Rehearsing for a Major Accident in a Metro Control Centre: A Naturalistic Analysis of Situation Awareness

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ABSTRACT

Introduction: Drawing on Peircean philosophy, this paper argues that shared situation awareness and decision making can be viewed as a process consisting of 'semiosis' or 'perception-action cycles': action is derived from perception of a 'sign' while each course of action implies meaningful basis for further action. **Method:** We analysed observation data of an accident rehearsal in a metro traffic control centre. The method includes interpretation of how courses of action are linked to each other and to situation awareness; it provides an overall description of how situation awareness is constructed in activity. **Results and discussion:** The process of creating situation awareness was heavily mediated; several individuals were needed for conveying knowledge from the scene of accident to the emergency response. The overall interaction pattern is explainable with the division of tasks in the control centre. The results point to practical ideas on how to streamline the flow of communication.

KEYWORDS

Situation awareness; transportation; accident management; metro traffic control; interaction analysis

INTRODUCTION

It is commonly thought that maintaining adequate situation awareness (SA) is a prerequisite for good decision making in safety-critical work. This paper proposes a theoretical background and method for studying situation awareness in work teams. We see SA as a phenomenon that progresses or builds-up hand-in-hand with work activity. This activity, in turn, is seen from a 'cultural' and 'ecological' perspective: activity is seen as intentional and attached to the 'meanings' offered by the environment of an actor. The method we are proposing consists of a meticulous step-by-step (or 'meaning/action-by-meaning/action') analysis of actions: each action potentially constructs SA and is a 'sign' for further actions. We demonstrate this method with a case study on metro control room work during a major accident rehearsal. Practical ideas on how the metro control work might be organised more efficiently are provided.

Situation awareness

The concept of SA has been discussed since the late 1980s (Endsley, 1988). At that time, the concept was used especially in the fighter aircraft domain to describe the pilot's observation of the opponent's moves and anticipation of future moves (Spick, 1988). After the success in the aviation domain, the concept diffused into various other safety-critical domains, such as transportation control centres (Golightlya, Wilsona, Loweb & Sharplesa, 2010), energy production control rooms (Burns, Jamieson, Skraaning, Lau & Kwok, 2007) and emergency medical dispatch (Blandford & Wong, 2004). Perhaps the most common definition of SA is by Endsley (1988, p. 97) according to which it is 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future'.

To apply SA in teamwork, the literature entails concepts such as 'shared situation awareness' (Endsley, Bolte & Jones, 2003), 'common ground' (Clark & Brennan, 1991), 'team cognition' (Salas et al. 2004) and 'team situation awareness' (Endsley, 1995). All of these concepts refer to shared understanding of a situation. Endsley and Jones (1997) have defined shared SA as the degree to which team members possess the same situation awareness. Team SA, in turn, as described by Endsley (1995), is the degree to which every team member possesses the SA required for his or her responsibilities. Team SA can be viewed to be constructed via collaboration, communication and co-operation between team members, and it also requires 'shared mental models' (Salmon, Stanton, Walker & Jenkins, 2009), that is, organized bodies of knowledge that enable members to anticipate each other's actions and to perform functions from a common frame of reference (Cannon-Bowers, Salas & Converse, 1993). All this seems theoretically coherent but blind spots in the literature

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have also been suggested. Salmon et al. (2009, p. 24) write in their review of the literature that '[i]t seems logical to assume that an increased level of teamwork will lead to enhanced levels of team SA; however the specific relationship between team behaviours and attributes and team SA remains largely unexplained'. Collaborative making of shared/team SA has been addressed with varying abstract models in which interaction and collaboration between team members is a central variable (Salmon et al., 2009), but it is this interaction that demands further elaboration.

This assumption of deficiency in the literature, however, can partly stem from lack of sufficient synthesis between study lines. A number of studies exist that have drawn from ethnography, ethnomethodology and conversation analysis to explore interaction and use of tools (Heath & Luff, 2000). Studies of this type have addressed the issue of collaborative sense making of situations. For example, in a study of a London Underground line control room it was found that workers rarely provide explicit information to each other. Instead, they monitor each other 'peripherally' and make their own activities visible for others with subtle gestures and glances directed toward the tools used and by talking 'to oneself' (Heath & Luff, 2000, pp. 88–124). Similar reciprocal monitoring has been found in dispatch centres (Whalen & Zimmerman, 2005) and air traffic control (Harper & Hughes, 1993; Mackay, 1999).

The approach of our study parallels with ethnomethodological / conversation analytical workplace studies in applying a naturalistic analysis of activity. Workplace studies or 'situated action models', as studies of this type have been dubbed elsewhere (Nardi, 1992), however, are *not* concerned with 'meanings' attached to activity (Heath & Luff, 2000, p. 18). In contrast, we infer how courses of activity relate to and produce an actor's understanding of a situation. Theoretical basis for this approach is explained in the following.

Semiotic analysis of activity that creates situation awareness

According to the philosopher Charles Sanders Peirce (1998), people connect themselves to the possibilities of the environment through continuous perception-action cycles. To explain this, one may first consider the three linked elements in Peirce's analysis of signs, or, semiotics. First comes the *sign*, which can be considered the physical or 'vehicular' element needed for conveying meaning, for example, an image or a sound (e.g., smoke as a sign for fire). The *object*, in turn, is what the sign refers to; the fire that is signified by smoke. The sign/object (e.g., ink/letter) relation would not exist, however, without the third essential element, the *interpretant*: it can be thought to refer to understanding of the sign (Atkin, 2010). Let us take an example from the field of control centre work. A 'sign' could be a beeping sound and the 'object' related to this sound could be an alarm if noticed by an interpreter, such as, a control centre worker. Two points should be emphasised here. First is the relation between the interpretant and object. There are, of course, different kinds of interpretants or manners of comprehensions and therefore different kinds of objects. One operator might perceive the same sound as something alarmingly grave while another might perceive it as a simple glitch, which does not require much further action; in any case, the reaction would depend on operator's perception of the reality. The second point to be emphasised is the 'cyclic' and social aspect of Peirce's model: each action attached to an interpretant (e.g., a reaction to the alarm sound) can be seen as a sign/object if perceived by, say, another worker within the control centre. A reaction to an alarm by a worker would, indeed, influence the actions of other workers. These actions would then serve as further signs/objects and the perception-action cycle continues in the social environment of the control room. Figure 1 illustrates Peirce's model and the example above.

As implied in the example above, one may see that analysing these perception-action cycles has clear potential for inferring how SA develops within a work team. It progresses as linked actions and perceptions take place: an alarm sound first signifies one thing, and then, as displays are observed and calls are made, along with short verbal exchanges within the team, SA gradually builds up and is maintained.

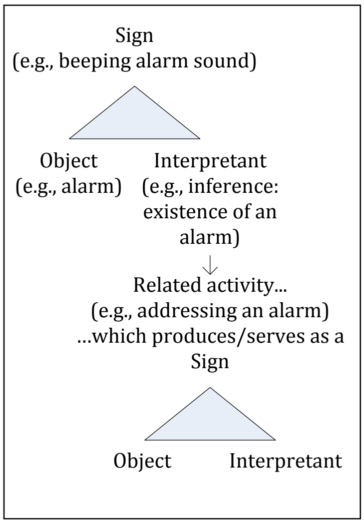

Figure 1. Illustration of Peirce's model

There is a myriad of ways to conduct semiotic analysis: the connections between signs, objects and interpretants can be examined in practically any given way. The approach adopted in this study draws from Norros's (2005; Savioja, Norros, Salo & Aaltonen, forthcoming) semiotic analysis of work. For Norros, 'action', what a worker does, is both a reflection of interpretant (worker's understandings and style of interpreting things) and a sign (especially for the other workers) and therefore a central point of analysis. Additionally, she argues that semiotic analysis of work activity should be preceded by a 'core-task analysis', that is, analysis of the essential content of the work activity: the aims, meanings and challenges of work. It is assumed that the major determinant of activity is its purpose, and therefore, it should be the major element considered by researchers of work activity. Referring to the cultural-historical theory of activity (Leont'ev, 1978), she also emphasises that these objectives should be understood in their social-historical context: people's actions reflect identities, hierarchies and organisational aims. These ideas are in line with Peirce's ideas on the analysis of signs: without understanding those who interpret (and their goals) it is impossible to understand signs/objects and consequent actions. The bottom line here is that researchers should become knowledgeable of the relevant particularities of a certain work context, such as, terminology, goals, tools, formal hierarchy and procedures if they are to do semiotic analysis on work activity.

In principle, the semiotic model has potential to complement work place studies (Heath & Luff, 2000) or situated action models (Nardi, 1992) by emphasising the element of 'meaning' in the analysis of interaction, this being an issue, which practitioners of these models de-emphasize. On the other hand, Peirce's model is perfectly compatible with the concepts of 'macro-cognition' (Schraagen, Militello, Ormerod & Lipshitz, 2008) and 'distributed cognition' (Hutchins, 1995), which are also popular among those studying real-life work contexts; these concepts emphasise the union of thinking and environment and imply the analysis of group efforts, culture and tools in examining how people accomplish cognitive tasks in naturalistic settings. Sign/object/interpretant-triad suggests unison between cognition and environment.

In the approach taken by this paper SA is central in the semiotic analysis of work activity: it is both a motive explaining activity (achieving SA is a goal) and a 'sign/object/interpretant' (that is, understanding of certain signs) needed for activity. Arguably, this approach addresses the challenge, identified by Salmon et al. (2009), of linking SA with actual team behaviour and team attributes.

THE SETTING

To understand the domain of metro operation and its traffic control work, several interviews were conducted before the actual accident rehearsal was studied. While a detailed analysis of the Helsinki Metro and its challenges have been presented elsewhere by us (Karvonen, Aaltonen, Wahlström, Salo, Savioja & Norros, 2011), in the following we depict shortly the accident rehearsal scheme and the traffic control room.

Accident rehearsal

In October 2009, a major rehearsal was organised in the Helsinki Metro. In the rehearsal scenario, due to construction work, metro trains coming from east to west have to be guided exceptionally to the south rail instead of the typical north rail; the metro system entails only a single forked line. In one of the metro stations near the city centre, called Hakaniemi, there is a long railway turning point, which can be driven with the speed of 60km/h (37.3mph). The accident train departs from Hakaniemi station and accelerates into the turning point with too much speed. This causes the train to derail and crash to the tunnel wall. Thirty of the passengers are injured. Finally, after the crash, a fire breaks out with large amounts of smoke filling the tunnel. In reality, the accident rehearsal train was simply stopped on the rails, and smoke was generated with smoke machines.

The rehearsal started at 00:30 (i.e., after the end of actual metro operation) and lasted for one and a half hours. In the rehearsal scenario story, the accident took place at 23:00, when the metro traffic is still operative. The passengers recruited for the accident train were actors, each playing their own assigned role in the scene of the accident (e.g., those without proficiency in Finnish, unconscious, disabled, in a wheel chair, under the influence of alcohol, etc.). According to the Helsinki Metro organisation, the accident rehearsal was the biggest in the history of the organisation. The goal of the rehearsal was to practice metro rescue tasks and co-operation between different actors during a major accident.

Traffic control room

During the accident rehearsal, the control room personnel consisted of a team that would have also been normally on shift at that time. The team included the following workers:

- Traffic Controller 1 (TC1), responsible for traffic control, also during the accident rehearsal;
- Traffic Controller 2 (TC2), responsible for traffic control, during the rehearsal responsible for taking care of the accident train;
- Traffic 1 (T1), otherwise a regular traffic controller, but during an accident is being called 'Traffic 1' and is responsible for taking care of the accident train's driver at the scene of the accident;
- Technical Controller (TeC), responsible for the technical control of the metro system's equipment (e.g., electricity control); during accidents it his/her responsibility to contact the emergency response centre.

Normally, traffic controllers' tasks include starting the traffic, inserting schedules, taking care that the drivers are in the right trains and securing that the rails are in order for the trains. More minor tasks include keeping a record on how long distances the trains have travelled, making passenger announcements, observing the platforms through CCTVs, instructing the train drivers and sending help to the field if necessary. Regular traffic controller work has been portrayed in previous publications (Heath and Luff, 2000; Smith et al., 2009; Theureau and Filippi, 2000). The main responsibilities of a technical controller, in turn, include electricity,

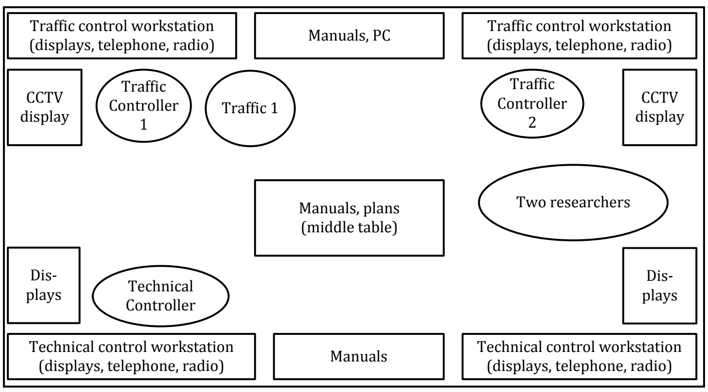

Figure 2. The control centre setting during the accident rehearsal

escalator and air conditioning management, and monitoring of devices. Figure 2 portrays the seating locations of the team during the accident rehearsal. The traffic controllers had workstations in the two corners of a large U-shaped table while TeC sat at another similar table. T1 sat next to TC1 when the accident rehearsal started. Two researchers were located next to a table between the U-shaped tables.

Traffic controllers' main tools include telephones, radio phones, platform announcement equipment, different manuals and check-up lists, CCTV camera monitors and their controllers, interlocking system's displays and controllers, and a general overview display of the traffic situation from which one can see where each train is located. TeC's main tools include electricity management displays, tunnel air flow monitoring system, telephones and radio phones.

OBSERVATION STUDY

Data collection

The metro control centre work was observed by two researchers while a third researcher observed the accident site (they were the authors of this paper). Three cameras were used for the control room observation. A stationed camera focused on TC2 during the whole rehearsal. Second camera was stationed to the middle of the room; it was vertically rotatable and focused mainly on the traffic controllers. The third camera was hand-held, focusing on where was deemed to be most activity. The recording started several minutes before the rehearsal; the whole rehearsal was video recorded. The length of the rehearsal was one hour and 15 minutes when calculated from the first communication of the accident to the end of the rehearsal.

Analysis

The aims of analysis were, first, to document and depict direct observations of the interactions and other meaningful events during the accident rehearsal. We also wanted to interpret why each course of action took place, that is, what kind of 'interpretant' or 'meaning' could be explicative of an action. Additionally, and also drawing from the idea of 'meaning/action'-cycles discussed above, we wanted to see how the interactions are interconnected: who interacts with whom and how these interactions promote situation awareness. Finally, the aim was to give some development recommendations for the transport company.

The analysis progressed in three phases. First, the video recording was transcribed: we wrote down what was said by whom and when during the accident rehearsal. Second, the transcribed data was categorised into 'events' in sequential order; an event refers here to a short reaction or period of activity by an individual (or by any agent, including non-human). For example, a question or request can be considered an event. Second, these events were listed to a spreadsheet for further annotation. In line with the aims of the analysis, this annotation included the following: 1) short paraphrasing of the content of the event (e.g., shortly the main content of said things), 2) the source of event data or the 'sign source'; this included both the device and/or the individual through which the event manifested, and 3) a short interpretation of the action was marked down; the assumed reason for the event was inferred here. After this, 4) the emerging situation awareness – produced by the event – was inferred and marked down. Finally, 5) the rightmost column of the spreadsheet was reserved for intuitive notes on anything that might make the analysis useful in practice. The video data was examined recurringly when these annotations were made.

After watching the whole video for several times, this detailed analysis was done for two crucial episodes in the making of SA. First, we wanted to study the first moments during which SA was construed within the control centre team. The question here was what was needed to be done prior calling the regional emergency centre. Second crucial episode, which immediately followed the first one, was making this call. Interactions took place while help was alarmed. We distinguish these two episodes because they entail different vantage point to the question of SA: in the first one it is examined how SA is produced within the control centre while the second was about 'transferring' SA for the regional emergency centre. Altogether, the detailed analysis was done to two minutes of the observation material.

The analysis method draws from a study by Norros, Hutton, Liinasuo, Määttä, Tukeva and Immonen (2009): the aim is to identify and name the relevant elements in chains of communication (activities, understandings and tools in particular). The method version of our study, however, provides a more refined presentation of the events during which SA is created by a work team.

Results

Table 1 portrays analysis of the first 50 seconds during which the view of the accident situation progressed within the control centre team. The first event and 'second count' starts from the moment where a radiophone alarm sound is addressed by TC2. The last event (no. 16), in turn, indicates the point in which the emergency response services are called. Overall, Table 1 portrays how situation awareness gradually builds up in interactions. Information first diffuses from the metro driver to TC2 (no. 2) who then repeats driver's utterances (no. 3). Although driver's voice is in principle audible for the whole team through a loudspeaker, it is quite possible that TC2's repetition serves as an 'outloud' further disseminating the message. They are short shouts of information that are not directed to any specific person. Previous studies report their use for construction of SA in control centres (Wahlström, Salovaara, Salo & Oulasvirta, 2011), and making an outloud can be considered more efficient than addressing a colleague because they allow that colleagues do not have to interrupt their tasks to deliver a response (Heath et al., 1993). Repeating out loud information that comes via radio arguably also serves the purpose of certainty: when the main content is repeated there is little chance for misinterpretation. This is necessary especially when understanding the message cannot be confirmed with body language, such as with affirmative nods. Both TC2 (no. 3) and the metro driver (nos. 5, 10, 15) repeat each other. In one occasion, the driver actually repeats himself, informing twice that he/she is hurt (compare nos. 2 and 10); this is perhaps a response to the lack of repetition by TC2, as this piece of information remains unrepeated by him/her (in no. 3).

Table 1. Events at traffic control room prior calling the emergency response centre (Episode 1)

No.	Time	Direct observation / *'sign'*	Sign source	Action (who involved) / *'interpretant'*	View of situation (among different actors) / *'object'*	Notes
1	0 seconds	Alarm sound rings	Alarm sound of a communication radio	Answering the radio call (TC2)	Something is wrong; someone wants to be in contact	
2	1–8s	Driver (D) (loudspeaker): train fell off the track, leaning against the wall, minor injury,	Driver / radio loudspeaker	Informing about the accident (D -> TC2)	train off the track, leaning against the wall, driver having minor injury	redundancy
3	8–11s	TC2 (shouts): train off the track	Traffic Controller 2	Outloud / repetition (TC2, D, whole control room)	[as above]	redundancy
4	12–16s	T1 (shouts): *cut the electricity between Hakaniemi and Kaisaniemi*	Traffic 1 / traffic control display	Request to Technical Controller (T1 -> TeC)	[as above] + approximate location of the derailed train + electricity will be cut	
5	12–16s	D (loudspeaker): *train derailed after Hakaniemi*	Driver / radio loudspeaker	Adding location information (D -> TC2)	[as above] + more detailed location of the derailed train	redundancy
6	15–16s	TeC: *should we call?*	Technical Controller	Asks from about calling to emergency response (TeC -> T1)	[as above]	questions 1
7	16–18s	T1: *call emergency services*	Traffic 1	Confirmation on calling ES (T1 -> TeC)	[as above] + help will be called	response 1
8	18–27s	TC2: *turning voltages down and sending help*	Traffic Controller 2	Informing the driver (TC2 -> D)	[as above] [now also for the driver]	
9	20–21s	TeC: *where is it exactly?*	Technical Controller	Asks about exact location (TeC -> T1)	[as above]	question 2
10	27–32s	D (loudspeaker): help is coming and I am hurt myself too	Driver / radio loudspeaker	Repeats what is known (D -> TC2)	[as above]	redundancy
11	27–30s	T1: *between switches A4-B4*	Traffic 1 / traffic control display	Response to question (T1->TeC)	[as above] + more exact location	response 2
12	32–34s	TeC: *it is both sides* [of the track]*?*	Technical Controller	Additional question on location (TeC-> T1)	[as above]	questions 3
13	34–40s	TC2: *can you inform the passengers on what has happened and not to leave the train?*	Traffic Controller 2	Gives guidance to the driver (TC2 -> D)	[as above]	guidance
14	34–37s	T1: both sides, at the switch	Traffic 1	Answers question (T1 -> TeC)	[as above]	response 3
15	40–45s	D (loudspeaker): *informing passengers and now smoke is coming from the train*	Driver / radio loudspeaker	Repeats and delivers more information (D -> TC2)	[as above] + smoke is coming from the train	redundancy
16	46–50s	TeC: this is a rehearsal call	Technical Controller / telephone	Calls the emergency response (TeC)	[as above]	

Alongside the interaction between the driver and TC2, a parallel exchange took place between T1 and TeC. It is TeC's responsibility to call the emergency response services but prior doing this a short series of questions and answers were made (Table 1, nos. 6 and 7; 9 and 11; 12 and 14). TeC does not have the means to gather the information required via his/her own workstation; therefore, s/he consults T1 who checks the needed information from the screens of TC1.

TeC's need for making questions to interact with the emergency response is visible also in Table 2. This table is a more reduced presentation of the events in the control centre than Table 1 since it only entails the interactions made by TeC during the emergency call; there were other interactions taking place as well, but they are not presented here for the purpose of clarity and simplification. In the beginning of the emergency call TeC explains the basic information about the situation (Table 2, no. 1); then repeats and further specifies the situation (no. 2). Questions are made for TC2 (nos. 3 and 4; 7 and 8).

Overall, the development of situation awareness and transferring it to the emergency response was a joint effort. Explicative of these interactions is the division of tasks between traffic controllers and TeC: the latter makes the emergency call while traffic controllers interact with metro drivers. Information reaches the emergency centre indirectly through exchanges involving the driver, traffic controllers and TeC.

The concepts 'sign', 'interpretant' and 'object' are marked on the tables to clarify the way in which Peirce's model is visible beneath our analysis. 'Sign' corresponds roughly with direct observations. While the 'vehicular' sign element of interaction is, in principle, directly visible, the workers' view of situation and related actions are the two interrelated elements that require interpretation during the analysis. The column 'Action', which is to describe the event and to grasp the basic reason of activity, reflects the 'interpretant' concept because assumedly people's actions and inferences are closely interrelated. On the other hand, the concept 'object' is needed here to represent the 'representational' content 'produced' in people's inferences and activity: see the column 'View of situation'. Each row in the tables corresponds to a sign/object/interpretant-triangle plus related action combination as presented on Figure 1. Actually, the example given in Figure 1 parallels with the event no. 1 on Table 1.

Table 2. Interactions of Technical Controller during an emergency call (Episode 2)

No.	Time	Direct observation / *'sign'*	Sign source	Action (who involved) / *'interpretant'*	View of situation (as shared with the emergency centre) / *'object'*	Notes
1	0m 46s – 1m 03s	TeC (speaks to phone): this is a rehearsal call, we have a train from Kaisaniemi to Hakaniemi and the driver let us know that the train has been derailed at the switch,	Technical Controller / telephone	Calls the emergency response centre (ERC) (TeC -> ERC)	train off the track, train location	
2	1m 05–35s	TeC (speaks to phone): yes towards Kaisaniemi, that is, the train is in the tunnel, the driver himself is hurt at least and there are passenger on board, and yes we have turned down electricity from both sides	Technical Controller / telephone	Repeats and explains further for emergency response centre (TeC -> ERC)	[as above] + more about train location, injured driver, possibly injured passengers, electricity has been cut from the track	specification
3	1m 39–42s	TeC (shouts): wait a second, how many train cars do they have	Technical Controller	Asks information on emergency response's behalf (TeC -> TC2)	[as above]	question 1
4	1m 42–44s	TC2: one train car pair, that is, two train cars	Traffic Controller 2	Answers the question (TC2 -> TeC)	[as above]	response 1
5	1m 44–46s	TeC (speaks to phone): two train cars, that is, one train car pair	Tech Controller / telephone	Provides requested information the for emergency response centre (TeC -> ERC)	[as above] + the amount of trains	
6	1m 46–47s	TC2: one train car pair	Traffic Controller 2	Repeats what has been said (TC2 -> TeC)	[as above]	redundancy
7	1m 53–55s	TeC: are there any signs of smoke	Technical Controller	Asks information on emergency response's behalf (TeC -> TC2)	[as above]	question 2
8	1m 55–56s	TC2: there is smoke in the train	Traffic Controller 2	Answers the question (TC2 -> TeC)	[as above]	response 2
9	1m 56–57s	TeC (speaks to phone): *yes there is smoke*	Technical Controller / telephone	Provides requested information for emergency response centre (TeC -> ERC)	[as above] + there are signs of smoke	

Practical implications

It is arguably a good practice to repeat information in safety critical communication. This redundancy (see 'notes' in Table 1 and 2) is likely to provide robust or fault-free communication. In contrast, the fact that information is mediated through several actors might cause mistakes. The information content might vary as it passes through different individuals; think of a game of Chinese whispers. Further, one may question the efficiency of mediated communication. For example, in this case, it took a minute and twenty seconds for the information on smoke to reach the emergency response (from event no. 15 in Table 1 to event no. 9 in Table 2).

For streamlining the flow of communication, one may first consider a change in responsibilities. The call to emergency response could have been done by the driver himself or by TC2. These options have their disadvantages, however. The driver might be seriously injured or not to have all the information needed. TC2 could make the call but then s/he would have two parallel tasks: 1) to give guidance for the driver (see Table 1 no. 13) and to talk with the response services. Further, there are pieces of information that can be accessed only by TeC. The emergency response might be interested on issues that are in TeC's domain, such as, tunnel wind flow directions and electricity being switched on or off in different areas and equipment. Later in the video data, a worker of rescue services, an incident commander, arrives to the control centre room and discussion takes place between him and TeC. They have to be sure, for example, that smoke is not killing the rescuers; this depends on air flow directions in the tunnel. In other words, there are good reasons as to why TeC is the connection point between the emergency response and the metro control.

A solution, however, might be a big shared screen with all the most important pieces of information, such as trains' locations and statuses. TeC would hence have much of the same information as traffic controllers. As this screen would be shared by all, it might also facilitate the discussion on the actualities at the metro track. A previous study reports the use of a screen of this kind in a rally control centre (Wahlström et al., 2011).

Even more technologically advanced possibilities can be imagined: the traffic control screen might be shared directly between the metro control centre and the emergency response; hence, the control centre workers could explain the situation with the help of a shared visual presentation. This might be beneficial since the discussion between the emergency response and TeC took quite long; TeC had to repeat and specify information (see Table 2, event no. 2). Further, it might be beneficial for TeC to have a predefined list of the issues that the emergency response needs to know; s/he could provide all the necessary information directly and not after inquiries made by the emergency response (see Table 2, no. 7). Also, given that TeC has to discuss with the traffic controllers, the physical seating arrangement is not optimal; the workers had to make 180° turns for interacting with one another. In any case, it would be better if the seating order promotes rather than hinders communication.

DISCUSSION

This study would have been a somewhat different if we would have applied 'situated action models' (Nardi, 1992) or 'workplace studies' (Heath & Luff, 2000) instead of the semiotic model of work activity. While those 'conversation analytical' methods aim to describe specific (and often very short) events in exact detail (featuring, e.g., intonations and lengths of pauses between words), the method used in this study featured somewhat less precise descriptions of 'functionally relevant episodes', that is, episodes in which certain function or task is accomplished by a work team. Arguably, the analysis method used in this study is more readily adoptable for those with practical rather than academic aims when compared to situated action models. It seems that conversation analytical workplace studies serve as an antithesis to 'individual centred' or 'cognitively orientated' human-computer interaction studies: by pointing out the collaborative nature of actual work practices one may, indeed, criticise 'the conventional wisdom of HCI which places the single user and their cognitive capabilities at the centre of the analytic domain' (Heath & Luff, 2000, p. 122). One may, however, also argue that cognitive concepts such as 'situation awareness' are intuitive (because people commonly use these concepts) and therefore they allow to present information in a readily understandable manner; this is exemplified by the two tables of this study showing how 'situation awareness' progresses with respect to time and activity. Avoiding the use of cognitive concepts can thus be problematic in practical terms. Conversation analytical findings are burdensome for the reader, which limits their practical usefulness.

Theoretically, in turn, a 'non-cognitive' (Heath & Luff, 2000, p. 18) approach to interaction is insufficient as some meanings, of course, underlie any human activity. Hence, interaction analysts should adopt a theoretical approach that takes into consideration the operative connection between individual perception, action and environment. Peirce's triadic model is applicable here; it enables to analyse the joint creation of meaning of a situation. Overall, although Salmon et al. (2009) are not entirely correct in their suggestion that relationship between team behaviours and SA remains unexplored – situated action models have addressed this issue – it is still justified to seek for new models and methods addressing the link between behaviour and situation awareness, as was done in this paper.

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