Chapter 6
Developing Observational Categories for Group Process Research Based on Task and Coordination Requirement Analysis: Examples from Research on Medical Emergency-Driven Teams

Franziska Tschan, Norbert K. Semmer, Maria Vetterli, Andrea Gurtner, Sabina Hunziker, and Stephan U. Marsch

Abstract In this chapter, we argue that the task is an important influence for teams and that task aspects should be more explicitly, and more specifically, included in the study of team processes and team performance. Using a cardiopulmonary resuscitation task as an example, we show how an adaptation of hierarchical task analysis that assesses task requirements (taskwork) and coordination requirements (teamwork) can be useful in identifying a task's goals and sub-goals, defining qualifiers of good goal attainment, identifying coordination requirements, and developing hypotheses about which teamwork and coordination behaviour should specifically be related to the performance of different aspects of complex tasks. Our argument is based on concepts that extend the general input–process–output model of groups.

F. Tschan (✉) and M. Vetterli
University of Neuchâtel, Institut de Psychologie du Travail et des Organisations, Rue Emile Argand 11, 2000 Neuchâtel, Switzerland
e-mail: franziska.tschan@unine.ch; maria.vetterli@unine.ch

N.K. Semmer
University of Berne, Institute of Psychology, Muesmattstrasse 45, 3000 Bern 9, Switzerland
e-mail: norbert.semmer@psy.unibe.ch

A. Gurtner
Applied University of Berne, Berner Fachhochschule, Fachbereich Wirtschaft und Verwaltung, Morgartenstrasse 2c, 3014 Bern, Switzerland
e-mail: andrea.gurtner@bfh.ch

S. Hunziker and S.U. Marsch
Departement für Innere Medizin, University Hospital of Basel, Abteilung für Intensivmedizin, Kantonsspital, 4031 Basel, Switzerland
e-mail: smarsch@uhbs.ch

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6.1 Introduction

Imagine the following situation: A physician talks with a patient resting in the recovery room after a small surgical intervention related to his heart condition. The surgery went well. The doctor controls the patient's vital signs and chats with him about an upcoming soccer game they both want to watch on television. Suddenly, the patient states that he is feeling dizzy; immediately thereafter, the patient suffers a sudden cardiac arrest, clearly visible on the surveillance monitor. The physician sounds the alarm, and by the time two other physicians rush into the room, she has already started cardiopulmonary resuscitation. She informs her colleagues that this is a cardiac arrest situation, and the three of them continue resuscitation, a complex task that is ideally performed in groups of three or four people. It is an emergency situation that has to be carried out under a lot of time pressure, as every minute of untreated cardiac arrest diminishes survival chances of a patient by 7–10% (von Planta 2004).

Although all physicians undergo regular resuscitation training, previous research has revealed important performance shortcomings of cardiopulmonary resuscitation, even when performed by well-trained hospital staff (Abella et al. 2005; Ravakhah et al. 1998). These shortcomings are often related to coordination and collaboration problems (Marsch et al. 2004a, b). Thus, it seems important to analyse what hinders or enhances the performance of these teams. The authors of this chapter are an interdisciplinary team of researchers (psychologists and physicians) who collaborate in studying teams of physicians and medical students confronted with complex medical problems. For this research, we use a high-fidelity patient simulator and video-tape processes of the medical teams as they perform the tasks. The overall goal of our research is to evaluate what influences team performance in emergency medical situations in order to help craft better training methods for such teams (Hunziker et al. 2010). To achieve this goal, we need good methods to assess group performance, and we need to identify teamwork and coordination behaviour that influence performance on the tasks we study. As we study complex tasks that are performed in groups of medical specialists, we need methods applicable for the analysis of performance as well as of coordination requirements of complex tasks. In this chapter we will show how and why task analysis can be an important help in studying groups.

There are a few instruments for group process analysis that are conceived as generic instruments applicable to a wide range of tasks. Their main advantage is that they suggest common categories for coding behaviour of a wide range of groups, permitting comparisons across groups and tasks. Their main disadvantages are that they either contain many categories, that may not all be of interest for specific research questions of categories for many applications (e.g. Kauffeld et al. 2009) or that the behavioural categories observed are defined in very general a way (Bales 1950; Futoran et al. 1989), limiting their application to specific tasks. Given this dilemma, in publications on current practices of group observation and analysis methods, method specialists emphasize that there is no agreed set of categories for team behaviour observed in groups and suggest that researchers should choose observational categories according to their specific research question (e.g. Brett et al. 2004; McGrath and Altermatt 2001; Weingart 1997). The choice of behavioural categories may be difficult, however, especially for complex tasks. In this chapter we contribute to this issue by emphasizing the utility and importance of assessing task requirements through detailed task analysis in order to develop observational categories and to assess group performance and group coordination, especially for complex tasks.

The chapter is structured as follows. First, we present the most important extensions of the general input–process–output (IPO) model of groups. Researchers who have suggested refining the IPO model advocate division of the general group process into smaller phases, episodes, or cycles (see Chap. 2). After presenting their arguments, we will show that knowledge about the tasks involved can be particularly helpful in identifying such phases. We then present hierarchical task analysis (HTA) (e.g. Shepherd 1998) as a way of disentangling and describing sub-tasks of the defining team task and its coordination requirements. Referring back to our example of the resuscitation task described above,[1] we will demonstrate a simplified HTA of this task. In the fourth section, we will argue that, for many tasks, performance should not solely be defined in terms of results or output, but in terms of process performance markers. Again, we will show how task analysis can help to define process performance markers, and we will illustrate the usefulness of performance markers in our own research. In the fifth section, we will show the usefulness of HTA for deciding which teamwork behaviours may be particularly important at a particular moment or phase in the group process. On this basis, we suggest that it is possible to develop hypotheses for *predicting* group performance. The chapter ends with a general conclusion.

6.2 Extensions of the General Input–Process–Output Model: Phases, Episodes, and Cycles

The well-known input–process–output (IPO) model of group performance suggests that *input* factors, such as group composition or the group's environment, influence the *group process* (taskwork and teamwork/cooperation) and that input as well as process variables influences the group's *outcome* (e.g. performance) (Hackman and Morris 1975; McGrath 1964). The generic IPO model thus distinguishes among "before the group has started working" as the input, "while the group

[1]The task-focused approach to group process analysis presented here is obviously not restricted to the cardiopulmonary resuscitation task. We will nevertheless use this task to illustrate how process performance markers can be developed and how the analysis of task requirements can be helpful in relating specific behaviour to performance. Examples referring to other tasks will also be mentioned.

interacts" as the process, and "after the group is done" as the output (note: the inclusive model presented in Chap. 2 overcomes this restrictive before- vs. during-process design. At first glance, this model seem to imply that a researcher who is interested in group performance can first measure or even manipulate input variables (for example, group composition, member experience, etc.). He or she will then assess the process of the group (for example, by observing the group members' behaviours) and then relate input and/or process variables (as mediators, moderators, or both) to the result, measured as the product after the group has finished working. One of the main advantages of the IPO model is indeed that it draws attention to and therefore emphasizes the group process and its relationship with productivity. Small group research has tended, and still tends, to neglect the analysis of the group process itself (McGrath and Altermatt 2001; Moreland et al. 2010; Weingart 1997).

Although focusing on the group process is very important, a number of questions arise with regard to its assessment. Many studies focus on process variables in general, such as the amount of communication, planning, and reflecting. Such an approach makes the assumption, at least implicitly, that these group processes are important throughout the whole time the group works on a task, and for all aspects of the task. This is a questionable assumption even for well-circumscribed tasks. Some process aspects, such as planning, typically are important at the beginning and at specific "turning points" (Hackman and Wageman 2005; Marks et al. 2001; Waller 1999); some, such as evaluation, are important throughout, but only after some action has been carried out (Tschan 1995, 2002); some are important only for specific sub-tasks (e.g. in an air traffic control task, planes identified as foes require different observation behaviour than do planes identified as friends; Tschan et al. 2000). Assessing behaviours in terms of frequencies over the entire process may therefore in many cases not capture the important aspects and may even yield misleading results.

The problems of overall process measures are even more pronounced in teams. Teams have a longer existence than the ad hoc groups often studied in group research. Multiple tasks and thus multiple processes, dynamic changes in tasks, as well as changes in input factors (e.g. in team membership, member competences, etc.) are very common for teams. Furthermore, a team may begin a new task while still continuing another one, and at the same time may terminate yet another task. Teams may thus have to coordinate between different tasks, and progress on one task may influence the work on another task. As different processes occur at the same time, it is difficult to analyse "the" process. Furthermore, as a team progresses on one task, team members may learn or change their attitudes, or members may leave or join a team, so that input factors may change as well. For teams, the boundaries of input, process, and output may be especially difficult. It is therefore not surprising that it is the domain of team research in which authors have critically discussed limitations of a general IPO model and have suggested important extensions (Antoni and Hertel 2009; Arrow et al. 2000; Ilgen et al. 2005; Marks et al. 2001; McGrath 1991). For these authors, the realities of teamwork – multiple tasks and changes in input factors – are the background to the argument that it may not be easy, or even inappropriate, to study teams according to an overall input–process–output framework. Thus, many researchers have recommended approaching the overall group process with more fine-grained analyses (Arrow et al. 2000; Marks et al. 2001; McGrath 1991; Tschan 1995; Weingart 1992, 1997).

Researchers who have extended the IPO models have suggested different conceptualizations of the overall group process. For example, Ilgen et al. (2005) adopted a temporal structure and distinguish several phases of the group's increasing experience (forming, functioning, finishing). They then related core topics to each of the stages. In the forming stage, trust, planning, and structuring are primordial, whereas in the functioning stage, bonding, adapting, and learning may be core concerns. Marks et al. (2001) suggested dividing the overall group process into temporal cycles of goal-directed activities they call *episodes*. Episodes are "IPO-type" micro-cycles and are defined as action-feedback cycles that are preceded and followed by periods of transitions between tasks, similarly to cycles described by Tschan (1995). Finally, McGrath and Tschan (2004) distinguished three hierarchical-temporal levels related to the overall group process: (1) at the purpose or project level, where the group selects, accepts, or modifies the group's projects; (2) at the planning level, where the group structures the process (what will be done, when, by whom and how); and (3) at the action level, where the process consists of a series of interrelated "orient–enact–monitor– modify" cycles. The cycles are related to the different goals or sub-tasks the group has to carry out. The cycle concept is similar to the concept of episodes and transitions suggested by Tschan (1995), and by Marks et al. (2001), described above. The three hierarchical levels (project, planning, and action) constitute a general temporal pattern similar to the one described by Ilgen et al. (2005). Thus, project choice and planning are more likely in the earlier stages (i.e. the forming stage), and the action level corresponds to the functioning stage.

All of these refinements of the general IPO model implicitly or explicitly assume that group goals (or group tasks that are defined by goals; see below) are an important influence on the overall group process: Episodes (Marks et al. 2001) and cycles (McGrath and Tschan 2004) are both defined as related to the group's tasks and goals; and observable episodes, transition, or cycles will depend on these goals and tasks. Based on similar considerations, the important influence of task requirements in groups for group process research has been widely acknowledged (Arrow et al. 2000; Cannon-Bowers et al. 1995; Hackman and Morris 1975; McGrath et al. 2000; Tschan and von Cranach 1996).

As group tasks and goals can be very different, they may require different types of episodes or cycles. It is thus necessary to develop a good understanding of the specific goals, sub-goals, and behavioural requirements of the tasks with which groups are confronted. One of the methods used to describe tasks as structures of goals and sub-goals that are hierarchically nested and temporally related is hierarchical task analysis (Annett 2004; Shepherd 1985), which will be presented next.

6.3 Task Analysis of Team Tasks

A task analysis that describes the steps and behavioural requirements necessary to fulfil a task is very useful for a more precise analysis of the relationship between teamwork behaviour and group performance. There are many different procedures for analysing tasks (cf. Konradt et al. 2006). In our research (Gurtner et al. 2007; Tschan 1995, 2002; Tschan et al. 2000) we have used a simplified version of the hierarchical task analysis (HTA) initially developed by Annett and Shepherd (Annett 2004; Shepherd 2001). This method describes tasks in terms of executable goals and is therefore well suited as an approach to the analysis of group behaviour.

HTA describes tasks as a set of steps to be carried out or goals that have to be achieved. Typically, a goal can be divided into sub-goals. HTA therefore describes tasks as a hierarchical structure containing *general goals as well as sub-goals that are related to the general goals*. It also specifies when a goal is attained: For each goal and sub-goal, *the criteria for judging goal attainment* are listed; these normally include qualifiers (e.g. time, correctness, etc.) of good goal attainment. For each goal, HTA specifies in what order (if any) sub-tasks have to be carried out as well as other conditions of goal attainment: For some tasks, a sub-goal can only be started after another has been finished (sequential requirements); for other goals, several sub-goals have to be pursued in a coordinated manner.

The description of the task in terms of a structure of goals and sub-goals, the criteria of goal attainment, and the description of the conditions for sub-goals are part of a classical HTA, which is often used to analyse tasks carried out by individuals. More recently, Annett et al. (2000) extended HTA to the analysis of group tasks. In accordance with recent concepts (Bowers et al. 1997; Marks et al. 2001; Salas et al. 2005) that distinguish between taskwork (what the team does) and teamwork (how the team coordinates its actions), they assess not only the task goals and sub-goals, but also the *teamwork or coordination requirements* related to each goal or sub-goal. In fact, Shepherd (2001) suggested that some teamwork requirements (for example "inform person x") can be seen as goals in themselves and can be included as separate goals in the system.

The main principles of HTA are relatively simple. As tasks become complex, however, conducting full-fledged HTA can become rather difficult. To perform HTA, the analyst has to know the task well. Classical HTA thus uses observation techniques, expert interviews, and document analysis as a basis.

We provide as an example a simplified version of HTA(one that does not use the elaborate notation of the original system and omits some sub-goals) for the resuscitation task. For this task, extended documentation is available, which is based on research that assessed which actions provide the highest chances of patient survival and recovery. The general guidelines for "advanced cardiopulmonary resuscitation" for medical professionals are regularly updated as new research becomes available. We base the task analysis on the European resuscitation guidelines

(Nolan et al. 2005; von Planta 2004), adapting it to our specific research context that involves a patient simulator.[2]

As described in the introduction, the "patient" in the simulator suffers from a cardiac arrest in the presence of a medical professional. We programmed the mannequin to display "ventricular fibrillation". At the beginning of a cardiac arrest, the heart often shows rapid electrical activity, which is, however, not synchronized enough to trigger a coordinated contraction of the heart muscle. Such electrical activity is called ventricular fibrillation or ventricular tachycardia. If the patient is connected to a surveillance monitor displaying heart activities, ventricular fibrillation is clearly recognizable by the trained physician. If a patient has this condition, defibrillation (application of electrical countershocks with the use of two panels placed on the chest of the patient) may help to restart synchronized cardiac activity and thus restore the heartbeat.

The main goals of cardiopulmonary resuscitation (see Fig. 6.1) are (1) diagnosing the cardiac arrest, (2) oxygenating the brain, and (3) attempting to reestablish spontaneous circulation. Each of the main goals can be further broken down into sub-goals. Cardiopulmonary resuscitation is best carried out by a group. On the most general level, teamwork and coordination requirements can be specified as the need to establish a shared mental model of the situation and the intervention, and to assign tasks to people.

The first goal, "Diagnose the cardiac arrest", contains three sub-goals: 1-1 confirms the absence of a pulse; 1-2 confirms the absence of breathing; and 1-3 confirms the loss of consciousness. Proper diagnosis has to be established before the group can start on goals 2 and 3. Note that the guidelines for advanced cardiopulmonary resuscitation (Nolan et al. 2005) allow only 10 s for the medical professional to diagnose a cardiac arrest, because it is essential to start cardiopulmonary resuscitation very quickly. Teamwork requirements for the diagnosis are that all team members have to be made aware of the diagnosis "cardiac arrest", because this knowledge should trigger the behavioural script "resuscitation". This script can be seen as an individually stored "shared mental model" that contains the most important aspects of the resuscitation procedure. As all medical professionals have received training in resuscitation, one can assume that the script is available. Given the high time pressure in the diagnostic phase, another important teamwork requirement is to terminate the diagnostic phase rapidly and move into the intervention phase in a coordinated fashion.

The second goal (oxygenating the brain) has three sub-goals. The first sub-goal, 2-1 "open airways", contains the sub-sub-goals "checking the mouth for foreign body" and "removing visible obstructions in the mouth" (not shown in Fig. 6.1). Sub-goal 2-2 is "ventilate" (providing oxygen to the lungs) and 2-3 "cardiac massage" (which substitutes for circulation and transports the oxygenated blood to the brain). Sub-goals

[2]In our simulator setting, (1) the patient was branched on a heart surveillance monitor, which facilitates diagnosis; (2) an intravenous line was already established; (3) the patient showed ventricular fibrillation; and (4) differential diagnostics was not required, because the simulator mannequin was programmed to wake up after proper resuscitation.

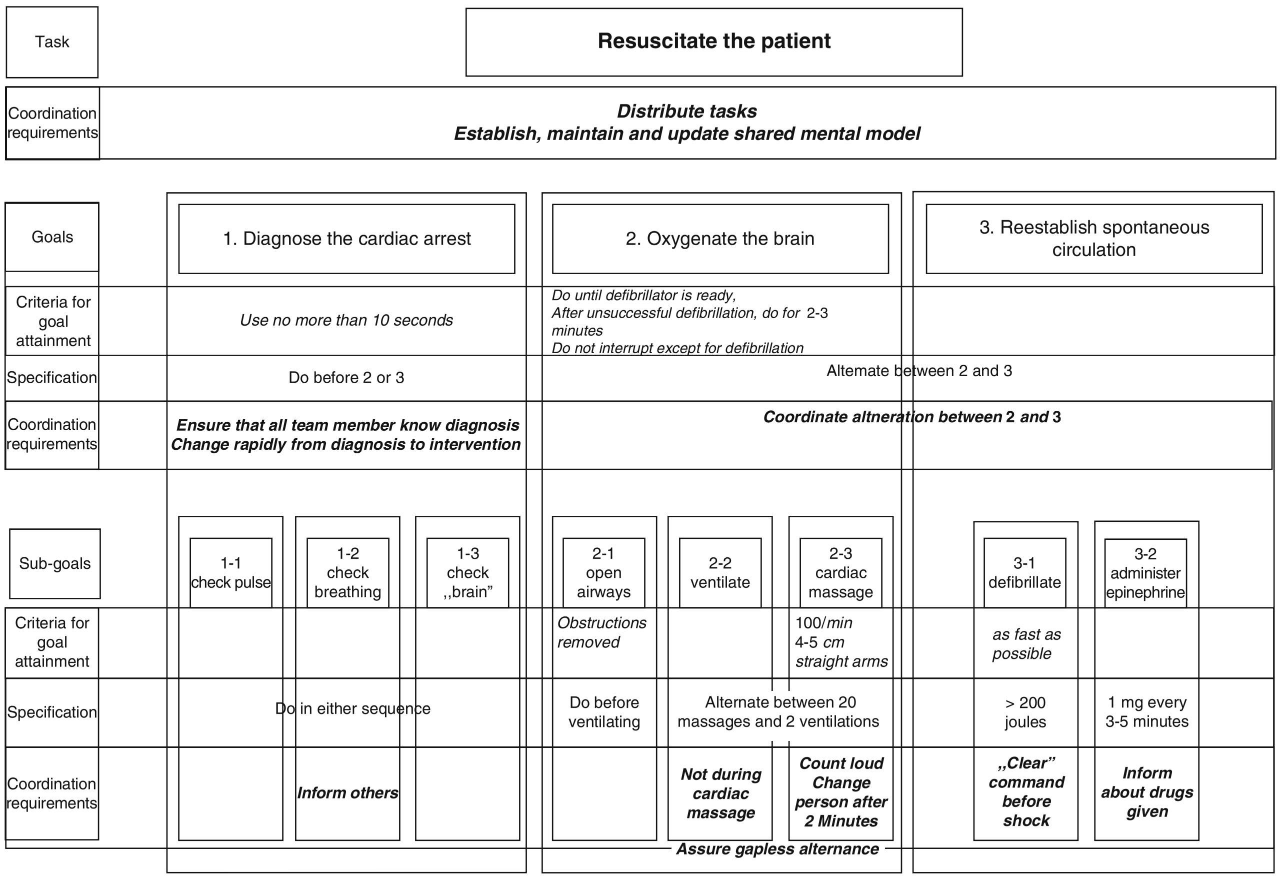

Fig. 6.1 Simplified hierarchical task analysis for the cardiopulmonary resuscitation task, including coordination requirements

2 and 3 are closely linked. The guidelines specify an alternate sequence of 30 chest compressions followed by two ventilations. The guidelines also specify criteria for good goal attainment: Cardiac massage has to be done at a rhythm of about 100 beats per minute and at a depth of about 4–5 cm. For patients who are not intubated,[3] cardiac massage and manual ventilation should not be done at the same time, but rather in an alternating but gapless sequence, which results in the coordination requirement to alternate between the person performing chest compressions and the person who ventilates. This coordination can be achieved better if the person performing cardiac massage signals when he or she has finished the 30 compressions; the recommendation is thus to count each compression out loud.[4] Sub-goal 3 (reestablishing spontaneous circulation) has two sub-goals: 3-1 defibrillation (applying electrical countershocks to convert the ventricular fibrillation to a regular heartbeat) and 3-2 administering epinephrine (adrenaline), a drug that constricts the vessels and increases pressure and can thus improve the effectiveness of defibrillation and cardiac massage. Coordination requirements for defibrillation are important, as during defibrillation all helpers should stay away from the patient or the bed, because the electric shock applied could harm bystanders. Thus, before defibrillation, a "clear" command should be given to ensure that none of the helpers touches the patient or bed. Administering epinephrine entails the coordination requirement of informing the group when the drug is given to update the group members' mental model.

The resuscitation guidelines also specify the temporal sequences and conditions to change from goal 2 (oxygenating the brain) to goal 3 (reestablishing spontaneous circulation): first, goal 2 has to be pursued until the defibrillator is ready; after unsuccessful defibrillation, 2 min of ventilation–cardiac massage cycles should be performed and epinephrine should be administered before the next defibrillation. Coordination requirements involve ensuring that the group keeps track of time and changes in a coordinated way between goals 2 and 3. Again, note that we have presented a simplified version here; many more specifications for this task are given in the guidelines.

Task analysis can be performed on different levels of specificity (from only a few general goals to a very elaborate system of goals and sub-goals), and it can be done for very different types of tasks. The resuscitation example describes a team task that usually lasts less than 30 min, but HTA is also suitable for broader and more complex activities. For example, Shepherd (2001, p. 124ff) provides an analysis of the main nursing tasks in a hospital ward, as well as several examples of management tasks (p. 126ff). Thus, HTA is not restricted to "hands-on tasks" but can also be used for the analysis of more cognitive team tasks, such as decision making or problem solving. In the next section, we show how the results of HTA can be helpful in developing process performance measures.

[3]Placement of a tube to allow artificial ventilation of a patient.

[4]For advanced life support, intubation (introducing a tube into the trachea of the patient to facilitate ventilation) is suggested as a more efficient way to ventilate the patient. If this is done, cardiac massage and ventilation no longer need to be alternated.

6.4 Assessing Process Performance Measures Based on Task Analysis

The general IPO model of group performance can lead to the assumption that group performance is best measured as the result available once the group has finished its work. Conceptualizations of work performance differentiate, however, between outcome and process (behavioural) aspects of performance (Sonnentag and Frese 2002) and see performance as a multidimensional construct (Campbell et al. 1993). Output aspects of performance are measures of performance effectiveness (how well or to what degree a goal is attained), whereas process aspects of performance can be related to efficiency measures of performance, where the output is related to the resources needed to achieve them (Pritchard and Watson 1992).

For many tasks, outcome performance is not the only, or the most important, aspect of task performance. For example, although the outcome can be that a crew landed a plane safely, crew performance also requires that the pilots descend smoothly on the correct area of the tarmac and perform the correct tasks in the right sequence during the landing approach. Although patient well-being and recovery are crucial outcome measures for judging the quality of surgery, it is also important that during surgery the right procedures are chosen and performed in a timely manner. Process measures of performance are also important because the relationship between process and performance is often less than perfect (Boos 1996), and many aspects apart from process parameters may be important for an outcome. If this imperfect association between process performance and outcome performance is neglected, a positive outcome may erroneously be taken as “proof” that a person, or a team, has acted perfectly.

The necessity to distinguish between process performance measures and outcome measures can be illustrated very well by the cardiopulmonary resuscitation task. One could be tempted to measure resuscitation performance as the outcome “patient survival”, as the main goal is to save the patient’s life. However, it would be erroneous to assume that if the patient survives, group performance was optimal and, if the patient dies, group performance was bad. Survival of a cardiac arrest depends on many factors other than the performance of the resuscitation team. An analysis of patient survival after in-hospital cardiac arrest has shown that physiological (the underlying problem) and demographic (e.g. age) aspects of patients are much more important predictors of cardiac arrest survival than the timeliness of starting the resuscitation or group skills (Cooper and Cade 1997). Although coordination quality does significantly contribute to the outcome, there is a substantial chance that a patient will die, even if the team does everything “right”. In this and many similar cases, relying solely on output performance will not lead to the most valid assessment of group performance.

Group performance, be it process or outcomes measures, is particular to each task, and generalizations across tasks are normally not appropriate (Mathieu et al. 2008). One has thus to develop and define performance measures separately for each task. Task analysis can be very useful here, because it already specifies the

Table 6.1 Example of process performance measures for the resuscitation task

Goal	Process performance measure	Possible operationalization
The diagnosis "cardiac arrest" should be done rapidly (goal 1)	Time until diagnosis is called	Coding time between onset of cardiac arrest and a person calling it a cardiac arrest
Resuscitation should be started as soon as possible (transition goal 1 to goals 2 and 3)	Time until the first meaningful intervention is started	Coding of time from cardiac arrest until any one of the following actions: chest compression; ventilation; defibrillation
There should be continuous, uninterrupted oxygenation of the brain (goal 2)	Time until ventilation-cardiac massage starts	Coding time between onset of cardiac arrest and first ventilation or cardiac massage
Cont. goal 2	Percentage of "hands-on" time (uninterrupted ventilation/ cardiac massage), of total time, excluding the episodes during which hands-on is not suitable (during defibrillation)	Second-by-second coding of hands-on time (yes-no); calculating the percentage of hands-on time in whole process
Cont. goal 2	Unnecessary interruptions of ventilation and cardiac massage	Assessing all interruptions of behaviour longer than 5 s, code if necessary or not
Remove potential obstructions in airways (2-1)	Visual control of mount and remove of potential airway obstructions	Dummy-code: yes, if a group member controls mouth visually or with fingers
Appropriate ventilation-cardiac massage cycles (2-2 and 2-3)	No overlapping ventilation – cardiac massage	Behaviour coding – instances cardiac massage and ventilation overlap (recoded)
Cont. goal 2-2/2-3	30:2 cycles	Overall behaviour rating (yes/ partially/no)
Technical aspects of cardiac massage (2-3)	Chest compression rate of 100 p min Depth Arm position	Behaviour coding, rating
Attempt to establish heartbeat (3)		
Defibrillate as soon as defibrillator is available (3-1)	Time elapsed until first defibrillation	Time between cardiac arrest and first defibrillation
Alternate between defibrillations and oxygenating the brain	Number of alternations Time of ventilation-cardiac massage between defibrillations	General rating
Use correct defibrillation strength	More than 200 joules	Note all defibrillations with correct strength; calculate percentage of correct defibrillations (behavioural observation)
Administer epinephrine	Correct dosage	Dummy coding, based on communication

Note: In our scenarios, the defibrillator is always at the same place; otherwise, the time needed to transport the defibrillator would have to be subtracted criteria for good goal and sub-goal attainment, which often allows process performance measures to be derived.

6.4.1 Developing Process Performance Measures for the Cardiopulmonary Resuscitation Task

We will illustrate process performance measures for the resuscitation task (see Table 6.1) used in our research (Hunziker et al. 2009; Lüscher et al. submitted; Marsch et al. 2004a, 2005; Tschan et al. 2006; Vetterli 2006). In the table we refer to the goal or sub-goal of the task analysis in the left column, specify the process performance measure in the middle column, and provide a short description of the operationalization in the right column.

Note that all the process performance measures presented here can be based on the observation of the overt behaviour of group members or communication between them, permitting performance assessment based on video recordings. Our experience has shown that high interrater reliability can be achieved for those codings (kappas between 0.75 and 1), although only after extensive training of the coders. The coders – particularly those who are not medical professionals – first take an online class on cardiopulmonary resuscitation to familiarize themselves with the guidelines and the research behind them to understand the basic resuscitation task. They are then trained on sample tapes based on a coding manual. Typically, a 10- to 15-h investment is necessary until satisfactory reliability of process performance coding is achieved. For time-based codings, good interrater reliability is easier; the other behavioural ratings need more extensive training.

Assessing several measures of process performance raises the question of how to use them. Principally, they could be used separately (and some of them may be omitted depending on the research purpose), or they might be combined into more general indicators or a single performance measure. We mentioned above that theories of performance often regard performance as multidimensional (Pritchard and Watson 1992; Sonnentag and Frese 2002). To the extent that this is true, the different indicators may represent rather different aspects of performance, and a single measure might miss important aspects.

We tested the hypothesis that the process performance markers are not simply different measures of a single overall performance, but represent distinct aspects. We coded four process performance measures in 29 groups of physicians and nurses confronted with a cardiac arrest that developed suddenly during a routine situation (Vetterli et al. 2009). Process performance markers coded in this study were (1) the time elapsed until the first meaningful intervention (transition from goal 1 to goals 2 and 3; see Fig. 6.1); (2) the percentage of hands-on time (goal 2); (3) the time until the first defibrillation (goal 3); and (4) the time until the first resuscitation cycle (goals 1 to 3), including administration of epinephrine, was completed. Table 6.2 shows the intercorrelation between these different process performance measures. Note that we recoded the time measures so that all measures now reflect a higher performance.

Table 6.2 Intercorrelations of four process performance measures for the resuscitation task

	1	2	3
1. (reversed) Time until first intervention	–		
2. (reversed) Time until first defibrillation	−0.393*	–	
3. (reversed) Time to complete goals 1–3	−0.274	0.603**	–
4. Percentage of hands-on time	0.275	−0.158	−0.020

Note: $N = 29$ groups
*p<.05 **p<.01

The results indeed show that the different process performance measures do not represent a global performance construct. Interestingly, a fast "start" in terms of resuscitation does not predict earlier defibrillation; on the contrary, it is associated with later defibrillation. This negative association may be because groups decide to defibrillate early on but neglect the task requirement to engage in cardiac massage and ventilation until the defibrillator is ready. As can be expected, the two performance measures "time to first defibrillation" and "time to complete goals 1–3" are highly intercorrelated. Here, substituting one of these variables with the other is possible. The conclusion that the different performance measures are not simply facets of overall performance is also reinforced by a reliability analysis of the performance measures mentioned in Table 6.2, which yielded a Cronbach's alpha of only 0.21.

This analysis underscores the necessity to assess performance separately for the different goals rather than, or at least in addition to, computing an overall performance measure.

6.4.2 Research Examples Relating Input Factors to Measures of Process Performance

The coding of process performance measures allows the effect of input variables to be tested (e.g. in terms of differences in experience, or in group structure) on group process performance. We will now present two examples of such analyses.

In one study (Hunziker et al. 2009), we manipulated the composition of teams of three physicians at the beginning of the cardiac arrest. The aim of the research project was to investigate whether, and how, the short period of common team experience in preformed teams influences performance in the resuscitation task as compared with the ad hoc teams. Half of the teams were thus "preformed" (condition 1); all three physicians were with the patient 2 min before the cardiac arrest started, and all physicians witnessed the cardiac arrest. For the other half of the teams (condition 2), only one physician witnessed the cardiac arrest, and he or she asked the other two physicians, who waited in the hallway, to join in and help when the emergency situation started. The latter situation, where an ad hoc team is formed, is far more typical of an emergency situation in a hospital, because it is often a first responder who sounds the alarm and summons other people to help. Note that in the ad hoc teams, the incoming team members joined immediately after the emergency occurred (fewer than 7 s after the cardiac arrest). The results show that ad hoc teams had a statistically significant lower percentage of hands-on time (51.7%) than the preformed teams (68.7%). Ad hoc teams took about 40 s longer to defibrillate and more than 50 s longer to administer epinephrine. Ad hoc teams did not need significantly longer to start cardiac massage, nor did they show a worse chest compression rate. These results show that basic aspects of the task (starting cardiac massage) were not influenced by the different group compositions. More complex aspects, however, such as defibrillation or decisions to administer medication, were significantly delayed in ad hoc groups. This indicates that even a short period of previous collaboration was beneficial for later team performance, particularly for the more complex aspects of the task.

In the same study, we also tested whether clinical experience (another input aspect) influenced process performance. Half of the groups studied were composed of general practitioners, and the other half were experienced hospital physicians, who were more likely to have experience with cardiac arrests (Hunziker et al. 2009). Analyses showed no differences between hospital physicians and general practitioners for hands-on time or time elapsed to start cardiac massage. Hospital physicians, however, defibrillated earlier, administered epinephrine more rapidly, and showed better performance in chest compression rates than general practitioners. This indicates that different professional background and experience influence the more complex aspects of the task, but not the more basic aspects. Similar findings emerged in another study where ad hoc groups of inexperienced medical students were compared with ad hoc groups of experienced general practitioners (Lüscher et al. 2010). Although medical students were as fast as general practitioners at diagnosing the situation, and were as good as or better than general practitioners in technical aspects of the task (e.g. chest compression rate), the experienced physicians outperformed the medical students in hands-on time, started cardiac massage about a minute earlier, and defibrillated significantly faster. Thus, although medical students were familiar with the resuscitation procedure (as indicated by their overall technical performance), they had much more difficulty with the more complex aspects of the task, which they performed with significant delay.

The results of these studies underscore again the usefulness of multiple process performance measures, at least for this task. As already mentioned, assessing process performance is especially important if the task outcome does not fully depend on the team process, but on other variables as well – in our case, for instance, patient condition (Cooper and Cade 1997). Similar arguments may actually hold for most tasks. For example, a team of air traffic controllers may have successfully guided all landing and starting planes so that no accidents occurred (outcome performance), but may have created dangerous situations or long delays that – for all kinds of reasons – did not result in an accident. A cockpit crew may land their plane on time (outcome performance), for example, but in order to do so successfully may have to make many flight path corrections during their descent.

6.5 Developing and Testing Hypotheses for the Relationship of Team Behaviour with Process Performance Variables

As explained above, concepts of team processes distinguish between taskwork and teamwork (Bowers et al. 1997; Marks et al. 2001; Salas et al. 2005). A similar distinction is made between the technical and non-technical skills needed for a task (Flin and Maran 2004; Flin et al. 2008). Taskwork, or technical skills, refers to behaviour related to the content of the task; and teamwork, or non-technical skills, refers to the coordinative aspects of the group's process. Usually, research on team performance is interested in the relationship between aspects of teamwork or non-technical skills and performance.

What coordination behaviour should be observed if one is interested in predicting group performance? There is a multitude of such behaviours, and several authors have developed lists. For example, communication, coordination, cooperation, and leadership have been named as major categories for medical teams (Flin and Maran 2004); others have also included gathering and exchanging information, supporting others (Fletcher et al. 2004), or monitoring behaviour (Healey et al. 2004). Some authors have suggested further division of some of these broad categories. For example, Xiao et al. (2004) suggested distinguishing different aspects of leadership, such as strategic planning, reporting and critiquing plans, coaching, maintaining awareness, and requesting information. The examples provided here are by no means exhaustive, and many more coordination behaviours are mentioned in the literature.

Some general coordination behaviours may be important for the performance of most, if not all, teams (Salas et al. 2005). Nevertheless, most authors explicitly or implicitly agree that different situations and tasks require different coordination behaviours. Thus, most researchers adapt their observational categories to a given task or task type. For example, Weingart and colleagues (Weingart et al. 2004) developed behavioural observation categories specifically for negotiation tasks. For hidden profile tasks, information exchange is the teamwork variable observed most frequently (e.g. Larson et al. 1998; Stasser et al. 1995). Boos and colleagues developed specific categories for complex problem solving in groups (Boos et al. 1990); Kolbe et al. (2009) developed their coding system for anaesthesia teams based on an analysis of coordination requirements in anaesthesia, and for complex decision making based on a task analysis of team decision making (see Chap. 9); and even the well-known interaction process analysis coding system (Bales 1950) was initially meant to code only decision-making tasks. There is indeed a general, albeit more implicit than explicit, agreement that the teamwork behaviours observed should be relevant for the task of the group.

We indeed think that the extensions of the general IPO model to include more task-related aspects, especially in combination with the coordination requirements specified in the task analysis, can be very useful for developing hypotheses about what coordination behaviour is important and should be observed, and which behaviours might be most important at what time or phase of the group process (Tschan et al. 2009). For instance, one can assume that directive leadership should be most useful for performance when a group begins a new task, especially when the task requires high initial coordination between team members and coordinated transitions between sub-tasks (Fernandez et al. 2008; Marks et al. 2001; Wageman et al. 2009). On the other land, leadership may not be so crucial for group performance in later, more routine phases when the group is already well coordinated. In routine phases, more direct leadership may even be associated with lower performance, as it may indicate that leadership is necessary in order to correct members' behaviour (Burtscher et al. 2010; Künzle et al. 2010). More educational leadership, however, may be important for later phases (Wageman et al. 2009).

To illustrate how coordination requirements derived from HTA may inform hypotheses on what coordination behaviour may be important and when, we again refer to the resuscitation task. Resuscitation teams need to change rapidly from the diagnostic phase to the hands-on action phase (see Fig. 6.1), and thus they may well profit from strong leadership at the beginning of this task. The concept of multiple IPO episodes or cycles suggests (Futoran et al. 1989; Marks et al. 2001) that leadership may regain importance immediately after a change in input variables, for example, if a new group member joins or leaves (Ballard et al. 2007; Wageman et al. 2009; Waller et al. 2004). Thus, we do not assume the same positive impact of leadership at all moments of the group process.

For the simulated resuscitation task, we investigated the link between leadership and performance for groups of nurses and physicians treating a cardiac arrest. At the beginning of the cardiac arrest, three nurses were alone with the patient, but after a few minutes into the cardiac arrest, a resident physician joined the group; thus, an important input variable changed (Tschan et al. 2006). Based on the assumptions that directive leadership is crucial at the beginning of a task and after input changes, we hypothesized that leadership should enhance performance (1) in the very early stages of the cardiac arrest when nurses respond to this emergency situation, and (2) immediately after the resident enters the group, because the group composition changes: The resident has to assume responsibility, and the group needs to adapt to this situation. Both hypotheses were supported by the data. There was a significant correlation of $r = 0.45$ between leadership utterances and performance when the nurses were alone. After the resident joined the group, more directive leadership by him or her significantly predicted performance ($r = 0.52$) – but only leadership during the first 30 s after he or she joined the group. As predicted, more leadership after this short adaptation phase was no longer a predictor of performance ($r = 0.27$, *ns*).

This example shows how important it can be to develop specific hypotheses about how and when specific teamwork behaviours may be most important for performance, and it also shows that knowledge about teamwork requirements can be helpful. Indeed, if we had only tested the general hypothesis that "leadership is important for resuscitation performance", we would have rejected this hypothesis based on our data. Note that these results are quite compatible with more general leadership theories, which advocate that leadership is only fruitful if it is adapted to the requirements of the situation and the followers (e.g. House 1971; Vroom and Yetton 1973; Wageman et al. 2009), as well as leadership conceptions for groups (von Cranach, 1985; McGrath 1962). In order to test such general assumptions, however, we need rather fine-grained analyses of specific task requirements.

The specificity of task requirements across time and sub-tasks has far-reaching implications. Among other things, it may imply that a group may be very good with regard to specific task requirements but not with regard to others. For instance, we compared the performance of teams in a routine situation vs. an emergency situation. It turned out that performance in one situation was only weakly related to performance in the other. As an example, some groups took quite some time to gather information. This behaviour was very useful in the routine situation; by contrast, it diminished performance in the emergency situation, where speed of reaction was crucial (Vetterli et al. 2009).

The importance of specific coordination requirements across tasks and time can hardly be overemphasized. We therefore want to illustrate two other examples. In a large study about pilot crew performance, behavioural observations were made for more than 300 flights (Thomas 2004). The researchers analysed predictors of successful error management across different flight phases (pre-departure preparation, takeoff, approach landing). It turned out that error management for the different tasks was predicted by different coordination behaviours. In the pre-departure phase, collaboration between pilot and co-pilot was especially important: During takeoff, contingency planning increased the probability of error management; and during landing, vigilance and problem identification as well as assertiveness of the co-pilot were predictors for good error management.

In another study in a hospital setting, Bogenstaetter et al. (2009) investigated errors made when nurses and physicians transmitted information to a physician who joined an ongoing cardiopulmonary resuscitation. They found that 18% of the information given to the incoming physician was inaccurate and contained errors. Most of these errors were related to information about two tasks, namely, (1) defibrillation and (2) medication. To remember how many defibrillations have occurred, and with how many joules, the best way to store this information is in the same way it needs to be retrieved – for instance, by saying loudly: “This is the third defibrillation”. This way of storing information is referred to as *transfer-appropriate processing* (Morris et al. 1977). Usually, however, people do not store information in this way; our study shows, however, that those who do commit fewer errors in transmitting information. Such results are directly transferable to training. Again, they refer to specific task requirements that are not easily detected without fine-grained task analysis.

6.6 Conclusions

In this chapter we showed that knowledge about specific taskwork and coordination requirements of a given task can be useful for small group research. We showed how task analysis can help to define process performance measures that allow us to tap into important aspects of group performance beyond “output” (Pritchard and

Watson 1992). Furthermore, we showed that task analysis can help to develop and test hypotheses about specific teamwork behaviour and performance.

We are not the first to stress the importance of tasks for small group research. It has long been acknowledged that the type of task is an important predictor of group processes and group performance. Accordingly, there is a long standing tradition in distinguishing among different task types (McGrath 1984; Shaw 1976; Steiner 1972) or different types of groups by type of task (Arrow et al. 2000; Hackman and Wageman 2005). Indeed, in early studies, Hackman (1968) and Kent and McGrath (1969) compared influences on group performance across different tasks. They found that task characteristics explain more than ten times the amount of variance than is explained by teamwork aspects.

The well-known task classifications, however, are often not fine-grained enough to uncover such specific requirements as the time when something has to be done, the period during which something is useful or not, etc. Furthermore, these classifications are often not suitable for complex tasks because these often contain different or mixed task types as sub-tasks. For example, in terms of McGrath's circumplex model (1984), the resuscitation task used as an example in this chapter contains the task types "choose", "decide", and "performance of psycho-motor tasks". Furthermore, the task is at the same time "conceptual" as well as "actional".

HTA does not describe task types and is thus more flexible. In HTA, we see the chance to define the task requirements in a flexible and adaptive way for many different tasks in group research. HTA is also flexible with regard to the level of specificity involved, as the level of specificity may be chosen depending on the knowledge and experience of the people involved. For instance, for medical personnel, it may be fine-grained enough to specify the task "defibrillate". By contrast, it may be necessary to present a hierarchical task analysis of the defibrillation sub-tasks for laypeople who are not familiar with that task.

Thus, there are advantages of including task aspects more explicitly in group research. First, more specific analyses about the relationship of teamwork and different task requirements can help to develop more precise knowledge, and can inform theories about the relationship between teamwork behaviours and aspects of group performance. Second, more precise knowledge about task and coordination requirements can be useful for team training. If groups have to carry out complex tasks, training probably has to be task-specific. For example, pilot crews learn takeoff and landing as different tasks; and in the operation room, an appendectomy surgery is a task that is very different from a hip implant surgery. As these different tasks require such different taskwork, it is also likely that coordination requirements vary as well. Gaining more precise knowledge about when which behaviour is needed for which task can help to train teams in a more specific way.

Of course, analysing group processes in terms of task requirements has disadvantages as well. First, generalization from one task to another is not easy, and thus such research may not immediately contribute to a "unified theory of group performance". Actually, a next step may have to consist of developing typologies of task requirements, possibly based on typologies of tasks. Some time ago, Wood (1986) called for a theory of tasks, conceptualizing and defining task complexity.

It may be fruitful to pursue such efforts. A second disadvantage is that performing task analysis is an additional step to the already high burden of group process research. Especially for complex tasks for expert actors, hierarchical task analysis can be very time-consuming and may require extended training. On the other hand, having more specific ideas about what behaviour should be observed and when can considerably decrease the time researchers spend on coding. Looking at the pros and cons, we feel that the advantages certainly outweigh the disadvantages.

In their treatises of group process analysis methods, Weingart (1997), McGrath and Altermatt (2001), as well as Zaccaro et al. (2005) all stated that it may not be possible to develop a single, overall behavioural coding system for all group processes. They thus suggested that the research goal should guide which behaviour(s) should be observed. We add to this recommendation that knowledge of the task may be helpful for choosing appropriate observational categories and process performance measures as well as for developing hypotheses about predictors of successful performance.

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