as ideal behaviour according to a stereotype identity. Thus when a person is in a context where a social identity part is prominent (e.g. family membership when being at home with all family) he will check the social practices pertaining to this social identity.

The second way the social identity plays a role is that when a person identifies a certain social practice to be relevant he will choose his own role in that practice depending on what he expects his social identity will dictate. Thus a family member of the patient with no medical expertise might prefer to play the family role in the practice rather than the caregiver role, because he is not sure whether he will have all competences that would be needed for that role.

Where social practices tie into the reactive side of the agent, being triggered by some elements of the environment, the motives can drive the agent to seek out particular situations that would possibly fulfil that motive. Thus if the need of affiliation is high the agent can try to connect to his friends or family and this move might then lead him to a situation in which he can apply a social practice. In our scenario this can be seen when a family member goes visit a patient and when arriving at the patient noticing that he needs to take his medicine. This situation causes a conflict between family member and caregiver social identities. Whether the family member then takes up the role of caregiver or as family member depends on the experiences in this situation. If the patient gets very irritated and does not take the medicine when advised, the family member might try more subtle ways to attract the attention of the patient to the medicine and act more as family than caregiver.

4 SAwICENA

To motivate how concepts of socially intelligent systems can be applied to *AVICENA* we introduce a representative scenario. Jordi is a 75 year old widower from Barcelona who has three children. The younger one (Barbara) lives in Barcelona, the middle one (Ana) in Amsterdam and the older one (Patricia) in Paris. Jordi is enrolled in the *AVICENA* platform, so he has an electronic pill dispenser for supporting his treatment adherence. Jordi's daughters are responsible for re-filling the pill dispenser when new medication doses are required and taking the patient to the doctor for regular health checks and treatment updates. Jordi spends time with his three daughters visiting them for fourth months each in their respective cities *BCN*, *AMS* and *PAR* where he has a doctor assigned. The patient travels with an electronic health record so the different doctors can update it, keeping track of his state. E-prescription systems are available in *BCN* and *AMS* but not in *PAR*. Therefore legal situations must be considered to allow a smooth transition between the health-care system of the different cities, accounting both legal and technological issues.

The above scenario requires a complex institutional or organizational implementation. This can be modelled in *AVICENA*, but we only refer to this in as far as it pertains to the social aspects of the scenario. First of all, it is clear that Jordi wants to be with all his daughters regularly. Thus his affiliation motive seems to be an important driver for his behaviour. The daughters have two social identities (related to the scenario), they are both daughters and caregivers. With respect to the first identity there is a strong norm that one has to respect and obey one's parents. As a parent, Jordi does not want to be dependent on his children, because as a parent one has to provide for one's children, take care of them, etc., but his medical condition is weakening his abilities to fulfill his father role, and this is creating some internal struggle. The social identity of the daughters as being a caregiver does give them the responsibility to take care of their father's health. This might lead to a situation where they have to give him orders with respect to taking his medication. Thus we see a tension between the two identities. The tension can be resolved in an organisational way by appointing professional caregivers only for the caregiver role. However, this is not very cost efficient and even sometimes impossible due to the fact that Jordi moves around every four months.

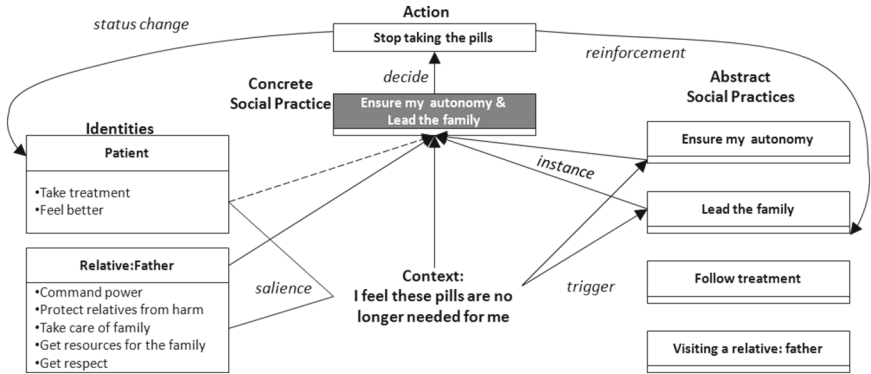


Fig. 4. Social deliberation for father/patient

We use the social practices to analyse the whole scenario. Figure 4 depicts the abstract social practices and identities associated to the patient Jordi and Fig. 5 the ones associated to his daughter Barbara. Those figures show snapshots of the social deliberation process during one of Jordi's visits to Barbara. The routine Jordi has to visit each of his daughters in turn every four months can be seen as a social practice. This social practice (*Visiting a relative*, shown in Fig. 3) stretches over the different locations in Barcelona, Paris and Amsterdam, and the actors involved are Jordi and his daughters. The social interpretation of the social practice is that the father loves his daughters and shows his devotion by visiting them in turn for equal length. The daughters show their love for their

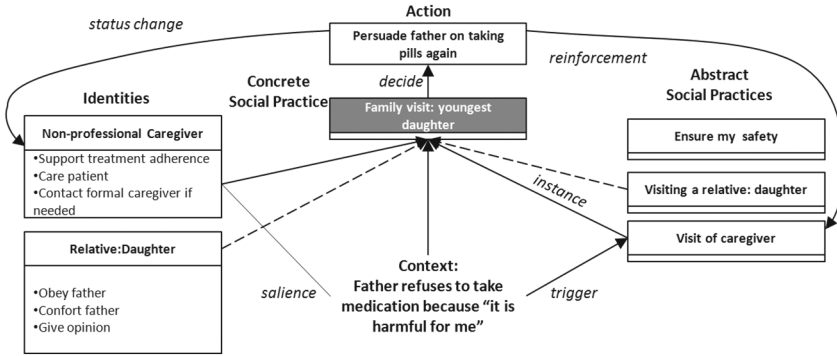


Fig. 5. Social deliberation for daughter/caregiver

father by hosting him for those four months. Thus the social meaning of the practice is to express the status of each in the family that is spread out over Europe. The roles are the father and the daughter role. The norms are that the father will provide for himself as much as possible, that the daughters involve their father in their family life, that the father commits to follow the round robin visits. The activities can be given as very general visiting and interacting of Jordi with his daughters. The plan pattern is just the round robin nature of the visits. The meaning of the whole social practice is to show the family ties and strengthen them. The competences expected are minimal. Jordi should have some financial means to travel and maybe contribute to the staying costs. The daughters should have the competence to cope with their father.

During their social deliberation process, actors' actions are guided by the set of abstract social practices that are triggered by the context. By default, in our scenario the *Visiting a relative* abstract social practice is associated to Jordi's and Barbara's father and daughter identities (*Relative:Father* and *Relative:Daughter* respectively) and instantiated into a concrete social practice (unifying actor variables to Jordi and Barbara). This concrete social practice will guide most of the social behaviour of Jordi and Barbara during his visit. In the same scenario there are other abstract social practices that may apply when medical issues are involved which are associated to Jordi's and Barbara's patient and caregiver social identities (*Follow treatment* and *Visit of caregiver* respectively).

Social practices start conflicting when Jordi's medication makes him feel weak due to some side effects (*e.g.* it causes nausea and dizziness symptoms). In this situation Jordi fears a loss of autonomy (*i.e.* a loss of power to decide over his own actions). Jordi thinks a father should be strong and provide for his family, so he does not want to be weak in front of his daughters. This situation creates a new context: *Medication makes me feel weak*, which strongly triggers the *ensure my autonomy* behavior. This leads to the familiar concrete social practice (see Fig. 4) where Jordi leads the family and *stops taking the pills*. Due to the electronic AVICENA system, Barbara will notice that her father

Concrete Social Practice - Family visit: youngest daughter	
Physical Context	<div>Resources</div> <div>Places</div> <div>Actors</div> medicines, AVICENA tools, Geometric position of all objects Jordi, Barbara
Social Context	<div>Social interpretation</div> <div>Roles</div> <div>Norms</div> Patient in bad health, care giver trusted, family loved Patient(Jordi), Father(Jordi), Non-professionalCaregiver(Barbara), Daughter(Barbara) Patient should comply to treatment Caregiver must support patient and respect autonomy of Patient Father should respect Daughter and Daughter respect Father Doctor is obliged to try to keep patient alive
Activities	Take medicine, give advice, comfort patient,...
Plan patterns	Comfort patient before give medicine Give advice before leaving
Meaning	Show love and respect
Competences	<ul style="list-style-type: none"> Domain knowledge and skills: know medicines Coordination skills : know when to consult Choice/deliberation skills: <ul style="list-style-type: none"> When health bad consult doctor When patient refuses medicine start enquiring why When doctor advices caregiver needs to be able to explain advice ...

Fig. 6. Concrete social practice for daughter/caregiver

is deviating from the prescribed treatment. The social practices of daughter-father interactions do not allow for her to order he father to take the medicine. She will first try to find out why her father did not take the medicine as it might be that he just forgot them. In that case the enquiry could be construed as an interest in her father's health and fit the social practice. However, when she realizes her father has strong arguments against taking the medicines the context changes from one where her father might have been forgetfull to one where he opposes to take the medicine any longer. In the context of (*Father refuses to take medication* as seen in Fig. 5), Barbara extends her identity from the *Relative:Daughter* identity to the *Non-Professional Caregiver* one, so the concrete social practice she was following (which was an instance of *Visiting a relative*) is extended with an instance of the *Visit of caregiver* social practice. The result is a new concrete social practice (shown in Fig. 6) which merges parts from the *Visiting a relative* and *Visit of caregiver* (shown in Fig. 3). By adopting the extended social practice Barbara will then take the action *Persuade father on taking pills again*, making Jordi understand that pills are not harmful. Note that this change cannot be established unilateral. Jordi should also accept that they enter a social practice in which his daughter takes the caregiver role. If he does not accept that role of his daughter they can break up at that point (get into a fight or end the visit). Otherwise, Jordi accepts that his daughter might also be capable as caregiver and accepts his role of patient in the social practice. The ensuing dialogue might cause Jordi to calm his concerns, change priorities among his motives and switch his main social identity from *Relative:Father* to *Patient* where following the treatment is his main concern. In case Barbara had not enough arguments to convince her father, she may contact the doctor to

better understand the side effects of those pills or even ask for some advice on how to convince patients like her father.

The next step is to tie all these elements into the scenario where the daughters are somehow co-responsible for the treatment of their father and check whether he takes his medicines. We have established that the father has an intrinsic motive to visit his daughters. The social practice establishes a practical way of realizing this. If we want the *AVICENA* system to support the family such that Jordi will take his medicines at the right time it should connect with this social practice. A simple way to force this is to connect the medicine dispenser to the electronic patient file. While the medicines are dispensed in the correct dose on the right days and times nothing is reported in the electronic patient file. However, whenever there is a deviation this can be marked in the file. If the electronic patient file has several of these marks it might signal this fact and forbid the patient to travel due to health risks. Thus this event will disrupt the social practice. Following the treatment correctly now becomes tied to showing his love to his daughters and is motivated by his affiliation motive. Thus Jordi gets an internal motivation that is in line with his behaviour and makes him aware of the medicines not only from a health perspective, but also from a family perspective.

The above shows already the use of the social aspects in designing the support system. We could also go one step further and include the social aspects in the agents that are part of the *AVICENA* platform. Given that these agents would have an understanding of their role and the role of all the humans in this scenario they can support the patient by aligning their actions with the social practices of the patient. In the above we used the very large social practice of visiting the daughters for a few months. However, there are also daily practices that can be used to combine with dispensing medicines. E.g. with dinner or when the daughter checks in with her father. In that way the visit of the daughter every day becomes combined with taking medicines. This in itself will make it easier for the daughter to remind her father to take the medicines, because it has become part of the visit to take the medicines.

We have given some very preliminary sketches to show the added value of incorporating social aspects in these complex socio-technical systems, but it already indicates its potential at different levels.

5 Related Work

Assistive Technologies (AT) can be effectively used for guiding elderly with their prescribed treatments, avoiding major problems such as non-compliance with the treatment and adverse drug reaction. There exists a range of different technological approaches, from the use of smart devices by patients (such as smart pill dispensers [13]) to Ambient Intelligence [1, 28] (AmI) environments supporting independent living. The specific area of health monitoring devices is currently characterised by application-specific and hardware-specific solutions that are mutually non-interoperable and are made up of diverse architectures. Furthermore, systems mainly focused on activity monitoring and reminders tend

to be rejected by end users, who may end up feeling that the system becomes too intrusive on their privacy [25]. Research on smart home environments and Ambient Assisted Living is moving towards a more holistic view, trying to create not only patient-centric AmI solutions, but also connecting the patient with other relevant actors in their medical treatments or even connecting patients to avoid isolation and depressive attitudes. In the rest of the section we will focus on some agent-oriented AmI solutions that are close to the work presented in the paper.

The GerAmi project [8] creates a networked AmI solution where agents are used to enhance communication and work scheduling, effectively making professional caregivers' working hours more productive. Based in the THOMAS organizational architecture [4], roles, organizational units and norms have been modelled. However, none of the articles explaining the THOMAS architecture analysed so far includes a clear example of such organizational definition, or how norms are operationalised. Furthermore, social concepts such as social identity, social relations, values or social practices are not present in the framework.

*COMMODITY*₁₂ [20] focuses on providing advice, recommendations and alerts to diabetic patients based on their data, and at the same time assist medical personnel, who is in charge of these patients, facilitating informed and timely decisions. The system consists in two main components: first, a set of devices that collect health-related data (e.g., activity and body signals). Second, a set of personal agents with expert biomedical knowledge that interpret the data via a reasoning process to generate a high level representation of patient's health status. These interpretations are then provided to relevant actors in the scenario (e.g., patients and health care professionals) in the form of feedback reports. The main idea is integrating sensors, intelligent agents, knowledge bases and users within a single system. The work introduces the *LAMA* architecture for developing software agents that can reason about a medical domain. Agents are deployed using the GOLEM agent platform [5]. Unlike other approaches analysed (e.g., GerAmi and *AVICENA*) *COMMODITY*₁₂ does not explicitly define the social structure where agents and devices operate. In *COMMODITY*₁₂ norms are reflected implicitly in the behaviours of the agents. Furthermore, the representation of the social context in *COMMODITY*₁₂ is not explicit but recent research [21, 22] demonstrates it can be acquired through lifestyle activity recognition of patient's interaction with the system.

In [2] a system for automated real-time monitoring of medical protocols is proposed. The system consists on two main components. First, a domain-independent language for protocol specification, accompanied by a user-friendly specification tool that allows health care experts to model a medical protocol and translate into the systems protocol specification language. Second, a semi-autonomous system that understands the protocols and supervises their application. Medical services are modelled as agents, and a medical protocol is interpreted as a negotiation process between agents. The system is able to observe the negotiation, effectively warning about forbidden actions and decisions. The system is applied to health care environments where every staff

person plays one or more roles. A role specifies a particular service (e.g., infirmary, surgery, *etc.*) and a medical protocol specifies possible interactions between the different services in front of a particular pathology. The protocol can suggest or forbid medical decisions depending on the medical history and evolution of the patient. Agent interactions are performed as message exchanges through a communication layer. *Supervisor agents* track such interactions and validate them. Suggested actions correspond to medical guidelines and forbidden actions to medical protocols. However, the social model is too protocol-driven, and there is no way to model important issues such as, e.g., the patients' motives.

Robot ecologies [29] are a growing paradigm in agent-based AmI in which several robotic systems are integrated into a smart environment. Such systems hold great promises for elderly assistance. Robocare [6] is a project deployed on a domestic test-bed environment that combines a tracking component for people and robots and a task execution-supervision-monitoring component. The system is composed of several software and hardware agents, each providing a set of services, and an event manager that processes requests to the different services and directs them to the appropriate agents. The system also includes a monitoring agent, with knowledge of the assisted person's usual schedule. However, agent coordination and monitoring are heavy computational processes, limiting the tested scenarios to only 2-3 persons and only a small portion of the domestic environment. The ILSA (Independent LifeStyle Assistant) project [17] passively monitors the behaviours of the inhabitants of the residential laboratory, alerting relatives in case of potentially dangerous situations (e.g., the user falls). ILSA presents two main innovations with regards to the Robocare project: (1) agents autonomously interact within them in order to achieve their goals, without the need of an event manager agent that coordinates them (but a centralized coordination agent is used to transform context-free perceptions provided by the agents into context-aware perceptions); and (2) agents are able to learn schedules based on the daily tasks performed by the inhabitants. However, once a schedule has been learned, the user is not able to deviate from it without raising an alarm. Focus in both systems is on activity monitoring and the coordination between the human and the artificial devices, and thus other social aspects such as the patients' relationship with caregivers are not part of the model.

An interestingly rich model is the AOE^2 framework presented in [7]. AOE^2 integrates (in a model that is both general and coherent) the main concepts to be considered in order to build an agent-based simulator for the particular domain of health care. It is able to reproduce the behaviour of the social system by presenting the decision making entities of the studied system as agents. The main idea behind the AOE^2 framework is focusing in high level conceptual issues regarding the health care model development process, while offering a guideline for carrying out this process independently of technical choices. The idea of applying a framework to agent-based simulations in the healthcare domain is appealing. The complexity and dynamics of the domain (e.g., the high degree of uncertainty inherent to clinical processes, the involvement of multiple distributed service providers and decision makers, *etc.*) make it useful for applying

agent-based simulations. Furthermore, the approach is also valid for providing a tool able to assess the possible outcomes of the different actions that can be taken in order to improve the system, making it more efficient or sustainable from an economic point of view. However the model does not include mental models of the individuals' motives, values and social identities, thus being unable to tackle the informal relations that we are trying to model in our work.

6 Conclusion and Future Work

In this paper we have shown the potential of extending the *AVICENA* system with social intelligence. We have outlined which social aspects seem of particular importance. I.e. *social motives*, *social identity* and *social practice*. We have sketched their role in the agent deliberation and have shown their use both in the design of a socially intelligent system as well as how individual agents could profit from these social enhancements.

From the *AVICENA* perspective, we have moved from previous models, based on a full normative description of the expected (goal-driven) behaviour by all actors fully enacting roles into a new, richer model where motive-driven actors may (partially) enact one or several social identities at the same time, guiding their behaviour by a composition of the social practices that are applicable to the social context they perceive.

This paper only describes some preliminary steps of our work. One of the next steps we plan to take is to give a more formal representation of the social aspects such that we can give a more precise and formal account of their influence on the agent deliberation. We hope to do some of this work while actually starting on an implementation of the scenario in *AVICENA*.

A second important step is to describe the relations between all these different aspects in an agent deliberation not just for particular scenarios but also in a more generic way. I.e. do agents always start with social practices and then decide on actions based on their motives or decide upon their roles in the social practice based on their identity? Or do they start with their identity and find social practices fitting with that identity? Or even better, is there no fixed order but is that determined by the situation?

As can be seen there are many interesting issues that should be looked into, but this paper shows at least that these are issues worth investigating.

Acknowledgments. Ignasi Gómez-Sebastià's work has been partially funded by the Torres Quevedo program of the Spanish Ministry of economy and competitiveness.

References

1. Acampora, G., Cook, D.J., Rashidi, P., Vasilakos, A.V.: A survey on ambient intelligence in healthcare. *Proc. IEEE* **101**(12), 2470–2494 (2013)
2. Alsinet, T., Ansótegui, C., Béjar, R., Fernández, C., Manyà, F.: Automated monitoring of medical protocols: a secure and distributed architecture. *Artif. Intell. Med.* **27**(3), 367–392 (2003)

3. Álvarez-Napago, S., Cliffe, O., Padget, J.A., Vázquez-Salceda, J.: Norms, organisations and semantic web services: the ALIVE approach. In: Workshop on Coordination, Organization, Institutions and Norms at MALLOW 2009 (2009)
4. Bajo, J., Fraile, J.A., Pérez-Lancho, B., Corchado, J.M.: The THOMAS architecture in home care scenarios: a case study. *Expert Syst. Appl.* **37**(5), 3986–3999 (2010)
5. Bromuri, S., Stathis, K.: Situating cognitive agents in GOLEM. In: Weyns, D., Brueckner, S.A., Demazeau, Y. (eds.) EEMMAS 2007. LNCS, vol. 5049, pp. 115–134. Springer, Heidelberg (2008). doi:[10.1007/978-3-540-85029-8_9](https://doi.org/10.1007/978-3-540-85029-8_9)
6. Cesta, A., Oddi, A., Smith, S.F.: A constraint-based method for project scheduling with time windows. *J. Heuristics* **8**, 109–136 (2002). <http://dx.doi.org/10.1023/A:1013617802515>
7. Charfeddine, M., Montreuil, B.: Toward a conceptual agent-based framework for modelling and simulation of distributed healthcare delivery systems. *CIRRELT* (2008)
8. Corchado, J.M., Bajo, J., Abraham, A.: GerAmi: improving healthcare delivery in geriatric residences. *IEEE Intell. Syst.* **23**(2), 19–25 (2008)
9. Dignum, F., Prada, R., Hofstede, G.: From autistic to social agents. In: AAMAS 2014, pp. 1161–1164, May 2014
10. Dignum, F., Dignum, V., Prada, R., Jonker, C.M.: A conceptual architecture for social deliberation in multi-agent organizations. *Multiagent Grid Syst.* **11**(3), 147–166 (2015)
11. Dignum, V.: A Model for organizational interaction: based on agents, founded in logic. SIKS Dissertation Series 2004-1, Ph.D. thesis, Utrecht University (2004)
12. Dignum, V., Dignum, F.: Contextualized planning using social practices. In: Ghose, A., Oren, N., Telang, P., Thangarajah, J. (eds.) COIN 2014. LNCS, vol. 9372, pp. 36–52. Springer, Cham (2015). doi:[10.1007/978-3-319-25420-3_3](https://doi.org/10.1007/978-3-319-25420-3_3)
13. Georgia Institute of Technology: Aware Home Research initiative. Technical report, Georgia Institute of Technology (2012). <http://www.cc.gatech.edu/fce/ahri/projects/index.html>
14. Gómez-Sebastià, I.: NoMoDei: a framework for norm monitoring on dynamic electronic institutions. Ph.D. thesis, Universitat Politècnica de Catalunya (2016)
15. Gómez-Sebastià, I., Garcia-Gasulla, D., Álvarez-Napagao, S., Vázquez-Salceda, J., Cortés, U.: Towards an implementation of a social electronic reminder for pills. In: VII Workshop on Agents Applied in Health Care (2012)
16. Gómez-Sebastià, I., Garcia-Gasulla, D., Álvarez-Napago, S.: Society of situated agents for adaptable eldercare. *ERCIM News* **87**, 23–24 (2011)
17. Haigh, K.Z., Kiff, L.M., Myers, J., Guralnik, V., Geib, C.W., Phelps, J., Wagner, T.: The independent lifestyle assistant (I.L.S.A.): AI lessons learned. In: The Sixteenth Innovative Applications of Artificial Intelligence Conference (IAAI-04), pp. 25–29 (2004)
18. Holtz, G.: Generating social practices. *JASSS* **17**(1), 17 (2014). <http://jasss.soc.surrey.ac.uk/17/1/17.html>
19. Istepanian, R., Laxminarayan, S., Pattichis, C.S.: M-Health. Springer, New York (2006)
20. Kafali, Ö., Bromuri, S., Sindlar, M., van der Weide, T., Aguilar Pelaez, E., Schaehtle, U., Alves, B., Zufferey, D., Rodriguez-Villegas, E., Schumacher, M.I., et al.: Commodity 12: a smart e-health environment for diabetes management. *J. Ambient Intell. Smart Environ.* **5**(5), 479–502 (2013)

21. Kafalı, Ö., Romero, A.E., Stathis, K.: Activity recognition for an agent-oriented personal health system. In: Dam, H.K., Pitt, J., Xu, Y., Governatori, G., Ito, T. (eds.) PRIMA 2014. LNCS (LNAI), vol. 8861, pp. 254–269. Springer, Cham (2014). doi:[10.1007/978-3-319-13191-7_21](https://doi.org/10.1007/978-3-319-13191-7_21)
22. Luštrek, M., Cvetkovic, B., Mirchevska, V., Kafalı, Ö., Romero, A.E., Stathis, K.: Recognising lifestyle activities of diabetic patients with a smartphone. In: Proceedings of Pervasive Health 2015: Workshop on Personal Health Systems for Chronic Diseases (to be published)
23. McClelland, D.: Human Motivation. Cambridge University Press, Cambridge (1987)
24. National Council on Patient Information and Education: Enhancing prescription medicine adherence: a national action plan. Technical report, National Council on Patient Information and Education (2007)
25. Niemelä, M., Gonzalez Fuentetaja, R., Kaasinen, E., Lorenzo Gallardo, J.: Supporting independent living of the elderly with mobile-centric ambient intelligence: user evaluation of three scenarios. In: Schiele, B., Dey, A.K., Gellersen, H., Ruyter, B., Tscheligi, M., Wichert, R., Aarts, E., Buchmann, A. (eds.) AmI 2007. LNCS, vol. 4794, pp. 91–107. Springer, Heidelberg (2007). doi:[10.1007/978-3-540-76652-0_6](https://doi.org/10.1007/978-3-540-76652-0_6)
26. Population Division UN Department of Economic Social Affairs: Population ageing and development: ten years after Madrid. Technical report. 2012/4, Population Division UN Department of Economic Social Affairs, December 2012
27. Reckwitz, A.: Toward a theory of social practices. Eur. J. Soc. Theor. **5**(2), 243–263 (2002)
28. Sadri, F.: Ambient intelligence: a survey. ACM Comput. Surv. (CSUR) **43**(4), 36 (2011)
29. Saffiotti, A., Broxvall, M., Gritti, M., LeBlanc, K., Lundh, R., Rashid, J., Seo, B., Cho, Y.J.: The PEIS-ecology project: vision and results. In: IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2008, pp. 2329–2335. IEEE (2008)
30. Schäfer, G.: Europe in Figures. Eurostat Statistical Yearbook (2008)
31. Shove, E., Pantzar, M., Watson, M.: The Dynamics of Social Practice. Sage, Thousand Oaks (2012)
32. World Health Organization: Adherence to long-term therapies. Evidence for action. Technical report, World Health Organization (2003)

Coordination, Organizations, Institutions, and Norms in
Agent Systems XII

COIN 2016 International Workshops, COIN@AAMAS,
Singapore, Singapore, May 9, 2016, COIN@ECAI, The
Hague, The Netherlands, August 30, 2016, Revised
Selected Papers

Cranefield, S.; Mahmoud, S.; Padget, J.; Rocha, A.P.
(Eds.)

2017, XIII, 171 p. 43 illus., Softcover

ISBN: 978-3-319-66594-8