Knowledge Elicitation in Naturalistic Decision Making: Collegial Verbalisation with "Conspective Protocols"

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ABSTRACT
For knowledge elicitation in work environments where participants are highly experienced, there exist two established verbalisation protocols – concurrent and retrospective – both of which are associated with methodological and practical issues. A third protocol – "conspective" verbalisation – and its theoretical background are presented together with Collegial Verbalisation (CV), a method that synthesises the use of the protocols into a cohesive methodological framework. Results from use of the CV method in three domains are presented. The method contributes to the unravelling of mental strategies and an enhanced understanding of naturalistic decision making tasks. Independent observers comment in the form of conspective protocols on the behaviour of target participants. It solves some of the problems with the established verbalisation protocols. Analyses of the protocols show the importance of regularities and environmental constraints in the organisation of decision making activities in as diverse domains as train traffic control, high-speed ferry operation, and train driving.

KEYWORDS
Decision making; Expertise; Transportation; Knowledge elicitation; Verbalisation

INTRODUCTION

Research conducted in the field of naturalistic decision making aims for careful understanding of how professional decision makers think and act in their specific work environments. One common goal is to account for the decision makers' acquired experiences while they perform different decision tasks. From an analysis point of view, this means that it is not enough to understand *why* people behave the way they do, or *what* they do in each situation, but also *how* they accomplish the activities associated with a certain decision task. Analyses of how activities are accomplished can be carried out through a strategies analysis, with a focus on mental activities, either in the form of categorised cognitive processes (Rasmussen, Pejtersen, & Goodstein, 1994), task procedures (Vicente, 1999), as sequences of mental and effector operations (Payne, Bettman, & Johnson, 1993), as task performance approaches distinguished by costs and benefits (Hassall & Sanderson, 2014) or adaptive heuristics for dealing with dynamics (Brehmer, 1990; Jansson, 1995). In all cases, some form of knowledge elicitation is necessary.

For the purpose of knowledge elicitation in naturalistic work situations, there are several methods available. Among them are different types of verbalisation methods. Traditionally, verbal reporting is carried out through concurrent or retrospective verbalisation protocols. Both these established protocols are associated with a specific methodological challenge: there is no necessary correlation between the mental behaviour responsible for the actions taken in a certain decision task and the mental behaviour behind the verbal reports about the same actions (Bainbridge, 1979/1999), this means that there is no guarantee that what is verbalised is an actual account of the mental processes involved in the performance of the decision maker. Historically, there were strong doubts about verbalisations as data because of this vagueness about the validity of the verbal protocols. These doubts came to an end however with the seminal work by Ericsson and Simon (1980, 1984) when they were able to support their claim for verbal reports as data with a strong theoretical model and concurrent verbalisations in the form of think-aloud protocols. There is however another issue with concurrent verbalisation procedures: they may jeopardise the representativeness of the decision task due to the fact that the work task is disrupted with the additional task of verbalising (e.g. Ericsson & Simon, 1980, 1984; Ericsson & Crutcher, 1991; Bartl & Dörner, 1998; Dickson, McLennan, & Omodei, 2000). This can have severe consequences in naturalistic decision investigations because the participants cannot prioritise verbalisations without changing the way they think and act (Dickson et al., 2000). Furthermore, it is often difficult to verbalise skill-related knowledge during task completion because much of the knowledge is tacit (Polanyi, 1967). Regarding retrospective verbalisations, the challenges are even bigger. Firstly, one can expect that time delays will affect the remembering of the control actions negatively since the mental behaviours corresponding to these measures will decay from working memory (Gibbons, 1983; Ericsson & Simon,

1984). Secondly, verbalisers often focus on problems closer at hand and thus infrequent problems might be overlooked (Wright & Ayton, 1987). Thirdly, since there is no way to separate the mental behaviour responsible for the non-observable actions taken and the mental behaviours responsible for the verbal reporting, we cannot learn from empirical data if a decision maker carrying out a verbalisation retrospectively is rationalising his or her behaviour (van Someren, Barnard, & Sandberg, 1994; Bainbridge, 1979/1999).

As a reaction to these challenges, a number of studies have explored different procedures of having others verbalise the actions of target users by, for example, letting colleagues or domain experts verbalise rather than users themselves (e.g. Dominguez, Flach, McDermott, McKellar, & Dunn, 2004; Miller, Patterson, & Woods, 2006; McIlroy & Stanton, 2011; Jansson, Erlandsson, & Axelsson, 2015). The rationale behind the aim of having an independent observer verbalise instead of the target user is to avoid the privacy problem (Bainbridge, 1979/1999) since this is a critical source to the issues discussed above. So far, it has however been little or no progress on theoretical explanations motivating the use of independent observers verbalising the actions of target participants. However, recently Jansson et al. (2015) provided a theoretical model motivating the use of the Collegial Verbalisation (CV) method, including a "conspective" verbal protocol. We have termed this form of verbalisation "conspective" due to the fact that the verbaliser is *observing* whilst thinking aloud. This distinction is important because this verbalisation can be performed both in real-time or with recorded material. The new protocol fits neither under concurrent verbal protocol since the verbaliser is not performing the work task, only observing it, nor under the retrospective verbal protocol since the verbaliser is seeing the events unravel for the first time.

The rationale behind concurrent, retrospective, and conspective verbal protocols is roughly similar: to extract data about mental behaviour associated with domain specific decision making behaviour and performance. The CV method suggests investigators to video record target operators performing work. The critical part of the method is the conspective verbalisation where colleagues of the target users verbalise on the recorded material. In conjunction with the conspective protocol, an investigator can choose to use (1) a concurrent protocol during recording of the target operator, (2) a retrospective protocol with the target operator, or (3) may choose to use both. Our objective here is to argue for the usefulness and value of this method for the purpose of knowledge elicitation in naturalistic decisions, emphasizing the role of long-term memory knowledge structures.

The Model Behind the Method – Theoretical Motivation

The established verbal protocol methods suffer from methodological issues which originate from the problem of verification of the validity and reliability of verbal reports. Introducing an independent narrator as a verbaliser on user actions will solve some of these problems. This has been recognised by previous authors where domain experts have been employed to verbalise on students or practitioners (Miller et al., 2006), or on other experts (Dominguez et al., 2004; McIlroy & Stanton, 2011). The CV method has similarities in procedure to the stimulated recall interview (Calderhead, 1981), however, CV is thought of as a verbalisation procedure utilising two or three data generation points. In using the CV method, it is important to notice that both the verbalising target operators and their colleagues are instructed to think-aloud without interrupting them with remarks for interpretations or clarifications. They should be exposed as closely as possible to the same control task procedure. Secondly, one assumption behind the CV method is that environmental constraints will affect the behaviour of experienced target operators and make it possible for likewise experienced colleagues to utilise the effect of these constraints when

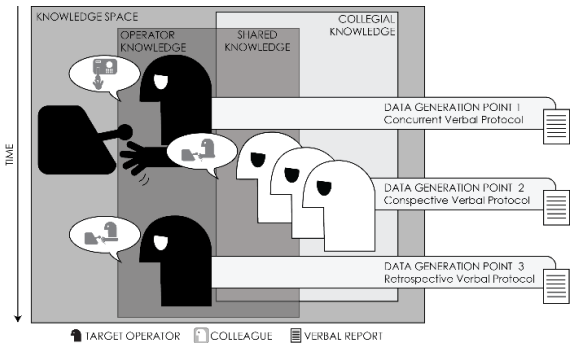

Figure 1. The Collegial Verbalisation method (repinted with permission from Jansson et al. 2015)

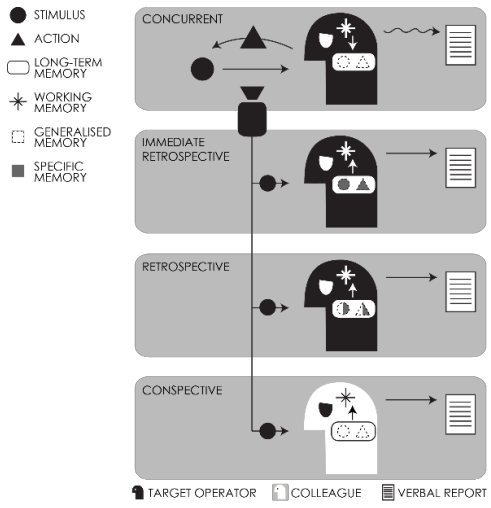

Figure 2. Verbal protocols in relation to time and familiarity (repinted with permission from Jansson et al. 2015)

they verbalise on the behaviour of their fellow operators. The critical part of the CV method is thus the conspective protocol, not its retrospective counterpart.

Collegial Verbalisation and Conspective Protocols

The CV model consists of three data generation points, one first point for data generation by a target operator (Data Generation Point 1), a second point for data generation by a colleague (Data Generation Point 2), and a third point for data generation retrospectively by the target operator (Data Generation Point 3). The three data generation points are referred to as Concurrent, Conspective, and Retrospective Verbalisation respectively (Figure 1). The first and second data generation points are independent of each other in the sense that at least two different narrators are involved. The same goes for the second and the third data generation points. The separation of data generation points is seen as the unique contribution of the CV method. However, a verbal protocol from any of the data generation points is not independent of the domain-specific task knowledge with which it is concerned. On the contrary, the content of the verbal reports is of central concern. Without reference to content, conspective protocols would be useless and the CV method meaningless. The consequence of this is that the method is restricted to research settings where the researcher has access to domain-specific knowledge in terms of expertise in the form of skill developed in relation to a specific task. Data generation is also, of course, limited by the number of operators or colleagues that can participate.

Even though the narrators participating are independent of each other at the data-generation points, they share experiences from the same environment, which means that their verbal reports will reflect these joint and common experiences. Here, it is interesting to note that Nisbett and Wilson (1977, p. 257) in their often cited review of verbalisation methods concluded that "[i]t is frightening to believe that one has no more certain knowledge of the working of one's own mind than would an outsider with intimate knowledge of one's history and of the stimuli present at the time the cognitive process occurred". We argue that Nisbett and Wilson (1977), perhaps accidently, pointed to two important aspects with their remark: (1) in everyday situations, verbalisations often reflect the use of both working memory and long-term memory in conjunction; and (2) even though it can be hard to accept that an outsider who knows oneself well can predict one's behaviour, this points to the possibility of having other people verbalising the actions of oneself. In environments where domain knowledge is shared between close colleagues, we might find that they also share cognitive strategies.

Figure 2 shows the relation between the three protocols when the retrospective protocol is divided into two phases, immediate retrospective and retrospective protocols, respectively. This organisation of the three protocols into four phases emphasise memory decay over time as the factor that ties the protocols together in a synthesised framework. As can be realised from the figure, a protocol based on immediate retrospective verbalisation is closer to protocols based on concurrent verbalisations, whilst protocols based on retrospective verbalisation distant in time from the target activity is closer to conspective protocols. The rationale for organising verbalisation protocols into these four phases is to show the importance and the role of long-term memory structures in domain-specific knowledge, and that knowledge elicitation using highly experienced decision-makers cannot ignore these long-term memory structures if the researchers' goal is to account for the decision makers' experiences when trying to understand their decision making behaviours.

EMPIRICAL FINDINGS

Below, the application of the CV method and the associated conspective protocol are described through three field studies, all of which had the same purpose: to understand in detail the behaviour and actions, including the mental behaviour, of the participating professional decision makers as a basis for suggestions for improved systems design. The procedures for implementing and using the conspective protocols and the CV method in the three different domains are briefly described. Details on the design of the individual studies can be found in Jansson, Olsson and Erlandsson (2006), Erlandsson and Jansson (2007, 2013), and the successive development of the method has been described in Jansson et al. (2015). The method was used differently in the three domains. Practical circumstances determined the number of participants available, both as target participants and as colleagues, as well as the design of the studies. The first two studies focused on the content of the verbal reports, in particular the conspective protocols in comparison with concurrent protocols, whereas the last study focused on the comparison between conspective and retrospective protocols from a methodological perspective. In all three studies, the colleagues were asked to describe what they believed the target operator in the recorded incident was paying attention to and taking meaning from, but not to imagine themselves being in the situation.

A Field-Study of Train Drivers

Method

Video recording sessions were conducted with six different professional train drivers while driving along four different types of real-schedule routes, such as long-distance routes, commuter traffic, and so forth. Three different video cameras were used to capture the driver, the instrumentation, and the signals along the tracks. They were asked to think aloud while they were driving. Seven other professional train drivers then individually performed conspective verbalisation while watching these video recordings. The recordings were muted so that they could

not hear the target driver's comments. This conspective procedure was also recorded. The protocols allowed for comparisons in-between the colleagues as well as between colleagues and target drivers.

Table 1. Examples of mental actions in train driving identified with the help of 'conspective' protocols

Non-observable actions		
Leaving a station	**Out on the route**	**Approaching a station**
Judging time available and preparing to get away quickly to save time	Judging speed ahead in order to avoid second level warnings and/or automatic braking	Calculating braking power and braking distance to end up at the right place at the platform
Calculating power needed to leave station smoothly	Judging time available to manage to be in time	Preparing the entering of the station, attention directed towards platform and signals for switches

Results

Analyses of the conspective protocols showed that the drivers use information from the signal system and the instrumentation in the cab, to a large extent they also use information from the surroundings near the track. For example, the colleagues noted that the target drivers were checking for particular signs along the track, for reference points in the surroundings on when to apply the brakes, focusing attention on people on platforms, preparing for and expecting certain braking capacity and so forth. All these behaviours are difficult for a lay person to detect and understand. With conspective protocols it was possible to understand that these non-observable behaviours are important in the train-drivers' organisation of the decision making activities. Furthermore, the analysis of the train-drivers' behaviours showed that the task of driving a train can be divided into three phases. Out on the route, between two stations, the drivers focus their attention on the speed-limit so that they do not exceed the critical limits where the train brakes automatically. They also adjust the speed of the train, constantly weighting goals such as efficiency, safety, and comfort against each other, that is, the drivers use the difference between actual speed limit and braking speed limit to manage to keep up with the time table. When approaching a station, their focus shifts towards the surrounding environment and the braking conditions of the train at this particular station, for example they monitor the slope of the track, weather conditions and other aspects. Furthermore, they also prepare for things they cannot control themselves, such as people on the platform, trains coming the other way, or expected clear-signals through the switches. When leaving the station, the drivers focus on the possibilities to leave as quickly as possible since this is the part of the journey that is most time critical from a time-table perspective. If they, for example, lose time here it is often difficult to catch up later on, but if they get away quickly, they can have a smoother ride further down the trackway. Other important things noted during the conspective verbalisations were the calculation of how much power is needed to get away smoothly and being extra cautious with respect to passengers arriving late. The colleagues also noted that domain-specific knowledge (route-knowledge) is essential if one wants to reach the goals of driving smoothly and at the same time keep ahead with the time-table. Table 1 shows the mental behaviours identified with the help of conspective protocols (Jansson et al., 2006).

A Field Study of High-Speed Ferry Operation

Method

Four different video cameras were used to capture the crew, instrumentation, and the surroundings. Two officers, one captain, and one navigator participated as target officers on the bridge during this recording. Four colleague officers individually watched and verbalised on the actions and decisions made by the target officers in the video. This conspective procedure was also recorded, and the protocols from these sessions were then compared to examine to what extent the four colleagues agreed on observed behaviours. The protocols from the colleagues allowed for comparisons in-between the colleagues only, not between colleagues and target officers since concurrent verbalisation was not utilised due to risks of interference with procedures on the bridge.

Results

A detailed examination of the protocols revealed that there was a high degree of agreement between the colleagues on the main series of events. Many of the comments concerned non-observable actions and behaviours impossible for a lay person to understand completely or correctly. A comparison between the colleagues' conspective protocols showed that there is conformity among the officers in many situations. Some specific statements conflicted however between the protocols, indicating the possibility of maladaptive mental models within at least one of the colleagues since both colleagues' conceptions cannot be reconciled with reality at the same time. From the following statements, it is clear that the verbalising colleagues think and reason differently:

- [The action of verbally] handing over [between the bridge wing and the centre control] is very important. Everybody knows the procedure, but as long as I haven't said anything, I'm still responsible.
- Now, the control is transferred back [to the centre control]. If anything would fail, [the officer] would bring it up, but otherwise there is no need for any verbal hand over [procedure].

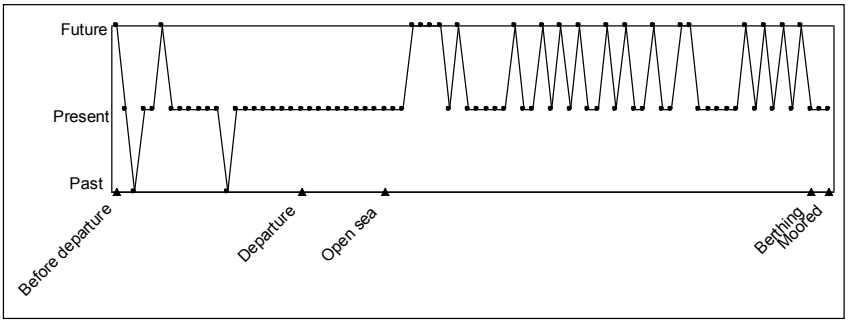

Figure 3. Past/present/future categories in a sequential order identified with conspective protocols. Each dot represents a verbal statement.

Moreover, the conspective protocols made it possible to categorise the sequential order of past/present/future events continuously discussed by officers on the bridge (Figure 3) revealing the importance of proactive decisions and historical events for present actions (Erlandsson & Jansson, 2007).

A Quasi-Experimental Field Study of Train Dispatchers

Method

A systematic comparison between conspective and retrospective verbalisation was made. Four train dispatchers were video recorded individually while working. These dispatchers then performed both a conspective and a retrospective verbalisation from these recordings in a quasi-experimental setup, that is, they verbalised on both their own actions and the actions of a colleague. It made it possible to compare conspective and retrospective protocols for the same events. In order to minimise the effect of remembering situation-specific details, there was a delay of a few weeks between the target situation and the verbalisations. By this procedure, the emphasis was on the comparison between long-term memory structures, assuming effects of recency to be under control.

Results

A comparison between the conspective and retrospective protocols was carried out on three different levels: (1) Protocol level – this is quantitative measure, showing the number of characters in the verbal protocols, measuring the amount of verbalisation activity going on during that sequence of verbalisation; (2) Statement level – this measure consists in number of assertions and utterances, measuring the amount of sentences and statements going on during the session; and (3) Topic level – this is a qualitative measure consisting in the amount of topics the participating dispatchers deal with during the session. As expected, there was a high degree of agreement on the protocol level between retrospective and conspective protocols, which means that the amount of text generated in the protocols varied as a consequence of the current activity. Also as expected, there was a very low degree of agreement on the statement level in that when the comparison is based on similarity in utterances and sentences, the conspective and retrospective protocols are very different. Finally, and most importantly, there was a high degree of agreement on the topic level between the retrospective and conspective protocols, that is, when statements were categorised into topics, the protocols covariate with the topics to a large degree. A Krippendorff's alpha reliability estimate showed a reliability coefficient of .8847, with a 95% confidence interval of .7912 – .9627 (Erlandsson & Jansson, 2013, p. 247).

Thus, the participating dispatchers seem to verbalise the same content to a large degree. This does not however necessarily mean that they interpret all specific actions in the same way. On the contrary, on some topics they have different explanations of whether the actions exhibited by the target operator are relevant behaviours in the particular situation or not. Table 2 shows an example where they agree on the content but disagree on the relevance of the actions. This information may be as important as any information showing the similarity between colleagues and target operators.

Table 2. Examples of statements where the colleague questions the actions of the practitioner (Erlandsson & Jansson, 2013)

Example	Retrospective	Colleague
#1	''Now I'm replanning some trains here. 537 are 7 min late''	''2135 were late, and 537. But now he is moving the wrong line for 537, but, yes also for 2135 perhaps. He is moving the departure, but they are also late on arrival to Katrineholm''
#2	''Yes, it says here, detected but not locked path for 2148. Since 2148 has a departure here, he cannot complete that, until there is a path through Åby''	''But he believes that he clicks on arrival, so now he does not understand why it says that 2148 are there. … As he clicks on departure, and that is a bit tricky, but he has to check this box in order to see the arrival condition''
#3	''I'm trying to move that rotation point down. I realise that they will be late''	''I'm not really getting why he moves this rotation point down here? That gave a speed of 50 km per h, having a 50-train from here to here. That is a bit unrealistic, unless he have gotten some information that they are driving without ATC, so that it becomes a 70-train''

DISCUSSION

Conspective protocols serve as a valuable complement to other information acquisition protocols in four different ways. First, it gives a lot more pieces of information than concurrent protocols do. Second, it specifically allows researchers to scrutinise the hypotheses on mental behaviours in naturalistic decision making tasks. Third, independent observers' verbalisations open up the possibility of having more participants verbalising on the same set of data. Finally, the introduction of independent observers also makes it possible to detect differences in understanding between target participants and colleagues.

It is only with the introduction of conspective protocols and the use of the synthesised CV method that it is possible to discriminate between different forms of understandings, something that can be critical in many domains, and an important input into future studies in the field of human factors. Since the colleagues in the high-speed ferry study were not present at the bridge when the target officers were running the craft, they, of course, cannot remember details from the particular situations. With the conspective verbalisation procedure, they rather recall similar situations in which they have been involved since the environmental constraints imposed on them in similar situations consist in regularities that are abiding. Erlandsson and Jansson (2007) concluded that the most controversial issue with the CV method and the conspective protocols is the idea of having other subjects than the target operators performing the verbalisations. With this approach, the colleagues have not been part of the target actions, and are therefore left with some form of recall when they verbalise. It is important to bear in mind, however, that the operators participating are highly familiar with the tasks, and that they all have long experiences with the same tasks and systems. Conspective verbalisation means a shift away from analysing working memory structures to analysing long-term memories. This also means different theoretical assumptions compared to more traditional forms of verbalisation tasks. Assuming that common experiences result in similar strategies for dealing with environmental constraints and regularities, multiple verbalisers constitute a possibility for field studies in the area naturalistic decision making. When data elicited through this protocol are in congruence with other protocols in the synthesised methodological framework, it is a valuable complement.

Knowledge elicitation in naturalistic decision making (Klein, Calderwood, & Clinton-Cirocco, 2010) as well as in dynamic decision making (Brehmer, 1992) demands new forms of verbalisation methods than existing models and methods (e.g., Ericsson, 2006). Concurrent verbalisation and think-aloud protocols may work well when it comes to chess players and math problems, or decision problems that are static or stationary, but expert performance in decision domains characterised by complexity, ill-structured problems, non-transparency and dynamics is based on recognition-primed decisions (Klein, 1992) and strategies for dealing with dynamics. In such study contexts, conspective protocols and the CV method have a role to play, we believe.

CONCLUSION

A model for verbalisation by colleagues is presented as the rationale for the Collegial Verbalisation (CV) method. It is based on the idea that in situations where domain knowledge is shared between colleagues one might find that they also share cognitive strategies that they can verbalise. Independent observers (colleagues) comment in the form of conspective verbal reports on the behaviour of a target operator. It solves some of the challenges associated with established verbalisation protocols like concurrent and retrospective verbalisation. The method is however sensitive to how close to the practitioner's experience the narrator is. Data generated by the CV method can, for example, be useful for practical purposes since correlations between colleagues' statements can be developed into team-learning and discovery of differences between team-members understanding of situations and contexts. It makes the method particularly interesting for research in naturalistic decision making. The most controversial issue, and at the same time the unique contribution, is the fact that it is not the practitioners themselves that provide the verbalisations. The narrator is left with doing some form of interpretation of the practitioner's actions based on their knowledge and experience. It is concluded that CV and conspective protocols are separate from existing verbalisation methods but that it is intended to be used in conjunction with these, not in isolation. The major implication is the contribution of an independent source of data to be used in applied research.

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