INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED15
27-30 JULY 2015, POLITECNICO DI MILANO, ITALY

MEETINGS IN THE PRODUCT DEVELOPMENT PROCESS: APPLYING DESIGN METHODS TO IMPROVE TEAM INTERACTION AND MEETING OUTCOMES

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Abstract

Design methods are used to support single steps of the product development process. They are expected to contribute to reducing the development time and to enhancing the degree of innovation of the outcome. But as they are time-consuming, cost-intensive and so far of little practical use, there is a call for new approaches and more appropriate selection of methods. The high level of abstraction and the theoretical overload of many design methods and their descriptions are seen as their main deficits. The inclusion of team competencies and team aspects (e.g., team size) is proposed to achieve a greater acceptance of design methods in practice. Supporting this idea, we present and evaluate the results of a single case study aiming at demonstrating the benefit of design methods in team meetings. Finally, we introduce an approach for using the observatory data to improve the use of design methods by means of an advanced methods assistance system.

Keywords: Human behaviour in design, Design methods, Team meetings, Single Case Study

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

In the product development process, team meetings are an important communication tool for achieving the specific goal of developing a new product or adapting an existing product to recent requirements: Information need to be shared, targets or mile stones need to be arranged, problems need to be solved, decisions need to be made, etc. (e.g., Feldhusen and Grote, 2013). Much is known about how team meetings in general should be designed for improving meeting quality (e.g., Cohen et al., 2011). A good summary of the existing research on crucial meeting design characteristics, such as agenda use, meeting length, and attendee characteristics, is offered by Odermatt et al. (in press). More specifically, Badke-Schaub and Frankenberger (2012) analysed team meetings during the product development process with regard to the management of critical situations during the development process. A special focus on the usefulness of design methods in this context is not explicitly mentioned. However, they can help to structure a meeting and to achieve meeting goals such as making a decision (Value Analysis), finding solutions or solving a problem (Morphological Diagram). Furthermore, design methods can support both the reduction of development time and the enhancement of the degree of innovation (e.g., Feldhusen and Grote, 2013; Lindemann, 2009). On the other hand, several deficits of design methods, which hinder their use in practice, are consistently named. The major ones are the complexity and high level of abstraction of many of them (Jänsch, 2007).
The aim of this paper is to demonstrate the usefulness of design methods during meetings of product development teams. Exemplarily, we accompanied a student engineering product development team for the entire time they worked together on a particular development task. We observed each team meeting, taking note of every one of the participants' face-to-face interactions, and asked them about their perceptions of the meetings. Thus, we do know when and how this particular team used design methods and how this affected the meeting outcomes. Afterwards, we used this information about the team and the general acceptance of learning methods from a database to propose a methods selection system. In particular, this system is intended for assisting the selection of design methods and for providing the information necessary for considering the competencies of the observed team.

2 STATE OF THE ART

After a further explanation of the practical use of design methods based on an exemplary survey, we will present the existing concept of a methods assistance system to provide information about design methods. Subsequently, we will introduce the aim of this paper.

Use of methods in practice

The lack of acceptance of design methods in practice is based mainly on their high complexity, high level of abstraction and the theoretical overload of the method descriptions (Jänsch, 2007; Reinicke, 2004). Additionally, many design methods do not provide the flexibility, which would be necessary for adapting them to real development situations. Hence, their benefits often do not justify the effort needed to implement the methods in practice (Wallace, 2011). Furthermore, limited human resources and restricted temporal capacity often prevent a proper introduction and implementation of design methods in practice (Geis et al., 2008). The missing consideration of the method users' characteristics and competencies represent another obstacle for the individual adaptation to the unique method user or to the team and the development situation (Badke-Schaub et al., 2011).
Moreover, the results obtained in the context of the survey *MuPro-KMU* (Methodical Support in the Product Development Process for Small and Medium sized Enterprises), which was presented in 2014 and examined the needs of small and medium sized enterprises (SME), reflect the same deficits of the design method use and the lack of acceptance in practice. Among the approximately 90 employees from five SMEs from the region of Brunswick (Germany) and from one large-scale company, a generally low use and knowledge of design methods were found. About half of the enquired methods, such as Quality Function Deployment (QFD) or Synectics, are not implemented or even known in the enterprises. On average, each employee uses four to five design methods him- or herself, but doing so in general is rare (Bavendiek et al., 2014). The reasons were similar to those mentioned in former research (e.g., Jänsch, 2007; Reinicke, 2004). The purposes of method use that were mentioned most frequently are searching for solutions, reviewing and comparing solutions subsequently, and decision making. Nearly three quarters of all respondents use the methods both in a team and by themselves,

which should be taken into account for the description and especially the selection of design methods (Bavendiek et al., 2014).

Methods assistance system

At the Institute for Engineering Design at TU Braunschweig (Brunswick, Germany) a concept for a methods assistance system was developed in previous research (Bavendiek et al., 2014). The purpose was to support the user in selecting a suitable method for his or her development task at its best.

The methods assistance system is divided into a methods description model and methods selection model, which have been developed with the aim of a situation-specific selection of methods, especially considering the developer or the team.

The methods selection model offers a targeted access to the methods stored in the methods description model by pre-filtering. In this way, the user receives a recommendation of appropriate methods according to his query. The query begins by collecting specific information on the user or the team leader who starts a pre-filtering by furnishing information on the actual situation of the development process. With the selected pre-filtering criteria, the query connects to the description model. The description model, in turn, responds by showing all relevant corresponding method data sheets. These pre-filtered methods are evaluated in the next step in the methods selection model with regard to further criteria, e.g. given by the user. Finally, the methods that were evaluated as corresponding to the user's needs are displayed as a recommendation for the respective development team. However, the final choice of a method remains the responsibility of the team leader, as does its acquisition in the case that an unknown method is selected. Therefore, the information and tools stored in the methods description model can only support, but not guaranty the acquisition and use of a method (Bavendiek et al., 2014).

Via the single case study described below, we investigate the importance of method use for both the teams' perception of its performance and its actual verbal meeting behaviour. Also accounting for the extent to which the team was able to implement new methods with the help of a conventional method database, we show the benefit of the proposed methods assistance system. Moreover, we extend the concept of the proposed system by the observed information.

3 CONCEPT OF THE CASE STUDY

Sample

We observed a single product development team consisting of four undergraduate mechanical engineering students over a period of four month during an entire student project. The project was a regular part of the students' curriculum. The task of the team was to develop a special fixture to hold an umbrella on a bike during cycling in the rain. The participants were 21- to 26-year-old male students. Prior to the study, they were taught about design methods, their aims and approaches. Especially with regard to the aim of the study, the team was asked to use design methods as often as possible. For doing so, the team had access to the methods database *Methodos* within the *GINA* (Holistic Innovation Processes in Modular Enterprise Networks) database (e.g., Franke et al., 2003). This database contains about 50 methods described in a structured way and supplemented by templates and exemplary forms. The team members were required to use the *Methodos* database as their main source for finding new methods. Moreover, the VDI standard 2221 (Systematic approach to the development and design of technical systems and products) (VDI, 1993) was given to guide the team while working on the development task.

Setup

For the team's project meetings, we provided a project room that was suitable and technically equipped with video cameras for the purpose. Furthermore, the room was equipped with computers and a flip chart for self-determined use. In addition, each participant were given a headset with a hands-free microphone, allowing to record the voice data with 48 kHz sampling rate and 24 bit resolution at a central point. Figure 1 graphically shows the room setup.

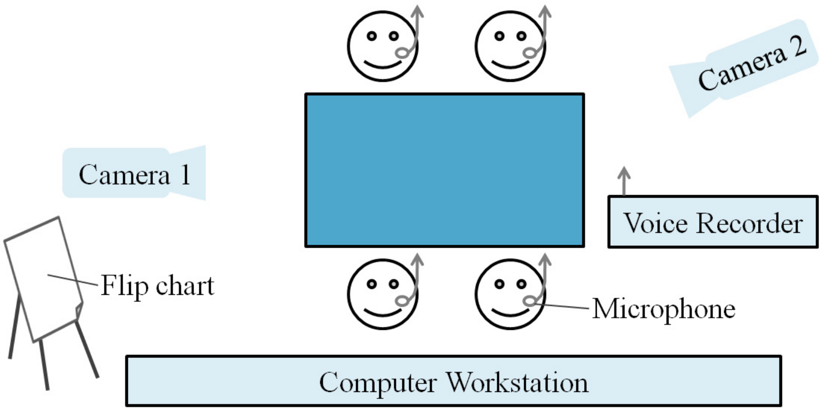

Figure 1. Project room setup

Participants were advised to ignore the video/audio equipment and to act as they would under normal circumstances. When asked afterwards, participants characterized their behaviour as typical of them. In total, the team as a whole met 15 times during the product development process. The duration of the meetings ranged from 1 to 3.5 hours. After each meeting, the participants were asked to fill a questionnaire regarding their perception of the particular team meeting.

For our analysis, we only consider the first nine meetings. The later meetings were not taken into account as they mainly contained elaborating and realizing the umbrella fixture. Thus, design method use was not applicable at the later stage. Design methods were used in five of the nine meetings. In the first meeting, the team chose to use multiple methods. Hence, in this meeting, we also compared meeting phases in which design methods were used with phases they were not used.

Measures

We collected two different kinds of measures for the two different foci: First, we used surveys to receive team members' information about the meetings. Second, we used the videotaped interaction during the first meeting to examine meeting phases.

(1) Survey constructs measured via questionnaires after each meeting

Task performance. Task performance was assessed with six German items adapted from Kirkman and Rosen (1999) using a 6-point response format ranging from 1 (strongly disagree) to 6 (strongly agree). A sample item is "As a team, we meet our quantitative and qualitative goals."

Team meeting satisfaction. Meeting satisfaction was assessed with the German measure used in Kauffeld and Lehmann-Willenbrock (2012). The four items (e.g., "I am completely satisfied with the results of the discussion.") were assessed using a 6-point response scale ranging from 1 (strongly disagree) to 6 (strongly agree).

Team affect. The affective state (mood) of the team was measured on three dimensions via the PANAVA-KS (Schallberger, 2005): positive affect, negative affect and valence. The dimension of positive affect expresses the extent of enthusiasm, alertness and activation a person is feeling. Persons with a high level of PA feel highly energized, concentrated, and positively engaged. Persons with a low level PA feel de-energized and lethargic. The dimension of negative affect reflects perceived distress and negative engagement. Persons with high levels of NA experience aversive moods such as anger, fear and nervousness. Persons with a low level NA feel calm and serene (Watson et al., 1988). The valence dimension indicates the pleasantness of the affect state (Schallberger, 2005). The participants were asked to rate their current affective state between pairs of opposing adjectives, e.g., tired – wide-awake (PA), calm – nervous (NA), unhappy – happy (VA), using a 7-point scale to rank the response for each pair.

(2) Interaction observed during the team meetings

Team interaction. The meeting interaction of the first videotaped meeting was coded using the act4teams coding scheme (e.g., Kauffeld and Lehmann-Willenbrock, 2012) and INTERACT software (Mangold, 2010) by two trained raters. Inter-rater reliability was assessed using Cohen's Kappa (Cohen, 1960). Kappa yielded a value of κ = .63, suggesting a good congruence (Fleiss, 1981).

Procedural statements (amongst three other types of team interaction statements) are coded using several categories, representing how effective the team is structuring its task. Positive procedural statements comprise goal orientation, clarifying, procedural suggestions, procedural questions, prioritizing, time management, task distribution, visualizing, and summarizing. Negative procedural statements are coded as losing the train of thought in details and examples. In addition to the category frequencies, we computed an overall procedural statement value by subtracting the negative from the positive statement value. We then divided the whole meeting into discussion phases (sets) either with or without design method use. As sets differed in length, we related the coded interaction data to a ten-minute period (*rates*).

Hypotheses

Although the usage of design methods in practice is only scarcely distributed, they can be found to contribute to a more successful product development process (Graner, 2013). They inherently support the user in structuring information and in coming up with ideas (see section 1). Therefore, we expect them to enhance both the procedural communication between team members and the affective state of the team. Procedural communication has been found to be linked to increased meeting satisfaction and other team outcomes (e.g., Kauffeld and Lehmann-Willenbrock, 2012). The structuring provided by design method use should also be observable in the meeting interaction of product development teams. Accordingly, we assume that team meetings proceed more successfully when using design methods than without them. More precisely, we posit the following hypotheses on the use of design methods within team meetings:

1. Design method use is related to higher perceived task performance.
2. Design method use is related to higher meeting satisfaction.
3. Design method use is related to a more positive team affect.
4. Design method use is related to a higher amount of proactive procedural behaviours and a smaller amount of counteractive procedural behaviours in the team meeting interactions.

4 ANALYSES

Accounting for the single case design and the lack of appropriate single case statistical approaches applicable for our dataset, we use descriptives (means, standard deviations and plots) to compare phases of design method use with those without design method use. However, we use a non-parametric permutation test, which should be applicable for the data as well (cf. Bortz and Döring, 2006) in order to identify different tendencies.

Table 1. Means and standard deviations (SD) of the survey constructs.
n: number of meetings with/without method use. [a]: means differ significantly.

Act4teams categories		Method use	n	Mean	SD
Meeting satisfaction[a]		no	4	3.70	.47
		yes	5	4.45	.34
Task performance[a]		no	4	3.28	.41
		yes	5	3.96	.18
Team affect	Positive affect	no	4	4.28	.30
		yes	5	4.30	.33
	Negative affect	no	4	3.33	.08
		yes	5	3.54	.30
	Valence	no	4	4.13	.14
		yes	5	3.90	.27

First, we compare the nine meetings with/without design method use regarding the assessed survey measures, which were aggregated on team level. Considering the statistics shown in Table 1, we observe that there is a slight trend of meetings, in which design methods were used, to go along with greater meeting satisfaction and greater task performance compared to non-method meetings.

Regarding the team affect, meetings with design methods on average tend to go along with no difference in positive affect, a slightly higher negative affect as well as with lower valence. However, only the difference on meeting satisfaction (Mann-Withney U= 1.500, $p<.05$, two-tailed) and task performance (Mann-Withney U= 1.000, $p<.05$, two-tailed) are significantly different, thus supporting hypotheses 1 and 2. Hypothesis 3 stating that design method use is related to a more positive team affect could not be supported. Both of those trends are illustrated in Figure 2. Considering meetings 4-6, we observe a strong decrease in task performance and meeting satisfaction from meeting 4 (with method use) to meeting 5 (without method use), increasing again to meeting 6 (with method use).

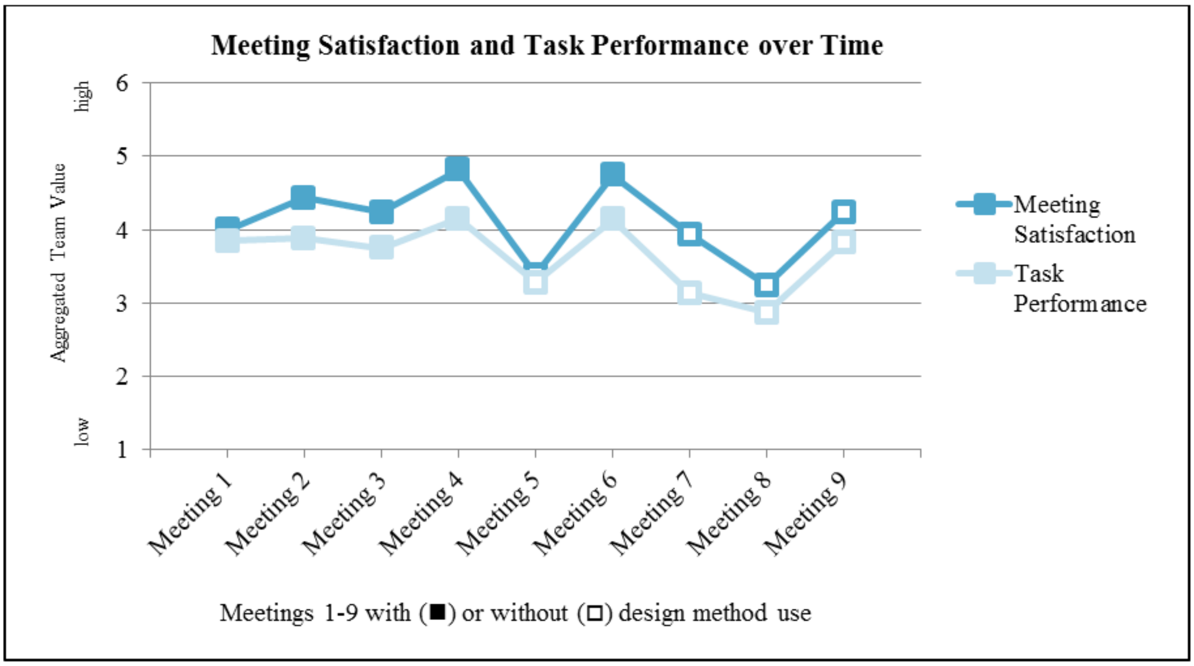

Figure 2. Team level meeting satisfaction values and task performance values over time.

Second, we compare the meeting phases of design method use with those of no use for the first meeting regarding the procedural statements (hypotheses 4). Considering the statistics shown in Table 2, we observe a slightly higher average goal orientation, clarifying, procedural suggestions, prioritizing, visualizing, and summarizing in meeting phases with method use, which is going in line with our expectations. Also expected was the lower value of losing the train of thoughts in details and examples in those phases. Contrary to expectations, procedural questions, time management, and task distribution are lower as well. However, we note large standard deviations and no statistical significance of these differences. Though, considering the difference on the overall value of procedural statements, we observe a very high and significant difference of meeting phases with method use compared to phases without (Mann-Withney U= 2.000, $p<.05$, two-tailed). In meeting phases without method use, we even observe an average negative value, indicating a negative procedural statement climate.

5 IMPLICATIONS AND FUTURE WORK

The results indicate that in this particular team the use of design methods in the product development process is connected with higher task performance, meeting satisfaction and a better ratio of procedural statements during the meeting.

5.1 Further research

Though, this study faces some limitations. The main limitation concerns the single student team, which represents the only sample to examine our hypotheses. Thus, our results cannot be generalized. However, we were able to monitor one team over the whole process of its product development. So, our results are a first indicator of how useful design methods are in context of team meetings.

Consequently, some more work has to be done to ease the acquirement of methods (e.g., due to method data basis with usage information) for product development teams in order to make the process more successful. In future research, the impact of the various methods should be examined based on a greater sample of teams and evaluated with engineering practitioners. As the quality of the final product is one of the most important parameter for measuring and evaluating the value of method use, multiple teams with the same task need to be observed. Thereby, it will be possible to compare the method use's outcome (the product). Furthermore, the usefulness of design methods in the different phases of the product development process could be analysed to give a more differentiated statement. In addition, we are aware of the fact that the observed team only used well-known methods (Competitor Analysis, Requirements Specification, Brainstorming, Morphological Diagram, Argumentative Balance as well as calculations of machine elements and CAD (for descriptions see Lindemann, 2009)). In a next step, the teams should apply design methods with higher complexity as well as evaluate their success.

Table 2. Means and standard deviations (SD) of the act4teams categories.
n: number of meeting phases with/without method use in meeting no. 1.
a: means differ significantly.

Act4teams categories	Method use	n	Mean	SD
Goal orientation	no	5	.00	.00
	yes	5	.60	.87
Clarifying	no	5	3.34	3.86
	yes	5	7.51	5.96
Procedural suggestions	no	5	2.87	4.16
	yes	5	4.82	4.96
Procedural questions	no	5	3.00	4.49
	yes	5	1.38	2.46
Prioritizing	no	5	.12	.26
	yes	5	.13	.29
Time management	no	5	1.18	2.65
	yes	5	.00	.00
Task distribution	no	5	2.19	2.98
	yes	5	1.47	1.63
Visualizing	no	5	2.60	3.59
	yes	5	11.78	12.02
Summarizing	no	5	.00	.00
	yes	5	.34	.50
Losing the train of thought in details and examples	no	5	33.94	23.36
	yes	5	6.13	5.72
Procedural statements[a]	no	5	-18.63	24.54
(total value = Σ positive statements - Σ negative statements)	yes	5	21.90	10.65

As outlined in section 3, the team affect during the meetings is currently measured by the participants themselves filling out a survey at the end of the meeting. Since the meetings have a duration of up to 3.5 hours, the affect of the teams can show large variation during a meeting, so it is desirable to get a higher resolution of the team affect. Thereby a higher frequency of filling out the survey is unfavourable, as this would implicate an interruption of the meeting. Additionally, by increasing the number of teams the effort of supervision and evaluation would grow enormously. In order to reduce the effort of the participants and the supervisor, an automatic assistance system monitoring the affect of the team members would be helpful. In the following, we briefly give an overview of this technical field and our future work to develop this approach.

In recent years, a new field called social signal processing has received more and more attention in the field of automatic pattern recognition. The aim of this research topic is an automatic analysis of human behaviour, especially in small groups, with a focus on interaction (e.g., turn taking, active listening), internal states (e.g., affect, emotions, interest), personality (e.g., dominance, extroversion) or social relations (Vinciarelli et al., 2012; Gatica-Perez, 2009). With the aid of the already recorded data by the headset microphones, it is our target to develop a real-time system, which analyses the conversation by means of the microphone signals regarding the general affect of the considered group and their team members for further investigations. In case of a negative team affect, a moderator could intervene and suggest a method to bring the meeting forward. Simultaneously, the system could observe if the affect of the team increases through the intervention of the moderator. Furthermore, this approach results in the ability to analyse manually the acceptance and the effects of the proposed methods afterwards, since the affect of every team member is recorded at any time.

However, the development of a robust automatic affect recognition system with a useful performance in real-time is still a big challenge. Depending on the database the usual accuracy rate of an affect recognition system is located in the range of 50 to 90% (Schuller et al., 2009), especially when using natural data the accuracy rate decreases. Note, however, even the human affect classification accuracy is distinctly below 100%. Zeng et al. (2009) give a comprehensive overview about the state of the art of affect recognition. Nevertheless, an automatic system would not only enable a more detailed analysis of a group meeting, but also reduce the effort of the so far manual processed evaluation, which would allow an increase of the number of investigated groups.

5.2 Practical use as an advanced methods assistance system

As the monitored team applied only well-known methods, assumedly to reduce the time for searching 'new' methods, we presented an existing concept of the methods assistance system (see section 2), which can facilitate the selection of an appropriate method. In further work, this concept will be realised, primarily for educational purposes. Evaluations with the aid of the methods assistance system can then contribute to develop method descriptions that enable the students to adopt the methods into practical work. In addition, we will introduce the system in practice (e.g. in SME) to improve the practice-focus by evaluating their experiences.

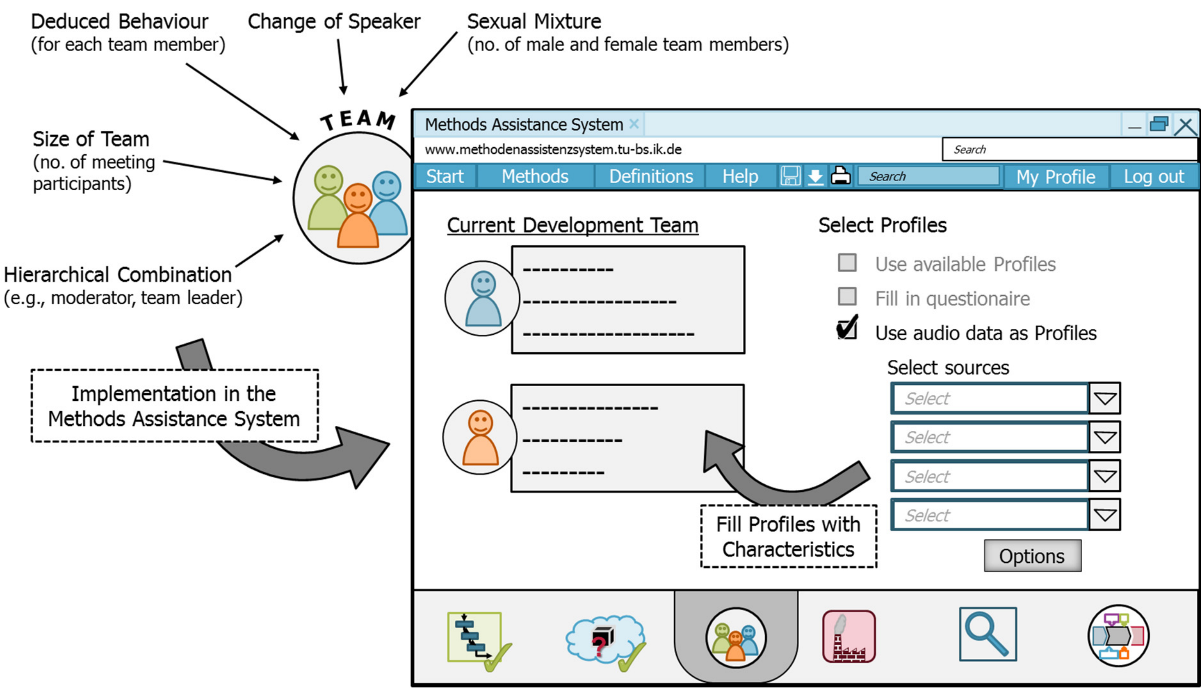

Figure 3. Potential implementation of team aspects obtained by the audio data to store in profiles in the methods assistance system

As an extension of the methods assistance system, we propose to link the system to the information extracted from the audio and video recording data. This information about the team and the current situation during a meeting gained from the observation data can be used as a complementary input for a methods query to propose adequate methods for the present development situation. For example, information on the actual situation, as the behaviour of individual team members in certain situations, is known from the observation data so this could be used as basis for a method selection. Consequently, it is not even longer necessary for the team leader to update information about his or her team during the meeting in order to perform a new method selection.
Figure 3 shows a possible graphical user interface that could be integrated into the existing concept of the methods assistance system to store the information gained by the audio and video record data into profiles. The so obtained additional information for a potential query could already lead to a recommendation of a method for the observed team.
Furthermore, statements about potentially chaotic or critical situations could be made by using the observation during a running team meeting. For this purpose, such situations have to be initially identified by examining the video records and the evaluated questionnaires. In a next step, the situations have to be correlated with parameters extracted from the synchronously recorded audio signal. These parameters would identify critical situations in an automatic, real-time computation with a certain accuracy rate. By linking the methods assistance system suitable methods for the present state could be sought as a way out of the critical situation.

6 CONCLUSION

The single case study we performed showed in a first approach that the use of design methods can achieve a higher perceived task performance within development team meetings. In addition, the observation indicated a higher meeting satisfaction and a better ratio of procedural statements while using design methods in a meeting. These hypotheses have to be proved in realizing further team observations with greater samples. Another point we identified as to be examined in additional research is the usage of recorded audio/video data for social signal processing. Moreover, a practical implementation in a methods assistance system was proposed to utilise the obtained information about the team to select appropriate methods that can support the development team working on their task.

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ACKNOWLEDGMENTS

We thank Markus Schleicher, undergraduate psychology student, for his support on data collection and preparation.