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# ADAPTER: Analysing and developing adaptability and performance in teams to enhance resilience

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ABSTRACT

In the current study, the concept of team resilience was operationalized by developing a first version of a questionnaire (ADAPTER) driven by the four essential abilities of resilience (Hollnagel E, 2011, Resilience engineering in practice: a guidebook, p. 275–96) and expanded with more relation-oriented abilities of leadership and cooperation. The development and administration of ADAPTER took place within two companies. Factor analyses using data of 91 participants largely supported the hypothesized 6-dimension taxonomy. Support was found for Team responding behavior, Shared Leadership and Cooperation with other teams/departments. Anticipation showed considerable overlap with the monitoring scale, possibly due to the fact that monitoring items dealt with prospective situations. Using ADAPTER questionnaire results as a starting point for further in-depth discussion among the different teams in the pilot companies proved very useful. Suggestions for future research include contextualizing the questionnaire by embedding it in actual cases or having it filled in after specific incidents. Also, support of organization should be included as a separate dimension in ADAPTER.



## 1. Introduction

Although the concept of resilience has been in use in the context of system safety since the beginning of the 21st century, it has been notoriously difficult to measure. This is undoubtedly partly due to the somewhat elusive nature of the concept itself, being centered around what a system does, and, in particular, what a system does right rather than wrong ([1], p. IXXX). Measuring system resilience therefore amounts to capture 'normal' system functioning with a focus on the ability of the system to sustain its functioning under both expected and unexpected conditions ([1], p. 275). Analyses at this level and with this focus have previously been carried out in the area of human factors, drawing on a long tradition that started with Rasmussen's ecological framework to systems engineering and that culminated in the approach known as Cognitive Work Analysis (CWA) [2]. CWA was developed in response to perceived limitations of traditional task analysis techniques that focused on routine procedures rather than unexpected performance variability as a result of external disturbances [3]. However, the field of resilience engineering has not embraced CWA as a technique, possibly because of its perceived claim to be able to model the 'complete' work domain of a system at various levels of abstraction [4]. Instead, a different method is proposed, the Functional Resonance Analysis Method (FRAM), as a way of modelling normal system functioning [5]. It is not our goal in this paper to compare both methods, although we feel that the differences between the various methods are sometimes exaggerated. The more fundamental issue that we want to raise is that both methods, even though they are focused on presumed 'normal' system functioning, do not make a direct connection with the concept of resilience.

It is, perhaps, for this reason that Hollnagel [1] has proposed a more pragmatic approach to measuring the resilience of a system, resulting in a Resilience Analysis Grid (RAG). According to Hollnagel [1], resilience consists of four abilities: responding, monitoring, anticipating, and learning. Although intuitively plausible, Hollnagel does not provide much empirical evidence as to the validity of these four elements that together are thought to constitute resilience. Our first aim in this paper is therefore to find evidence for the construct validity of these four abilities.

Secondly, this paper will put these four elements in the context of team level functioning within an organization. Although resilience has been defined as a system level construct in the context of system safety, applying this construct to a practical case nearly always involves moving across levels of analysis [6]. In particular, we argue that the team level provides the linking pin between individuals and organizations. Teams play an important role in today's increasingly complex work environments [7,8], as work demands frequently exceed an individual's capabilities of dealing with these demands. Although at the organizational level, strategic

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guidance, reward mechanisms, and resources are provided, the 'rubber hits the road' at the team level.

Conceptually, the four abilities proposed by Hollnagel to constitute resilience, are not tied to the team level, but are defined at the organizational (system) level. In principle, one could envision teams performing monitoring, responding, anticipating and learning activities. For instance, Hollnagel [1] explicitly stated that monitoring must cover the system's own performance as well as changes in the environment. Empirical evidence showed that teamwork is made up of five core components: team leadership, mutual performance monitoring, backup behavior, adaptability, and team orientation [9]. According to Salas et al., these core components require supporting coordinating mechanisms, such as shared mental models, closed-loop communication and mutual trust [9]. Applying the monitoring capability to the team level, there is a clear connection between Salas et al.'s 'mutual performance monitoring' and Hollnagel's 'monitoring' when applied to the team's own performance. Likewise, applying the responding capability to the team level, there is a clear connection between Salas et al.'s [9] adaptability and Hollnagel's 'responding' when applied to the team's own performance. Adaptability is described as 'the ability to adjust strategies based on information gathered from the environment through the use of backup behavior and reallocation of intrateam resources. Altering a course of action or team repertoire in response to changing conditions (internal or external)' [9].

As our primary aim in this study was to find evidence for the construct validity of the four abilities proposed by Hollnagel [1], we took these abilities as the core set to be operationalized. These four abilities are complemented by two important components derived from the teamwork literature: leadership and cooperation with other teams. Shared, or transformational, leadership training [10] has been shown to positively impact team resilience [11,12]. It is one of the five core components mentioned by Salas et al. [9] and may be viewed as a driver for all four essential capabilities of resilience as put forth by Hollnagel [1].

Cooperation with other teams, a defining characteristic of multi-team systems [13], is more important than ever, given that teams no longer work in isolation [14]. According to West, resilient teams are both high in task reflexivity and high in social reflexivity. They often review their strategies, methods and ways of communicating, as well as providing each other support and dealing constructively with conflict. They are therefore able to adapt to changing circumstances, more likely to innovate and more likely to work effectively with other teams in the organization. Embedding teams within the broader organizational context is important for achieving high reliability and resilience, as these micro-systems depend on the structure, mechanisms, and culture of the macro-system [15].

## 2. Methods

### 2.1. Literature review

Our goal in this study was to develop a practical and validated team-level tool based on the four main abilities that constitute resilience, extended with team-level specific concepts.

In order to achieve a motivated set of questions, clustered by hypothesized construct, a conceptual mapping exercise was conducted, informed by a literature review on teamwork and resilience. Our initial literature search in scientific databases (Scopus, Osh Update, Pubmed) yielded only four empirical articles on team resilience in the period 2000–2013. Extending the search with more general search terms[1] including other literature (Google Scholar, conference proceedings, white papers) resulted in 277 articles, which were down selected to 47 by three independent reviewers on the basis of the abstracts. This number was further reduced to 11 on the basis of full articles. Inclusive criteria used were:

- factors must be related to the resilience abilities of Hollnagel (i.e., monitoring, learning, responding and anticipating);
- must address teams and/or teamwork;
- written in English or Dutch;
- quantitative and qualitative research; and
- conference proceedings and peer reviewed journals.

The literature review identified several team resilience abilities corresponding with the general essential capabilities of Hollnagel [1]. If we further elaborate this table with the Big Five components mentioned by Salas et al. [9], we get the following mapping (see Table A1).

### 2.2. Existing tools

Given the fact that we wanted to stay as closely as possible to the views of the experts in the resilience domain, rather than impose our own views as researchers, we chose to develop a questionnaire that could be administered within a relatively short amount of time based on the team resilience abilities in Table A1. Items were developed to measure the different resilience abilities identified. The preoccupation with failure items from Weick [16] were specifically adapted to match the resilience ability of anticipation (e.g., foreseeing deviations and unexpected situations). Responding was inspired by team responding behavior [17] and was extended with regard to the immediate handling and resolution of deviations and unexpected situations. Also, already extensively validated subscales of the Transformational Leadership Questionnaire (TMLQ, [10]), team learning questionnaire [18], and the Situation Awareness and Team Effectiveness (SAnTE) questionnaire [19] were used in their original version. The SAnTE assessment tool identifies what goes well and what should be improved in the team. It should be noted that SAnTE is based on and incorporates constructs such as distributed situation awareness [20,21], shared (collective) sensemaking [22–24], and heedful interrelating [25]. SAnTE was originally developed for use by military teams on strategic and operational levels. However, the SAnTE assessment tool can also be used for civilian teams, such as emergency management teams or process control teams.

### 2.3. Item development

The instrument was primarily targeted at Dutch companies, hence we translated the English questions into Dutch. Then we organized the sets of questions according to the classification of the four core resilience abilities and removed duplication and redundant questions. Finally, some general questions with background variables were included (see the final composition of the questionnaire in Table A2).

After an initial pool of 170 items was developed, the items were reviewed by a panel of three experienced psychologists. These psychologists were asked to ensure that the team resilience items were consistent with the definition of the corresponding dimension, as provided in [1] as well as that the items for each dimension were comprehensive in their coverage of the different aspects of that dimension. Revisions were made on the basis of the psychologists' comments and the items were assessed for clarity once more. In addition, highly similar items were eliminated to reduce the length of the team resilience questionnaire, yielding a total of 156 items (7–48 items for each dimension). A 5-point Likert scale was used across all items, ranging from 'strongly disagree' (1) to 'strongly agree' (5).

[1] Keyword combinations for the (initial) literature search can be obtained from the authors.

#### 2.3.1. First pilot trial session with fault mechanics

Before administering the questionnaire to an entire study population it was decided to first conduct a trial session with a convenience sample of fault mechanics within a gas installation and infrastructure maintenance company. A pilot session was organized in which four technicians from the same team completed the questionnaire. They were asked to assess comprehensibility and wording of the items, relevance to their work and to their team's functions. This session resulted in a reduction and rephrasing of the questionnaire.

#### 2.3.2. Development of final version

The questionnaire was adjusted in line with the recommendations made by the fault mechanics. The aim was to shorten the questionnaire in such a way that respondents could fill in the questionnaire in approximately 20 min. To reduce the 156 questions to less than 80, the items were evaluated independently by the panel of three psychologists again for overlap or duplication and, if necessary, removed. Finally, all response categories were unambiguously formulated and various sub-headings were removed at different scales in order to prevent confusion on the part of the respondents.

The second version of the questionnaire was finally reduced to 78 questions. Major decisions that led to this result were the reduction of the questions in the shared leadership scale from 48 to 14 and removing several background questions. Since only transformational leadership is related to team resilience and team effectiveness [10], we decided to keep only those 14 items. After pre-testing the items of the ADAPTER questionnaire only two items of the original TMLQ questionnaire remained. The other 12 were adjusted in such a way that they were better understood by respondents but without compromising the construct validity. Resulting in a completely new shared leadership scale. In Table A3, the composition of the final version of the Dutch questionnaire is shown with a clear distinction between items removed and the remaining items.

#### 2.3.3. Final judgment of the fault mechanics

The final version was tested once again in a trial session with two fault mechanics (junior and senior technician) from the same team mentioned above. The questionnaire was completed within 20 min by both mechanics. They both found the questions to be very clear and relevant and were of the opinion that this version could be administered to the larger population (of fault mechanics).

### 2.4. Procedure

As our primary aim in this study was to find evidence for the construct validity of the team resilience abilities identified, these abilities were taken as the core set to be operationalized within the ADAPTER questionnaire. An opportunity sample of Dutch fault mechanics/gas fitters and their client counterparts (operational network coordination at a Dutch gas distribution company) was asked to participate in the study. Also, a Dutch chemical process company with operator teams was included.

For both groups of respondents tailored instructions were provided to ensure that participants were able to fill in the questionnaire with their own specific work context in mind. A description was provided of what was meant by the term 'team' and what was meant by 'sudden variations/unexpected events, which can occur during your work in the process installation or during troubleshooting'. An example instruction for the chemical process company is provided below:

> *"The team: refers to the team where you are normally employed (team A, B, C, D or E)*
> *The control of the installation process is often carried out in various shift compositions; within your company that is the teams A, B, C, D or E. When you read the word 'team' in this questionnaire, it will always refer to the entire team (sometimes 4 or 6 people) in which you operate yourself. To make answering the questions simple, you should envision the entire team each time a question is answered. "*

Also, several examples were given to illustrate what was meant by sudden variations and unexpected events, for instance:

- The situation in the field (the plant) may be different than you expect;
- (Spare) materials or tools are missing, not for use or broken;
- People you need (e.g., mechanic) are not available, cannot be reached or are called away;

For the gas fitters, examples were given that related to their own work and context.

Respondents were asked to answer the questions with these deviations in mind, collectively referred to in the questionnaire as: unexpected situations or events.

Completing the questionnaire took about 20 min. The answers were processed anonymously so confidentiality was respected.

### 2.5. Participants

ADAPTER data were collected from a total of 91 participants: 50 faults mechanics/gas fitters, 15 operational network coordinators and 26 chemical process operators. The process operators were divided in 4 teams of 5 operators and 1 team of 6 operators (this represents all shifts within the company). The sample demographics were as follows for the gas fitter company: 1 division leader, 8 team leaders, 41 gas fitters. Likewise, the sample demographics for the chemical company were as follows: 6 team leaders, 2 assistant team leaders, 4 senior operators, 15 operators and 1 apprentice operator. All participants were male. The response rate was 100%.

### 2.6. Data analysis

To evaluate ADAPTER, we computed descriptive statistics and reliability estimates for the whole sample using SPSS 22.

Before reliability and validity of the questionnaire were evaluated, first the assumption of deviance from normality was tested. The Shapiro–Wilk test of normality [26] showed that all items were normally distributed within the questionnaire and could therefore be used as (quasi)-interval variables when analyzing reliability and construct validity.

#### 2.6.1. Reliabilities

With reliability assessment, the quality of reliability coefficients and the quality of procedures used to calculate these reliabilities were evaluated. Reliability coefficients were calculated with Cronbach's Alpha, a measure of internal consistency of the items used. When decisions will be made on group level, coefficients above .70 are rated as good and below .60 as inadequate [27].

#### 2.6.2. Construct validity

With construct validity, the research question will be answered if the construct of team resilience has been measured with the ADAPTER questionnaire. This includes the characteristics of team resilience already described above. In general construct validity is tested by inspection of the correlations between items, or inter-item Pearson correlations [32]. These relationships depend on the defined characteristics of team resilience. Secondly, construct validity can be analyzed by inspecting the factor structure of the ADAPTER questionnaire with Principal Component Analysis (PCA). Here again, items more strongly correlated with each other will be more likely to be defined by an underlying factor or construct. PCA was used to ensure relationships encountered in the correlation analysis could actually be grouped into one factor. Finally, internal reliability can also be tested for each of the characteristics of team resilience. To test the team resilience taxonomy,

factor analysis was conducted on the sample to examine the underlying factor structure of the data.

## 3. Results

### 3.1. Reliabilities

Internal consistency reliabilities were computed for each of the nine final Team Resilience Questionnaire dimensions as mentioned in Table A3. As Table A4 shows, the alphas ranged from $\alpha$=.49 to.94. These alpha levels indicate a high degree of internal consistency for the items that compose each dimension except for the team learning behavior dimension which is relatively low (Cronbach's Alpha $\alpha$=.49). The highest alpha ($\alpha$=.94) of the transformational (shared) leadership scale corresponds with the reliability level of the transformational leadership scale in the original English TMLQ questionnaire; $\alpha$=.91 and $\alpha$=.89 ([10], p. 24). The internal consistency for the two learning scales, team psychological safety ($\alpha$=.49) and team learning ($\alpha$=.76), are lower than the original reliability scores of the learning scales of Edmondson (team psychological safety ($\alpha$=.82) and team learning behavior ($\alpha$=.78), [18]). Only team psychological safety was removed from further analysis due to considerable low internal consistency.

Table A4 presents descriptive statistics and inter-item correlations between the nine team resilience dimensions. As the table shows, the correlations among the dimensions ranged from .20 to .61. More specifically, reasonably high correlations (*rs* ranging from .56 to .79) were found for the following pairs of dimensions: situational assessment and team responding behavior, preoccupation with failure and team factors; situational assessment and heedful interrelating; and between shared leadership and team learning behavior. The correlation between cooperation between teams/departments and shared leadership was low ($r$=.20).

Before factor analysis was carried out, scales with poor internal consistency (team learning behavior) and individual items that did not fit with the total scale measured were removed. The rest of the sample was used to conduct a confirmatory factor analysis to examine the underlying factor structure of ADAPTER.

### 3.2. Factor analysis

As discussed in Section 1, team resilience was expected to consist of four task oriented capabilities (responding, learning, monitoring and anticipating) and two relationship oriented capabilities (cooperation with other teams and departments and team transformational leadership). The factor analysis we conducted was a principal components analysis with a Varimax rotation using an eigenvalue-greater-than-l.0 criterion. The Kaiser–Meyer–Olkin Measure of Sampling Adequacy was .67, indicating relatively compact patterns of correlation in the data (values should be higher than .50 in order to continue with the factor analysis). Bartlett's test of sphericity was highly significant, $\chi^2(1770, N=91)=4312$, $p<.001$, indicating that items were correlated with other items. These are important prerequisites for continuing the factor analysis. The six resulting factors almost exactly mirrored the six dimensions of team resilience hypothesized to be measured by ADAPTER (Table A5).

Only loading factors above .4 were considered (shown in bold) and, where this led to multiple loadings, a minimum difference of .2 was imposed [28]. According to these criteria the solution in Table A5 shows eight cross-loading items (more than one loading factor above .4 with difference between them below .2; (shown in bold and italic) and two non-loading factors (no loading factor above .4; shown in italic only). Subsequently items were removed the basis of non-loading (e08 and e09) and cross-loading (b03, b12, c08, c11, d01, d07, f02 and g05). Overall, loading coefficients are sufficiently high, which demonstrates a strong correlation between items and their loading components. Team responding behavior (b items), team learning (d items), Shared Transformational Leadership (c items+d06) and cooperation with other teams/departments (h items), perfectly mirror the dimensions of team resilience hypothesized to be measured by ADAPTER. Anticipation items (e) have considerable overlap with the monitoring items (f and g). Furthermore, a new factor appeared which consists of items from the other hypothesized factors (b05, g03, g07 and g10) and can be characterized as 'heedful interrelating'. Example questions are:

If an irregularity/unexpected situation arises during a repair job…

- "…the people in my team explicitly discuss the allocation of tasks and responsibilities"
- "…my team checks that the shared information is clearly understood"
- "…my team forms a mental picture of the significance of the information for the tasks of each member"

Overall, results of the ADAPTER analyses largely support the notion that team resilience is a multidimensional construct that requires different types of team resilience abilities (task and relationship oriented). An English version of the final questionnaire can be found in Appendix.

### 3.3. Results ADAPTER in different teams

Our second aim was to put the team resilience elements in the context of team level functioning within a real organization (Table A6). Therefore, mean comparisons on the measured scales between the different teams within the two companies that participated to fill in the ADAPTER questionnaire were examined. In addition to the quantitative results of the questionnaire, several group interviews were held with the teams in the pilot companies. This allowed us to review if the theoretical team resilience factors indeed reflected important abilities necessary to cope with unexpected situations and performance variations based on comments made by respondents.

At this time there is still insufficient data to calculate benchmark scores and thereby being able to determine if the score on a single item can be judged as (in)adequate. Therefore it was decided to use a criterion of 40% for assessing the scores to determine items that needed to be improved. For example, when more than 40% of the respondents gave a negative response to an item, then this was seen as a signal that something needed to be done to enhance resilience. Likewise, positive results can be used to encourage certain resilient behavior.

#### 3.3.1. Gas fitter and energy distribution companies

The gas fitter team in Region 1 displayed a significantly lower score on the Shared Transformational Leadership scale ($U$=2.7, $p<.05$) than the other gas fitter and ONC teams. Detailed examination at item level shows that this team largely disagrees ($\geq$40%) with items related to what is called Intellectual Stimulation (promote creativity and innovation) which is one of three sub dimensions of Shared Transformational Leadership [10]:

"encourage each other to rethink ideas which had never been questioned before" (44.8% )

"question the traditional way of doing things" (43.3% )

"seek a broad range of perspectives when solving problems" (53.3%)

"look at problems from many different angles" (40% )

Examples of remarks during the group interview from the gas fitter team in Region 1 with regard to the lower score on the Shared Transformational Leadership scale were:

"We will have discussions when they are needed."

"We also have to work."

"The atmosphere in the team must remain good."

These remarks seem to indicate that team members did not see the value of challenging each other, for instance, by taking a different perspective while troubleshooting. Also, intellectual stimulation appeared to be viewed by the team as a burden disrupting their work activities or potentially ruining the atmosphere. A separate interview

with their team leader afterwards revealed that he displayed a rather transactional style of leadership with a strong focus on productivity output. His behavior in turn was strengthened by the fact that the organization primarily steered on productivity output measures. This led him to decide not to invest in additional activities promoting collective team learning and problem solving abilities as long as the organization did not provide room for such activities to take place.

In contrast to the other teams the ONC team in Region 1 displayed the highest (significant) score on the Shared Transformational Leadership scale ($U=4.0$, $p<.05$). Detailed examination at item level shows that this team, more than the other team, largely agrees ($\geq 40\%$) with items related to all three sub dimensions of Shared Transformational Leadership [10]:

1. *Intellectual Stimulation (promote creativity and innovation)*
   "think it is important to discuss the different approaches when you are trying to solve problems together" (50%)
2. *Inspirational Motivation (articulate an attractive and/or recall a contagious vision of the future)*
   "have high standards, expect a lot of each other" (63%)
   "think up new solutions to existing problems" (50%)
   "are enthusiastic when they talk about their work" (75%)
3. *Individual consideration (coaching & mentoring)*
   "learn from each other and help each other" (88%)

Examples of remarks during the group interview from the ONC team in Region 1 with regard to the higher score on the Shared Transformational Leadership scale were:

"Cooperation within the team is good, we tell each other the truth and discuss problems."

"Openness and honesty characterize our team."

The output of the group discussion based on the questionnaire results seem to indicate that team members of ONC in Region 1 support and stimulate each other more than the other teams on task and interpersonal team processes. Although not statistically significant, this ONC team also scores higher than the other teams on other team resilience abilities as well: learning, anticipating and monitoring. A possible explanation could be that this team, compared to the other teams, seemed more homogeneous of composition; i.e. team members with the same disciplinary background, type of work and working in a limited number of regions to operate. Also, this team had a team leader who appeared to be quite stimulating on task and interpersonal team processes which might have reflected on their shared team leadership. Additionally, it may be that this team was less affected by the ongoing restructuring of the two organizations as indicated by the project leader who was the counterpart of this study for the gas fitter and distribution company.

### 3.3.2. Chemical process company

Within the chemical process company Team 1 scored higher on anticipating (Table A6; $U=4.2$, $p<.05$) than the other teams which was explained during the group interview as a result of the fact that this team in particular actively adapted and rethought its work practices after a near incident or when something unexpected happened. Those situations were perceived as shortcomings that needed to be dealt with and should be prevented in the future. Moreover, their team supervisors' leadership style was mentioned as an explanation, quote: "The team leader (referring to team leader Team 1) likes to give space to people so they can develop themselves and become a more self-managing team. Other team supervisors have a more directive style." When asked what is better for resilience, they answered: "Evaluating success with the team leader and/or teams together. Then you are really equal partners of each other."

The group interviews also gave more qualitative information illustrating the importance of the subscales monitoring and learning in the process industry. And addressing relevant issues important to the resilience of teams in the context of the broader organizational system. Several examples of these team discussions within the chemical process company are given.

Monitoring of operational processes (e.g. fluid flows, installation temperatures and availability of raw materials) is very important in a chemical company to maintain reliability and availability of the installation. To keep an accurate mental model of these processes and the overall status of the plant all teams must fill out a shift report that is verbally handed over to the upcoming shift. Although monitoring is a critical aspect of the job, several problems emerged from additional group discussions about the shift handover which can ben illustrated by the following quote: "There is no standardization in the manner in which the shift transfer is molded. Everyone puts in different accents. It is also true that you will only see some teams twice every 12 weeks. The shift book is used as a central monitoring system for plant conditions. However, for the sake of completeness, you depend on how elaborate and clear it is filled in by team members and the way it is used by the different shift leaders. In addition, it happens that some team members will already be with "one leg out of the door" when the shift handover is held. Thereby crucial information can be missed that might be important for your shift." The shift logbook and verbal transfer of issues that come up during the shift are complementary. The shift handover is performed by team members responsible for monitoring the same plant section in their corresponding shifts. Sometimes these handovers are rushed only stating NP: No Particulars. But sometimes you cannot settle for NP because what a 'NP' is for one is not 'NP' for someone else. So the company needs a way to operationalize 'NP' better. Also, the way the information about plant processes is gathered during a shift is discussed. "Routine inspection rounds are held frequently in different sections of the plant. The question is whether the mindset of team members is such that truly critical issues (early warnings) are adequately observed (seen, heard and smelled), registered in the shift logbook and/or debriefed during the shift transfer." To be able to monitor the plant processes adequately and maintain the reliability of the installation both the quality of information provided and the transfer thereof by different shifts are crucial and of vital importance for the overall system resilience.

Also, interesting insights with respect to the learning ability was obtained illustrated by this quote: "In the past an experienced operator would present a new operator with a potentially divergent scenario and ask him how he would solve this. Nowadays that does not happen anymore. And it often happens that we have to say, do this and do that and cannot explain why because we do not have enough time for this with four people in the shift when something is going on. That is teaching a monkey a trick, and not adequate training. That will only get worse and seems to be the opposite of increasing resilience! If the operational situation is only slightly different from the operator's procedure it is not well recognized and the process in turn runs wrong. We need the Unit-training (form of scenario training) back and also learn to solve disruptions and deal with unexpected situations in everyday operations. Also, who knows how to handle a plant shutdown anymore since plant conditions have become much more reliable?" It appeared that the formal Unit training was not given any more for quite some time. This, in combination with little opportunity to train for unexpected scenarios on the job was perceived as a major shortcoming. And the mentoring of trainee operators is completed by the various shifts differently depending on the role conception a senior operator has about this. The degree to which learning takes place within shifts seems therefore dependent on the individual approach used within the teams what appears to be the result of inadequate (feed forward) control of the organization. This brings up the importance of the organization in maintaining the resilience of teams.

Although not explicitly addressed in the ADAPTER questionnaire group interviews revealed that 'support of organization'

(factors influenced by organization) is very important to cope with unexpected situations and variety. Representative examples provided by the interviewees were:

- Reward systems: incentives to cooperate within and between teams (secured within a personnel evaluation system that defines and assesses necessary competencies for task and team-oriented capabilities).
- Resource availability: providing adequate (maintained) materials and skilled personnel
- Management/supervisory control: (expert) coaching/leadership style (of direct supervisor)
- Organizational climate: responsiveness, compliance with rules/procedures, craftsmanship/professionalism and safety culture within the organisation
- Education systems: mentorship, (unit) training aimed at improving knowledge/skill and experience (e.g. worst case scenario training)
- Information systems: all kinds of data available in the organization that is important to be able to perform the job properly (e.g. whiteboard with outstanding permits, shift reports, incident reports, registered plant modifications, alarm management)
- Intergroup relations: the degree of conflict/competition occurring between shifts as a result of not working together effectively at the task level and insufficient sharing of resources (data, equipment and expertise) which can be detrimental for overall organizational resilience.

Based on the interviews, several improvements were suggested to increase team resilience by the different operator teams:

- improving shift handover process;
- sharing lessons learned by for instance evaluating STOPs and critical incidents with all shifts together;
- re-introducing unit training (e.g. scenario training to improve handling unexpected events), supplemented by training of soft skills: 1) technical plant training, 2) identification of early warnings (scenario thinking, what-if), and 3) together with mentoring/learning on the job for (new) team members;
- an improved form of running inspection rounds in the plant facility must be found to communicate more by 'elicitation': explicit process to communicate experience and results of observations by sharing perceptions, assumptions, doubts, insecurities and feelings with respect to possible safety critical signals related to the plant process state so that departments, team members and team leaders are optimally informed (e.g. storytelling). This all needs to be recorded in an easily accessible information carrier. Information retrieved by this enhanced form of running plant inspections must be coupled with data from maintenance, management of (organizational) change and safety studies. Thereby, such an enhanced form of running plant inspections by the teams can serve the identification and updating of new risk scenarios and data can be used by the organization as input to training, mentoring and plant simulations.

## 4. Discussion

Unexpected performance variability and other demanding work situations require workers to deal with new and varied situations at work. The present research is an important first step in articulating the team resilience abilities in safety critical organizations such as petrochemical and energy distribution companies and contributes to the literature in three important ways. First, it offers a conceptual framework for defining and understanding team resilience that previously did not exist in the literature, thereby fulfilling the need to expand our current conceptualizations of the resilience domain to include team resilience. Second, although it seems intuitively plausible that team resilience is multidimensional, this research is the first effort that has been undertaken to systematically identify potential abilities of team resilience and to empirically examine the dimensionality of this construct. Finally, this research provides an instrument, ADAPTER, that can be used to diagnose team resilience requirements of safety critical jobs.

The major results of this research can be summarized as follows: First, team resilience appears to be a multidimensional construct, as evidenced by factor analysis of ADAPTER data that supported a six-dimension taxonomy. Three of the six dimensions perfectly mirror the dimensions of team resilience hypothesized to be measured by ADAPTER: team responding, Shared Transformational Leadership, and cooperation with other teams/departments. Two dimensions, anticipation and monitoring overlap with each other to some extent. This can be explained by the fact that monitoring component of anticipation does not involve the monitoring of real-time processes, but rather processes that have yet to materialize. The questions ask about future situations that involve monitoring of unexpected situations. Since they involve future situations, these questions show overlap with anticipation items.

Additionally, a new factor appeared and can be characterized as 'heedful interrelating'. This dimension also overlaps with both monitoring and responding to some extent. It can best be viewed as a subscale of the monitoring scale. Heedful interrelating addresses the way team members interact with each other in unexpected situations, rather than addressing situation assessment and collective sensemaking. The importance of heedful interrelating has also been demonstrated in medical teamwork, particularly in the case of unexpected and difficult problems that require the connection of individual know-how to meet situational demands [29].

These results show that there is only a partial match with the four resilience capabilities proposed by Hollnagel [1]. A similar failure to find the four main resilience factors was reported by Ferreira et al. [30]. They attributed this to the need to design questions in such a way that respondents can relate to them from a personal rather than organizational perspective. In other words, organizational factors are not likely to be captured by a questionnaire, according to Ferreira et al. Our results showed more overlap with the four resilience capabilities proposed by Hollnagel, even though the overlap was not perfect. In contrast to Ferreira et al.'s work, we included shared leadership and multi-team aspects, in order to embed teamwork in a broader organizational context. As our principal component analysis showed clear evidence for these two factors, we hypothesize that these play an important role in making teams more resilient. This hypothesis needs to be tested in field studies that measure team resilience more directly than through a questionnaire.

Moreover, additional analysis demonstrated the importance of team resilience abilities as assessed by ADAPTER within real organizations. It became clear that a transactional leadership style displayed by a team leader can be detrimental for the promotion of creative and innovative behavior during unexpected or demanding work situations. This result underlines once more the importance of the leadership dimension for resilience in organizations [31,32]. Leadership style of the supervisor should therefore be included as a separate dimension in ADAPTER.

Also, it became clear that several organizational support structures are important in relation to resilience abilities on the team level (e.g., reward systems, resource availability, management/supervisory control, organizational climate, education systems and information systems) and should be included as a separate dimension in ADAPTER. This result once again highlights the importance of embedding operational teams within the broader organizational (macro-)system. To operate effectively and maintain resilience, the team (micro-)system depends on the organizational system for providing the right structure, mechanisms and culture [15]. The connection between both systems lies in adequate and dynamic regulatory processes achieved with both feedback-controlled and feed-forward-controlled mechanisms. For example, direct corrective feedback (briefings) shortly before or during the execution of the work (e.g. process feedback or feedback with

respect to task performance and situational conditions) can be given by the team upward to higher organizational levels if necessary. Or providing feedback after finishing work or a project by the operational team to management using institutionalized After Action Review (AAR) processes [33,34]. In order to be proactive in the management of core processes including but not limited to safety, and to anticipate and forestall major safety changes or other relevant performance domains more information about overall system functioning is required [35]. Data from (pre-)briefing and AARs (both objective measurement scores and subjective judgments) provide crucial information on both the output of the processes but also from intermediate activities performed during operational processes. Thereby serving as early indications or faint signals of problems that start to occur in task performance or core processes [36]. These data can be used as indicators enabling management to take actions to forestall potential adverse outcomes. Moreover, feed-forward-controlled adjustment mechanisms from the macro-system (supervisor level and top management level) can improve the starting conditions of the microsystem by providing the right resources, information and support systems to enhance their resilience. Monitoring changes in the (internal and external) environment of the organization and making anticipatory changes in the core processes and operating conditions to accommodate them are important for the long-term stability and resilience of the entire system. This was also clearly demonstrated during group discussions held in this study.

For further study, it would be interesting to see whether interventions aimed at improving particular resilience abilities will have effects on overall team resilience and will persist in the long term. Additional data collection should further validate the ADAPTER questionnaire and will enable us to indicate whether certain team resilience abilities changed (permanently) as a result of resilience interventions and/or improvement strategies.

Valuable possibilities for improving team resilience have already been identified [37–39]. For instance, there is a need within the chemical process company that participated in this study to develop communication processes that allow for better elicitation and monitoring of early warnings during plant inspection rounds. Sutcliffe [39] also addresses the need to develop richer forms of communication and suggests the use of STICC. The STICC protocol may be useful in situations such as handoffs: S=Situation ("Here's what I think is going on"); T=Task ("Here's what I think we should do"); I=Intent ("Here's why"); C=Concern ("Here's what I think we should keep our eye on"); C=Calibrate ("Now, talk to me"). This protocol may be used to improve monitoring capabilities of the team under study. Furthermore, the team addressed the need for training unexpected scenarios (Unit training) to improve responding capabilities. One solution might be the error exposure training as proposed by Kontogiannis [40] which involves learning both from personal experience with errors and from vicarious exposure to errors (e.g., watching someone else commit errors). This type of training builds more accurate mental models of trainees, prevents repetition of errors, and increases transfer of skills to novel situations. Such training would not only support better learning but also increase error recovery and tactical re-planning of operating teams in safety critical domains.

Several remarks can be made with respect to the study design. This research is based on a sample of 91 cases. For factor analysis it is advised to use 100 cases or more [41]. The use of smaller samples was justified in our case on the basis of reliability or saturation of the measures, as indicated by loadings of the measures on the factors. In this study, several items and scales with low internal consistency were removed before analysis thereby allowing factor analysis on a smaller sample. Another area for future research is to empirically evaluate the construct validity and unique contribution of the proposed taxonomy compared with other team resilience taxonomies in literature.

Currently, the questions used in the ADAPTER questionnaire are phrased in a context-independent manner, that is, not tied to specific cases or incidents. We suspect that more valid responses may be obtained if the questions are framed in the context of a specific case or incident. Respondents will then have a particular case in mind when answering the questions, and results will be more comparable across respondents. Another approach to improve the applicability in practice could be to adopt Marks et al.'s [34] time-based conceptual framework of team processes for mapping the team resilience capabilities. This framework delineates action (i.e., task engagement) from transition (i.e., task preparation and post-task reflection) phases. They argue that certain team-performance processes are more relevant during the transition phase when the team is preparing or ending an engagement (i.e., mission analysis, goal specification, strategy formulation and planning), whereas other processes are more important when the team is engaged in action (i.e., monitoring goal progress, systems monitoring, team monitoring and back-up behavior, coordination). Other processes are temporally independent and relevant across phases (i.e., conflict management, motivating and building confidence, affect management). Likewise, the team resilience capabilities in ADAPTER hypothetically might be more relevant in certain performance episodes of the team. For example, responding and monitoring primarily in action phases, learning and anticipation during transition phases and shared leadership as an interpersonal team process would be relevant across all phases.

Finally, the generalizability of the results needs to be further evaluated in future research. This sample is limited due to its nature (convenience sample) and the exclusive participation of several Dutch companies. Therefore replications in other domains and nations using ADAPTER are highly recommended.

## 5. Conclusion

In conclusion, important team resilience properties are team responding, Shared Transformational Leadership, cooperation with other teams, proactive awareness of envisioned unexpected situations, and heedful interrelating amongst team members during unexpected situations. Our objective with the ADAPTER framework was, first, to find evidence for the construct validity of the four abilities (responding, monitoring, anticipating and learning) proposed by Hollnagel [1]. This evidence was only partially obtained, in that team psychological safety was removed because of statistical reasons and monitoring and anticipating were found to overlap to a considerable extent. Our second objective was to embed team performance within a broader organizational context by adding team leadership and cooperation with other teams as important constructs. We found clear evidence for the independence of these two relationship oriented constructs. We applied the ADAPTER framework successfully during interviews and workshops with the teams involved. For one team, lower scores on Shared Transformational Leadership on the questionnaire were mirrored by the team's focus on productivity rather than intellectual stimulation. This could hamper their resilience and is an area for team improvement. For the other team, the higher scores on anticipating were mirrored during discussions showing that the team actively tried to learn from incidents and thus anticipated future unexpected situations. Moreover, the importance of several organizational support structures were mentioned and should be included as a separate dimension in ADAPTER. The fact that we now have a partially validated measurement instrument (ADAPTER) to measure and assess resilience capabilities at the team level makes it possible to obtain these data, provide feedback to teams and thus enable continuous improvement of team resilience.

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## Appendix

See the appendix Tables A1–A6

**Table A1**
Team resilience abilities.

| |
|---|
| **Monitoring** |
| Distributed situation awareness [20,21] |
| Collective sensemaking/ situation assessment [22–24] |
| Heedful interrelating [25] |
| **Responding** |
| Adaptability [9] |
| Emergency preparedness [17] |
| **Learning** |
| Collective learning behavior [18] |
| Team psychological safety [18] |
| **Anticipation** |
| Preoccupation with failure [42] |
| **Cooperation with other departments** [19] |
| **Shared (team transformational) leadership** [43] |

**Table A2**
Composition of the ADAPTER (analysing and developing adaptability and performance in teams to enhance resilience) questionnaire.

| ADAPTER scales | Source | Original number of items |
|---|---|---|
| **Generic questions (1)** | TNO [a] | 18 |
| **Responding** | | |
| Team responding behavior | TNO [b] | 12 |
| **Learning** | | |
| Collective (learning) behavior team | Team learning survey [18] | 7 |
| Psychological safety team | Team learning survey [18] | 7 |
| **Anticipating** | | |
| Preoccupation with failure | Audit 5.4 [16] | 10 |
| **Monitoring** | | |
| Situation assessment | SAnTE [19] | 16 |
| Heedful interrelating | | |
| Teamfactors | | |
| **Cooperation with other departments** | SAnTE [19] | 12 |
| **Shared Leadership** | TMLQ [10] | 48 |
| **TOTAL** | | 156 |

[a] General questions - background variables such as gender, birth date, highest level of education and team role.
[b] TNO translated and reformulated the items based on questions Emergency Preparedness, [17] in the unity with style and response categories of the questionnaire.

**Table A3**
Composition of the final ADAPTER Questionnaire.

| ADAPTER scales | Source | Number of items | | | Example question [c] |
|---|---|---|---|---|---|
| | | Original | Removed | Remaining | |
| **Generic questions (1)** | TNO [a] | 18 | 13 | 5 | What year were you born? |
| **Responding** | | | | | |
| Team responding behavior | TNO [b] | 12 | | 12 | There are enough people and resources in my team to respond promptly to unexpected situations and events. |
| **Learning** | | | | | |
| Collective (learning) behavior | Team learning survey [18] | 7 | | 7 | We regularly reserve time to improve the working methods in our team. |
| Psychological safety team | Team learning survey [18] | 7 | 2 | 5 | The members of my team are sometimes dismissive of people because they are different. |
| **Anticipating** | | | | | |
| Preoccupation with failure | Audit 5.4 [16] | 10 | | 10 | My team regularly revises our working methods after a near-incident. |
| **Monitoring** | | | | | |
| Situation assessment | SAnTE [19] | 16 | 3 | 13 | If an irregularity/ unexpected situation arises during a repair job my team searches actively for information to get a clearer understanding of it. |
| Heedful interrelating | | | | | If an irregularity/ unexpected situation arises the people in my team explicitly discuss the allocation of tasks and responsibilities. |

**Table A3** (*continued*)

| ADAPTER scales | Source | Number of items | | | Example question [c] |
|---|---|---|---|---|---|
| | | Original | Removed | Remaining | |
| Teamfactors | | | | | If an irregularity/ unexpected situation arises the people in my team know exactly what to expect of each other. |
| **Cooperation with other departments** | SAnTE [19] | 12 | | 12 | Senior managers in other departments have the right knowledge and experience for the job. |
| **Shared leadership** | TMLQ [10]/TNO | 48 | 34 | 14[d] | The people in my team think it is important to discuss the different approaches when you're trying to solve problems together. |
| **TOTAL** | | 156 | | 78 | |

[a] General questions—background variables
[b] TNO translated and reformulated the items based on questions Emergency Preparedness, [17] in the unity with style and response categories of the questionnaire.
[c] A 5-point Likert scale was used across all items, ranging from 'strongly disagree' (1) to 'strongly agree' (5).
[d] TNO translated and reformulated 12 TMLQ items after pre-testing and adjusted them in line with the style and response categories of the questionnaire. Therefore only 2 items of the original TMLQ remained.

**Table A4**
Descriptive statistics, reliability coefficients, and correlations between ADAPTER dimensions.

| ADAPTER scales | *n* items | *M* | SD | Cron-bach's Alpha | ADAPTER scales | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1. Team responding behavior | 12 | 3.91 | .43 | .83 | – | | | | | | | | |
| 2. Shared Leadership | 14 | 3.50 | .67 | .94 | .36** | – | | | | | | | |
| 3. Psychological safety | 5 | 3.42 | .53 | .49 | .45** | .60** | – | | | | | | |
| 4. Team learning behavior | 7 | 4.00 | .53 | .76 | .26* | .40** | .46** | – | | | | | |
| 5. Preoccupation with failure | 10 | 3.65 | .41 | .65 | .37** | .49** | .34** | .44** | – | | | | |
| 6. Teamfactors | 3 | 4.00 | .63 | .84 | .39** | .53** | .49** | .40** | .50** | – | | | |
| 7. Situation assessment | 7 | 3.86 | .50 | .87 | .56** | .50** | .50** | .37** | .61** | .61** | – | | |
| 8. Heedful interrelating | 3 | 4.00 | .57 | .71 | .51** | .42** | .40** | .32** | .52** | .51** | .79** | – | |
| 9. Cooperation with other departments | 12 | 3.25 | .41 | .71 | .27** | .20 | .27* | .28** | .24* | .24* | .36** | .42** | – |

*Note.* $N=91$.
The statistical measure of central tendency that is used here is the median (*M*); applicable for variables measured on an ordinal level and above.
Cronbach's Alpha is a measure for the internal consistency of a dimension.
Correlations are calculated using Pearson Correlations (r) (2-tailed);

* Correlation is significant at the .05 level (2-tailed).
** Correlation is significant at the .01 level (2-tailed).

**Table A5**
Principal Component Analysis Component Matrix of ADAPTER dimensions.

| Items | Components | | | | | | Communalities |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| b01 | .24 | .26 | **.57** | .00 | .22 | .02 | .50 |
| b02 | .16 | .14 | **.75** | .00 | .09 | .07 | .62 |
| b03 | .00 | .20 | ***.48*** | *.12* | ***.48*** | −.03 | .52 |
| b04 | .23 | −.11 | **.68** | .10 | .14 | .25 | .62 |
| b05 | −.04 | .05 | .28 | 26 | **.53** | .23 | .48 |
| b06 | .23 | .21 | **.51** | .17 | .10 | .19 | .43 |
| b07 | .22 | .20 | **.51** | −.08 | −.20 | −.17 | .42 |
| b08 | .06 | .37 | **.57** | −.04 | .17 | .07 | .50 |
| b10 | .12 | .35 | **.45** | .17 | .07 | .10 | .38 |
| b11 | .16 | .18 | **.63** | −.05 | .24 | .16 | .54 |
| b12 | ***.46*** | .23 | ***.41*** | −.01 | .03 | .24 | .49 |
| c01 | **.71** | .16 | .29 | .03 | .03 | .12 | .63 |
| c02 | **.70** | .22 | .16 | −.05 | .32 | −.06 | .67 |
| c03 | **.71** | .21 | .18 | .06 | .20 | −.12 | .64 |
| c04 | **.68** | .15 | .30 | .01 | .21 | .03 | .61 |
| c05 | **.74** | .25 | .06 | −.03 | .28 | .07 | .70 |
| c06 | **.67** | .13 | .24 | .03 | .34 | −.07 | .63 |
| c07 | **.74** | .06 | .05 | 14 | −.09 | .30 | .66 |
| c08 | ***.55*** | .14 | −.08 | −.20 | .07 | ***.41*** | .55 |
| c09 | **.78** | .27 | .18 | .03 | .08 | −.08 | 73 |
| c10 | **.74** | .16 | .00 | .22 | −.06 | .23 | .69 |
| c11 | ***.57*** | −.07 | −.09 | .18 | .05 | ***.41*** | .54 |
| c12 | **.75** | .31 | .02 | .18 | −.14 | −.06 | .72 |
| c13 | **.72** | .18 | .28 | .09 | −.02 | .16 | .66 |

**Table A5** (*continued*)

| Items | **Components** | | | | | | Communalities |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| c14 | **.78** | .29 | .22 | .03 | .10 | .12 | .76 |
| d01 | .13 | .12 | .16 | .14 | ***.49*** | ***.49*** | .56 |
| d02 | .02 | .18 | .15 | −.03 | .05 | **.61** | .43 |
| d03 | .31 | .04 | .28 | .15 | .26 | **.40** | .42 |
| d04 | .09 | −.02 | .11 | −.09 | .04 | **.77** | .62 |
| d05 | .25 | .29 | .21 | 19 | −.07 | **.49** | .47 |
| d06 | **.45** | .26 | .31 | .14 | −.28 | .17 | .49 |
| d07 | ***.47*** | ***.47*** | .20 | −.03 | −.08 | .17 | .51 |
| e01 | .22 | **.58** | .17 | −.12 | .30 | .14 | .54 |
| e02 | .38 | **.58** | .16 | .10 | .38 | .20 | .70 |
| e03 | .16 | **.69** | .01 | .07 | −.04 | .18 | .54 |
| e04 | −.04 | **.52** | .17 | .11 | −.10 | .04 | .33 |
| e06 | .16 | **.67** | .09 | .05 | −.08 | −.09 | .50 |
| e08 | *.32* | *.16* | *.16* | *.26* | *.18* | *−.30* | .34 |
| e09 | *.37* | *.32* | *.03* | *.19* | *.01* | *−.20* | .31 |
| f01 | .23 | **.52** | .24 | .11 | .11 | −.03 | .41 |
| f02 | .31 | ***.48*** | .06 | .05 | .11 | ***.47*** | .56 |
| f03 | .34 | **.60** | .26 | .13 | .14 | .03 | .59 |
| g01 | .25 | **.58** | .38 | .01 | .18 | .05 | .58 |
| g02 | .15 | **.62** | .12 | −.04 | .37 | .15 | .58 |
| g03 | .29 | **.61** | −.06 | .14 | **.46** | .04 | .70 |
| g04 | .29 | **.64** | .00 | .01 | .31 | .15 | .61 |
| g05 | .21 | ***.43*** | .21 | −.02 | ***.56*** | .06 | .60 |
| g06 | .29 | **.60** | .18 | .02 | .20 | .08 | .53 |
| g07 | .06 | .37 | .31 | .22 | **.60** | −.01 | .65 |
| g08 | .23 | **.64** | .15 | .22 | .28 | .15 | .63 |
| g09 | .16 | **.62** | .31 | .04 | .21 | −.05 | .56 |
| g10 | .18 | .30 | .08 | .12 | **.59** | −.01 | .49 |
| h01 | .19 | .15 | .08 | **.74** | −.15 | .07 | .64 |
| h02 | .24 | .00 | −.10 | **.80** | −.10 | −.06 | .72 |
| h05 | .02 | .34 | −.08 | **.67** | .07 | .15 | .60 |
| h06 | .02 | .26 | −.13 | **.82** | .03 | .08 | .76 |
| h07 | .12 | .21 | −.03 | **.57** | .35 | .13 | .52 |
| h09 | .01 | .02 | .11 | **.67** | .29 | −.17 | .57 |
| h10 | −.07 | −.13 | .21 | **.65** | .07 | −.05 | .49 |
| h11 | .04 | −.18 | .19 | **.68** | .38 | −.02 | .68 |
| % Variance | 30 | 7 | 6 | 5 | .4 | 3 | |
| Eigenvalue | 17.9 | 4.5 | 3.9 | 2.9 | 2.5 | 2.0 | |

*Note.* $N=91$. Entries in the "Item" column represent the 60 unique items that appeared in ADAPTER. Rather than present each item in the table, the team resilience dimension that the item was intended to tap is indicated with a letter. Boldface indicates the highest factor loading for each item. Italic items are non-loading factors. Both italic and boldface indicated items are cross-loading factors. Team Responding Behavior (b), Shared Transformational Leadership (c), Team Learning Behavior (d), Anticipation (e), Monitoring (f and g) and Cooperation with other departments (h) correspond to Factors 3, 1, 6, 2, 2 and 4, respectively. ADAPTER = analysing and developing adaptability and performance in teams to enhance resilience; 1 = Shared Transformational Leadership; 2 = monitoring & anticipating; 3 = responding; 4 = cooperation with other departments; 5 = heedful interrelating; and 6 = learning.

**Table A6**
Mean comparisons between participating companies.

| **ADAPTER scales** | **Teams**[a] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **N:** | **Region 1** | | **Region 2** | | **Chemical company** | | | | | Total |
| | Gasfitters | ONC | Gasfitters | ONC | 1 | 2 | 3 | 4 | 5 | 91 |
| | 30 | 8 | 20 | 7 | 6 | 5 | 5 | 5 | 5 | |
| Responding | 4.0 | 4.0 | 3.9 | 4.0 | 3.9 | 3.5 | 4.0 | 3.9 | 3.6 | 3.9 |
| Shared Transformational Leadership | 2.7▲ | 4.0▲ | 3.5 | 3.6 | 3.6 | 3.3 | 3.7 | 3.8 | 3.5 | 3.3 |
| Learning | 3.4 | 3.5 | 3.5 | 3.8 | 3.8 | 3.2 | 3.3 | 3.6 | 3.3 | 3.5 |
| Anticipating | 3.5 | 3.9 | 3.5 | 3.7 | 4.2▲ | 3.9 | 3.9 | 3.7 | 3.6 | 3.7 |
| Monitoring | 3.8 | 4.3 | 3.9 | 3.8 | 4.1 | 3.9 | 3.8 | 3.8 | 3.7 | 3.9 |
| Teamfactors | 4.0 | 4.5 | 4.0 | 4.0 | 4.3 | 4.3 | 4.1 | 4.3 | 4.0 | 4.1 |
| Situation assessment | 3.8 | 4.1 | 3.8 | 3.8 | 3.9 | 3.7 | 3.8 | 3.8 | 3.6 | 3.8 |
| Heedful interrelating | 3.8 | 4.3 | 3.9 | 3.7 | 4.2 | 3.7 | 3.7 | 3.6 | 3.7 | 3.9 |
| Cooperation with other departments | 3.3 | 3.0 | 3.3 | 3.0 | 3.3 | 3.3 | 3.2 | 3.4 | 3.4 | 3.3 |

*Note.* Means are tested with Independent-Samples Mann-Whitney *U* Test (horizontal comparisons). The contrast is subgroup vs other cases (weighted deviation contrast). ▲: $p < 0{,}05$ (and ▼): significantly high (low) means (2-tailed). *P*-values Bonferroni corrected. Symbols are based on significance only, not on effect size.

[a] ADAPTER data was collected from 91 participants: 50 faults mechanics/ gas fitters, 15 operational network coordinators and 26 chemical process operators. The process operators were divided in 4 teams of 5 operators and 1 team of 6 operators.

| Items | ADAPTER scales and questions (English version) |
|---|---|
| | **Responding** |
| bb01 | My team responds well to unexpected situations and events |
| bb02 | My team can keep an unexpected situation or event under control |
| bb04 | There are enough people and resources in my team to respond promptly to unexpected situations and events |
| bb05 | It is clear who is in charge in my team when we respond to unexpected situations and events |
| bb06 | My team may decide independently to solve an unexpected situation or event |
| bb07 | My team is prepared for unexpected situations and events that happen more often |
| bb08 | In my team we know when to get help to solve an unexpected situation or event |
| bb10 | My team is good at improvising when we are solving an unexpected situation or event |
| bb11 | My team responds well to unexpected situations and events |
| | **Shared Transformational Leadership** |
| | *The people in my team…* |
| cc01 | have high standards, expect a lot of each other |
| cc02 | think it is important to discuss the different approaches when you're trying to solve problems together |
| cc03 | listen carefully to each other |
| cc04 | think up new solutions to existing problems |
| cc05 | encourage each other to discuss things that are taken for granted |
| cc06 | focus on improving each other's strengths |
| cc07 | talk optimistically about the future © |
| cc09 | learn from each other and help each other |
| cc10 | are enthusiastic when they talk about their work |
| cc12 | treat each other with respect |
| cc13 | look at problems from many different angles © |
| cc14 | give each other good advice aimed at improvement |
| dd06 | We sometimes ask people outside the team for information that is relevant for the way we work |
| | **Learning** |
| dd02 | In my team differences of opinion are resolved in private and not in the team as a whole |
| dd03 | My team collects as much key information as possible from people outside the team |
| dd04 | My team searches regularly for new information, and then it may happen that we that we tackle the situation totally different |
| dd05 | There is always someone in my team who makes us think about how we do our work |
| | **Anticipating** |
| ee01 | My team considers all mistakes and irregularities in the work and tries to understand what caused them |
| ee02 | If something unexpected happens, my team tries to find out if we could have prevented it |
| ee03 | When something almost goes wrong (a near-incident) my team sees that as a shortcoming that we need to resolve |
| ee04 | My team regularly revises our working methods after a near-incident |
| ee06 | The people in my team report mistakes even when no-one else has noticed them |
| | **Monitoring** |
| ff01 | Within my team, we know each other and we know exactly what to expect of each other |
| ff03 | In my team we have insight into each other's craftsmanship (knowledge and skills) |
| | *If an irregularity/unexpected situation arises when solving a disturbance then…* |
| gg01 | my team searches actively for information to get a clearer understanding of it |
| gg02 | my team checks whether the information is correct |
| gg03 | my team forms a mental picture of the significance of the information for the tasks of each member |
| gg04 | my team forms a mental picture of how it develops |
| gg06 | the people in my team ask each other critical questions to get a clear idea of the situation and our tasks |
| gg07 | the people in my team share relevant information in time and on their own initiative |
| gg08 | we address each other as we have different understanding about what is going on |
| gg09 | the people in my team do not hesitate to speak out openly when they think differently about the solution |
| gg10 | my team searches actively for information to get a clearer understanding of it |
| | **Cooperation with other departments** *(For other departments, read [insert dept A], [insert dept B], [etc.])* |
| hh01 | Senior managers in other departments have the right knowledge and experience for the job |
| hh02 | The people in other departments have the right knowledge and experience for the job |
| hh05 | It is clear which departments should perform which tasks |
| hh06 | The tasks are allocated to the departments which have the right expertise |
| hh07 | When we work with other departments it is clear who has the power to take decisions |
| hh09 | My team is dependent on other departments for carrying out tasks |
| hh10 | The exchange of information between my team and other departments runs smoothly |
| hh11 | Decision-making runs smoothly in other departments |
| | **Heedful interrelating** |
| bb05 | My team has a protocol for responding to unexpected situations and events |
| | *If an irregularity/ unexpected situation arises when solving a disturbance then…* |
| gg03 | my team forms a mental picture of the significance of the information for the tasks of each member |
| gg07 | my team checks that the shared information is clearly understood |
| gg10 | the people in my team explicitly discuss the allocation of tasks and responsibilities |

*Note*. Respondents are asked to read the statements described above and have to indicate how far they agree or disagree with the statement scoring a 5-point Likert scale used across all items, ranging from 1= strongly disagree, 2=disagree, 3= neither disagree nor agree, 4=agree to 5=strongly agree.
The c and g-items use a pre-sentence/ antecedent. For h-items regarding the cooperation with other departments respondents are asked to keep departments in mind with whom they regularly collaborate. Those are company specific and should be customized according to relevant departments within your study.
This is a back translated English version of the final Dutch questionnaire and still needs to be validated correspondingly. 

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