Value Sensitive Design of Automated Workload Distribution Support for Traffic Control Teams

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Abstract. This paper studies the effects of automated support for workload distribution in traffic control teams on human values such as security, autonomy and privacy. The paper describes a workshop in which the support system's stakeholders, their values, and the effects of the support system on these values were analyzed. The workshop results were used to derive design recommendations that minimize the negative effects on the stakeholders' values. The main conclusions are that in order to minimize negative impacts on privacy, trust and team spirit, the type and amount of information that is shared to improve workload distribution should be adjustable, depending on the role of the receiving party.

1 Introduction

Traffic management usually involves a team of operators that together control the traffic flow. One of the problems in traffic control teams is that workload is not always distributed evenly over team members [23]. A way to harmonize workload distribution in such teams is by adding an electronic partner (ePartner) [15] to the team that monitors the workload of the operators and shares this information with others. With this information, team members or the team leader can decide to take over or reallocate tasks, respectively. Thus, the ePartner provides automated support for workload distribution in traffic control teams.

Developing workload distribution support yields several challenges. The operators' activities and physical states need to be assessed, the ePartner should be able to reason about these observations, e.g. to determine workload and to decide when to inform whom, and the ePartner's interface should be usable. Besides these more technical and usage-oriented challenges, the design of an ePartner also yields ethical challenges, which we will focus on in this paper. An ethical issue, for instance, is how the ePartner affects the team members' values such as team spirit. Whereas the first type of challenges can be addressed with techniques from software engineering [24] and usability engineering [20], ethical challenges can be addressed by Value Sensitive Design [8].

Value Sensitive Design (VSD) is a methodology that aims to account for human values in the design of technology. The idea behind VSD is that humans esteem values such as autonomy, security, privacy, responsibility and well-being [6], and that technology can either support or hinder these values. In a

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human-automation team, for instance, automation should be *understandable* for its human team members, it should ensure their *safety*, and it should not hinder their *autonomy*. Hindering these values may lead to a decrease in motivation, which in turn can have a negative impact on team performance [4]. VSD offers a collection of theory, tools and methods to account for values in design.

In this paper, we describe how we used VSD techniques for the design of an ePartner that supports workload distribution in train traffic control teams. For that, we organized a Value Sensitive Design Workshop with subject matter experts in the domain of train traffic control. In the workshop, we presented an existing system for assessing someone's cognitive workload and emotional state [17], and sketched how this technology could be used to support workload distribution. Subsequently, we analyzed the stakeholders of this technology, their values, and the possible effects of different solutions on these values. Based on the outcome of the workshop, we derived a number of design recommendations for the ePartner to be developed.

The focus of this paper is not on a final solution, but on the design process and how we accounted for human values in that process. By that, the contribution of this work is two-fold. First, it contributes to the development of a value-sensitive ePartner supporting workload distribution for traffic control teams. Second, it contributes to the development of VSD by applying some of its techniques and discussing our experiences with that.

The outline of this paper is as follows. In section 2, we describe the train traffic control team we studied and how workload is currently distributed in that team, and we describe the solution we envision to improve workload distribution in this team. In section 3, we provide a short introduction into VSD. In section 4, we describe how we setup the VSD workshop and provide its results. In section 5, we discuss the implications of the workshop outcome for the design of the workload distribution support. In section 6, we end the paper with a discussion.

2 Workload in Train Traffic Control Teams

For this research, we studied train traffic control teams in ProRail, the organization that is responsible for controlling train traffic in The Netherlands. The Dutch railway network is used by multiple passenger and cargo transporters. All this train traffic is managed from thirteen regional control centers and one national control center. The regional control centers are occupied by a team of train traffic controllers (treindienstleiders) and a team leader. In this section we first describe how workload is currently distributed over time and team members in the train traffic control teams we studied. Subsequently, we describe the CLES monitor and ePartner by which we aim to improve the distribution of workload in these teams.

2.1 Current Situation

In the traffic control teams we studied, the distribution of workload over time is rather uneven. In a normal situation, train traffic is automatically regulated by a train traffic control system that follows fixed schedules describing the train traffic flow. When there is a small disruption, the system automatically reschedules the trains. Under these circumstances, train traffic controllers mainly monitor the situation, and their workload is rather low. In case of a larger disruption, however, the system cannot provide satisfying solutions, and is usually switched off by the train traffic controllers. Instead of relying on the system, they manually regulate train traffic by controlling the signals and switches on the rails, and informing train drivers about the changes. Depending on the complexity of the disruption, this may yield high levels of workload.

The distribution of workload over team members is based on the division of railway sections over train traffic controllers. Each train traffic controller is responsible for a particular section of the railway network, e.g. one station, and performs the work associated to that section. Thus, when a disruption only affects certain sections of the network, it may occur that the train traffic controllers responsible for those sections experience high levels of workload, whereas the others do not have much to do. It is possible that train traffic controllers perform tasks that are associated to railway sections of colleagues to alleviate their workload. In practice, however, this rarely happens because train traffic controllers do not always know how much workload their colleagues experience. Moreover, they tend to solve their own problems as much as possible and ask for help at a relatively late stage of a disruption.

2.2 Adding Automation

In the train traffic control domain, distribution of workload over time can hardly be controlled due to the unpredictability of disruptions on the railway network, but the distribution of workload over team members can be changed. To improve workload distribution in a team, insight in the distribution of workload over members is needed.

Motived by the current, at times uneven distribution of workload in operational teams, Neerincx et al. [17] developed a CLES monitor that assesses workload of train traffic controllers by measuring their Cognitive Load and their Emotional State. The cognitive load measurement is an implementation of Neerincx's model for cognitive task load [14, 18], describing the effects of task allocations on performance of operators working in dynamic, critical and high-demand task environments. The emotional state measurement assesses the operators' arousal and valence, which predict the affective load they experience [11, 16]. With these two measures an operator's workload can be determined. For details about the CLES monitor we refer to [17].

Collecting information with a CLES monitor in itself does not lead to an improved workload distribution. We envision a solution in which an ePartner, representing the operator, reasons about the information gathered by the CLES monitor, and informs (the ePartners of) other team members when necessary. When an ePartner receives information from another ePartner, it can provide (part of) this information to the person it represents, e.g. by showing the information on an awareness or observability display [1–3].

This solution requires policies that describe *what* information an ePartner should share *when* and *with whom*. There are many possibilities. Information can involve actual cognitive load and emotional state values, a value that combines both values, an indication of an unusual pattern, or a suggestion to take over someone's work. The information can be shared continuously, every n seconds, only if the train traffic controller gives permission, in emergency cases, or when the CLES values are high or unusual. Information can be shared with only to the train traffic controller being monitored, to his team leader, to all members of the team, or only to team members with a low workload. Based on these options, policies for the ePartner can be, for instance, that it is obliged to continuously provide all information about the operator it represents to the team leader, or that it is authorized to provide cognitive load information to team members with a low workload if the operator gives permission.

3 Value Sensitive Design

In this section we provide a short introduction to Value Sensitive Design (VSD), the methodology we use to account for values in the design of the ePartner. VSD has been developed over the last 25 years and can be defined as follows [8].

> *Value Sensitive Design is a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process.*

Central to VSD are analyses of direct and indirect stakeholders, and their values. A value refers to what a person or group of people considers important in life. Values that could play a role in the design of technology are, for instance, autonomy, security, privacy, safety, trust, responsibility, sustainability, and fun.

Designers are confronted with value tensions. For example, supporting the value of security, e.g. by placing more surveillance cameras, may hinder privacy, and supporting safety by making actions with a safety risk impossible, may hinder a user's autonomy. VSD aims to make designers aware of these tensions during the design process so that they make informed design choices. The objective is to strive for improvements rather than perfection.

VSD includes investigations on three levels: the conceptual, empirical and technological level. Conceptual investigations involve analyses of direct and indirect stakeholders, and how their values are affected by technology. Empirical investigations can be interviews, surveys, and prototype testing. Technological investigations refer to both the examination of existing technological solutions and the development of new technology. These investigations are intended to be iterative, so that the designer can modify the design continuously.

This paper describes our conceptual investigations regarding the ePartner providing automated workload distribution support. Within VSD, a collection of techniques for conceptual investigations has been developed, such as value scenarios [13], value dams and flows [12], and envisioning cards [7]. The workshop we held is most similar to the value dams and flows method. The value dams and flows method starts with identifying stakeholders of the (envisioned) system, then for each stakeholder group the potential harms and benefits of the system are identified, and then the values underlying those harms and benefits are identified. The workshop we held also started with the identification of stakeholders. The second step of our workshop, however, involved the identification of values of these stakeholders, and only after that, the effects of the system on these values were identified. The reason for changing the second and third step of the value dams and flows method was to bring even more focus on values rather than on the system design.

4 VSD Workshop

4.1 Setup

The workshop was held at the railway company ProRail with four participants who were all employed by ProRail. Three of the participants were ICT experts responsible for the design and development of new ICT systems, and one of them was a research coordinator. At the start of the workshop, none of the participants was familiar with the VSD methodology. The workshop took two hours and was lead by the first author of this paper, assisted by a colleague who recorded the whole session on video.

The workshop started with an interactive presentation about the role of values in the design of technology to introduce the participants to the basic ideas of VSD. Subsequently, the CLES monitor and the envisioned solution of the ePartner supporting workload distribution were presented to the participants. Several possible displays to provide information were shown, such as a continuous graph of cognitive load and emotional state values, and display with messages reporting about abnormal cognitive load and emotional state values. Then, the participants were asked to perform a stakeholder and value analysis regarding the CLES monitor. Following the workshop setup we described in the previous section, the workshop participants discussed the following questions.

1. Who are direct and indirect **stakeholders** of the monitor?
2. What are their **values**, relevant with respect to the monitor?
3. What are the **effects** (positive or negative) of the monitor on these values? Give an explanation for this effect.

The findings were written down on a white board. The workshop ended with a short discussion about the value of VSD for developing human-automation teams for the railway organization.

4.2 Results

The participants identified two direct and nine indirect stakeholders. The direct stakeholders they identified were: train traffic controller (TTC) being monitored, and team leader. The indirect stakeholders they identified were: TTC in operation, TTC in preparation or evaluation, regional traffic controller, train driver,

Stakeholder	Value	Effect	Explanation of the effect
TTC being monitored	Insight	+	Monitor gives a TTC more insight in his own functioning
	Openness	+	Monitor ensures that a TTC provides more openness towards others
	Trust	-	Monitor can be interpreted as if a TTC is not trusted in letting others know about the height of his workload
	Privacy	-	Monitor discloses possibly privacy sensitive information about a TTC
	Recognition	+/-	Hardworking TTCs can feel recognized when the monitor shows others how hard they work, but it can also be seen as a sign of distrust in how hard they are working, i.e. they are not being recognized
	Power	-	Monitor makes a TTC more vulnerable, e.g. when others see that he performs poorly
Team leader	Trust	+	Monitor increases a team leader's trust in his own judgments when the monitor confirms his intuitions about TTCs
	Insight	+	Monitor gives a team leader more insight in the functioning of TTCs
	Support decisions	+	Monitor can confirm a team leader's assumptions about the functioning of TTCs on which he bases his decisions
	Control	+	More insight increases a team leader's feeling of being 'in control'
Team member, also TTC	Being important	+	Taking over work of a TTC with high workload gives a team member the feeling that he is useful and important
	Politeness	+	Monitor ensures that when a TTC has a high workload, team members will only disturb him with really important matters
	Helpfulness	+	A team member knows better when to help a TTC when he has insight in his workload
	Team spirit	+/-	Helping each other when it is busy increases team spirit, but constantly monitoring each other's functioning decreases team spirit
	Curiosity	+	Monitor satisfies curiosity in each other's functioning
	Availability	+	Monitor ensures that a team member is more quickly available if that is really necessary

Fig. 1. Stakeholders, values and effects identified in the VSD workshop

transporters, travelers, broadcast, TTCs in next shift, and leader safety operation. Figure 4.2 displays the identified values of the most important stakeholders, and the effects of the CLES monitor on these values.

The stakeholders 'TTC in operation' and 'TTC in preparation or evaluation' were identified to have the same values, effects and explanations. In the table they are therefore depicted as 'team member, also TTC'. Interestingly, TTCs in operation and TTCs in preparation or evaluation were initially identified as indirect stakeholders, whereas team leaders were identified as direct stakeholders. In the value and effect analyses, however, this distinction seemed to disappear, as in the explanations, all were envisioned to be able to receive workload information about team members. It could therefore be argued to consider all of these as direct stakeholders.

The results show that, according to the workshop participants, the monitor supports most of the stakeholders' values. In their view, the values trust, privacy and power were hindered by the monitor, and the values recognition and team spirit could be both supported and hindered by the monitor.

5 Implications for Design

We aim to use the results of the value and stakeholder analyses for the design of the ePartner. However, neither the value dams and flows method nor any other VSD technique offers much guidance on how to incorporate the results of a conceptual analysis in an actual design [10, 5]. For instance, there is no structured method for what to do in case two values are in conflict with each other. Furthermore, VSD offers no concrete method for translating stakeholder and value analyses into actual design requirements. In this section, we will therefore adopt a rather informal approach to derive design recommendations from the workshop results.

As mentioned earlier, three important questions in designing workload distribution support are: what information should be shared, when, and with whom? Examining the participants' explanations in Figure 4.2, they all seem to concern the situation where most or all information gathered by the CLES monitor is shared to all other participants. Therefore, in this section we will explore how we can minimize the negative effects of the CLES monitor by sharing less information, while maintaining the positive effects associated to sharing information. This section is organized according to the three stakeholder groups, starting with the TTC being monitored, followed by team members and the team leader.

An examination of the values of the **TTC being monitored** shows that only the value 'insight' refers to sharing the information collected by the CLES monitor to the TTC being monitored himself. The associated explanation is that 'the monitor gives a TTC more insight in his own functioning'. For a maximum insight in one's functioning, it is helpful to receive information about actual values of cognitive load and emotional state continuously. Providing such information to the TTC being monitored does not hinder any of the other values, neither of the TTC, nor or the others. The only danger can be that when CLES values are displayed for the TTC, that others may see them on the TTC's display as well, which would go against the TTC's values of privacy and power. To overcome this problem, the TTC should have the freedom to switch off the display. Moreover, for situations where a TTC switches off the display or when he is too busy to look at the display, he should have the possibility to inspect the data at a later moment.

For **team members**, receiving information about a colleague TTC has mostly positive effects. For the TTC being monitored, however, that has mixed effects. On the one hand, sharing information with others supports the value of openness, but on the other hand, it might hinder the values of trust, privacy and power. The explanations show that most of the team members' values relate to helping team members when necessary, either by taking over tasks or not disturbing them. To support these values, it is sufficient to receive suggestions about whom to help every now and then, and continuous information about a TTC's cognitive load and emotional state is not necessary. This option removes the negative effect on team spirit, as team members cannot constantly monitor each other's functioning this way, and it greatly relieves the negative impacts on the TTC's values of trust, privacy and power. Though this solution has large benefits, it may decreases the positive effects of the monitor on 'curiosity' of team members, and on 'openness' of the TTC being monitored.

It was indicated that for the **team leader** receiving information about a TTC has only positive effects. The reasons for these positive effects are related to the team leader's desire to have insight in the functioning of the TTC. To support these values, it is likely that team leaders would like to receive more rather than less information. For the TTC being monitored, however, this will hinder his values of trust, privacy, recognition, and power. Thus, there is a value tension for which no easy solution is available. We suggest to search for a middle ground in this situation, e.g. by only sharing workload information every now and then (not continuously), only in case of a disruption in the environment, or only if the TTC agrees on doing that.

To summarize the above discussion into concrete recommendations for the design of an ePartner that harmonizes workload distribution, we believe that the ePartner should be adaptive with regard to what information should be shared with whom. First, the ePartner should provide cognitive load and emotional state values to the TTC being monitored. Second, the ePartner should limit the information it shares with team members to letting them know when their help is needed, and when they should not disturb the TTC being monitored. Third, the ePartner should be able to provide different types of information to the team leader, e.g. depending on the TTC's preferences, the team leader's preferences, and the situation at hand. Following these recommendations should minimize the negative effects of the monitor on the stakeholders' values.

6 Discussion

The work presented in this paper is part of a project that aims to develop automated support for improved workload distribution in train traffic control teams, while taking human values into account. In this paper we described our view of an ePartner that collects information about the workload of a TTC, and shares this information with (ePartners of) the TTC's team members and his team leader. The intended result of this information sharing is that TTCs more often take over each other's tasks and thus establish a harmonized workload distribution. To account for human values in the design process of such an ePartner, we analyzed its stakeholders, their values, and its effects on these values in a VSD workshop. The results showed that monitoring and sharing TTCs' cognitive load and emotional state supports most stakeholder values, but that it may hinder the TTCs' values of privacy, trust and team spirit. In the previous section, we made several recommendations to overcome these hindrances.

The VSD workshop we held was an adaptation of the value dams and flows method in the sense that in our workshop values were identified before the effects of the technology on values, rather than the other way around. According to our observations, the adaptation was successful and workshop participants had no difficulties in coming up with values. The reactions of the workshop participants on the workshop were positive. In a final discussion about the use of VSD for developing human-machine interfaces for train traffic controllers, participants indicated that VSD offers a valuable perspective that often receives too little attention in their organization. Participants stated that it would be valuable to organize a similar VSD workshop with direct users of the envisioned technology, i.e. with train traffic controllers and team leaders. Finally, the results of VSD workshop are in line with other findings in the literature, in which tensions between information sharing and privacy were encountered as well [22, 21].

As mentioned in Section 5, VSD offers no structured method for moving from value analyses to an actual design. This could be seen as a shortcoming of VSD [10], but it may also be that this is not part of VSD's objectives. Despite the lack of a concrete method, we were able to derive design recommendations. For future work, however, we believe that it would be beneficial to develop a more structured method. This would make the process more transparent and it could enhance the quality of the recommendations that are derived. We suggest an approach that draws on techniques from situated Cognitive Engineering [19] to derive and refine requirements specifications, and techniques from requirements engineering [9] to prioritize over multiple requirements.

In future work, we will implement a prototype of the ePartner following the recommendations derived in this paper. This is in line with the VSD methodology, prescribing rapid prototyping and an integrative approach of conceptual, empirical and technical investigations. After implementing a first prototype, we plan to test our design in a user study, and investigate whether workload distribution is actually improved and whether the support system supports the stakeholders' values.

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