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Author(s): Saariluoma, Pertti; Karvonen, Hannu; Rousi, Rebekah

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Techno-trust and rational trust in technology – a conceptual investigation

Pertti Saariluoma[1], Hannu Karvonen[2], Rebekah Rousi[1]

[1] University of Jyväskylä, 40014 Jyväskylä, Finland
[2] VTT Technical Research Center, Vuorimiehentie 3, 02044 Espoo, Finland
pertti.saariluoma@jyu.fi

Abstract. Trust is essential when using technology. If people do not trust new technology, they do not accept it. If people do not accept new technologies such as autonomous ships, their development is hampered in the absence of financial support. The importance of trust brings into question the essential conceptual components of phenomena that contribute to trust. This knowledge is required for the basis of investigating trust in technology. Especially, it is important to understand why humans trust. The reasons can be intuitive but they can also be supported by rational arguments. The latter type of trust can be called rational trust. A beneficial way of considering rational trust in technology can be reached by defining aspects of technologies that should be investigated when attempting to design for trust in technology. Therefore, the basic conceptual dimensions of technology supported actions are analyzed in order to define the essential elements of rational trust in technology.

Keywords: Rational Trust, Techno-Trust, Human-Technology Interaction, Design.

1 Introduction

Trust is the most commonplace pre-condition and emotional state for people interacting with technology. Emotional states are important for an individual as they determine the positioning (physical, social, cultural, psychological, contextual etc.) of external and internal phenomena [1]. Thus, as an emotional state, trust defines the relationship between a person, and self, in regards to the phenomena that are to be trusted. Consequently, trust is vital in determining how people should act in situations that require the dependency of an individual towards something for which there is no definite outcome [2]. People decide to undergo positive actions if they trust the consequences of taking action, but they hesitate or take a negative stance in situations where they do not trust.

Normally, trust concerns people and the interactions between people. Yet, trust can also be associated with technical artifacts and technologies. In the latter case, trust can be called techno-trust. Trust in aviation technology means trust in aircraft, as well as trust in pilots, technicians and air traffic controllers [3]. Thus, technology should be seen in the context of techno-trust in a broad systemic sense and not only as a technical artefact.

Although trust is based on emotions or feelings, it involves cognition. Indeed, human emotions are always implicated with cognition. The mind operates as a whole. Cognition is important in representing and interpreting what the situation at hand entails and emotions define its value to the individual. The process which integrates emotions with cognitions is often referred to as appraisal [1, 4, 5, 6].

Emotions are intimately linked to the human self and their motives [1, 3]. Motivation is the trajectory of human action [7]. Motivation drives people towards a particular goal, due to the fact that human action is goal oriented. Humans are intentional in thought and action [8, 9, 10, 11, 12]. Mostly these affairs are characterized by positive or at least better feelings and states than the initial state, and for this reason feelings are important in analyzing motives for action [13]. However, before it makes sense to pursue some definite goal acting person, one must trust that the goal can be reached without harmful consequences.

Technology comprises tools to reach the goals in life and for this reason trust in technology, i.e. techno-trust, is so important in understanding why people behave with technical artifacts in the way that they do. This is why the cognitive-affective theory of emotion - Appraisal [1] - also plays a central role in investigating motives and motivation related to technology supported actions. If a person does not feel positive about an action that is to be taken, or about its technical support, one very probably will not take this action.

An important issue in investigating trust is why people trust someone or something. The critical question is that of what justifies our trust. People can trust, because they feel that the trustee is trustworthy. However, their gut feelings and intuition can betray them, and one can ask a question as to why one trusts something. The "why" question essentially changes the nature of trust. Feeling-based trust is intuitive. It does not have any solidly justifiable grounds. However, upon asking and answering the question "why", the condition of trust is converted into a form of grounded or rational trust. Thus, instead of emotional belief, trust can be based on justifiable reasons such as the laws of science. Trusting based on justifiable or provable reasons and arguments can be called *rational trust* [14, 15, 16].

All the so-far presented viewpoints to trusting in technology require elaboration. Therefore, the paper's authors shall consider the conceptual structure of rational trust in technology in this paper. The goal is to explicate the conceptual structure of rational trust in technological contexts. To satisfy this task, one must firstly study what rationality means in trusting. Secondly, it is essential to consider how techno-trust differs from other common forms of trust. Thereafter, it is possible to consider the plausible main components of trusting technology, i.e., these entail the issues one must pay attention to while developing trust in a specific technology. Finally, it is possible to summarize the main arguments and present why it makes sense to analyze the conceptual structure of techno-trust

2 Rational Trust

For any individual, trust is a mental state [17, 18]. Therefore, trust can be very intuitive or tacit by nature. The schema is simple: I feel so good about this thing/person/situation, and therefore I trust it/ them. Such emotional and intuitive trust is not based on reflected considerations and it can easily lead to serious errors. Positive feelings do not guarantee that phenomena are really trustworthy and that they can perform the tasks that the user expects them to. Especially, long-range consequences of use may be difficult to assess on the grounds of good feelings or gut instincts.

An interesting example of a feeling based technology is a cigarette. Smoking feels good. It may be relaxing and even presents a means of social interaction and bonding. Therefore, many people like smoking. However, the long term consequences are controversial. Smoking can cause illnesses and early death. Yet, these facts do not necessarily concretize as any form of potential reality in the minds of many smokers as for them, the future consequences do not belong to their present life experiences. In the case of smokers, a positive intuitive emotional state is sufficient for using cigarettes.

It is not difficult to find similar technical artifacts, which are chosen rather on the grounds of immediate intuition than grounded reflections. Ready examples can be seen in many building materials such as asbestos, paints, and glues. In fact, all products have possible risks in some respect, though they do not have the same kinds of lethal consequences as cigarettes. Consumers do not know, for example, all the important details of technologies and therefore their trust is based on intuition. However, it makes sense to ask as to whether or not it is sufficient that one feels confident with a technological artifact or system in order to trust it.

The notion of rational trust emerges from the above dilemma. Rational trust means that people have good grounds to trust some technology. Instead of just feeling confident, in rational trusting people ask whether they have reasonable grounds to trust it. They test their feelings by considering how just their feelings are. Thus, a medical doctor who has to remove parts of patients' throats every week may easily see the risks of smoking differently to a smoker who lacks expert health knowledge. She or he has different reasons for feelings towards smoking.

The question of feeling confident takes on another form when one asks why she or he trusts some form of technology. One may ask what the well-founded or rational reasons for trusting something are. Rational trust is important as it entails the idea of testing and verifying trust. Thus, the notion of rational trust converts trust and trusting from everyday emotional intuition into scientifically grounded action. Rational trust means that people seek evidence, confirming the justification of their trust [16].

In the case of rational trust, the trustor should have facts upon which grounds the trust is based. These facts are empirical observations or other methodologically established states of affairs. This means that the focus of analyzing trust should be refocused from the emotional towards empirically tested and confirmed thinking. However, before any empirical analysis is possible, the researcher should have ascertained a thorough understanding of the issues to which attention should be placed in order to ground the trust.

Rational trust thus means trust which is based on rational arguments. In order to trust a person, there must be justifiable grounds for trusting. He or she needs to have knowledge about the factors which affect the trustworthy components of a technology. Decent grounds for believing that one can trust transforms thinking from emotional to knowledge-based trust. There are seldom any instances in which anyone can be sure that all the relevant data is present, and whether or not the most optimal interpretation of this data. Rational trust would however, be based on information that exceeds that of purely the information delivered by invested stakeholders, e.g., developers/owners of a company issuing the technology. Thus, the more data collected about the technology and its components, the more rational the trust relationship becomes, because there are justifiable reasons to trust the system.

3 Techno-Trust

The above section focused on rational and knowledge-based trust. This is important for technology design, particularly from the perspectives of both functionality and reliability in the mechanical and automation sense. It is also important to understand the psychological mechanisms behind what contributes to the rational basis of trust in human-technology interaction. Trust is a notion, which is normally associated with other people [15, 17]. One can trust a spouse, teenagers, business partners, medical doctors and maybe even some strangers. In special cases, trusting a person can also mean the question of confidence (in the other) and self-confidence (in oneself), i.e., trusting that one can do what he or she hopes to do. In both cases, one can speak about human-to-human trust as the same kind of trust as reliance on how a human being can and will behave in some context.

Another common form of trust is reliance on organizations. Examples can be seen in governments and companies. People trust organizations as they have grounds to trust them [16]. They do not always have any possibility to check that the organizations act in a trustful manner. People in governments and in companies keep changing. Only the organizational identities and structures are somewhat stable. This is why trust in organizations is focused rather on the way the organizations operate than on individual members of the organizations. This type of trust is common in politics and business life.

However, trust in technology is not precisely like the two types of trust presented above. In techno-trust, technical artifacts bring a new kind of additional element into discourse [18]. The new question is how well people can predict the behavior and performance of technologies when they support human actions. A tool, which cannot help people in their everyday life, is not trustworthy.

Techno-trust requires, thus, on the one hand trusting machines - causal systems - and on the other hand, trusting people whose actions area intentional (e.g., the design and/or operation of the machines). The difference between causal and intentional can be explained as follows: causal actions are consequences of internal states of machines, their behavioral history and the immediately preceding events. Intentional actions must be explained on the grounds of states of affairs (motivation, goals, direction), which guide and influence the future states of affairs. The duality of techno-trust makes it a challenging concept. People have intention, machines exhibit causality, and while the machines are not intentional in themselves, there are always people behind (designing, developing and using) the machines. One must have an idea about what people will and can do with technology that has special performance capacities.

4 Technology-Supported Actions

Technologies are meant to make human life easier and to raise the quality of life. When technology is involved in human action, the actions are referred to as technology-supported actions (TSAs) [3, 19]. The term TSA has been largely embraced by the rationale of the design methodology of Life-Based Design (LBD) [3, 19]. The reason why this is significant in the present context is that TSAs describe any action that is enabled and mediated by the use of a technological artifact or system. Technical artifacts are mostly used to aid the accomplishment of a goal during some kind of human action, whether for every day, safety critical or entertainment purposes. These are just some instances in which technology-supported actions play a major role in the life context of humans. Thus, human action is the key attribute of any kind of technology, which renders the element of trust and act of trusting as paramount to human technology interaction.

Technological innovations are meant to make our actions easier and on a general level. Techno-trust means that technology should be reliable in terms of its capacity to improve people’s lives. Steamships were used to transport people and goods. To trust in the new transportation technology of that time meant that people expected this technology to operate successfully. Thus, trust in technology means trust in technology’s function and performance and its ability to aid the progression of human life.

For example, if a bike keeps breaking down, it is not trustworthy. A bike owner cannot trust such a bike and it can be said that the bike is unreliable. People often distrust technologies because the technology cannot help them reach their action goals, even though they should. However, it is essential to ask which aspects of any technology should be considered as contributing to trust building in relation to any particular technology. A useful concept for the analysis f this issue is that of the ‘technology-supported action’ (TSA) [3, 19].

While the concept of TSA refers to any action during which people use technology, we can see that the notion of trust is vital for the commitment of an individual to rely on any artefact or service in order to anticipate the successful completion of a task based on this technological support. Thus, its conceptual structure can be used to present ontologies for human use of technology. Ontologies are systems of general concepts in differing fields that explicate basic information contents, or common understandings, associated with the field in question [3, 20, 21, 22].

TSAs have similar structures across fields. The structure is important when further developing conceptual analyses of trust. Here, a general model of action is utilized comprising five conceptual components. These components can be called conceptual attributes of a TSA. The components include: the goal, agent or human being, technical artifact, object of action and context [3, 19].

Generally a TSA can be referred to as any human action that a person undertakes with the aid of any technical artefact. It is easy to see that this very simple definition is valid in any situation in which people use some artefact. It does not matter whether a person uses a hammer and nails to fix a staircase or nuclear power stations to keep machines operating. They always carry out technology supported actions.

The first point of any action is its goal (driven by motivation) [13], which also determines why the action is undertaken and how the action is described and classified. For instance, the goal of travelling is to move from one place to another and possibly provide experiences of extraordinary, or out of the ordinary, phenomena. Actions are something that people actively engage in (intentionally or unintentionally) rather than passively receiving them. If a tractor accidentally hits a person it is the unintentional event of an accident situation, if the person has jumped in front of the tractor in order to commit suicide, it is an intentional action. This difference between the unintentional and intentional also delineates the difference between design (intentional) and non-design (unintentional). Glen Parsons argues that inventions and innovations no matter how effective are not design in the first instance if they were unintentionally, or accidentally, created [23]. An object or system only *becomes* design, once there is intention behind its application, promotion and eventual use or action. In order to understand action it is essential to define the goals of the acting person.

Another necessary component of TSAs is the agent or the human being who carries out the action. He or she can be called the actor or agent. If no one intentionally engages in action (such as design or use), actions cannot be spoken of from the perspective of deliberate action. Therefore, deliberate actions are intentionally committed by agents performing these actions [3, 8, 9, 10, 12], while undeliberate actions (as the result of fear response or surprise when designs malfunction etc.) remain somewhat outside the scope of intentional design-use ontologies. For example, a surgeon is operating on a patient. He is therefore the actor. The patient is the object of the action, yet, in many cases while the patient is not active they have intentionally made the choice to seek medical help. In turn, when trusting a surgeon, one trusts the surgeon's expertise. Trust in their expertise is the sum of the surgeon's training plus past patient cases. Thus, once again, trust in a service in determined by the data supporting or rejecting this trust.

The third conceptual component of TSAs is the technical artifact. The term technical artifact refers to some tool, instrument, machine or program, which people use to support their actions. Technical artifacts either make it easier to carry out actions or they entirely enable actions that would otherwise be impossible. Thus, microscopes, for example, enable people to see bacteria or cells. Consequently, artifacts can in the case of TSAs be seen as enablers.

The fourth conceptual component or conceptual attribute of technology-supported actions is the object of action. An object of action is anything that can be affected by the action. For instance, the goal of mining is to mine minerals in order to be used in the production of everyday life objects. Alternatively, the goal of a movie is to provide information or entertainment to the agent. Objects can be natural, social as well as informational. Their main feature is that they form an essential goal component of intentions in TSAs.

Finally, the last attribute of TSAs is context. Context is not an object of action, but it belongs to the action's environment - framing the interaction and encounter upon which the state of trust is established [24]. The environment of any TSA can be physical, biological, social or just informational. The main feature in the context is that in some way it defines the form of action. Yet, it has no role as a goal of action, although it often times sets the parameters of what the goal is, or could be, and why. Wind, for example, can make flying much more difficult, or frost can make the operations of harbor cranes more risky, but they are not targets of transporting.

In sum, TSAs have five conceptual components [3]. They are:

- Action
- Agent
- Technical artefact
- Object
- Context

These conceptual attributes define the contents of TSAs. If they can be explicated, it is possible to determine what the action is and to define why one can trust the action. Indeed, trust in TSAs connotes trust in the individual components of that action. If the agent cannot be trusted, or the rationality of action itself cannot be trusted, then trust in the particular action is not viable. However, all the given attributes of TSAs play a role when rational trust is built.

5 Autonomy and Trust

One example of considering how to build rational trust is provided by autonomous technologies. They operate more independently and issues of trust are for this reason a current point of discussion and speculation [25]. It is worthwhile questioning why people should trust autonomous cars, planes, air traffic controllers or ships.

Autonomous technologies can be used to undertake complex tasks, which have normally been occupied by people [26]. Of course, there is no level of general trust for any autonomous technology but one must analyze the intentions of users case by case. Thus, autonomous transportation of goods or autonomous radiology can be considered as trustworthy actions. However, smuggling drugs with autonomous drones is less so. This highlights the various dimensions of trust, that are often people-bound and intention dependent. In any case, most autonomous or semiautonomous actions that are increasingly being undertaken by technology are actions that people have done before. Thus, the focus on trust issues is more problematic than other attributes in regards to TSAs such as the goals of actions themselves.

Secondly, one must consider the issues of users. Autonomous technologies are more complex than most of the previous technologies. This is why it is essential to pay careful attention to the education and training of users. On the other hand, autonomous technologies replace users. Many truck drivers must reeducate themselves to undertake new tasks and professions. Of course, it is in many cases important to use the skills of people who have previously operated in the same tasks and retrain the professionals in the new ways of performing old tasks. The critical points in creating trust for people around autonomous technologies focus additionally on direct end-users, programmers, designers, and management. The skills of all these people should be analyzed and updated to improve the level of trust.

The most problematic issue in defining trust for autonomous technologies is the artifact itself. Autonomous technologies are novel forms of technical artifacts. This is why many theoretically and practically complex issues must be solved during the process of building trust towards these kinds of technical artifacts. For example, autonomous technologies may seem to have independent intentional capacities even if they do not possess any form of actual consciousness - the mechanism for intentionality [9].

Nevertheless, technical artifacts follow the laws of nature. They do not have intentions of their own. Even "intentions" of autonomous artifacts can eventually be seen as human defined intentions. Autonomous ships are used to transport goods. As ships can transport cargoes between many locations, it makes sense that routing is made by autonomous systems. They can choose their targets independently and vary these targets according to given parameters. These systems can normally learn new internal configurations and new ways of setting goals. Moreover, users cannot really determine the input values as the environment around autonomous systems keeps changing independently of the system, its users and its designers. This is why the systems can be said to have intuitive or spontaneous properties. Consequently, it can also be considered that they in some sense the systems have intuition as a consequence of their apparent spontaneity.

However, machines are not like people with their intentions [8, 9, 10, 11, 12]. Machines do not independently define the semiospheres [27], or context-dependent language sets (language games [28]) in which they operate. Their alphabets and the meanings of the alphabets and all data elements have been defined by programmers and designers. Also, algorithms are the result of a designer's (designers') work. This is why machines normally operate in limited semiospheres or domains [27, 29]. They do not have general intentions, which surpass semiotic (sign and symbol related systems) limits of predefined domains [30]. Thus, chess machines play chess well, but they are useless in terms of plotting out how to create the best painting of the century. Yet, this is not to say that developers of general artificial intelligence are not working on machines that can do just this - to flexibly multitask and transfer 'thought'.

Techno-trust concerns the performance capacities of the technical artifacts. The crucial question relates to whether or not machines can do what they are supposed to do. This is why it is possible in theory and in principle to fully predict the behavior of any machine to the minutest detail and explain it causally. Whether or not the same can be done with human operators is a different type of problem.

While there are certain structures and systems (socio-cultural for example) that guide, frame and limit people in thought and behavior, individuals still have the capacity to set their intentions and to an extent semiospheres (areas of language, e.g., pertaining to particular hobbies, professions, social groups and class etc.) freely. They can intentionally perform positive and/or negative deeds, for example. They can change their tasks and professions without any deterministic processes. In this sense, human intentions are different from the "intuitions" or algorithms of machines. People set their own goals. Thus, in order to be able to predict human actions in technological contexts it is essential to be able to understand human motives and respective intentions.

Objects of actions for autonomous systems are still human objects. Autonomous systems are new kinds of tools for people to carry out more complex parts of human tasks. However, the ultimate goals and objects remain by far the same as before. People need to transport goods from one place to another. However, the object of this action does not change the ways in which humans are directly involved in controlling movement, its direction and defining routes. Autonomous machines are designed to realize human action goals and for this reason the action related trust issues do not essentially change.

Finally, one must pay attention to the contexts of action. It is evident that social contexts shall change in many ways. Firstly, there are jobs that will most certainly disappear [31]. The main goal of adopting autonomous technologies is to free people from various types of jobs that exist today and allow autonomous technologies to undertake them instead. However, if the social change is not taken seriously from the very beginning, the technologies will lose considerable amounts of trust.

The issue (changing forms of life) [19], or life circumstances, can be even more complex in relation to trust, than in relation to the artifacts themselves. Even such an elementary issue as to how autonomous technologies can operate in human contexts is an extremely complex network of systems. For example, autonomous parcel services have caused many problems in San Francisco, and consequently, the community needed to react in the form of establishing rules in order to operate with these systems.

It is essential to determine what future life will be like and how to eliminate harm caused to people. Social, organizational, economic, management and ethical issues remain to be solved. The fate of nuclear technologies shows how people can lose their trust in some technologies as the consequence of negligent actions. This is why it is important to develop autonomy in a very holistic manner. Contexts are really important in building trust in relation to autonomous technologies.

6 Why does ontology-based design management make sense?

The example of developing autonomous systems illustrates that systematic analysis of techno-trust is important. The ontological structure of techno-trust, i.e. action, actor, artifact, object and context, can aid in developing holistic technology, innovation, design and development practices. Life-Based Design is an illustrative example of such practice [3], as Life-Based Design includes consideration for overall life systems, rather than simply those involved in technology interaction situations.

Ontologies for strengthening rational trust help people see what the main attributes are to be solved during such design processes. The goal of ontology work is to explicate the main design questions in some domain of design issues [3, 33, 34, 35]. These questions can be reused in managing subsequent design processes.

Ontology directed design is beneficial as it allows for the accumulation of design relevant information. Designers and innovation managers can know in advance what the critical issues are and even how they have previously been solved. This is why they need to always start from scratch. Rational trust exemplifies the use of ontologies in the design process in order to understand and predict trust conditions.

Thus, in conditions of rational trust, the foundations of the trust state can be identified and explicated. However, this is a complex process due to the changing semiotic conditions of the technology, its interaction and use context, person/actor (in their entirely) and their experience. For this reason it is worth applying explanatory models to investigate grounded trust, and more pertinently, techno-trust. If something defies expectations and fails to perform in a satisfactory way, it is possible to search for the reason or cause of why the trust relation failed. Therefore, it is also possible to identify the reasons for failure and thus dismiss or reject the foundations of rational trust.

Expectations depict the individual's anticipation of the end state. In the case of rational trust the trustor should be sufficient reasons and justifications (information) to predict and thus expect successful results. When observing the case of aircraft, aircraft design is the result of years (centuries) worth of research and development. The amount of data collected and applied as a result of this research and development means that people have substantial reason to trust the aircraft. Furthermore, the investment and knowledge generated through the years' worth of development also have resulted in aircraft being one of the safest forms of transport.

The represented schema of design for rational trust is important also as it makes design processes much more transparent and readily re-definable. The openness of processes and arguments is a suitable basis for building ontologies in design management. Through deciphering how to approach trust and its rationality, affords the development of a model on how to approach the problems of complex and socially holistic design issues.

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