EVALUATING THE EFFECTIVENESS OF METHODS FOR CAPTURING MEETINGS

Hall, Mark John (1,2); Bermell-Garcia, Pablo (1); McMahon, Chris A (2); Johansson, Anders (2); Gonzalez-Franco, Mar (1)
1: Airbus Group Innovations, United Kingdom; 2: University of Bristol, United Kingdom

Abstract

The purpose of this paper is to evaluate the effectiveness of commonly used methods to capture synchronous meetings for information and knowledge retrieval. Four methods of capture are evaluated in the form of a case study whereby a technical design meeting was captured by; (i) transcription; (ii) diagrammatic argumentation; (iii) meeting minutes; and (iv) video. The paper describes an experiment where participants undertook an information retrieval task and provided feedback on the methods. This work contributes to knowledge by presenting the relative merits and weaknesses of existing methods through the use of a mixed qualitative and quantitative experimental approach.
The conclusions from this study show that there is no evidence of a single method for capturing meetings that is effective at providing an overview of the meeting, capable of containing its details and decision rationale, while remaining retrievable in a timely manner. Consequently different methods are recommended depending on retrieval requirements. Recommendations are provided for the appropriate selection of a method to capture a meeting, depending on retrieval requirements.

Keywords: Meetings, Decision making, Collaborative design, Information management, Knowledge management

Contact:
Mark John Hall
Airbus Group
Airbus Group Innovations
United Kingdom
mark.hall@eads.com

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

1.1 Context & Contribution

The purpose of this paper is to present the results of an experiment to evaluate the effectiveness of four commonly used methods to capture synchronous meetings, such as design reviews, for information and knowledge retrieval. This paper presents the results of the experiment, and discusses both the advantages and disadvantages of each method.

1.2 Background & Motivation

A meeting is one of the most pervasive *knowledge events* in working life (Selvin, et al., 2001). Indeed, a meeting can be simply described as an activity where information elements are communicated, processed and transformed (Kennedy, et al., 1997). Synchronous meetings involve individuals and teams working on the same activity at the same time, e.g. engineering design review meetings, which are described as 'key elements of the design control process' (Huet, et al., 2007). More precisely, during design review meetings participants typically update their information about the design, discuss rationale leading to a collaborative plan of action, and share past experiences (Huet, et al., 2007). Some of the rationale and lessons learned that are discussed during meetings are recorded explicitly; however, Huet suggests that most of this information is part of an internal process and therefore is only retained in participant's memories: "In a design project, a great deal of information about the aspects of the product being developed and the progress of the project is exchanged during meetings. However, reports which constitute the formal records of meetings are often limited in the extent to which they capture the information exchange. New recording and facilitation technologies for meetings are improving but further work is needed to enable the efficient capture of knowledge and experience from the discourse" (Huet, et al., 2007).

Activities such as design related meetings are prime examples of social and collaborative instances where valuable information and knowledge can be communicated not only through explicit channels such as speech and interaction, but also through the sometimes tacit or implicit expertise of the meeting participants. Therefore, much of the rationale behind the decisions can be lost without the appropriate knowledge capture process (Conway, et al., 2008). There is common agreement in the research community that capturing design knowledge has the potential to aid the design process and through-life support of the developed systems (McMahon, et al., 2005) (Ball, et al., 2006). It is also acknowledged that current tools are not always fit to support designers in this task (McMahon, et al., 2005) (Aurisicchio & Bracewell, 2013). However, the assumption that currently used methods of capturing synchronous collaboration are ineffective could be too naive, and a proper experimental testing is needed in order to assess the real limitations of existing methods. Here we present an experiment to evaluate the use of different capturing methods by analysing how well participants are able to retrieve essential information out of them. This approach builds on previous work, presenting the relative merits and weaknesses of existing methods through the use of a mixed qualitative and quantitative experimental approach, i.e. thus being an empirical contribution to the field of knowledge retrieval and information capture in the context of synchronous meetings.

2 METHODS

2.1 Experimental Setup: "The Meeting"

A meeting was held by a team to review two possible technologies to be used across several projects in the context of engineering design. The meeting consisted of five people discussing the pros and cons of each design option, and then making a decision to select one as part of the discussion. The meeting was captured using the following four methods:

- **Method 1: Transcription** - an electronic transcription of the meeting, outlining each verbal utterance with an associated timestamp and speaker ID (350 utterances, 5 speakers).
- **Method 2: Diagrammatic Argumentation** - a diagrammatic representation of the decision-making argumentation in the form of a design rationale tree diagram (Moran & Carroll, 1996), produced by attendees as part of the meeting, lead by a facilitator (23 node graph, 1-page).

- **Method 3: Meeting Minutes** - an electronic document of the meeting minutes, generated post-meeting by one of the attendees (1-page, standard format).
- **Method 4: Video** - a multimedia video recording of the meeting with audio (33 minute duration).

2.2 Experimental Design

In order to evaluate the effectiveness of these four widely used methods to capture the meeting, an information retrieval experiment was conducted. This is presented in the current paper in the form of a case study by collecting and analysing data from 12 volunteers (see Sec 2.3 for details) that undertook a task to review the material from the meeting. The experiment was designed as an in-between subjects study; therefore each participant in the experiment was assigned with only one of the capture methods to review the meeting that took place. A total of three participants were allocated to each method. This allocation process was blind to the experimenter and randomised across the participants.
An electronic version of the meeting material was provided to each participant. There was no restriction on the time that participants could dedicate into studying the material, but the time taken to complete the task was recorded. Participants were asked to answer a questionnaire about the meeting based on the questions shown in Table 1. These questions were derived based on important aspects the discussion. There are of course many more questions that could have been asked, but these questions were chosen as they are representative of the types of queries that may occur when reviewing such a meeting. The questions were aimed to evaluate the effectiveness of the methods based on the following four factors:

- **Factor A: Retrieval Time** - the speed of information retrieval, i.e. how effective is the method in providing a timely retrieval of information from the meeting?
- **Factor B: Overview** - the overview of information contained, i.e. how effective is the method in presenting a summary overview of the meeting?
- **Factor C: Details** - the detail of information contained, i.e. how effective is the method in capturing the details of the meeting?
- **Factor D: Rationale** - the decision rationale and traceability captured, i.e. how effective is the method in capturing the rationale behind a decision?

Table 1. Task Questions

No.	Question	Factor
1	Which participant chaired the meeting? (multiple choice)	Details
2	Provide a brief descriptive summary of the meeting	Overview
3	List the main conclusions of the meeting	Overview
4	Which option was accepted as the final design choice? (multiple choice)	Overview
5	List the advantages of design option 1	Rationale
6	List the advantages of design option 2	Rationale
7	List the disadvantages of design option 1	Rationale
8	List the disadvantages of design option 2	Rationale
9	Which design option is a commercial tool? (multiple choice)	Details
10	Were there any disagreements amongst participants for which option should be accepted as the final design choice? (multiple choice)	Rationale
11	What is the relationship between cost and development effort for each design option? (multiple choice)	Details

Volunteers were also interviewed at the end of the experiment. The semi-structured interview was divided into the following topics: (i) summary overview of the meeting; (ii) speed of information retrieval from the material; (iii) details about the meeting; (iv) understanding the rationale behind the final decision; (v) being a usable or operable method to review the meeting; (vi) other - open discussion and general comments.

2.3 Experimental Procedure

All 12 participants (11 male, mean age 40 years ± 15) were employees working in a corporate research organisation. All were native English speakers who volunteered to participate; no incentive was given

to them. Participants ranged from junior employees with less than five years experience to senior researchers and engineers. Some participants were knowledgeable in the meeting subject matter, whilst others only had an awareness of the domain. Employees that were present in the original meeting were excluded as participants in the experimental task.
Each participant was taken to a private room and sat at a computer. The outline of the briefing explained that the experiment was related to capturing and retrieving information from meetings. The task was then described to the participant. They were told that they would be given some material from the meeting and would need to answer a series of questions based on that material. The structure of the questionnaire was briefly shown to the participant. They were told that the task would be timed, but that they should not rush it nor spend any longer than was necessary. For each method, a short explanation of what the material contained was provided. No detail was given to participants on the material content itself, only the allocated method. For example, the structure of the transcription was briefly explained to show that each of the three columns contained a timestamp, speaker identification and the verbal utterances. Similarly, the concept of the diagrammatic argumentation (design rationale) was briefly explained along with how one is constructed and what it represents (note that this was explained independently of the meeting material itself).
The participants were then left alone to complete the task and the timer was started. On completion of the task, the time was noted and a semi-structured interview was conducted to obtain qualitative feedback on the effectiveness of the material. The interviewer made notes throughout the interview and clarified these with the participant to ensure it correctly reflected his or her view.

2.4 Quantitative and Qualitative Data Capture & Analysis

Qualitative data was collected from the interview conducted after the experiment task. The verbal responses to the interviewer's questions were noted. In the analysis of this data, key phrases and points from the responses were compared between different participants and methods. The purpose of this qualitative data collection and analysis was to capture and understand the participant views and evaluations of the effectiveness of the method provided in retrieving the information from the meeting.
The participant's questionnaires were scored quantitatively based on a crib sheet of answers that was produced by an individual who was present at the meeting. In parallel the quantitative data was encoded within the common requirements for information retrieval from synchronous meetings in the form of the four differentiated factors (A-D).
The scores of the participants were added for each method (1-4) against each factor (A-D), then normalised to compare results. The purpose of collecting this quantitative data was to provide some validation to the qualitative data that was captured. For example, a participant may claim that meeting minutes are a timely way to retrieve information, but the reality may not be reflected in the measurable outcome of the task, i.e. time taken to complete. This quantitative scoring was therefore used to provide evidence that the views of the participants reflected reality in an attempt to identify any subjectivity or anomaly in the responses.

3 RESULTS

The scoring results for the experiment are shown in the Appendix. Mean values were calculated for the retrieval times along with the standard deviations (s.d.). Table 2 shows the overall results to quantitatively evaluate the effectiveness of each method. Each method is ranked based on its percentage. A graphical comparison is shown in Figure 1 and Figure 2 (note that the dotted line in Figure 1 represents the meeting duration itself, and each bar represents a participant).

Table 2. Scoring and Ranking Overview

Factors:	**A. Retrieval Time**		**B. Overview**		**C. Details**		**D. Rationale**	
Methods:	Mean Time (mins)	Rank	Score	Rank	Score	Rank	Score	Rank
1. Transcription	60 (s.d.47)	4	62%	3	94%	2	74%	3
2. Diag. Arg.	20 (s.d. 1)	2	95%	1	61%	3	89%	2
3. Minutes	14 (s.d. 3.8)	1	67%	2	61%	3	54%	4
4. Video	40 (s.d. 5.7)	3	57%	4	100%	1	94%	1

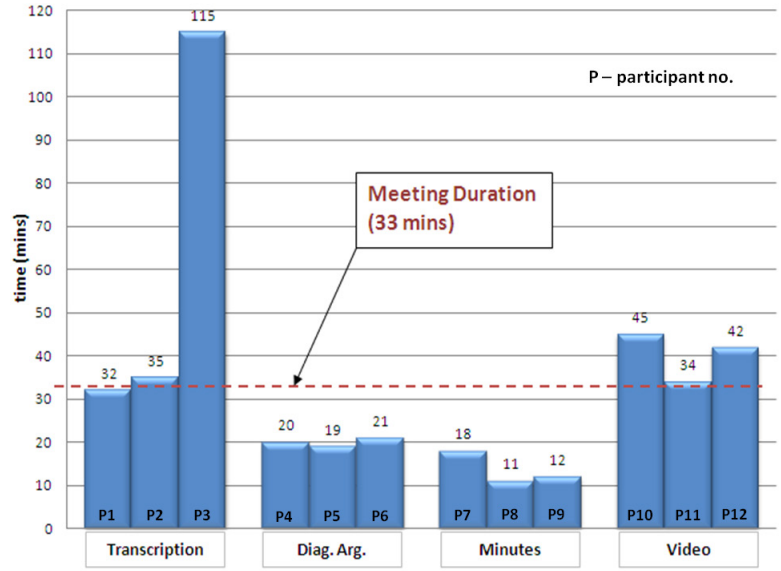

Figure 1. Comparison of methods for information retrieval time (Factor A)

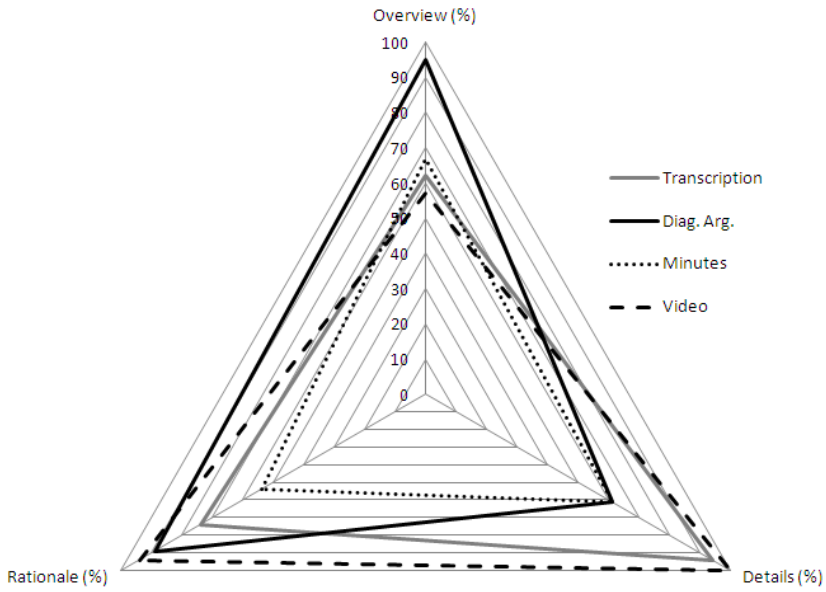

Figure 2. Comparison of methods for overview, details and rationale (Factors B-D)

The qualitative responses were collected, then categorised based on each participant's responses, dependent variable and method. These verbal responses were then compared to the quantitative scoring. The following discussion of results addresses each of the four methods in turn, comparing the qualitative data to the related quantitative data for each method.

3.1 Method 1: Transcription

The qualitative responses from the transcription method suggest that it successfully contains the details of the discussion. However, according to the participants it is an ineffective means to get a general overview of the topics discussed and the key conclusions, as it is difficult to follow written natural language to retrieve the information. Participants highlighted that this method requires time to build an overview of the discussion, nevertheless it was regarded as an effective tool for keyword searching.

The quantitative scoring of the participants in undertaking the tasks supports their interview responses, where the method scored highly at 94% in retrieving details, but only 62% for retrieving an overview and 74% for understanding the rationale behind decisions. In terms of time taken to complete the task,

one participant took considerably longer than the other two for the transcription method. Two of the participants took approximately the same amount of time as the duration of the meeting itself to review the material (32 and 35 mins for a 33 min meeting), but one participant took 115 mins, nearly 3.5 times the duration of the meeting. This may be an anomaly, which highlights one of the limitations with this experiment, in terms of the limited sampling. Ignoring the third participant momentarily, the completion time of the two participants is still comparable to the meeting itself. A further investigation would be useful here to determine the relationship between the meeting duration and the time required to review the material, to see how the review time changes with respect to the meeting duration increasing. On talking with the third participant during the post-task interview it was clear that he was not particularly comfortable in sifting through such a large volume of text. However, the other participants appeared to take to the method more naturally, explaining that they even identified some tangential conversations and humorous nuances during the meeting.
This may indicate that there is not a best-fit method, but perhaps some individuals favour certain methods based on factors such as their background, experience, etc. Therefore, effectiveness of each method becomes a very subjective measure and very much dependent on the type of person using it. For example, a text-based natural language method may not be very intuitive for some people to use, but other people use it naturally. If this is the case, it would be very difficult to generalise.

3.2 Method 2: Diagrammatic Argumentation

The qualitative responses from the participants using the Diagrammatic Argumentation method suggest that it is effective at providing an overview of the meeting, but does not contain much detail. One participant described it as a "good summary tool", but stated that they needed more explanation for some parts as this method, as it does not contain the detail of what different people said, nor weightings of importance associated with each discussion point (i.e. nodes in the diagram). One suggested that it was an effective method to use for a manager to review a meeting, but provided no depth of insight into the discussion, which would be required for someone at a team-worker level. It was said that it was easy to follow and "gives a flavour" as to what was discussed, but in general participants felt that there should have been more accompanying information. In terms of decision rationale, the feedback from one participant suggested that the method was "adequate at providing briefing material, but inadequate as an historic record of the decision rationale". Another participant stated that it is "clear that a decision was made, but not how it was made... (it) presents facts, but whether they capture the entire discussion is not clear from this diagram". All three participants raised the issue of importance (weightings) to each discussion point (or node in the diagram), stating that the views of the people are not conveyed to understand the relative importance, and "a complete picture is not presented". Other issues raised were the use of specialist terminology and acronyms to someone not familiar with the topic, which makes it difficult to understand.
The quantitative scoring of the participants in undertaking the task supports their responses, where the method scored highly at 95% in obtaining an overview, but only 61% for retrieving details. However, the score for understanding the rationale behind decisions was 89%, which appears to be relatively high considering the participant feedback. This may be explained by the fact that the task was aimed to score the rationale based on 'why decisions were made' and not 'how decisions were made (Wang, et al., 2012). In terms of time taken to complete the task, the three participants took a similar length of time (19, 20 and 21 minutes), which is less than the meeting itself at approximately two thirds of the length of this particular meeting (at 33 minutes).
Another factor to consider with this method is that the argumentation diagram was produced as part of the meeting activity itself, but this may not be possible for other cases. Indeed it has long been recognised that there is a great potential for diagrammatic argumentation such as design rationale capture tools, especially where they can fit naturally with the working methods of designers and not impede them (Bracewell, et al., 2009).

3.3 Method 3: Meeting Minutes

The qualitative responses from the participants using the meeting minutes suggest that the method is an effective means to provide an overview of the meeting, but lacks some details of the discussion. E.g. "the conclusions are well documented, but lack detail to make further decisions, on contrary the decisions that were made were explained clearly". In terms of time taken to complete the task, the average was 14 minutes, which is less than half of the duration of the meeting itself. With the

completion times ranging from 11 to 18 minutes, which the participants described as being effective, e.g. "...you can very quickly get an overview of the meeting", but then went on to comment on the lack of detail contained within the minutes.
The quantitative scoring of the participants in undertaking the tasks supports their responses for the lack of detail and rationale, scoring 61% and 54% respectively. Furthermore, the score for providing an overview was also surprisingly low at 67%. This may be explained by a limitation with the scoring used at validating an effective overview, but could also be due to the minutes themselves which could have been produced subjectively, and it is fair to assume that although they were agreed on by participants, they would be different if another person had produced them. This may be a limitation of the study, as only one version of the minutes was created for a single meeting, which makes it difficult to generalise. However, it does highlight the issue that the creation of meeting minutes can be subjective, and may differ in the quality, the level of detail and the perspective of different people involved. As one participant commented "a bad set of minutes can be worse than none", so quality is evidently important. Another described that "the level of detail and overview needed depends on your role". Similarly, one suggested that, "meeting recording should be appropriate for the audience and participants. For a certain audience, a short record is fine. The problem arises where there are some conflicting views, then a detailed record is better".
Overall, the feedback from the participants stated that they could see what decision was made from the minutes, but could not understand the discussion that led to the decision. *Robert's Rules of Order*, a manual to conduct orderly productive meetings, states that, "Minutes are a record of what was done at a meeting, not a record of what was said" (Robert, 2011). Highlighting thus an important point, in that it is considered improper to record this information within the minutes, however, the feedback from the volunteers suggests that this information is important to review the meeting properly. Participants made comments such as "who disagreed (during the discussion) is not contained within the meeting minutes" and "as a manager you would be looking for who pushed the decision in which direction", which was not captured by the minutes. In relation to the decision rationale, one participant states that "a greater depth of analysis that underlies that decision is not there", but goes on to say that minutes are "an effective way of recording what happened in a meeting...and a good starting point...usable as a guide to know where to go for further information".

3.4 Method 4: Video

The qualitative responses from the participants using the video method suggest that it contains the details of the discussion and rationale, but it is not a particularly effective means to quickly gain an overview of the discussion. In a similar way to the transcription method, the video contains all of the discussion verbatim, but with the added advantage of containing the words with audible expression, body language and other visual signs. It is considered that the vast majority of communication importance is carried within the visual and audio channels. The result of research studies (Mehrabian & Ferris, 1967) give the 55/38/7 formula for channels of communication importance, whereby 55% of communication is carried through body language, 38% is the tone of voice and only 7% of communication are the actual words spoken. So it is not surprising that participants viewed the video as "getting the full story... (where) you get everything which leads to the point where that decision was formed" and "it captures everything...there is nothing missed...no room for interpretation". One participant even described the video as comparable to being in the meeting in real-time, whilst another said that they had identified speaker biases from the video along with a conscious balancing from the chairperson. In general all participants agreed that the level of detail contained within the video is very high. However, the main issue encountered by participants was the timely accessibility of these details from the discussions.
Feedback from participants included, "it is difficult to retrieve some specific information that you need", and "you have to *suffer through* the waffle to retrieve the information required that may be important". All three participants made comments related to the structure of the meeting, stating that because the meeting was fairly structured it made it considerably easier to follow, and without this structured meeting protocol, it would be difficult to do this. But even though this is challenging, the participants agreed that because you get the full conversation, "it is possible to *pull out* (information) and write a summary", but obviously this requires both time and effort to review. In terms of decision rationale, the participant's views were all positive, stating, "you can see what people are saying with a

video" and "you get the context of what the points were...an impression of where they are coming from".
The quantitative scoring of the participants in undertaking the tasks supports their responses, where the method scored 100% in retrieving details and 94% for understanding the decision rationale, but only 57% for gaining an overview of the discussion. In terms of time taken to complete the task, the participants obviously took longer than the meeting itself, because they needed to be able to watch the video in full. On interviewing participants it became apparent that there were two different techniques that were used to review the meeting using the video which appear to influence the time taken. The first technique was the 'fly on the wall', where the video was watched from start to finish and the questions answered during the playback, resulting in the task time taking approximately the same as the meeting itself. The second technique was the 'rewind and re-play', where the video was watched, paused, rewound, skipped, etc, resulting in the task taking longer than the meeting itself, by approximately 27% and 36% more time. In relation to the effectiveness of a video as being a timely method, one participant expressed that "the effectiveness depends on the length of the meeting. For short meetings it is effective, but for long meetings it is less effective because you have to re-live the meeting".

4 DISCUSSION

4.1 Limitations

- The experiment was based on a single case. The experiment was limited in external validity because the findings are based on a single meeting.
- The sampling is limited. The participants were chosen from a single company in the aerospace industry as a case study, which is not necessarily representative of wider industry. The number of participants is too small to be able to get any statistical significance. This means that the quantitative data collected from the experiment may produce anomalies, so there is more value in the qualitative data. The variation in the participants is not controlled which may skew results between participants with different demographics, experience, expertise and prior knowledge of the meeting material.
- The material is subjective. The material generated from the meeting is not necessarily representative of the type of quality and style that is often produced. For example, meeting minutes can be widely varied in terms of length, depth, quality, etc. So the experiment is limited because participants are evaluating the effectiveness of the material type based on a single instance of the material.

4.2 Discussion Summary

Considering all four methods it is evident that each has both advantages and disadvantages. Depending on their use and context, different methods should be selected based on their effectiveness to capture discussions and decisions from meetings, to retrieve information effectively and provide traceability for decisions. Looking at each method in turn it is possible to see that the video method is effective in capturing the details of the meeting and the rationale behind decisions. However, it can be seen that a video recording is relatively ineffective at providing a quick overview and reviewing a meeting in a timely manner. A transcription is effective at containing much of the detail of the discussion and thus the rationale to decisions based on this, but it is again not particularly effective in gaining an overview of the discussion in a timely way. A set of meeting minutes appear to be a reasonably effective means to provide an overview of the meeting, while minimising the investment of retrieval time, but lack details of the discussion and rationale and remains very subjective. The diagrammatic argumentation seems to also require a low time investment. Whilst perhaps being a more objective method than the minutes, it qualifies as the most effective method at providing an overview of the meeting (see Figure 2), but also does not contain much detail when compared to the transcription or to the video methods. In summary, when selecting an appropriate method for effectively capturing a meeting, it is important to consider the trade-off between time and the level of detail required. There is also the 'overhead' to consider in producing these materials. For example, video is a fairly passive means of capturing a meeting, whereas producing a good set of meeting minutes requires time both during and after the meeting.

Overall, it is evident from this experiment that there is not a single method for capturing meetings that is effective at providing an overview of the meeting, along with containing details and the decision rationale, and all retrievable in a timely manner. Instead, the lesson learned from this experiment is that the appropriate method should be selected based upon the circumstance and the level of retrieval required for the task. There is not one single method that performs well for all criteria; therefore the selection of the method depends on the application and context.

- A meeting transcription is an effective method for applications and contexts that require the capture of detailed discussion, but where a clear overview and rationale are not important to understand in a timely way.
- An argumentation diagram is an appropriate method for applications and contexts that require an overview to be presented with rationale clearly outlined, but where the detail of the discussion is not important. Even though this method proved very effective for retrieval under timely limitations it requires extra dedication to the production of the material which may not be possible in certain circumstances.
- A set of meeting minutes are an appropriate method for applications and contexts that require a general overview to be captured, but where the detailed discussion and decision rationale are not important. Even though this method is very commonly used, it has the downside of being very subjective dependent, which in the long term may bias the information retrieval.
- A video is an appropriate method for applications and contexts that require the capture of detailed discussion and the rationale behind decisions, but where a clear overview is not important to understand in a timely way.

There is an opportunity here to develop methods and tools where all four factors (Retrieval Time, Overview, Detail and Rationale) are similarly effective. Each of these methods evaluated has strengths as well as weaknesses, but this experiment highlights the need to develop alternative methods that have the effective characteristics of the existing methods, but perform well for all criteria. Such methods and tools would need to have a low overhead and minimise the intrusiveness in capturing.

In recent years there have been advancements in a variety of research fields to improve the capture of meetings for re-use. Meeting support techniques include video segmentation and semantic transcription markups. Another area of development has been Instrumented Meeting Room technologies (Renals, et al., 2007) where automated transcriptions are produced through speaker diarisation and speech-to-text technologies (Sinclair & King, 2013) (Zwyssig, et al., 2012), supported with video playback through a meeting browser. It is clear that many of these methods have potential to improve effectiveness; however, it is evident that there are barriers to wider adoption within industry. Such methods are not widely embraced and many still rely on basic methods such as those outlined within this study, which are evidently limited in their effectiveness. Therefore, further research is proposed to address such barriers, whether technical, social, or both. The challenge remains as how to capture and store information in a way that is both simple and efficient, whilst remaining unobtrusive to the designers involved (Conway, et al., 2007).

5 CONCLUSION

This paper has analysed the effectiveness of four commonly used methods of capturing discussions and decisions from meetings, to retrieve information effectively and provide traceability for decisions. An experiment was conducted and presented as a case study, whereby participants were asked to perform a task and provide feedback on one of four meeting material types.

The conclusions from this study show that there is not a single evident method for capturing meetings that is effective at providing an overview of the meeting, capable of containing its details and decision rationale, while remaining retrievable in a timely manner. Instead, the appropriate method should be selected based upon the circumstance and the level of retrieval required for the task.

Future work would include expanding this study to involve more participants from a wider sampling pool. Another area would be in exploring the relationship between the duration of the meetings and the time taken to review them. Also, exploring new methods to capture meetings and evaluating them against these commonly used methods.

REFERENCES

Aurisicchio, M. & Bracewell, R., 2013. Capturing an integrated design information space with a diagram based approach. *Journal of Engineering Design,* pp. Vol.24, No.6.

Ball, A. et al., 2006. A Grand Challenge: Immortal Information and Through-Life Knowledge Management (KIM). *The International Journal of Digital Curation,* pp. 53-59.

Bracewell, R., Wallace, K., Moss, M. & Knott, D., 2009. Capturing design rationale. *Computer Support for Conceptual Design,* pp. 173-186.

Conway, A. P. et al., 2008. *Holistic Engineering Design: A Combined Synchronous and Asynchronous Approach.* New York, ASME, pp. 1227-1236.

Conway, A., Wodehouse, A., Ion, W. & Juster, N., 2007. *A study of information & knowledge generated during engineering design meetings.* s.l., s.n.

Huet, G. et al., 2007. *Communication, Information and Knowledge Processes Observed during Engineering Design Reviews.* Paris, The Design Society.

Kennedy, J., Pinelli, T. & Barclay, R., 1997. The production and use of information by U.S. aerospace engineers and scientists. *Knowledge diffusion in the U.S. aerospace industry: managing knowledge for competitive advantage,* pp. 263-323.

McMahon, C., Giess, M. & Culley, S., 2005. Information Management for Through Life Product Support: The Curation of Digitial Engineering Data. *nternational Journal of Product Lifecycle Management,* pp. 26-42.

Mehrabian, A. & Ferris, S., 1967. Inference of Attitudes from Nonverbal Communication in Two Channels. *Journal of Consulting Psychology,* pp. 248-252.

Moran, T. & Carroll, J., 1996. *Design Rationale: Concepts, Techniques, and Use.* Hillside: L. Erlbaum Associates Inc..

Renals, S., Hain, T. & Bourlard, H., 2007. *Automatic Speech Recognition & Understanding.* s.l., s.n.

Robert, H., 2011. *Robert's Rules of Order Newly Revised (11th edition).* s.l.:Da Capo Press.

Selvin, A. et al., 2001. *Compendium: making meetings into knowledge events.* Austin, s.n.

Sinclair, M. & King, S., 2013. *Where are the challenges in speaker diarization?.* s.l., s.n., pp. 7741-7745.

Wang, H., Johnson, A. L. & Bracewell, R., 2012. The retrieval of structrued design rationale for the re-use of design knowledge with an integrated representation. *Advanced Engineering Informatics,* pp. 251-266.

Zwyssig, E., Renals, S. & Lincoln, M., 2012. *Determining the number of speakers in a meeting using microphone array features.* s.l., s.n., pp. 4765-4768.

APPENDIX

Quantitative Scoring for each Participant (P)

		A. Speed	B. Overview			C. Details		D. Rationale	
Material Type	P	Time (mins)	Q2 - Summary (max. 4)	Q4 - Decision (max. 1)	Q3 - Conclusions (max. 2)	Q1 - Chair (max 1)	Q9 & Q11 - Detail Questions (max. 5)	Q5-Q8 - Pro/Con (max. 17)	Q10 - Agree (max. 1)
1. Transcription	1	32	3	0	2	1	5	15	0
	2	35	3	0	0	1	5	13	0
	3	115	3	1	1	0	5	12	0
2. Diag. Arg.	4	20	4	1	2	0	5	17	0
	5	19	3	1	2	0	4	14	0
	6	21	4	1	2	0	2	17	0
3. Minutes	7	18	2	1	2	1	4	11	0
	8	11	2	1	1	1	0	8	1
	9	12	2	1	2	1	4	9	0
4. Video	10	45	3	1	1	1	5	16	1
	11	34	3	0	1	1	5	16	1
	12	42	1	0	2	1	5	17	0